

*Cranfield*  
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CONOR WHELAN



**EVALUATING AND IMPROVING  
WORLDWIDE IMPLEMENTATION  
OF FUTURE AIR NAVIGATION SYSTEMS**

**COLLEGE OF AERONAUTICS**

**AIR TRANSPORT GROUP**

**PHD THESIS**

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**ACADEMIC YEAR 2000-01**

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OF FUTURE AIR NAVIGATION SYSTEMS**

**SUPERVISOR: J SNOW**

**MARCH 2001**

**THIS THESIS IS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY**



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## ABSTRACT

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Air traffic congestion problems in many areas of the world are well known and have been highly publicised in recent years. This airspace dilemma, which results in delays and other undesirable knock-on effects, is escalating at a phenomenal rate and requires immediate attention. Correspondingly, there is concern about safety standards in some worldwide airspace regions. In addition, it is imperative that the significant projected growth in air transport movements over the next two decades is accommodated. Thus, there is an urgent need to solve the current airspace problems and plan in a responsible manner to meet forecast demand.

Solutions to these predicaments have been developed and are encompassed under the auspices of the term, 'future air navigation systems'. The systems include technologies and procedures that merge to optimise the potential of airport and airspace resources so that the capacity, flexibility and safety of these resources are maximised, while delays and their operating costs are minimised. Future air navigation systems use automated communications, navigation and surveillance technologies to provide enhanced air traffic management through continuous information on aircraft positions and intentions so that reductions in separation are possible without compromising safety.

However, confusion exists regarding what technologies and procedures constitute these future air navigation systems. Additionally, their current worldwide integration status is not as advanced as it should be and, in fact, remains largely unknown. Indeed, their successful introduction is far from guaranteed at present. Therefore, this research addresses these requirements by evaluating and improving implementation of the systems on a global basis. Ultimately, this thesis provides a comprehensive analysis that discovers what systems are pertinent and whether or where they have been applied to date, in addition to developing and validating a framework strategy for improved introduction of the future air navigation systems around the world.

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## ACKNOWLEDGEMENTS

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The author would like to express his sincere thanks to the following people from the Air Transport Group, Cranfield University, for their much appreciated help and support:

- In particular, his supervisor, John Snow, who has always been available and extremely helpful;
- Dr Fariba Alamdari, the PhD Programme Co-ordinator;
- Peter Morrell, Head of the Air Transport Group;
- All the other staff and PhD students at the Air Transport Group.

For a variety of different reasons relating to this research, many thanks are also due to:

- Bernard Pels and Horst Feuerstein from the European Investment Bank;
- Captain Fintan Ryan;
- David Morrow, previously Editor of air traffic management magazine;
- Dr Harrison Fox and Lonnie Bowlin of US ATM firm, Aerospace Engineering;
- Fabio Gamba, CANSO's Business Manager;
- Gabriel Hartl, President of the US Air Traffic Control Association;
- Jeannine Golding;
- Kieran Daly, former Editor of Air Navigation International;
- Knut Fuglum and Kai Sollid from the Norwegian CAA, Luftfartsverket;
- Lindsay Norrish of Inmarsat;
- Nikki Goldschmid from ICAO's Paris office;
- Professor David Allerton, College of Aeronautics, Cranfield University;
- Professor Rigas Doganis;
- Sallie Edwards, Gideon Ewers and Angela Jones of RBI's Conference Services;
- Sue Christiansen, Editor of air traffic management magazine;
- The Royal Aeronautical Society's Professional Development Steering Group;
- Vincent Galotti of ICAO's Air Navigation Bureau, Montréal;
- Windsor Greene, Secretary General of the Roberts Flight Information Region.

**THIS DISSERTATION IS DEDICATED TO THE MEMORY OF**

**ROBERT (BOB) GOLDING**

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## GLOSSARY

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Noting that the aviation industry is very acronym-friendly, the following abbreviations are used in this dissertation<sup>1</sup>:

<b>A</b>	
AAC	Aeronautical Administrative Communication
AAIM	Aircraft Autonomous Integrity Monitoring
ABAS	Aircraft-Based Augmentation Systems
ACARS	Aircraft Communications, Addressing and Reporting System
ACAS	Airborne Collision Avoidance System
ACC	Area Control Centres
ACP	Audio Control Panel
ADEXP	Air traffic services Data EXchange Protocol
ADF	Automatic Direction Finder
ADL	Aeronautical DataLink
ADNS	ARINC's Data Network Service
ADS	Automatic Dependent Surveillance
ADS-B	ADS – Broadcast
ADS-C	ADS – Contract
ADSP	ADS Panel
AEA	Association of European Airlines
AEEC	Airlines Electronic Engineering Committee
AES	Aircraft Earth Stations
AEV	Annual Equivalent Values
AFAS	Aircraft in the Future ATM System
AFS	Aeronautical Fixed Services
AFTN	Aeronautical Fixed Telecommunications Network
AGADE	Air-Ground Automatic Data Exchange
AIC	Aeronautical Information Circulars
AIDC	ATS Interfacility Data Communications
AILS	Airborne Information for Lateral Spacing
AIM-FANS	Airbus Interoperable Modular – Future Air Navigation System
AIP	Aeronautical Information Publications
AIS	Aeronautical Information Services
AMACS	Airport Monitoring And Capacity System
AMASS	Airport Movement Area Safety System

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<sup>1</sup> The list does not include abbreviations for European projects in Appendix 4.2.

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AMCP	Aeronautical Mobile Communications Panel
AMS	Aeronautical Mobile Services
AMSS	Aeronautical Mobile Satellite Service
ANC	Air Navigation Commission
ANO	Air Navigation Orders
ANP	Air Navigation Plans
ANS	Air Navigation Service
ANS	Air Navigation System
AOA	ACARS Over Aviation
AOC	Aeronautical Operational Control
AOC	Air Operator's Certificate
AOC	Aircraft Operations Centre
AOP	Aeronautical OSI Profile
APALS	Autonomous Precision Approach and Landing System
APANPIRG	Asia/Pac Air Navigation PIRG
APC	Aeronautical Passenger Communication
APL	Airport PseudoLites
ARTCC	Air Route Traffic Control Centres
ASAS	Airborne Separation Assurance System
ASD	Aircraft Situation Display
ASDE	Airport Surface Detection Equipment
ASE	Altimetry System Error
ASECNA	Agence pour la Sécurité de la Aérienne en Afrique et à Madagascar.
ASM	AirSpace Management
A-SMGCS	Advanced Surface Movement Guidance and Control Systems
ASOS	Automated Surface Observation System
ASR	Airport Surveillance Radars
ATA	Air Transport Association
ATAG	Air Transport Action Group
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATMCP	ATM operational Concept Panel
ATMP	Air Traffic Management Partnership
ATN	Aeronautical Telecommunications Network
ATNP	ATN Panel,
ATS	Air Traffic Services
ATSU	Air Traffic Services Unit
AVOSS	Aircraft VOrtex Spacing System
AWIN	Aviation Weather Information Network
AWOP	All Weather Operations Panel
AWOS	Automated Weather Observing System
AWR	Airborne Weather Radar

**B**

BITE	Built-In Test Equipment
BNTS	Beidou Navigation Test Satellite
B-RNAV	Basic-RNAV

**C**

C/AFT	CNS/ATM Focused Team
CAA	Cargo Airlines Association
CAA	Civil Aviation Authority
CAATS	Canadian Automated Air Traffic System
CAM	Collaborative Airspace Management
CANSO	Civil Air Navigation Services Organisation
CAR/SAM	CARibbean/South AMerican
CASA	Civil Aviation Safety Authority
Cat	Category
CAT	Clear-Air Turbulence
CBA	Cost-Benefit Analysis
CDA	Continuous Descent Approach
CDI	Course Deviation Indicators
CDM	Collaborative Decision Making
CDS	Common Display System
CDTI	Cockpit Display of Traffic Information
CEATS	Central European ATS
CFIT	Controlled Flight Into Terrain
CFMU	Central Flow Management Units
CHA	Channel of High Accuracy
CIDIN	Common ICAO Data Interchange Network
CLK	Chek Lap Kok
CMA	Central Monitoring Agency
CMU	Communications Management Unit
CNS	Communications, Navigation & Surveillance
CO	carbon monoxide
CoA	Certificate of Airworthiness
COCESNA	Corporacion Centroamericana de Servicios de Navigacion Aérea.
CODA	Central Office for Delay Analysis
COMESA	COMmon Market for Eastern and Southern Africa
COTS	Commercial Off-The-Shelf
CPDLC	Controller Pilot DataLink Communications
CRCO	Central Route Charges Office
CRM	Crew Resource Management
CRT	Cathode Ray Tube
CSA	Channel of Standard Accuracy
CTAS	Centre TRACON Automation System
CTR	ConTRol zones



## D

DADI	Downlinking of Aircraft Derived Information
DAP	Down-linked Aircraft flight Parameters
DARP	Dynamic Airborne Re-routing Procedures
DARPS	Dynamic Aircraft Route Planning System
D-ATIS	Digital Automated Terminal Information Service
DCDU	Datalink Control & Display Units
DCF	Discounted Cash Flows
DDTC	Datalink Delivery of expected Taxi Clearances
DETR	Department of the Environment, Transport and the Regions
DGNSS	Differential GNSS
DGPS	Differential GPS
DH	Decision Heights
DME	Distance Measuring Equipment
DOC	Direct Operating Costs
DROMS	Dynamic Runway Occupancy Measurement System
DSR	Display System Replacement

## E

EASA	European Aviation Safety Authority
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme
EATMP	European Air Traffic Management Programme
EATMS	European Air Traffic Management System
EBRD	European Bank for Reconstruction and Development
EC	European Commission
ECAC	European Civil Aviation Conference
ECGD	Export Credit Guarantee Department
EDCT	Estimated Departure Clearance Time
EFIS	Electronic Flight Instrument System
EFR	Electronic Flight Rules
EFR	Extended Flight Rules
EGNOS	European Geostationary Navigation Overlay Service
EGPWS	Enhanced GPWS
EIB	European Investment Bank
ELS	Electronic Library System
ENPRM	European Notice of Proposed Rule-Making
era	european regional airline association
ESA	European Space Agency
ESARR	Eurocontrol SAfety Regulatory Requirements
ETFMS	Enhanced Tactical Flow Management System
ETMS	Enhanced Traffic Management System
ETOPS	Extended Twin-engine OperationS
ETSI	European Telecommunications Standards Institute
EU	European Union
EUROCAE	EUROpean Organisation for Civil Aviation Equipment
Eurocontrol	European Organisation for the Safety of Air Navigation.

EVS	Enhanced Vision Systems
<b>F</b>	
FAA	Federal Aviation Administration
FANS	Future Air Navigation Systems
FAR	FAA Airworthiness Requirements
FASID	Facilities and Services Implementation Document
FASTEX	Fronts and Atlantic Storm Tracks Experiment
FAT-BOB	FANS Action Team for the Bay of Bengal
FCS	Flight Control System
FDPS	Flight Data Processing Systems
FFAS	Free Flight AirSpace
FFP1	Free Flight Phase 1
FIR	Flight Information Region
FIS	Flight Information Service
FIS-B	Flight Information Service – Broadcast
FISDL	Flight Information Service DataLink
FIT	FANS Interoperability Teams
FL	Flight Level
FM	Frequency Modulation
FMC	Flight Management Computer
FMS	Flight Management System
FRAP	Free Route Airspace Project
FREER	Free-Route Experimental Encounter Resolution
FSF	Flight Safety Foundation
FSG	FANS Stakeholders' Group
FTK	Freight Tonne-Kilometres
FUA	Flexible Use of Airspace
<b>G</b>	
GA	General Aviation
GASP	Global Aviation Safety Plan
GATM	Global Air Traffic Management
GBAS	Ground-Based Augmentation Systems
GBWR	Ground Based Weather Radar
GE	General Electric
GLS	GPS Landing System
GNP	Gross National Product
GNSS	Global Navigation Satellite System
GNSSP	GNSS Panel
GPS	Global Positioning System
GPWS	Ground-Proximity Warning System
GSTARS	Ground Safety Tracking And Reporting System
<b>H</b>	
HC	hydrocarbons

HF	High Frequency
HF	Human Factors
HFDL	HF DataLink
HMI	Human-Machine Interfaces
HPA	High Power Amplifier
HUD	Head-Up Displays
<b>I</b>	
IACSP	International Aeronautical Communication Service Providers
IASA	International Aviation Safety Assessment
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ICG	Implementation Coordinating Groups
ICIS	Integrated Crew Information System
IDF	International Development Fund
IFALPA	International Federation of Air Line Pilots' Associations
IFATCA	International Federation of Air Traffic Controllers Associations
IFE	In-Flight Entertainment
IFPS	Initial Flight Plan Processing Systems
IFR	Instrument Flight Rules
IKSANO	Information Co-ordination Council for Debts in Air Navigation Service
ILS	Instrument Landing System
INS	Inertial Navigation System
IPO	Initial Public Offering
IRR	Internal Rate of Return
IRS	Inertial Reference System
ISA	International Standard Atmosphere
ISO	International Organisation for Standardisation
IT	Information Technology
ITC	In-Trail Climbs
<b>J</b>	
JAA	Joint Aviation Authorities
JFA	Joint Financing Agreement
JTSO	Joint Technical Standard Orders
<b>K</b>	
KFW	Kreditanstalt Für Wiederaufbau
KPA	Key Performance Areas
KPI	Key Performance Indicators
<b>L</b>	
LAAS	Local Area Augmentation System
LAHSO	Land And Hold ShOrt
LAN	Local Area Networks
LATCC	London ATC Centre



LCD	Liquid Crystal Display
LEO	Low Earth Orbiting
LES	Land Earth Stations
LRNS	Long Range Navigation Systems
LVLASO	Low Visibility Landing And Surface Operations
<b>M</b>	
MA	Monitor Alert
MADAP	Maastricht Data Processing and Display System
MAS	Managed AirSpace
MASPS	Minimum Aircraft System Performance Specifications
MATSE	Ministers on the Air Traffic System in Europe
MDA	Minimum Descent Altitudes
MEL	Minimum Equipment List
MEO	Medium Earth Orbit
MET	METeorological services
MIDANPIRG	Middle East Air Navigation PIRG
MLS	Microwave Landing System
MMLS	Mobile MLS
MMR	Multi-Mode Receiver
MNPS	Minimum Navigation Performance Specification
MNT	Mach Number Technique
MoD	Ministry of Defence
Mode S	SSR Mode Select
MOPS	Minimum Operational Performance Standards
MSA	Minimum Sector Altitudes
MSAS	Multi-functional transport Satellite Augmentation System
MTOW	Maximum Take-Off Weights
MTR	Minimum Time Route
MTSAT	Multi-functional Transport geostationary SATellite
<b>N</b>	
NADN	National Aeronautical Data Network
NAMPG	North AMERICAN Planning Group
NAS	National Airspace System
NAT	North ATLantic
NATCA	National Air Traffic Control Association
NATS	National Air Traffic Services
NATSPG	North ATLantic Systems Planning Group
ND	Navigational Display
NDB	Non-Directional radio Beacons
NEAN	Northern European ADS-B Network
NEAP	North European ADS-B Applications Project
NERC	New En-Route Centre
NEXCOM	Next Generation Air-Ground Communications System
nm	nautical mile

NOTAM	NOTices to AirMen
NO <sub>x</sub>	nitrogen oxide
NPR	North Polar Region
NPRM	Notice of Proposed Rule Making
NPV	Net Present Value
NRP	National Route Programme
NTSB	National Transportation Safety Board
NTSO	National Technical Standard Orders
NUP	Network Update Programme
NWP	Numerical Weather Prediction

## O

OACC	Oceanic Area Control Centre
OCD	Operational Concept Document
OCP	Obstacle Clearance Panel
OLDI	On-Line Data-Interchange
ORD	Chicago
OSI	Open Systems Interconnection
OTF	On Track Flexibility
OTP	On-Time Performance
OTS	Organised Track Structure

## P

PAAST	Pan American Aviation Safety Team
PACTS	Parliamentary Advisory Committee on Transport Safety
PANS	Procedures for Air Navigation Services
PAR	Precision Approach Radar
PDC	Pre-Departure Clearance
PDT	Procedure Design Tools
PENS	Pan-European Fixed Network Services
PETAL	Preliminary Eurocontrol Test of Air-ground dataLink
pFAST	passive Final Approach Spacing Tool
PFD	Primary Flight Display
PFI	Private Finance Initiative
PHARE	Programme for Harmonisation of ATC Research in Eurocontrol
PIREP	Pilot REPort
PIRG	Planning and Implementation Regional Groups
PPM	Possible Pricing Mechanism
PPP	Public-Private Partnerships
PRC	Performance Review Commission
PRM	Parallel Runway Monitors
P-RNAV	Precision-RNAV
PRR1	Performance Review Report
PRU	Performance Review Unit
PSR	Primary Surveillance Radar

**R**

R&D	Research & Development
RA	Radio Altimeter
RA	Resolution Advisories
RAIM	Receiver Autonomous Integrity Monitoring
RCP	Required Communication Performance
RCS	Route Charges System
RFU	Radio Frequency Unit
RGCSPP	Review of the General Concept of Separation Panel
RHSM	Reduced Horizontal Separation Minima
RNAV	aRea NAVigation
RNP	Required Navigation Performance
ROI	Return On Investment
ROTO	Roll-Out and Turn-Off
RPI-X	Retail Price Index
RPK	Revenue Passenger Kilometre
RPPI	Reason Public Policy Institute
RSD	Retinal Scanning Display
RSP	Required Surveillance Performance
RTA	Required Time of Arrival
RTCA	Radio Technical Commission for Aeronautics
RTSP	Required Total System Performance
RVR	Runway Visual Ranges
RVSM	Reduced Vertical Separation Minima

**S**

SADC	Southern African states Development Community
SAE	Society of Automotive Engineers
SAR	Search And Rescue
SAR	Synthetic Aperture Radar
SARPs	Standards And Recommended Practices
SAS	Situational Awareness System
SASG	Safe African Skies Group
SATCOM	SATellite COMmunications
SAVE	Situation Awareness Virtual Environment
SBAS	Satellite-Based Augmentation Systems
SCAT-1	Special Cat I
SCATR	Specific Clear-Air Turbulence Risk
SDU	Satellite Data Unit
SELCAL	SElect CALling
SGS	Surface Guidance Systems
SICASP	SSR Improvements and Collision Avoidance Systems Panel
SID	Standard Instrument Departure
SIGMET	SIGNificant METeorological information
SMA	Surface Movement Advisor



SMGCS Surface Movement Guidance and Control Systems  
 SOP Safety Oversight Programme  
 SOPAC SOuthern PACific  
 SRC Safety Regulation Commission  
 SS Storm Scope  
 SSR Secondary Surveillance Radar  
 STAR STandard ARrival  
 STARS Standard Terminal Automation Replacement System  
 STDMA Self-organising Time Division Multiple Access  
 STOL Short Take-Off and Landing  
 SUA Special Use Airspace  
 SUPPS SUPPLEMENTary procedureS  
 SWOT Strengths, Weaknesses, Opportunities and Threats

## T

TA Traffic Advisories  
 TAAATS The Australian Advanced Air Traffic System  
 TACAN TACTical Air Navigation  
 TAP Terminal Area Productivity  
 TAWS Terrain Alerting and Warning Systems  
 TCAD Traffic and Collision Alert Device  
 TCAS Traffic alert and Collision Avoidance Systems  
 TCB Technical Co-operation Bureau  
 TCP Technical Co-operation Programme  
 TDMA Time Division Multiple Access  
 TEFL Thin-Film ElectroLuminescent  
 TFM Traffic Flow Management  
 TLS Target Level of Safety  
 TLS Transponder Landing System  
 TLS Transportation Landing System  
 TMA TerMinal control Areas  
 TMA Traffic Management Advisor  
 T-NASA Taxi-Navigation And Situational Awareness  
 TPLD Traffic Prediction Load Devices  
 TWIP Terminal Weather Information for Pilots

## U

UA Upper Airways  
 UMAS UnManaged AirSpace  
 UNDP United Nations Development Programme  
 URD User Requirements Document  
 URET User Request Evaluation Tool  
 US United States (of America)  
 US GAAP US General Accepted Accounting Principles

**V**

VAAC	Volcanic Ash Advisory Centre
VDL	VHF DataLink
VFR	Visual Flight Rules
VGS	Visual Guidance System
VHF	Very High Frequency
VLA	Very Large Aircraft
VLF	Very Low Frequency
VNAV	Vertical NAVigation
VOR	VHF Omni-directional radio Range
VORTAC	VOR TACTical air navigation
VSAT	Very Small Aperture Terminal

**W**

WAAS	Wide Area Augmentation System
WACS	Wireless Airport Communication System
WAFS	World Area Forecast System
WAFTAGE	Winds Analysed and Forecast for Tactical Aircraft Guidance in Europe
WAN	Wide Area Networks
WATS	World Air Transport Statistics
WMO	World Meteorological Organisation
WMS	Wide area Master Stations
WPR	Waypoint Position Reports
WRC	World Radio Conference
WRS	Wide area Reference Stations
WSI	Weather Services International

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**CHAPTER 1**  
**FUNDAMENTALS**

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## 1.1 Introduction

Air traffic congestion problems in many areas of the world are well known and have been highly publicised in recent years. Correspondingly, there is concern about safety levels in some worldwide airspace regions. For instance, the International Federation of Air Line Pilots' Associations (IFALPA) publicly denounced African airspace as "very dangerous" in 1996. Thus, there is an urgent need to alleviate airspace saturation. This airspace dilemma, which results in delays and other undesirable knock-on effects, is escalating at a phenomenal rate and requires immediate attention. Accordingly, it is imperative that significant growth in air transport movements does not reduce the safety of operations. Indeed, safety standards should be improved in some airspace regions.

Aircraft are currently controlled by a plethora of different air traffic systems that co-ordinate with pilots to guide aircraft to their destinations<sup>2</sup>. However, methods are sometimes seen as inefficient and unable to guarantee punctual or safe services at present, yet alone in the future. A multitude of reasons explain these problems. For instance, fragmentation of national systems prevents optimum use of the world's airspace. In addition, inherent limitations of Air Traffic Control (ATC) technologies and procedures mean that it is usually not possible to separate numerous aircraft on random routings. Thus, aircraft must often plan their flights along routes and be channelled so that necessary separation is maintained. Airspace capacity is consequently constrained.

Nonetheless, some solutions to the aforementioned predicaments have been developed and are encompassed under the auspices of the term, 'future air navigation systems'. This research investigates these systems and their worldwide implementation in the civil aviation arena. Specifically, this thesis addresses the need to evaluate and improve the introduction of the future air navigation systems around the world.

Thus, this chapter covers the fundamentals of these systems and this dissertation by:

- Emphasising that changes are necessary to current ATC based on stated economic facts and air transport delay statistics;
- Detailing efforts made by the International Civil Aviation Organisation (ICAO) to address this worldwide problem;
- Contrasting ICAO's efforts with the endeavours of other system 'stakeholders'<sup>3</sup>;
- Determining the scope for research in this area, followed by a list of objectives and the analytical methodologies that are employed;
- Outlining this dissertation's layout.

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<sup>2</sup> The objectives of air traffic services are to prevent collisions between aircraft, expedite & maintain an orderly flow of air traffic, provide advice or information useful for safe & efficient flights and to notify appropriate organisations regarding aircraft in need of search & rescue aid.

<sup>3</sup> Stakeholders are deemed to include airports, Air Navigation Service (ANS) providers, civil aviation authorities, financial institutions, general communities, ICAO, (aircraft and CNS/ATM equipment) manufacturers, military authorities, nations, (network service/satellite) communication providers, regions, regulators, in addition to (cargo/passenger airline, general aviation, leasing company and military) users and their staff. It should be noted that many of the aforementioned groups have representative associations or bodies.



## 1.2 Implications of congestion

With reference to the air congestion problems cited in **Section 1.1**, this section stresses the need to maintain satisfactory safety standards and reduce delays by highlighting basic civil aviation economic facts, in addition to discussing current safety levels and economic impacts of delays. Therefore, this section justifies the urgent requirement for worldwide implementation of future air navigation systems.

### 1.2.1 Economic essentials

By virtually any measure, civil air transport is a major economic force, as highlighted by the following facts from the Air Transport Action Group (ATAG)<sup>4</sup>:

- Over 1,600 million passengers used civil aviation in 1998;
- Based on 1998 Revenue Passenger Kilometre (RPK)<sup>5</sup> figures, North American airlines flew 40% of the world's total passenger traffic, while European carriers accounted for 26% and Asia-Pacific operators transported 24%. Accordingly, Middle Eastern airlines flew 3% and African carriers carried 2%;
- Almost 40% of the estimated 600 million annual worldwide international tourist arrivals were by air in 1998<sup>6</sup>;
- More than 29 million tonnes of freight were transported by air in 1998, representing approximately 40% of the world manufactured exports (by value);
- A turnover of \$307 billion<sup>7</sup> was generated by airlines in 1998, which is higher than the Gross National Product (GNP) of many economies;
- More than 3.9 million people were directly employed by air transport in 1998;
- In 1998, the world's airlines had a total fleet of about 18,000 aircraft operating over routes of approximately 15 million kilometres and serving nearly 10,000 airports.

Therefore, noting that the civil air transport industry benefits from global economic prosperity, it is evident that the industry is an essential part of the world's economy. In addition to transporting millions of people and goods, many industries rely upon and support air transport. Indeed, civil aviation significantly impacts the global economy through direct and indirect economic impacts: the aforementioned ATAG study calculates that, in 1998, civil aviation had a \$320 billion direct impact and \$390 billion indirect impact. It should be noted that recent decades have witnessed considerable economic growth rates up to these 1998 levels, which have been due to many factors, including the falling cost of air travel, increases in disposable incomes and liberalisation

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<sup>4</sup> *'The economic benefits of air transport (2000 Edition)' – Air Transport Action Group, 2000*

<sup>5</sup> RPK are obtained by multiplying the number of fare paying passengers on each flight by the corresponding sector distance. RPK indicates the size of a market.

<sup>6</sup> *'Economic assessment' – ICAO Rio de Janeiro Conference, 1998.*

<sup>7</sup> It should be noted that, to ease comparisons, all financial references are presented in US Dollars, with suitably timed conversion rates applied. Therefore, the symbol "\$" is used throughout the dissertation and does not refer to any other currency.



of airline markets. Such increases have placed ever-growing strain on Air Traffic Control (ATC) systems. It should be added that the rising trend is set to continue over the next two decades, according to the following forecasts:

- Air Transport World estimates that worldwide scheduled airline Revenue Passenger Kilometres (RPK) will increase in 2001 by 9% over 2000's value to 3,312,280 million, which represents an 80% rise from 1991 levels<sup>8</sup>;
- The International Civil Aviation Organisation (ICAO) forecasts that the world's scheduled passenger traffic will grow by 5.5% in 2001 and 5.3% in 2002, with rates varying from 4% to 7.4% for individual regions<sup>9</sup>. ICAO computes that the average annual rate of increase over the period 1997 to 2020 is 5%<sup>10</sup>;
- The International Air Transport Association (IATA) expects passenger and freight traffic to increase at an average annual rate of 4 to 5% until 2010, when the number of people travelling by air could exceed 2.3 billion<sup>11</sup>;
- Accordingly, Airbus Industrie's 1999 market forecast<sup>12</sup> predicts that RPK will grow at an average 5% per annum until 2018, while cargo traffic will grow at an average annual rate of 5.9% in terms of Freight Tonne-Kilometres (FTK), which is the cargo equivalent of RPK. In addition, the Airbus forecast believes that the active worldwide passenger fleet will nearly double from 10,000 in 1998 to 19,106 in 2018. Most importantly, however, is the forecast fact that "the world's airports and air traffic [control] systems will have to accommodate a 95% increase in numbers of passenger flights". Noting that freight traffic is not included, this latter point emphasises the sheer scale of forward planning that is required for adequate provision of future air navigation systems;
- In a similar manner, the Boeing 2000 forecast<sup>13</sup> believes that passenger traffic growth will average at 4.8% and cargo traffic at 6.4% per annum until 2019. However, in contrast with the Airbus finding, Boeing believes that the passenger aircraft market will consist of 28,558 aircraft in 2019, while 3,197 will serve freighter markets. This reiterates the point that ATC systems will have to accommodate much greater levels of traffic in the next two decades;
- Correspondingly, the Rolls-Royce 2000 forecast<sup>14</sup> calculates that 18,740 aircraft deliveries will be required between 2000 and 2019, with 7,360 to replace existing airplanes and 11,380 to accommodate market growth. Rolls-Royce predicts that the worldwide passenger fleet in 2020 will consist of 22,600 aircraft, noting that this figure lies in between the Airbus and Boeing forecasts. Irrespectively, it confirms the present estimations that aircraft numbers will double over the next two decades.

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<sup>8</sup> 'Rising hopes for a soft landing' – *Air Transport World*, January 2001.

<sup>9</sup> 'ICAO forecasts strong short-term scheduled passenger growth' – *Air Transport Intelligence*, 23 June 2000.

<sup>10</sup> 'Traffic forecasts' – *Working Paper 13, ICAO Air Navigation Services Conference 2000*.

<sup>11</sup> 'The economic benefits of air transport (2000 Edition)' – *Air Transport Action Group*, 2000.

<sup>12</sup> 'Global Market Forecast (GMF'99)', *Airbus Industrie*, 1999.

<sup>13</sup> 'Current Market Outlook', *Boeing*, 2000.

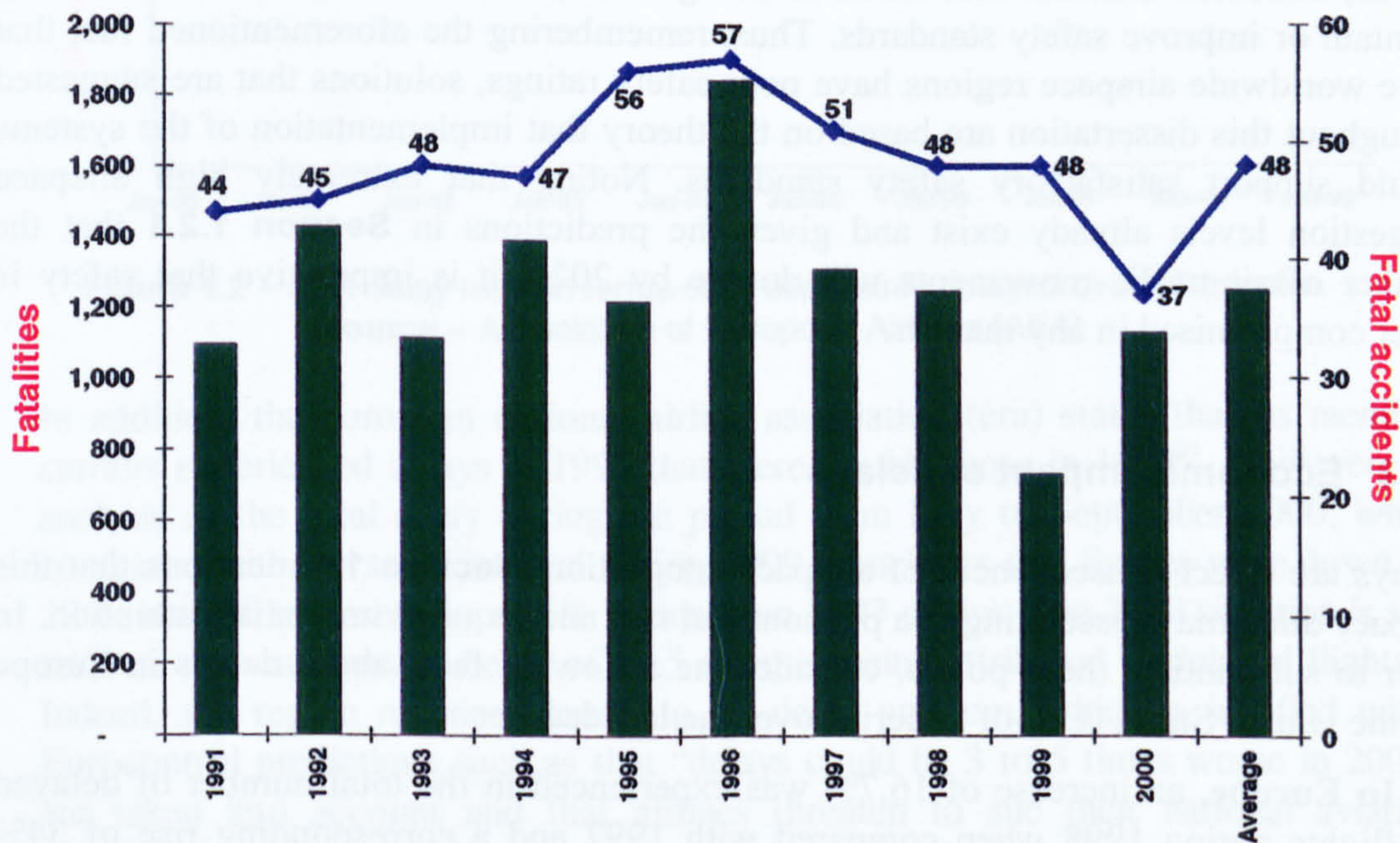
<sup>14</sup> 'the outlook', *Rolls-Royce*, 2000.



## 1.2.2 Safety standards

Accidents and incidents in recent years have caused concern among the general public and aviation officials alike. For instance, the Singapore Airlines Boeing 747-400 that crashed at Taipei airport in poor weather conditions during October 2000<sup>15</sup> has worried the industry because 83 people were killed when the cockpit crew of an aircraft with sophisticated systems on-board tried to take-off from a closed runway. Correspondingly, the incident at Oslo Gardermoen airport in March 2000, when a cascade of errors left three Boeing MD-80s landing and taking-off simultaneously on the same runway<sup>16</sup>, distresses those thinking about the fact that runways will have to accommodate higher numbers of aircraft in the future in order to meet demand. It is feared that, ultimately, the increased presence of aircraft on the ground and in the air will saturate the system, leading to incidents more frequently, which will result in more accidents.

However, **Figure 1.1** demonstrates that, with the most notable exception of 1996, the number of fatal accidents and fatalities in civil aviation accidents per annum during the 1990s remained relatively constant. Indeed, when coupled with the fact that, as stated in **Section 1.2.1**, worldwide traffic levels in 2001 are 80% higher than during 1991, it is evident that the average fatality rates have been declining in the last decade.



**Figure 1.1** – Number of fatal accidents and fatalities in civil aviation from 1991 to 2000

Source – Flight International (23 January 2001)

Accordingly, data produced in 2000 by the United Kingdom's 'Airprox Board', which was set up as an independent body by the country's Civil Aviation Authority (CAA) and

<sup>15</sup> 'SIA captain ignored crew warnings in Taipei 747-400 crash says report' – Flight International, 27 February 2001.

<sup>16</sup> 'MD-80s avoid disaster at Oslo' – Flight International, 21 March 2000.



Ministry of Defence (MoD), indicate that incidents in their airspace were significantly reduced over the period 1990 to 1999 in terms of air proximity rates per 100,000 flight hours<sup>17</sup>. Noting that there was a 48% increase in UK air transport flying hours during that time interval, the statistics reconfirm that relative safety was improved. In addition, this fact is reiterated by results from experts<sup>18</sup>, who claim that the present worldwide fatal accident rates for Western-built jet transport aircraft at 0.2 per million flights and 0.4 per million flights for Western-built turboprops, may be compared with their 1990 corresponding values of 0.3 and 0.8 respectively.

Nonetheless, the latter experts believe that present worldwide fatal accident rates for jets must halve during this decade if acceptable levels of risk are to be maintained. The rate by which accidents must apparently fall for turboprop aircraft is one-fifth. Therefore, it would appear that, although safety standards have improved in recent years and are currently being maintained, there is a need to adopt a safety-conscious culture in all aspects of air transport so that the actual number of accidents and incidents remains constant, if not reduced. The good news is that future air navigation systems can aid this process, but the bad news is that their successful worldwide implementation is far from guaranteed at present: this is one of the explanations of why **Section 1.1** mentions the need to improve the introduction of the systems around the world.

Indeed, this thesis assumes that future air navigation systems are only introduced if they maintain or improve safety standards. Thus, remembering the aforementioned fact that some worldwide airspace regions have poor safety ratings, solutions that are suggested throughout this dissertation are based on the theory that implementation of the systems should support satisfactory safety standards. Noting that extremely high airspace congestion levels already exist and given the predictions in **Section 1.2.1** that the number of air traffic movements will double by 2020, it is imperative that safety is never compromised in any manner.

### **1.2.3 Economic impact of delays**

Delays are direct consequences of airspace congestion. **Section 1.1** mentions that this airspace dilemma is escalating at a phenomenal rate and requires immediate attention. In order to substantiate these points, consider the following facts about delays in Europe and the United States (US) of America over the last decade:

- **In Europe**, an increase of 16.7% was experienced in the total number of delayed flights during 1998 when compared with 1997 and a corresponding rise of 34% over the period 1998 to 1999. An average delay value attributed to every flight indicates that 1998's value was 24.5% higher than 1997, noting that the average delay was 46.6% higher during the summer of 1998 than 1997, while the equivalent rate for winter was 20.2% greater in 1998 than in 1997. There was a subsequent, significant increase of 50% during 1998/1999. Accordingly, the system experienced

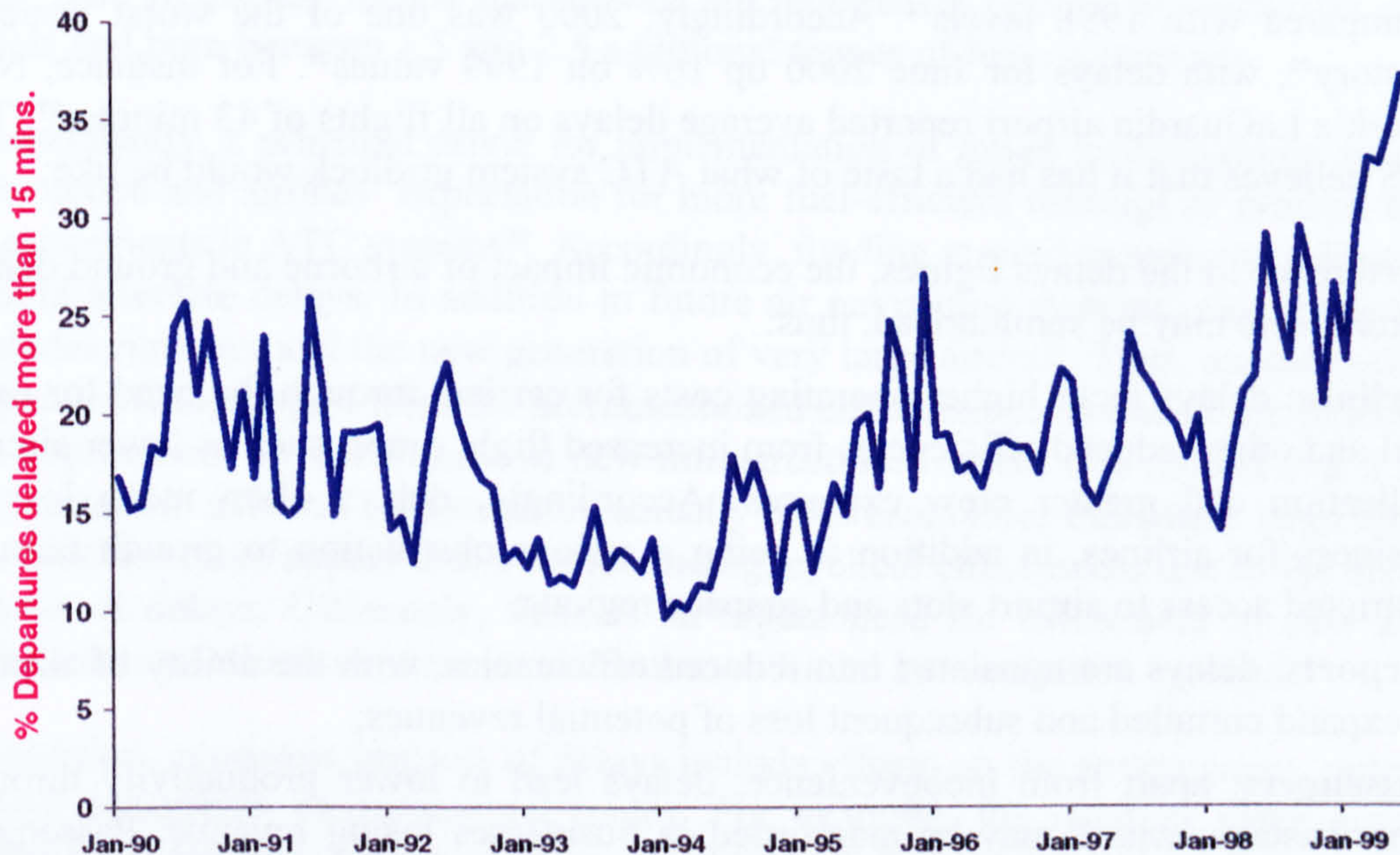
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<sup>17</sup> 'UK airprox figures show cause for optimism' – Air Transport Intelligence, 2 October 2000.

<sup>18</sup> 'Jet accident rate must halve by 2010: UK CAA' – Air Transport Intelligence, 14 June 2000.



a total delay, in terms of minutes, in 1998 that was 30.7% greater than 1997's. The corresponding change between 1998 and 1999 was +58%<sup>19</sup>, which equates to 320 aircraft being permanently grounded<sup>20</sup>. Additionally, statistics in terms of the percentage of departures delayed over 15 minutes, that are produced on a monthly basis by the Association of European Airlines (AEA) for its member carriers on European routes, portray the evolution of delays in the European region during the 1990s (see **Figure 1.2**). The trend towards increased levels of delay in the latter half of the 1990s is confirmed.



**Figure 1.2** – AEA delay rates in terms of % departures delayed over 15 minutes  
**Source** – Association of European Airlines (AEA)

In addition, the European regional airline association (era) states that its member carriers experienced delays in 1999 that were double those in 1998<sup>21</sup>. However, an analysis of the total delay during the period from May to September 2000, when compared with the same interval during 1999, concludes that figures were down by 29%, but still representing a 21% increase on 1997 delays. The 2000 situation is still serious, with an average delay of 19.5 minutes being attributed to delayed flights<sup>22</sup>. Indeed, the region remains alerted to its delay problem, which is justified when Eurocontrol predictions such as that “delays could be 3 to 5 times worse in 2005” are taken into account and that airlines threaten to sue their national aviation authorities over failing to reduce the costly delays<sup>23</sup>;

<sup>19</sup> Eurocontrol cites the implementation of a new route network and the Kosovo crisis as major factors for this increase. In addition, no measurable increase in overall system capacity was achieved in 1999, primarily due to a lack of capacity in a small number of sectors.

<sup>20</sup> ‘1999 delays equivalent to 320 aircraft permanently grounded’ – era regional report, April 2000.

<sup>21</sup> ‘1999 congestion-induced delays doubled’ – era performance, October 1999.

<sup>22</sup> ‘delay figures still poor’ – era regional report, October 2000.

<sup>23</sup> ‘Lufthansa threatens government with court over delays’ – Air Transport Intelligence, 6 March 2000.



- **In the US, a similar saga exists regarding the escalation of delays: the Air Transport Association (ATA) estimates that the average delay among all departures by US carriers in 1998 that were attributable to Air Traffic Control (ATC) was 7.9 minutes per aircraft. Noting that there were over 8 million departures by US carriers in 1998, this ATC-related delay equates to over 1 million hours, which is the equivalent of not using 365 aircraft for an entire year, based on an average use of 3,000 hours per aircraft. Indeed, it should be noted that US carriers experienced an increase of nearly 20% in flight delays during the first 8 months of 1999 when compared with 1998 levels<sup>24</sup>. Accordingly, 2000 was one of the worst years in history<sup>25</sup>, with delays for June 2000 up 16% on 1999 values<sup>26</sup>. For instance, New York's LaGuardia airport reported average delays on all flights of 43 minutes<sup>27</sup>. The US believes that it has had a taste of what ATC system gridlock would be like;**

With reference to the delays figures, the economic impact of airborne and ground delays on stakeholders may be summarised, thus:

- **Airlines:** delays incur higher operating costs for carriers through the need for extra fuel and other reduced efficiencies from increased flight times, such as lower aircraft utilisation and greater crew expenses. Accordingly, delays often mean loss of business for airlines, in addition to being a serious obstruction to growth through restricted access to airport slots and airspace regions;
- **Airports:** delays are translated into reduced efficiencies, with the ability of airports to expand curtailed and subsequent loss of potential revenues;
- **Passengers:** apart from inconvenience, delays lead to lower productivity through time wastage, which may be manifested in businesses losing revenue. Passengers undoubtedly pay more for flight tickets due to congestion because airlines often pass on their costs. Indeed, US carriers have recently created a fuel surcharge tax, which is added to the ticket price. Although this is primarily designed to offset increases in average fuel costs, delays magnify the burden. In addition, delays reduce the propensity of passengers to fly due, mainly, to operational unreliability;
- **Aircraft manufacturers and their supporting firms:** congestion can lead to lower production of aircraft as fewer may be required due to restrained growth, although it could be argued that users will purchase more aircraft to accommodate delays;
- **Nations:** governments are deprived of tax and fee income, with corresponding loss of revenues.

Hence, delays are manifested by higher costs. Indeed, noting the sheer size of the civil aviation industry (see **Section 1.2.1**), the costs are bound to be significant. For instance, calculations by Eurocontrol<sup>28</sup> suggest that the cost to airlines and passengers of air traffic delays in Europe during 1999 was approximately \$5.9 billion. In the US, a 1999

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<sup>24</sup> *'The economic benefits of air transport (2000 Edition)' – Air Transport Action Group, 2000.*

<sup>25</sup> *'FAA figures paint dismal 2000 delay picture' – Air Transport Intelligence, 1 February 2001.*

<sup>26</sup> *'US ATC delays soar again' – Airline Business, August 2000.*

<sup>27</sup> *'FAA outlines full extent of LaGuardia delay horror story' – Air Transport Intelligence, 9 November 2000.*

<sup>28</sup> *'Special Performance Review Report on delays' – Performance Review Commission, November 1999.*



study by the ATA indicates that air traffic control delays in 1998 cost US airlines and their passengers more than \$4.5 billion<sup>29</sup>. In order to put these figures into context, consider IATA's claim that a \$2.6 billion one-off capital cost to airlines for future air navigation system avionics is predicted<sup>30</sup>, while the potential annual benefit to the global aviation community from implementation of the systems is estimated at between \$5.2 to 6.6 billion<sup>31</sup>. It should be noted that additional fuel requirements are part of these cost estimates, which, in addition to their environmental implications (see hereunder), increase airline expenses. For instance, congestion on routes between Europe and South East Asia frequently means that aircraft are required to operate at inefficient cruising levels and burn between 1.5 and 2.5 additional tonnes of fuel on each trip.

Consequently, a principal driver for implementation of future air navigation systems is their scope and airlines' expectation for more fuel-efficient routings or profiles through improvements in ATC systems<sup>32</sup>. Accordingly, funding ground or airborne infrastructure should alleviate delays. In addition to future air navigation systems, new infrastructure includes runways and the new generation of very large aircraft. Thus, another economic impact of delays, apart from the aforementioned additional costs due to inefficiencies, is the requirement for investment in new infrastructure. Indeed, it is argued that a lack of investment in aviation infrastructure actually costs economies extremely large amounts. It would therefore appear that a compounding, cyclical effect exists due to the economic impact of delays. Ultimately, there is an urgent need for investment in new aviation infrastructure, which requires an evaluation of future air navigation systems.

In addition, economic impacts of delays include effects on the environment, noting that delays exacerbate environmental issues. For example, the need to place aircraft in holding or stacking patterns results in additional fuel usage and noxious emissions, which are wastes of energy and lead to unnecessary pollution. Therefore, there is a need to reduce this undesirable consequence of delays, which is possible by increasing the environmental efficiency of aircraft engines. Indeed, given the success indicated by the following facts<sup>33</sup>, it is essential that engines continue to be improved:

- Aviation consumes approximately 12% of the transport industry's oil supplies;
- Jet aircraft produce 2-3% of global, man-made nitrogen oxide (NO<sub>x</sub>) emissions;
- Aircraft presently being produced are 75% quieter than 30 years ago;
- Airlines have doubled their fuel efficiency over the last 30 years;
- Modern engines emit virtually no carbon monoxide (CO) or hydrocarbons (HC).

Thus, fuel-efficient engines should be amalgamated with the worldwide implementation of future air navigation systems to minimise the negative economic impact of delays.

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<sup>29</sup> *'The economic benefits of air transport (2000 Edition)' – Air Transport Action Group, 2000.*

<sup>30</sup> <http://www.iata.com>.

<sup>31</sup> *'Report of the Fourth Meeting of the Special Committee on Future Air Navigation Systems' – ICAO Doc 9524, 1988.*

<sup>32</sup> The ATAG believes that improvements in fuel burn per trip of 6-12% are possible.

<sup>33</sup> *'Aviation & the environment' – Air Transport Action Group, 2000.*



## **1.3 ICAO's future air navigation systems**

Problems with current Air Traffic Control (ATC) systems are mentioned in **Section 1.1**, while **Section 1.2** discusses associated safety standards and implications of delays. The urgent need for changes to present ATC systems is evident from both sections. Indeed, reference is made in the sections to the fact that future air navigation systems have been developed to replace the current ATC infrastructure. Accordingly, this section describes the efforts conducted by the International Civil Aviation Organisation (ICAO).

### **1.3.1 The FANS committees and their concept**

ICAO's Special Committee on Future Air Navigation Systems (FANS), which was formed in 1983, was tasked with studying, identifying and assessing new technologies, including satellite technology, in addition to making recommendations for the future development of air navigation for civil aviation over a twenty five year period. The committee completed its work in 1988. Aside from determining that the shortcomings inherent in the ATC systems of the time were incapable of supporting the future needs of civil aviation, the committee concluded that satellite technology offered the only viable solution. Indeed, it stressed that satellite-based systems would be the key to worldwide improvements in civil aviation<sup>34</sup>.

On the recommendation of the FANS committee, ICAO set up the FANS Phase II committee in 1989 to monitor and co-ordinate the development and transition planning to the future air navigation system. It instantly recognised that the satellite-based system, by definition, would be a shared resource<sup>35</sup>. This was contrary to traditional implementation of systems, whereby individual nations procure, certify, operate and maintain their own ground-based portions of air navigation systems. It should be noted that ICAO's air navigation plans enable use of this infrastructure for international civil aviation purposes. Therefore, it was realised that, if the new systems were to be successfully implemented on a global scale, a radically different attitude to system integration between neighbouring civil aviation authorities would be needed. Nations could no longer form air traffic systems to suit their own needs in terms of individual, military and political interests. This would result in interfacing problems, which would inhibit the smooth flow of information and air traffic.

The FANS Phase II committee determined that the goals of the future system should include "enhanced safety, accommodation of the full range of aircraft types and airborne capabilities, improvement of provision of information to users (weather, traffic situation, availability of facilities), flexible airspace management, efficient use of airspace, increased user involvement in ATM decision making (through air-ground

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<sup>34</sup> 'FANS Committee proposes a consolidated global CNS plan' – ICAO Bulletin, June 1988.

<sup>35</sup> 'Specialist providers offer cost-effective approach to obtaining ATS satellite communications' – ICAO Journal, June 1993.



computer dialogue) and creation, to the extent possible, of a single continuum of airspace where boundaries are transparent to the users.”<sup>36</sup> The committee completed its work in 1993, recognising that implementation of related technologies and expected benefits would not arrive overnight, but that they would evolve over a period of time depending upon the region and its nations’ aviation infrastructures. It also agreed that much of the technology they were considering was becoming available.

Correspondingly, the committee report outlined the ICAO Future Air Navigation Systems (FANS) concept that had been developed. The following two quotes by Dr Kotaite, President of the ICAO Council, introduce the FANS concept and underline the need to assess its implementation from a global perspective:

“The future air navigation system, which departs significantly from the conventional one, requires global implementation” (1992)

“The future air navigation systems [FANS] concept, which has been developed by ICAO and has now evolved to become known as the ICAO Communications, Navigation, Surveillance and Air Traffic Management [CNS/ATM] systems (concept), is essentially the application of today’s high technologies in satellites and computers, datalinks and advanced flight deck avionics, to cope with tomorrow’s operational needs” (1993)

In essence, CNS/ATM encapsulates the objective of ICAO’s FANS, which is to:

- Enhance **communication** links between aircraft and air traffic controller;
- Improve pilots’ abilities to **navigate** their aircraft safely;
- Increase air traffic controllers’ capacities to monitor and **survey** flights;
- Apply more efficient and flexible **air traffic management** techniques.

Therefore, CNS/ATM involves the implementation of new technologies and procedures that fuse together to optimise the potential of airport and airspace resources so that the capacity, flexibility and safety of these resources are maximised. According to Galotti<sup>37</sup>, the CNS/ATM systems concept involves a complex and interrelated set of technologies (and procedures), dependent mainly on satellites<sup>38</sup>. The concept aims for automated CNS systems to provide enhanced ATM through continuous information on aircraft positions and intentions so that a reduction in aircraft separation is possible without compromising safety requirements. CNS/ATM systems are intended to enhance safety, reduce delays, increase capacity, enhance system flexibility and reduce operating costs. Accordingly, CNS/ATM’s desire for standardised systems located worldwide aims to harmonise airspace regions. With reference to the aforementioned fact that CNS/ATM systems consist of many technologies and procedures, there is a need to evaluate how CNS/ATM is structured and whether each is being developed in an expeditious or timely manner.

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<sup>36</sup> *Report of the Fourth Meeting of the Special Committee for the Monitoring and Co-ordination of Development and Transition Planning for the Future Air Navigation System* – ICAO Doc. 9623, 1993.

<sup>37</sup> *The Future Air Navigation System* – Chapter 1, V Galotti, 1997.

<sup>38</sup> It is thought that a detailed list of CNS/ATM’s technologies and procedures is beyond the scope of this chapter. Therefore, it is given in subsequent chapters.



### **1.3.2 Post FANS II: the 10<sup>th</sup> Air Navigation Conference to date**

In September 1991, representatives from ICAO contracting countries gathered for the 'Tenth ICAO Air Navigation Conference' in order to consider and review the work achieved by the FANS committees<sup>39</sup>. Ultimately, the conference<sup>40</sup> endorsed the official designation for the FANS concept (CNS/ATM) and noted that "the exploitation of technology, especially in space and ground segments, had progressed to the point where airspace users were beginning to derive significant benefits. Maritime transport, for example, had already made extensive use of satellites for navigation and communication. The pace of change was quickening, and aircraft operators and air traffic service providers were committing themselves more and more to the available technology."

Conference representatives recognised that the CNS/ATM systems concept offered solutions to the shortcomings of present ATC systems, whilst taking advantage of existing and foreseen technologies. However, even though the CNS/ATM concept has identified certain technologies and procedures, it should be noted that other systems exist, which will undoubtedly be part of the future air navigation systems. Indeed, this is another reason why an (independent) evaluation of future air navigation systems is needed. Nonetheless, by definition of ICAO's international rôle, its CNS/ATM systems concept may be seen as the basis of future air navigation systems. Additionally, given its mandate to guide worldwide civil aviation, ICAO is ideally placed to further the implementation of CNS/ATM systems.

Thus, there is a need to discuss the next major milestone in the CNS/ATM calendar during the 1990s: ICAO convened the representatives of the world's civil aviation authorities, aviation industry and the financial community during May 1998 to discuss financing arrangements for the CNS/ATM systems in Rio de Janeiro<sup>41</sup>. They also discussed a global strategy for managing the future air navigation systems. The importance of CNS/ATM to the world economy and the potential for a healthy return on investment were the main themes. The conference stressed the need for partnership among nations, manufacturers, airlines and financial institutions. Ultimately, according to Dr. Kotaite, the "meeting succeeded in focusing the attention of the world aviation community like never before on the primary issues of financing and management of CNS/ATM systems."

Although the conference emphasised that comprehensive implementation of future air navigation systems merely required addressing financial and management issues, in addition to the fact that the introduction of CNS/ATM technologies and procedures would solve all problems, little progress in terms of uniform introduction has been witnessed since the 1998 meeting. Thus, there is a distinct requirement for development of methods to expedite the worldwide implementation of future air navigation systems.

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<sup>39</sup> *'The Future Air Navigation System' – Chapter 1, V Galotti, 1997.*

<sup>40</sup> *'Report of the Tenth Air Navigation Conference' – ICAO Doc. 9583, 1991.*

<sup>41</sup> *'Rio Conference explores innovative approaches to financing and managing CNS/ATM systems' – ICAO Journal, June 1998.*



### 1.3.3 The ICAO process

Given the important rôle that ICAO plays in international aviation and in the CNS/ATM arena, an overview of its structure and mechanisms is deemed pertinent as part of this discussion on ICAO's efforts. Additionally, noting that this thesis frequently refers to the ICAO process, it is considered useful to provide a background synopsis of the organisation. However, this summary aims to only be introductory in nature because ICAO activities are referred to throughout this dissertation.

ICAO was formed in 1944, ironically to harmonise international aviation, when it accepted the established US communications and navigation systems as the worldwide standard for air traffic control. One of ICAO's original goals was to standardise the world's aviation systems through the development and dissemination of suggested procedures for aviation regulatory agencies. Thus, ICAO develops Standards And Recommended Practices (SARPs)<sup>42</sup>, which are classified as Annexes to the ICAO Chicago Convention. Annexes 2 and 11 to the Convention detail the rules of the air and air traffic services<sup>43</sup> respectively, which are also covered in a 'Procedures for Air Navigation Services' (PANS) document. ICAO's regulatory powers are minimal, but countries use its SARPs as the basis of their national rules, albeit at each country's discretion. Even though all countries produce their own legislation, the adoption of SARPs by all ICAO Contracting countries, which is a prerequisite for joining ICAO, means that similar navigation aids and procedures are employed around the world.

ICAO's Air Navigation Commission (ANC) has the responsibility for examining, co-ordinating and planning the international navigation standards and procedures. Hence, it plays a pivotal rôle in ICAO's decision-making process. Its panels<sup>44</sup>, whose members include representatives from industry, carry out a lot of the technical work. Accordingly, regional Air Navigation Plans (ANP) establish the necessary requirements for air navigation facilities and services<sup>45</sup>, which contracting countries agree to implement. The ICAO Planning and Implementation Regional Groups (PIRG) perform planning at a regional level, sometimes in conjunction with other regional bodies. The world is split into seven regional planning groups, thus:

- APANPIRG for the Asian & Pacific region;
- APIRG for the African region;

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<sup>42</sup> It should be noted that SARPs are continuously reviewed and updated. It should also be added that new SARPs have and continue to be created for CNS/ATM systems.

<sup>43</sup> Annex 11 pertains to the establishment of airspace and services necessary to promote safe, orderly and expeditious flow of air traffic.

<sup>44</sup> Examples of the ANC's panels are the ADS Panel (ADSP), Aeronautical Mobile Communications Panel (AMCP), ATM operational Concept Panel (ATMCP), ATN Panel (ATNP), All Weather Operations Panel (AWOP), GNSS Panel (GNSSP), Obstacle Clearance Panel (OCP), Review of the General Concept of Separation Panel (RGCSPP), in addition to the SSR Improvements and Collision Avoidance Systems Panel (SICASPP).

<sup>45</sup> The plans encompass aerodrome operations, air traffic service routes & nav aids, airspace & traffic management, air traffic services, aeronautical information services, meteorological services, search & rescue services and aeronautical communications.



- EANPG for the European region;
- GREPECAS for the Caribbean & South American region;
- MIDANPIRG for the Middle Eastern region;
- NATSPG for the North Atlantic region;
- NAMPG for the North American region.

To ensure that the regional plans are harmonised, the ICAO PIRGs report to ICAO's Council, ANC and ALLPIRG. The ICAO ALLPIRG is an interregional co-ordination mechanism and advisory group, which represents the PIRGs and aviation stakeholders. Hence, in addition to presence on panels for some stakeholders, all factions now have direct input to the ICAO regional process. Additionally, the PIRGs participate with developing or updating SARPs and providing technical assistance to countries. PIRGs specify requirements for infrastructure facilities and services to supply adequate air navigation services, which are based on computed traffic forecasts. Indeed, in its most basic form, the output from the regional process is a listing of air navigation facilities and services together in the relevant regional ANPs.

ANPs also cite each region's basic operational requirements and planning criteria. In addition, the plans contain regional SUPplementary procedureS (SUPPS), which ICAO develops in conjunction with SARPs and PANS. SUPPS may indicate modes of implementing provisions in SARPs and PANS. Technical manuals and guidance material are issued so that countries introduce SARPs and PANS. Accordingly, it should be noted that a Global ANP has been created as a living document. It aims to be the basis for development of a Facilities and Services Implementation Document (FASID), which plans to contain future regional-specific details.

The ICAO Council adopted a new strategic action plan in 1997, which is the first comprehensive re-evaluation of ICAO's mission since it was formed, so that ICAO can adapt to the changing air transport environment. In addition, the plan states that ICAO will, among other objectives:

- Foster, develop and adopt new or amended SARPs;
- Ensure that regional ANPs are current;
- Strengthen the legal framework;
- Provide guidance on economic regulation.

One key activity of the plan is the creation of a Safety Oversight Programme (SOP), which audits countries' aviation systems, including air traffic services, using a method that is based on the US Federal Aviation Administration's International Aviation Safety Assessment programme. In addition, the SOP provides technical assistance to overcome shortcomings. The SOP, which is part of ICAO's Global Aviation Safety Plan (GASP), was one of the first decisions by ICAO member countries that did not require a vote.

Correspondingly, it should be added that ICAO is also active in some non-air navigation matters that impact the implementation of future air navigation systems. For instance, ICAO produces numerous publications with data on airline and airport traffic. In addition, ICAO provides technical co-operation and training programmes.

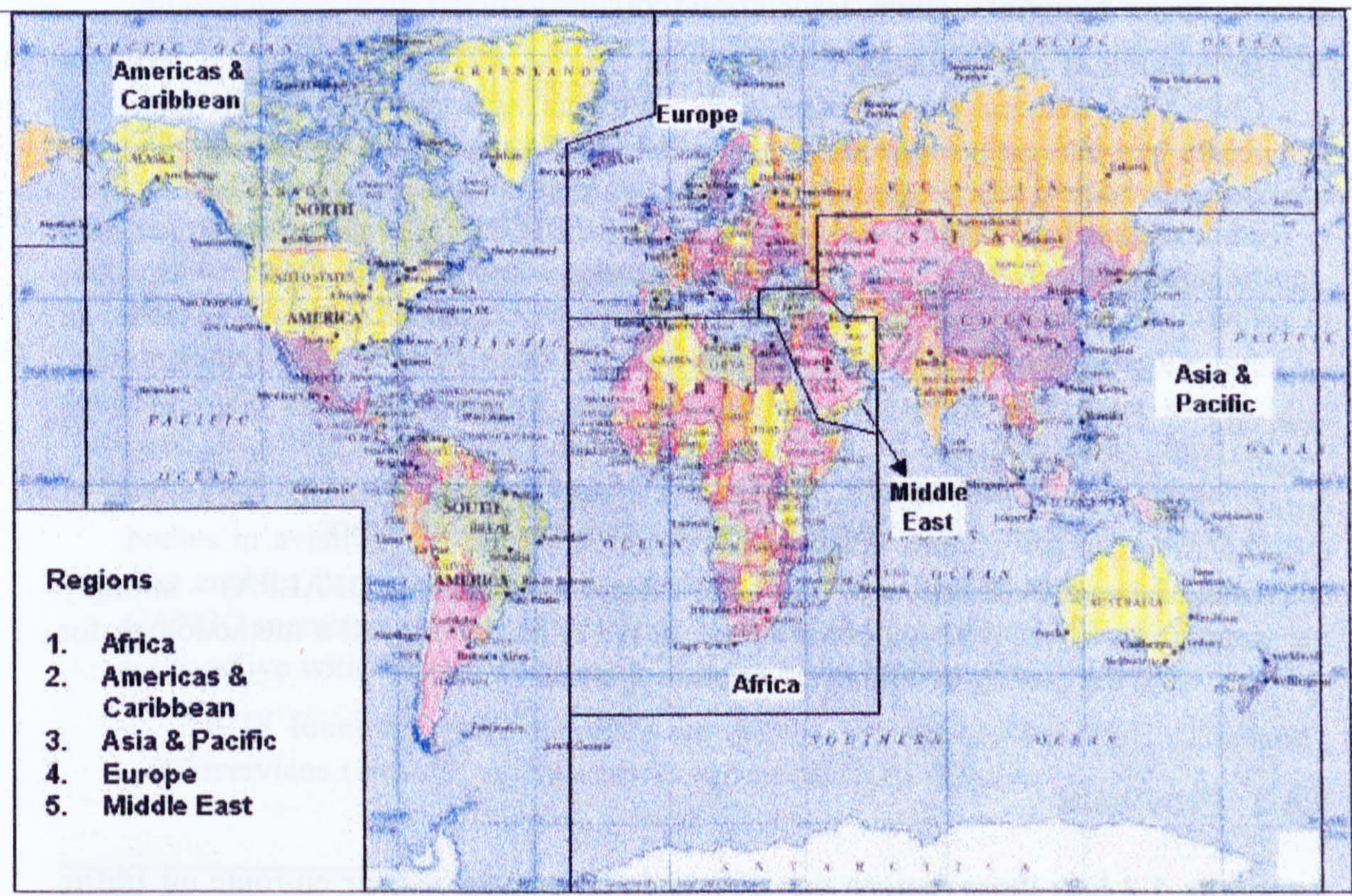


## 1.4 Other stakeholders' CNS/ATM

In contrast with **Section 1.3**'s discussion on efforts by ICAO regarding future air navigation systems, this section highlights other stakeholders that are actively pursuing the worldwide implementation of CNS/ATM and briefly overviews their endeavours so that the main players are identifiable. It should be noted that the term 'CNS/ATM' has become synonymous with all 'future air navigation systems' and not just those in the ICAO concept. Thus, any reference in this thesis to either term has the same meaning.

### 1.4.1 Nations and regions

With reference to **Appendix 1.1**, this research considers 205 countries so that analyses on future air navigation systems adopt truly worldwide perspectives. As outlined in the appendix and portrayed in **Figure 1.3**, the nations are divided into five regions, although specific reference is sometimes made to oceanic regions. It should be noted that the map portrays approximate locations of the regions' borders, given that the specific layout of Flight Information Region (FIR) boundaries affects line positions.



**Figure 1.3** – World map indicating the five regions used in this dissertation

185 of the 205 nations in **Appendix 1.1**'s list are ICAO Contracting States. Therefore, by definition of their membership obligations, these countries should be involved in furthering the worldwide implementation of CNS/ATM. However, some national



aviation authorities are much more progressive than others. Indeed, many have not prepared any plans yet. This emphasises the need for an investigation of future air navigation systems' implementation to date. In addition, those 20 non-ICAO nations or territories are usually so small and attach little importance to national aviation that their implementation plans would not greatly affect the worldwide process. Correspondingly, with reference to the list of ICAO regional groups in the **Section 1.3.3**, it is clear that each of the five regions is pursuing integration of CNS/ATM systems, albeit at different levels of activity.

#### **1.4.2 Users**

In addition to participation by many airlines in flight trials and certification processes, different user industry representative bodies are involved in furthering the introduction of CNS/ATM. They include:

- ❑ **Air Transport Association (ATA) in the US;**
- ❑ **Association of European Airlines (AEA);**
- ❑ **European regional airlines association (era);**
- ❑ **International Air Transport Association (IATA) – IATA is extremely active in CNS/ATM matters. Being aware that a regional approach to implementation of future air navigation systems is essential, IATA produced an action plan for European Air Traffic Control (ATC) based on Eurocontrol plans and has developed other regional plans that have become part of the ICAO regional planning process. Accordingly, IATA has helped some nations around the world with their CNS/ATM plans through its industry support initiative. The IATA technical committee is on ICAO panels, while the IATA financial committee has endorsed aspects such as cost-benefit analysis and cost recovery of CNS/ATM systems through user charges. In addition, IATA runs the annual 'Global Navcom' conferences and produces the 'FANS FACTS' newsletter. However, the newsletter is being published at less frequent intervals than in previous years;**
- ❑ **International Federation of Air Line Pilots' Associations (IFALPA) – strongly supporting CNS/ATM implementation, IFALPA has developed a methodology for assessing the quality of countries' aviation systems.**

#### **1.4.3 Providers**

**Appendix 1.2** lists those nations that outsource all or part of their en-route air traffic services to regional provider agencies. Five main agencies exist in various regions of the world and are described in **Appendix 1.3**. Similar to the ICAO regional groups mentioned in **Section 1.4.1**, the en-route agencies vary in their commitment and activities related to the worldwide implementation of future air navigation systems. It should be added that the endeavours on the part of Eurocontrol, in particular, are cited throughout this thesis.



Correspondingly, many air traffic controller associations exist, which are quite powerful in terms of their ability to severely disrupt the system. For example, the International Federation of Air Traffic Controllers Associations (IFATCA) voices the perspectives of its member organisations. Accordingly, the National Air Traffic Controllers Association (NATCA) is influential in decisions made regarding ATC in the US. NATCA has produced studies on ATC 'provocative issues' and it should be added that NATCA represents more disciplines than air traffic controllers<sup>46</sup>.

#### 1.4.4 Multi-stakeholders

Organisations that have members from a range of stakeholder types exist<sup>47</sup>. Noting that such co-operative tendencies enhance the worldwide CNS/ATM system implementation process, the following multi-stakeholder organisations exist:

- **Air Transport Action Group (ATAG)** – the ATAG is active with CNS/ATM. For instance, it is participating in the European Commission's Industry and Social Group, dealing with Air Traffic Control (ATC) systems. ATAG consists of airlines, controllers, pilots, airports and ATC providers. Its aim is to lobby for capacity improvements in an environmentally responsible manner. Airbus Industrie, Boeing and IATA are its funding members, although it has 80 other members<sup>48</sup>. **Section 1.2** draws from some of its recent reports;
- **CNS/ATM Focused Team (C/AFT)**<sup>49</sup> – originally founded in 1996 by Boeing as an informal, airline-driven group, C/AFT now also has representatives from Airbus Industrie, Eurocontrol, MITRE and the US Federal Aviation Administration. It is split into four separate focus groups: Financial Performance, Integrated Solutions, NEXCOM and Operations Analysis. C/AFT is presently redirecting its efforts to concentrate on airline markets rather than CNS/ATM functional issues;
- **Civil Air Navigation Services Organisation (CANSO)**<sup>50</sup> – CANSO, which was formed in 1997 by 18 commercialised suppliers of air navigation services<sup>51</sup>, represents and support its members by presenting their views to decision making bodies in aviation, similar to IATA's representative rôle for the airlines. CANSO also enables its members to improve their efficiency. The 23 full and 20 associate CANSO members, comprising a range of stakeholders, are listed because many are quite active with the introduction of CNS/ATM on individual bases, thus:
  - The 18 founding (full) members are AENA (Spain), AEROTHAI (Thailand), Airservices (Australia), Airways Corporation (New Zealand), ANS CR (Czech

<sup>46</sup> 'FAA financial staff choose NATCA representation' – *Air Transport Intelligence*, 7 February 2000.

<sup>47</sup> It should be noted that many airframe and CNS/ATM equipment manufacturers involved in the worldwide implementation of future air navigation systems are in multi-stakeholder groups.

<sup>48</sup> 'ATAG more relevant than ever' – *Air Transport Action Group News*, June 2000.

<sup>49</sup> <http://www.boeing.com/caft>.

<sup>50</sup> <http://www.canso.org>.

<sup>51</sup> Commercialised refers to the fact that providers are no longer run by a government department, although they may still be government owned. Such providers tend to be more efficient.



- Republic), ATNS (South Africa), Austro Control (Austria), DFS (Germany), IAA (Ireland), LGS (Latvia), LVNL (the Netherlands), NATS (UK), Nav Canada, NAV-EP (Portugal), Romatsa (Romania), SERCo (UK), Swisscontrol (Switzerland) and UksATSE (Ukraine);
- The following other full members now exist: Belgocontrol (Belgium), Estonian Air Navigation Services, ATS of the Slovak Republic, MoldATSA (Moldova) and the Roberts Flight Information Region;
  - Accordingly, the non-commercialised sector's SLV Denmark, SCTA France, Norway's NCAA, LfV Sweden and the US FAA are associate members. It should be noted that Norway and Sweden have 'autonomous status'. Other associate members are the Air Transport Association of Canada, Air Canada, ARINC, Airsys ATM, Boeing, Concordia University, Crossair, Frequentis, Indra, Integra, Lockheed Martin, Mitre, PriceWaterhouseCoopers, Raytheon Systems Company, Roberts, Roach and Assoc., Sedgwick Group and SITA;
- **FANS Stakeholders' Group (FSG)** – under the leadership of IATA, the FSG aims to act as an industry facilitator for implementation of CNS/ATM. Its members include ARINC<sup>52</sup>, ATAG, CANSO, IAOPA<sup>53</sup>, ICCAIA<sup>54</sup>, Inmarsat<sup>55</sup> and SITA<sup>56</sup>. However, it should be noted that the FSG has not been too vocal in recent times. Indeed, its last 'bi-monthly' newsletter was produced in May 1999. Nonetheless, the FSG published a short overview of CNS/ATM in 2000. In addition, it has created a CNS/ATM database of routes, although it is not comprehensive;
  - **Radio Technical Commission for Aeronautics (RTCA)** – representing many stakeholders, the RTCA is very active in the US regarding development of the 'Free Flight' concept. In addition, the RTCA has started drafting documents to support the introduction of CNS/ATM with the EUROpean Organisation for Civil Aviation Equipment (EUROCAE), its European equivalent. EUROCAE's members also include airframe, engine and equipment manufacturers, in addition to national aviation authorities. Both EUROCAE and the RTCA are involved in the standardisation of CNS/ATM systems.

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<sup>52</sup> ARINC, the Aeronautical Radio INCorporated, develops and operates communications and information processing systems for the aviation and travel industries. It was established by airlines in 1929 to be the single licensee for aeronautical communications frequencies and to provide safety communications on behalf of the US government.

<sup>53</sup> IAOPA, the International council of Aircraft Owner & Pilot Associations, represents nearly half a million pilots and aircraft owners by protecting their interests regarding air traffic control and other issues.

<sup>54</sup> ICCAIA, the International Co-ordinating Council of Aerospace Industries Association, comprises the worldwide aerospace industry associations. ICCAIA represents airframe manufacturers, avionics suppliers and ATC equipment firms.

<sup>55</sup> Inmarsat is an international satellite organisation that provides satellite communications for the aviation, maritime and land shipping industries. It began operations in 1979 and was owned by over 60 countries' telecommunications organisations until 1999, when it became a private company. Inmarsat is presently planning an Initial Public Offering (IPO).

<sup>56</sup> SITA, the Société Internationale des Télécommunications Aéronautiques, is the world's largest data communications network operator.



## 1.5 Scope for research

Previous sections in this chapter emphasise that changes are necessary to current Air Traffic Control (ATC) technologies and procedures so that the highlighted present levels of congestion may be reduced. Indeed, the delays being experienced in Europe and the US, which are near gridlock in some cases, stress the urgent need to augment ATC systems that are currently employed. Delays are producing phenomenal amounts of economic and time wastage to all stakeholders in worldwide regions. Accordingly, although average safety statistics show that safety is being controlled, there is a requirement for some airspace regions' existing safety standards to be improved.

Therefore, it is evident that the present system must be adapted in order to cope with the demand. If, however, the traffic projections cited in **Section 1.2.1** are considered, then the dilemma that the aviation industry faces is even more apparent. Indeed, other economic statistics in that section also convey the magnitude of this industry and its effect on the world's economies. Thus, the ramifications of this dilemma are transferred to the global economy. When considering safety-related facts quoted in **Section 1.2.2**, such as the requirement for present worldwide fatal jet accident rates to halve by 2010 if acceptable levels of risk are to be maintained, the need for drastic action is clear.

Nonetheless, the sections also state that solutions to the aforementioned predicaments have been developed and are encompassed under the auspices of the terms, 'future air navigation systems' and 'CNS/ATM', which both have the same meaning. CNS/ATM involves the implementation of new technologies and procedures that fuse together to optimise the potential of airport and airspace resources so that the capacity, flexibility and safety of these resources are maximised. Thus, it is envisaged that delays and operating costs will be minimised. The concept aims for automated Communications, Navigation & Surveillance (CNS) technologies to provide enhanced Air Traffic Management (ATM) through continuous information on aircraft positions and intentions so that a reduction in aircraft separation is possible without compromising safety.

However, even though some CNS/ATM systems have already been implemented, the successful worldwide introduction of CNS/ATM systems is far from guaranteed at present. Indeed, if future air navigation systems that were drafted by the ICAO FANS Committees (see **Section 1.3**) were sufficient in content and planning, then the current crises would not exist. Accordingly, if the timing of recommendations by the FANS Committees were taken literally, then most countries would have started to decommission their land-based navigation aids in lieu of satellite alternatives by now. In a similar manner, any derivative or different CNS/ATM technologies and procedures developed by other stakeholders would have solved the problems cited previously.

Consequently, there is plenty of scope for research in the area of civil aviation's future air navigation systems. With particular reference to the aforementioned problems, there is a specific, timely need to evaluate what technologies and procedures form CNS/ATM, in addition to determining the degree to which the future air navigation systems have been implemented to date. Accordingly, there is a desperate requirement to improve the introduction of CNS/ATM systems around the world over the next two decades.



## **1.6 Objectives of dissertation**

With reference to the scope for research cited in **Section 1.5**, the ultimate aim of this thesis is two-fold, namely:

- 1 To provide a comprehensive evaluation of CNS/ATM systems and a determination of the degree to which future air navigation systems have been implemented to date around the world;
- 2 To develop a framework strategy that improves worldwide introduction of future air navigation systems. Noting that many stakeholders are involved with CNS/ATM systems, the framework strategy should allow for use by any industry player.

Clearly, it is necessary to perform the first main objective to realise the second. This approach has a dual effect of fulfilling the first objective by ascertaining present progress with the current development or implementation of identified future air navigation systems, which also serves to highlight the stumbling blocks to successful introduction of CNS/ATM for the second aim.

Both objectives endeavour to generate an original study on CNS/ATM systems that are capable of overcoming the shortcomings of the present system and accommodating forecast traffic levels in a cost-effective, efficient, flexible, safe manner so that airspace regions are harmonised with one another. With reference to the delay and safety issues that are referred to elsewhere in this chapter, this endeavour is extremely relevant at this time. Indeed, it is very important that these matters are addressed and rectified as soon as possible, if civil aviation is to meet projected demand. Accordingly, air transport is one of the safest forms of travel and must remain thus.

Once the aims are realised, the research should have produced a handbook on CNS/ATM that enables any analyst or stakeholder to determine what technologies or procedures are pertinent for their particular situation and subsequently advise them on how to integrate the CNS/ATM system(s) or what options they have. Within this advice, the analyst or stakeholder should be able to access a wealth of information, which, in itself, should expedite the implementation of future air navigation systems. For instance, an analysis of other stakeholders' experiences with the particular system(s) would aid analysts or stakeholders when planning their project.

Ultimately, it is certain that a framework guide to introduction of CNS/ATM is required because the present problems with congestion would not exist if future air navigation systems had been applied. Accordingly, the current collection of diverse air traffic control systems would have merged into a harmoniously interfaced network, providing efficient flight trajectories, with resultant fuel savings, and time-optimised operations from gate to gate. The need for this analytical tool will become more apparent over the coming years as the potential for CNS/ATM systems is realised and as it dawns on air transport stakeholders that they have no choice other than to embrace CNS/ATM.



## 1.7 Methodology of analysis

With respect to this dissertation's two main objectives, which are given in **Section 1.6**, it is possible to fulfil their respective aims using the following methodologies:

- 1 **Conducting a detailed assessment of technologies or procedures that constitute the future air navigation systems and whether or where specific CNS/ATM systems have been implemented to date.** In order that this exercise is accurate and impartial, it is imperative that the evaluation draws from as many information sources as possible. Thus, every effort is made to refer to sufficiently different material, so that analyses are developed using separate perspectives. It is necessary, therefore, to refer to hundreds of publications. It should be noted, however, that sources can repeat one another, so a concerted effort is made not to reference different material that convey the same information. Correspondingly, it should be added that the multitude of coverage given to CNS/ATM systems in the press and at conferences means that a questionnaire approach is superfluous. In fact, this latter method could be more biased and not as representative. Accordingly, noting the low average return rate of questionnaires, the chosen approach would undoubtedly have to be undertaken to supplement the questionnaire. However, it should be noted that results are incorporated from a publication, which has obtained information using a pseudo-questionnaire method for some countries. Ultimately, even though many different sources exist, a similar evaluation of future air navigation systems has not, hitherto, been performed in an independent manner. **Section 1.8** details how this assessment is structured;
- 2 **Drafting solution methods for expeditious and successful introduction of future air navigation systems around the world.** Using the study on current implementation status of CNS/ATM systems, which is conducted for the first objective, to identify the stumbling blocks to their worldwide integration, it is possible to create the skeleton of a framework strategy that should improve the introduction of such systems because a comprehensive worldwide strategy has not yet been developed and a solution is urgently required. Within the skeleton, obstacles to implementation are placed with similar hindrances, so that the framework strategy is made up of sections. Each section has a specific intention and consists of numerous components. The latter are developed and discussed, with suggestions on how to improve the specific problem(s) and guide implementation. It should be noted that the perspectives of all stakeholders and worldwide regions are considered. **Section 1.8** outlines the layout of the framework. Remembering that this framework's objective is to expedite the introduction of CNS/ATM systems, greater amounts of analysis of particular aspects are warranted. For instance, proper financing and performance of CNS/ATM systems will improve the implementation process. Validation of the framework strategy is conducted using assessments of best practice examples or benchmarked indicators that are established and computed for the purposes of this endeavour. It should be noted that components refer to results from the CNS/ATM evaluation for the first objective.



## 1.8 Layout of thesis

Given the aforementioned objectives and methodology of this research, the dissertation is structured as follows:

### Part 1 – To evaluate CNS/ATM and its current implementation status

- Chapter 2 appraises current and future Communications, Navigation & Surveillance (CNS) technologies;
- Chapter 3 analyses the Air Traffic Management (ATM) concepts that have been or are being developed;
- Chapter 4 examines the present implementation status of CNS/ATM systems by investigating developments, trials and operational experiences for each technology and procedure. In addition to assessing the CNS/ATM equipment market, a worldwide survey of national and regional CNS/ATM activities is conducted;

### Part 2 – Framework to improve worldwide implementation of CNS/ATM

- Chapter 5 identifies the main obstacles to a comprehensive installation of future air navigation systems and attributes them as components of the framework strategy to different sections. Each section develops and discusses its aspect of the strategy;
- Chapter 6 develops financial components of the framework strategy, recommending a charging principle for recouping of costs, based on a worldwide survey of air navigation charges, and highlighting other funding options;
- Chapter 7 drafts and computes indicators on performance, in addition to assessing the parameters involved in flight analyses;

### Conclusions

- Chapter 8 contains the numerous conclusions and recommendations from this dissertation, in addition to mentioning the potential for further academic evaluations;

### Appendices

- The appendices contain data and case study or survey information that support and validate analyses in the main text. In addition to conducting their respective assessments, the contents should prove very useful to stakeholders when wishing to conduct specific integration projects.

Therefore, the structure of both parts adheres to the suggested PhD approach: explain the problem, describe the solution, do the analysis and show the results.

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# **PART 1**

## **TO EVALUATE CNS/ATM AND ITS CURRENT WORLDWIDE IMPLEMENTATION STATUS**

**“THIS IS THE MOST FAR-REACHING PROJECT EVER INITIATED IN THE HISTORY OF CIVIL AVIATION AND, AS SUCH, IT WILL REQUIRE AN UNPRECEDENTED LEVEL OF COLLABORATION BY ALL GOVERNMENT AGENCIES INVOLVED IN AIR TRANSPORT AND ALL MEMBERS OF THE AIRLINE INDUSTRY. IT IS THEREFORE CRUCIAL THAT EVERY PLAYER INVOLVED IN THE PROCESS GAIN AN INTIMATE KNOWLEDGE OF THE CONCEPT, ITS ADVANTAGES AND ITS REQUIREMENTS”**

**PHILIPPE ROCHAT, FORMER SECRETARY GENERAL, ICAO**



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## **CHAPTER 2**

# **CNS SYSTEMS**

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## 2.1 Introduction

The key to air traffic flow optimisation is the introduction of automated Communications, Navigation & Surveillance (CNS) systems that can provide enhanced Air Traffic Management (ATM) with continuous information on aircraft position and intentions. Hence ICAO's insistence that Future Air Navigation Systems (FANS) be known as CNS/ATM, which is a way of using technology to:

- Enhance *communication* links between aircraft and air traffic controllers with computers selecting the optimum method of transmission;
- Improve pilots' abilities to *navigate* their aircraft safely;
- Increase air traffic controllers' capacity to monitor and *survey* flights.

This chapter provides an overview of CNS/ATM systems' technological aspects. Noting that ATM is dealt with in **Chapter 3**, the separate sections of this chapter look at the individual components of CNS, namely Communications, Navigation and Surveillance systems. A contrasting approach between current and future systems is adopted to highlight the transition over the next two decades of CNS equipment that aircraft use to migrate through the world's airspace.

Additionally, the fact that most new systems should be phased in using evolutionary approaches is another reason to describe existing means of CNS, because such equipment and tools will still be used for years to come. Indeed, given the experiences of delayed integration to date, the future CNS/ATM system will undoubtedly contain an inherent level of present technologies, certainly until the end of this decade.

Each entity is described to investigate how it will figure in the evolved, planned future environment. This serves to highlight the functional shortcomings of present systems and the potential benefits if new technologies are implemented. Correspondingly, noting the distinct lack of progression in terms of implementing new technologies and procedures over the last decade, **Chapter 4** also assesses how much success has been achieved to date with their application.

Thus, this chapter does not describe the integration of CNS components in great detail. It serves as an overview of each technology's applications and usefulness. In addition, the contents of this chapter form the basis of subsequent analyses in this dissertation.



## 2.2 Current communications technology

The main objective of an aeronautical communication service is to ensure that telecommunications and radio aids necessary for the efficiency, regularity and safety of air navigation are continuously available and reliable. Indeed, ICAO maintains<sup>57</sup> that “communication is a vital part of the provision of air traffic services and its timely and dependable availability has a significant effect on the quality of service provided. This is true not only of the availability of communication means, but of the quality of performance and reliability”. Two categories of communication are presently conducted, thus:

- **Air-ground:** fixed aeronautical ground stations and aircraft communicate using Very High Frequency (VHF) or High Frequency (HF) technology, depending on local signal availability: VHF transceivers are used to provide voice air-ground contact between pilots and ATC when within short range, line-of-sight coverage; HF is used over long range areas exceeding VHF’s limits, such as in oceanic and remote continental areas. Datalink is also provided between the aircraft and ground to transfer data. VHF datalink’s first application, Aircraft Communications, Addressing and Reporting System (ACARS), has been around for over 20 years. Current datalink systems, such as ARINC’s GLOBALink Services and SITA’s AIRCOM include VHF, HF and satellite-based datalink. Inmarsat is employed as a means of satellite air-ground communications. It should be noted that ARINC, Inmarsat and SITA are described in **Chapter 1**;
- **Ground-ground:** adjacent Air Traffic Service (ATS) units are linked by dedicated telephone lines between controllers. However, ATS units are also linked via the Aeronautical Fixed Telecommunications Network (AFTN). In addition, many airlines are connected with the ATS units through the AFTN. ARINC’s Data Network Service (ADNS) provides a communications interface between airlines, AFTN, Air Route Traffic Control Centres (ARTCC) and weather services<sup>58</sup>. ADNS is also used to transport air-ground datalink messages and ACARS. With similar applications, SITA has a worldwide telecommunications network that is primarily based on its Data Transport Network. In the US, ATC ground infrastructure includes the National Aeronautical Data Network (NADN) facilities.

The two main components of present air-ground communications systems, VHF and HF, are individually discussed in **Sections 2.2.1** and **2.2.2** respectively.

<sup>57</sup> 'The Air Traffic Services Planning Manual'. 1<sup>st</sup> Ed. ICAO Doc. 9426. 1984.

<sup>58</sup> 'FANS CNS/ATM Starter Kit' – Section 2. IATA/ICAO.



## 2.2.1 VHF communications

Very High Frequency (VHF) air-ground communications are integral components of today's air transport communications infrastructure. VHF transceivers are used to provide voice contact between fixed aeronautical ground stations and pilots when within line-of-sight coverage, which is invariably near or over land in dense traffic areas.

Due to the nature of VHF signal propagation along the curvature of the Earth, it can be received and transmitted over greater distances at higher altitudes. As an example of its signal propagation, **Appendix 2.1** portrays the lack of VHF air-ground radio communications coverage in the North Atlantic region. Coverage charts are given for FL100, FL200 and FL300. They show how aircraft are able to receive and transmit on VHF at greater distances when flying at higher altitudes due to the radio signals being limited to line-of-sight along the curvature of the Earth<sup>59</sup>.

VHF technology is also used by other applications for communicating data, thus:

- **Aircraft Communications, Addressing and Reporting System (ACARS)**, which has been used since 1978, sends telex-type Aeronautical Operational Control (AOC) type messages between the air and the ground. With a keyboard, display and printer on the flight deck, ACARS is operated by ARINC using VHF technology in Asia, Europe and North America<sup>60</sup>. ARINC ACARS is integrated with HF and satellite services on a global basis as part of its GLOBALink Services. SITA's ACARS combines its ground network with specific VHF and satellite equipment to offer their solution for airlines' in-flight communication requirements, AIRCOM<sup>61</sup>. ACARS was originally planned for AOC communications and for sending engine technical data, but it has been augmented for ATC applications, such as Pre-Departure Clearance (PDC)<sup>62</sup>, ATS Interfacility Data Communications (AIDC), Digital Automated Terminal Information Service (D-ATIS) and Terminal Weather Information for Pilots (TWIP)<sup>63</sup>. In addition, ACARS presently supports Automatic Dependent Surveillance (ADS) and Controller Pilot DataLink Communications (CPDLC<sup>64</sup>) with aircraft in flight. Services also include Waypoint Position Reports (WPR) and flight information services. ACARS's airborne management unit can be connected to onboard computer systems such as the Flight Management Computer (FMC) to host ATC/AOC functions and selects which datalink to use depending on

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<sup>59</sup> 'Private Pilot Manual' – Jeppesen Sanderson. Chapter 2. Section D.

<sup>60</sup> <http://www.arinc.com>

<sup>61</sup> <http://www.sita.com>

<sup>62</sup> 'VDL Mode 2 Implementation & Trends' – G Lake, ARINC. 5<sup>th</sup> Air Navigation Conference, Amsterdam. September 1999.

<sup>63</sup> 'Demystifying CNS/ATM' – CANSO. June 1999.

<sup>64</sup> CPDLC has been standardised by ICAO as datalink that allows digital communication of strategic and tactical ATS messages currently conveyed by voice.



the aircraft's operating environment<sup>65</sup>. Rockwell Collins' Hermes datalink message handling system provides an e-mail type system for contacting aircraft, together with a series of other ACARS functions<sup>66</sup>. Over 6,000 aircraft are ACARS-equipped, but its technological problems include poor spectrum efficiency and being non-compliant with future systems. In addition, current ACARS VHF capacity is nearing limits<sup>67</sup>. However, ARINC is developing ACARS's successor, VDL Mode 2, in tandem with SITA. In ARINC's case, the VDL service is part of its GLOBALink Services, which additionally include VHF-ACARS, HF and satellite portions<sup>68</sup>. In 1998, each aircraft with ARINC VHF datalink handled an average of 2,700 messages per month<sup>69</sup>. 6,000 oceanic clearances were conducted per month over the North Atlantic Ocean, in addition to 7,500 waypoint position reports and 4,100 CPDLCs per month over the Pacific Ocean;

- **VHF DataLink (VDL)** has forms other than ACARS that have enabled electronic messages such as ATC clearances to be sent from the ground to the cockpit since the early 1990s. This development of VHF technology has enabled airlines to automatically receive oceanic clearances and Extended Twin-engine Operations (ETOPS)-related information. For example<sup>70</sup>, a clearance message may be sent from the Gander Automated Air Traffic System computer via Air Canada's air-ground communications system (their own ACARS equivalent) to the airline's flight deck, thus allowing pilots more time to adjust to any unexpected change<sup>71</sup>. A second copy goes to the Air Canada flight dispatchers in Toronto, where they can verify the clearance to see if it has changed from what was originally filed. If a change has occurred, dispatchers can issue a completely new computerised flight plan that is transmitted to the aircraft over the VHF datalink in a short length of time. It arrives on the flight deck, where a hard copy is printed out. Additionally, aircraft have been using satellite data communications facilities on operational bases in the Pacific Ocean since 1991. **Section 2.3.2** covers the next generation of VDL.

## 2.2.2 HF communications

High Frequency (HF) radio is used over areas exceeding VHF's range, such as in oceanic or remote continental areas. Pilots communicate with area centres via aeradio

<sup>65</sup> 'Technology and Procedures report' – Honeywell AATT.

<sup>66</sup> 'Alaska Airlines to take Collins' Hermes for ACARS' – Air Transport Intelligence, 1 March 1999.

<sup>67</sup> 'VDL Mode 2 and HF Data Link: Next Generation Data Link' – G Lake, ARINC. Air Traffic Management: Prospects for Free Flight Conference, London. January 1999.

<sup>68</sup> <http://www.arinc.com>

<sup>69</sup> 'Migration to VDL Mode 2 ICAO compliant VHF datalink' – G. Lake. 4<sup>th</sup> Air Navigation Conference, Amsterdam. September 1998.

<sup>70</sup> 'Air Canada expects ETOPS success to bring faster approvals in future: on board Air Canada flight 866' – Aviation Week & Space Technology, 13 April 1992.

<sup>71</sup> 'New Communications, Navigation systems will increase North Atlantic capacity' – Aviation Week & Space Technology, 20 November 1989.



stations manned by communicators who relay messages by radio-teletype from the ground station to the relevant station for action.

The fact that HF requires the propagation of its waves to be reflected from the ionospheric layers above the earth is often a drawback, because destructive interference can occur, where the transmitted signals arrive at the receiver at different times because they were reflected at different ionospheric levels and, consequently, sent via different routes. Additionally, there is limited availability of frequencies that work reasonably on any given day.

The need for pilots to constantly monitor their assigned HF frequency is removed if SElect CALling (SELCAL) is fitted on the aircraft. Pilots provide the relevant code in the flight plan and maintain a SELCAL watch. A ground station wishing to call the aircraft sends out a specific SELCAL code. A visual and aural indication of the call occurs in the cockpit because the SELCAL decoder is permanently scanning the signals for the required code. Satellites can be used for SELCAL. However, the inventory of available codes for use in SELCAL was depleted in 1997, so aircraft are being assigned duplicate codes, implying that vigilance is essential<sup>72</sup>. SELCAL code assignments are co-ordinated, on behalf of ICAO, around the world by ARINC.

Nonetheless, despite its shortcomings for voice communications<sup>73</sup>, a portion of the radio spectrum can provide reliable air-ground data communications. Similar to VHF DataLink (VDL), HF DataLink (HFDDL) is also being used to provide aircraft position reports as well as other operational data. HFDDL has coverage in the Polar Regions, where satellites presently do not. HFDDL finds the best HF frequency for transmission of data from a suitable pool of frequencies, as propagation anomalies rarely affect the entire HF band everywhere. HFDDL also processes digital signals to compensate for distortion in the HF channel and automatically selects the data rate depending on the propagation conditions. The system employs geographically separated and networked ground stations to provide space diversity.

Although the data rate of HFDDL is significantly lower than communications satellites, the cost of adding the datalink is much less expensive than installing satellite communications equipment for aircraft already equipped with HF radio. Indeed, ARINC claims that HFDDL can be used in place of SATCOM as a cost-effective, long-range datalink, where SATellite COMmunications (SATCOM) is too expensive<sup>74</sup>: costs for HFDDL avionics are under \$60,000, in comparison with \$350,000 for a multi-channel SATCOM system and the price per message transmission is competitive.

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<sup>72</sup> 'Inventory of available code assignments for use in the SELCAL system has been depleted' – ICAO Journal, November 1997.

<sup>73</sup> 'Airlines test HFDDL datalink' – Aviation Week & Space Technology, 31 May 1993.

<sup>74</sup> 'HF datalink: near term implications for European ATM' – P Perine, ARINC. Air Traffic Management in Europe: the business case for CNS/ATM Conference, London. 1997.



### 2.2.3 Inmarsat satellite communication facilities

Inmarsat satellites provide communications for air, land and maritime applications, but this section only considers the aeronautical activities. Inmarsat offers the only presently available SATCOM facilities using geostationary<sup>75</sup> satellites. The satellites have worldwide coverage, including remote regions, but not at high latitudes and are consequently not usable in the Polar Regions. They facilitate voice and data communications for Air Traffic Control (ATC), Airline Operational Communications (AOC) and passenger telephony purposes. It should be noted that the latter SATCOM services provide airlines with opportunities to generate revenue and thereby offset some of the equipment costs<sup>76</sup>.

The Inmarsat system includes the following aeronautical cockpit and passenger voice and data communication services:

- *Aero mini-M* – designed for small corporate aircraft and general aviation users;
- *Aero-I* – designed for short and medium-haul aircraft, it is also certified for ATS purposes;
- *Aero-C* – a low-cost messaging and data reporting service that provides aircraft with the possibility of reporting positions, as well as updating weather and flight plans;
- *Aero-H and H+* – high-speed service supporting multi-channel communications that use the Inmarsat-3 spot-beams to offer more robust performance;
- *Aero-L* – a low-gain aeronautical SATCOM service offering real-time, two-way air to ground data exchange.

The Inmarsat aeronautical system consists of three basic elements:

- **Geostationary satellites** in a 36,000km orbit above the earth. Inmarsat has four older satellites from a previous generation space segment, termed Inmarsat-2s, and five higher-powered Inmarsat-3 satellites, which are located over the Indian Ocean at longitude 64.5°E, the Pacific Ocean at longitude 179°E, the Atlantic Ocean West at longitude 55.5°W and the Atlantic Ocean East at longitude 15.5°W, with an in-orbit spare at 25°E. The Inmarsat-2s are back-up satellites that provide aeronautical communications on lower segment frequencies than the Inmarsat-3s;
- **Land Earth Stations (LES)**, which providing the interconnection between the satellites and international telecommunications networks. Each satellite may be accessed through at least two LESs, providing the redundancy needed for high system integrity<sup>77</sup>. LESs are owned and operated by telecom operators. As no single Inmarsat signatory operates LESs in all four oceanic regions, commercial consortia exist in order to offer their customers global services. Such organisations include

<sup>75</sup> Geostationary – circular orbit in the earth's equatorial plane for which the orbital period is equal to the rotational period of the earth.

<sup>76</sup> 'Aligning ATC Datalink Requirements with Airline Requirements' – P Clinch, *Air Traffic Management: Prospects for Free Flight conference*. SMI. 1999.

<sup>77</sup> 'Satellite Communication Serving the Aircraft Operator' – L Normish. *6th Air Navigation Conference*, October 2000.



Satellite Aircom (Australia, Canada, France and SITA), Skyphone (ARINC, Norway, Singapore and the UK), and Skyways Alliance (ARINC, Indonesia, Italy, Japan, Korea, Malaysia and the Philippines)<sup>78</sup>;

- **Aircraft Earth Stations (AES)**, which are aircraft installed equipment, capable of communicating via satellite with a LES for access to international communications. Inmarsat avionics packages exist for the aforementioned Aero-C, Aero-H, Aero-I, Aero-L and Aero mini-M services. An airborne SATCOM system consists of a Satellite Data Unit (SDU), a High Power Amplifier (HPA) and a Radio Frequency Unit (RFU). To enable digital data communications, the SDU is connected to a communications processor such as the ACARS management unit, thereby providing SATCOM datalink for all pertinent avionics.

In addition to controlling the constellation, Inmarsat is the system design and service definition authority for the aeronautical satellite communications applications supported by its satellites. Services are provided to end-users by operators and not by Inmarsat: customers sign up with a specific operator and calls are passed through the operator or its partner service providers. Inmarsat wholesales satellite capacity to its signatories who, individually or in consortia, provide communications services to airlines and other airspace users. To facilitate ATC voice calls, Inmarsat has a list of short-codes for each Flight Information Region (FIR).

ARINC's GLOBALink and SITA's AIRCOM service use Inmarsat for the satellite portion of their services. The satellite services expand ACARS facilities for enhanced AOC and ATC datalink communications. The airborne management unit instigates SATCOM as the form of datalink when required, such as in oceanic and remote airspace when the aircraft is out of radar and VHF coverage. The SATCOM air-ground datalink service makes use of ACARS protocols for message transmission<sup>79</sup>. Aside from coverage issues, SATCOM datalink has the advantage over VHF datalink of not requiring the installation of many purpose-built local ground stations to provide access to the service. Other applications exist: for instance, an in-flight entertainment provider uses SITA's AIRCOM air-ground datalink<sup>80</sup>.

Inmarsat-3 satellites incorporate 'spot beam' antenna technology, whereby each satellite can generate up to five spot beams that concentrate the satellite's radio frequency power over much smaller areas of the Earth's surface than the normal beam. It should be noted, however, that these areas are still quite large and can cover most of Australasia, for instance. Together, the beams cover most of the globe. Aero-I has been designed to work specifically in the spot beam environment of the satellites, enabling general aviation or business aircraft to use equipment with reduced weight, size, cost and complexity. Inmarsat-3 satellites also have navigation transponders to enhance other satellite systems. **Section 2.4.3** covers their functionality.

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<sup>78</sup> 'Aeronautical Satellite Communications, Navigation and Surveillance via Inmarsat' – D Featherstone, *Integrating Global Air Traffic Management*. ISC & ICAO. 1998.

<sup>79</sup> 'Demystifying CNS/ATM' – CANSO. June 1999.

<sup>80</sup> 'SITA to provide air-to-ground link for Internet services' – *Air Transport Intelligence*, 27 October 1999.



## 2.3 Future communication systems

The objectives of the communications element of CNS/ATM systems, which will be used in support of specific navigation and surveillance functions, are to enhance coverage, accessibility, capability, integrity, security and performance of aeronautical communication systems in accordance with ATM requirements<sup>81</sup>. Two basic categories of communication service are envisaged, with CNS/ATM systems capable of carrying:

- Safety-related communications, requiring high integrity and rapid response;
- Non-safety related communications.

With reference to both air-ground and ground-ground portions, the fundamental differences between conventional and future communications systems are that the former will have:

- Most routine communications performed by data interchange;
- Voice communication used mainly in emergency and non-routine situations;
- More emphasis on global operation.

The future communications systems will therefore allow more direct and efficient linkages between ground and airborne automated systems. At present, more than 50% of the controller's workload is associated with radiotelephony procedures<sup>82</sup>. This necessitates many changes in air-ground/ground-ground communication data and voice transmission techniques, which will be manifested by:

- A gradual reduction in the number of current terrestrial (HF and VHF) voice communications. However, analogue HF will remain in place over the Polar Regions for some time even though datalink and satellite communications are much faster. Similarly, analogue VHF and a more satellite-based Aircraft Communications, Addressing and Reporting System (ACARS) are predicted to remain for the foreseeable future;
- More emphasis placed on transferring information using methods of high quality, near real-time digital data transfer, namely enhanced modes of datalink. Digital techniques will provide a high efficiency information flow and optimum use of automation. ACARS will migrate to VDL Mode 2 during this decade;
- Continued introduction of satellite-based data and voice communication technology. This will not be subject to the many limitations of today's communications infrastructure, thereby ensuring greater, global availability and integrity of such services;

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<sup>81</sup> 'Global Air Navigation Plan for CNS/ATM systems' – Volume I, ICAO. 1<sup>st</sup> Ed., 2000.

<sup>82</sup> 'CNS/ATM Implementation: Progress and Priorities from a User Perspective' – J White, IATA. 4<sup>th</sup> Air Navigation Conference, Amsterdam. September 1998.



- The Aeronautical Telecommunications Network (ATN) through the interchange of digital data between end users over dissimilar air-ground and ground-ground communication links. Ground-ground communications will still take place over the Aeronautical Fixed Telecommunications Network (AFTN), even though it is slow and can be unreliable.

Indeed, noting that **Section 2.7.2** of this chapter covers Automatic Dependent Surveillance (ADS), ICAO maintains that “the communications infrastructure should be designed to support evolutionary development towards an ATM system in which, ultimately, the capability exists to control all aircraft ... using near real-time surveillance data acquired either by radar or ADS”.

Correspondingly, communications will no longer be encumbered by standards and protocols unique to specific operating environments, such as air-air having a different protocol than air-ground. The hallmark of the future will be the true interoperability between the various nodes in the systems, which will be independent of their location in the networks of the communication scheme<sup>83</sup>.

This section analyses the envisaged air-ground communication systems by independently discussing the rôle of analogue VHF in the future, datalink techniques, satellite-based communication facilities, the ATN and the concept of Required Communication Performance (RCP). Secondary Surveillance Radar (SSR) Mode S is covered as a surveillance tool in **Section 2.7.1**. These are all anticipated to form the foundation of the FANS communications element.

### 2.3.1 Analogue VHF

Analogue VHF is predicted to remain in widespread use for the foreseeable future and it is thought that the transmission of voice will continue to take place over existing VHF channels for instantaneous service in high traffic density terminal areas and in emergency situations, which both require high integrity and rapid response. However, the availability of VHF spectrum channels in the long term is a concern. The effects can be minimised through:

- Maximum allocation of the VHF spectrum to aviation. Due to the proliferation of increased cellular use of spectra, aviation’s use of all bands is under scrutiny and must now justify requirements;
- Narrowing of bandwidth to reduce channel spacing from 25KHz to 8.33KHz, which more than doubles the number of available VHF voice communication channels<sup>84</sup>.

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<sup>83</sup> ‘Technology & Procedures Report’ – Honeywell AATT.

<sup>84</sup> ‘The World Market for ATC Equipment’ – Jane’s Information Group. September 1996.



Dedicated direct speech circuits will gradually be replaced by aeronautical switched networks, which are capable of handling both voice and data. There will also be a trend to use fully digital voice switching and signalling techniques as more flexible and less costly digital leased lines become widely available.

It is unfortunately ironic that airspace capacity can be increased through the creation of more ATC sectors. However, this also increases the workload on the pilot and controller, in addition to reducing the efficiency of the system through the requirement for more VHF frequencies.

### 2.3.2 Datalink applications

With reference to the discussion on present datalink technologies in **Section 2.2.1**, it is envisaged that most routine air-ground communications in the en-route phase of flight will eventually be conducted via direct and efficient digital data interchange techniques: Controller Pilot DataLink Communications (CPDLC) uses displays instead of voice and may be seen as the key to development of new ATM concepts. With CPDLC, pilots select a particular message from a pre-constructed set using a screen menu and add some specific parameters or text before sending it. CPDLC is claimed to be a function that allows controllers to communicate quickly and reliably with pilots, in a manner that facilitates accurate recording of exchanged information: pilots have a written version, which removes potential communicative misunderstandings<sup>85</sup>, and controllers can easily retrieve aircraft if they tune to a wrong frequency<sup>86</sup>.

There is concern about the speed of CPDLC's execution being lower than VHF voice. However, ATC voice congestion is significantly reduced when datalink is added. Thus, use of CPDLC will reduce the communications workload of pilots and controllers. Indeed, according to a study by the US FAA<sup>87</sup>, "controllers using CPDLC were able to provide ATC services that improved terminal approach control productivity and increased flight efficiency in congested arrival airspace". These effects were reflected in reduced arrival delays and more efficient use of airspace. In addition, the results showed an increase in the safety margin and in economic savings. A similar study<sup>88</sup> in the en-route environment showed that CPDLC improved en-route sector productivity and efficiency. Hence, there is a need to determine the optimum amount of CPDLCs that should be based on automated processes.

In addition to Airline Operational Communications (AOC) applications, datalink's functions can be used on a more widespread basis for issuing clearances to aircraft,

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<sup>85</sup> 'You don't have mail' – air traffic management, September-October 1999.

<sup>86</sup> 'Controllers' perspective on CPDLC' – Journal of ATC, January-March 2000.

<sup>87</sup> 'Benefits of Controller-Pilot Data Link ATC Communications in Terminal Airspace' – US DoT FAA Document CT-96/3. September 1996.

<sup>88</sup> 'User Benefits of Two-way Data Link ATC Communications: Aircraft Delay and Flight Efficiency in Congested En Route Airspace' - US DoT FAA Document CT-95/4. February 1995.



consequently removing the need for some present, lengthy systems. Correspondingly, the ability to load clearances and flight plan information automatically properly formatted into the Flight Management System (FMS) reduces the possibility of flight crew read-back and data errors, while enhancing the controller's ability to manage dynamic flight planning and tactical route changes. Another new datalink service is the Flight Information Service DataLink (FISDL), which has been developed by the US FAA for the collection and dissemination of flight information services such as SIGNificant METeorological information (SIGMET) and Pilot REPorts (PIREPs) to and from the aircraft<sup>89</sup>.

It is envisaged that existing VHF, which provides voice and data communications, will not be able to support the high volume of traffic in the future. Thus, different types of datalink will be integral in a seamless communications system with some voice VHF. As previously mentioned, voice VHF will certainly remain throughout the first half of this decade. Future datalink is thought to be the key issue with CNS/ATM<sup>90</sup>, with the following VHF DataLink (VDL) and HF DataLink (HFDL) based systems playing a rôle:

- **VDL Mode 1** – uses the radio and data modulation scheme of ACARS to transmit data between aircraft and their operating agencies through special ground stations and interconnecting networks at a data rate of 2,400 baud;
- **VDL Mode 2** – employs digital radio modulation scheme techniques to support different protocol suites for various operational applications, thereby greatly increasing the efficient use of the VHF channel. VDL Mode 2 is generally accepted as the logical successor to ACARS in high traffic density areas over the next few years and is ATN-compliant<sup>91</sup>. This will permit the use of FANS ADS/CPDLC applications in denser airspace than is possible now<sup>92</sup>. It will enable information to be received in graphic form in contrast with the present text-only ACARS. In order to ensure a smooth transition to the ATN, Mode 2 will initially be used to support an ACARS Over Aviation (AOA) VHF link control service. Hence, ARINC and SITA are evolving their ACARS services to Mode 2<sup>93</sup>, which provides a data rate 13 times faster than ACARS VHF, noting that operators will still be able to transmit messages on VDL Mode 2 using their ACARS equipment;
- **VDL Mode 3** – implements a Time Division Multiple Access (TDMA) digital radio technique to integrate both voice and data communication systems to offer a maximum of 4 times the number of channels. It will use VHF channels previously employed for voice communications, noting that VDL-3 is particularly suited to

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<sup>89</sup> 'Timely data link weather information in cockpit will prevent weather-related accidents' – ICAO Journal, March 2000.

<sup>90</sup> 'Swedavia Paper' – J Nilsson. Air Navigation '97 Conference, Amsterdam. September 1997.

<sup>91</sup> 'ACARS to ATN evolution of VHF datalink' – Air Traffic Technology International '99.

<sup>92</sup> 'Existing systems provide essential communications while development of datalink carries on' – ICAO Journal, September 2000.

<sup>93</sup> 'ARINC, SITA begin deploying VDL datalink networks' – Air Transport Intelligence, 30 November 2000.



- digital voice communications<sup>94</sup>. However, VDL-3 relies on synchronisation from ground stations, which restricts its global coverage;
- **VDL Mode 4** – uses a Self-organising Time Division Multiple Access (STDMA) technique, which, in addition to providing its intended data communication functions, makes navigation and surveillance datalink capabilities available. VDL Mode 4 can link with ATN services. It is suited to transmitting short messages, making it ideal to support ADS and ADS-B functions. Therefore, on-screen pictures of surrounding traffic in cockpit, ATS surveillance and airline fleet management are possible with Mode 4<sup>95</sup>;
  - **Secondary Surveillance Radar (SSR) Mode S datalink** – covered in **Section 2.7.1**, SSR Mode S provides surveillance capability, which also serves as an air-ground datalink that is specifically suitable for limited data messaging in high-density airspace. There is a considerable cost involved, however, in obtaining and down-linking Mode S parameters from aircraft;
  - **HFDL** – is covered as a present form of communication in **Section 2.2.2**. In the future, HFDL will provide primary capability and will be used as a backup to SATCOM, especially in Polar Regions, where satellites in geosynchronous orbit are not usable<sup>96</sup>;
  - **Inmarsat Data 3** – is a digital datalink that allows non-routine and emergency ATC messages, in addition to airline AOC functions. According to CANSO, “Data 3 is an ATN-compliant satellite service presently carrying non-ATN-compliant satellite ACARS/AIRCOM traffic including CPDLC and ADS for air traffic services using ARINC protocols”. Inmarsat Data 3 standard is compatible with global X.25 networks and allows data messages to be routed directly to the intended recipient;
  - **Gatelink** – is a high-speed, two-way data communication link established between a parked aircraft and a ground-based communications system using infrared technology or manual connections to enable cockpit information to be transferred<sup>97</sup>. This has the disadvantage of requiring aircraft to be positioned at an exact location for the transfer of data to occur. *Ground Link*, however, has been developed and uses a radio spectrum to create a generic wireless local area network. It has the ability to transfer large amounts of data, which facilitates downloading of aircraft Flight Data Recorders and Flight Management Systems. Ground Link can also be used to update the on-board Electronic Library System (ELS), which is complete maintenance documentation used with Built In Test Equipment (BITE).

Accordingly, whether satellite or terrestrial-based, datalink will continue to become the primary method of obtaining weather reports for more operators, in lieu of the current Automatic Terminal Information Service (ATIS). Additionally, datalink will enable more ATS units and airlines to send NOTices to AirMen (NOTAM) and other

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<sup>94</sup> 'ICAO to adopt vital new datalink standards' – *Air Transport Intelligence*, 3 April 2000.

<sup>95</sup> 'Take off for VDL Mode 4' – *Flight Deck International*, October 2000.

<sup>96</sup> 'Airlines test HFDL datalink' – *Aviation Week & Space Technology*, 31 May 1993.

<sup>97</sup> 'Demystifying CNS/ATM' – CANSO, June 1999.



aeronautical information to pilots en-route. Capability will increasingly exist in the datalink environment for emergency and other non-routine messages to be initiated by the pilot in a simple manner. Correspondingly, other datalink functions will evolve, such as the Datalink Delivery of expected Taxi Clearances (DDTC) system, which has been tested at airports in the US by ARINC, FAA and airlines.

Digital air-ground communications bring high levels of efficiency, reliability and safety to the ATC environment<sup>98</sup>. It is realised that datalink is the heart of CNS/ATM<sup>99</sup>. Therefore, there is a need to maximise the potential of datalink, which may be conducted by optimising its technical features within systems<sup>100</sup>. Features include message handling capacity, the integrity of messages (with minimal errors, noting that datalink can suffer from fading), the ability for sub-networks to support multiple communications and the issue of common avionics. The ultimate goal is the concept of Air-Ground Automatic Data Exchange (AGADE)<sup>101</sup>, which will not require the input of CPDLC.

### 2.3.3 Satellite-based communication facilities

Satellite data and voice communications will continue to be introduced, using Aeronautical Mobile Satellite Service (AMSS) technology that won't be subject to the many limitations of today's communications infrastructure, thereby ensuring greater, global availability and integrity of such services. Satellite communications, which are integral to the future CNS/ATM system, will increasingly have VHF-like quality and be of digital format. Priority and over-ride capability should be given to satellite voice communications.

The Inmarsat constellation of satellites, described in **Section 2.2.3**, will undoubtedly be an important and available resource for continued implementation of CNS/ATM technology. Given its compatibility with the ATN, which is covered in **Section 2.3.4**, the current Inmarsat-3 and its successor, Inmarsat-4, will most likely be integral components of the future system. Indeed, Inmarsat satellites will continue to be the backbone of geostationary satellite communications: the Inmarsat-4 satellites will operate with existing Inmarsat-3s to provide global coverage<sup>102</sup>. It should also be noted that Japan's Multi-functional Transport geostationary SATellite (MTSAT) programme will be able to provide AMSS communication in addition to its navigation capabilities.

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<sup>98</sup> 'Innovative digital communications links will enhance future air-ground data applications' – ICAO Journal, May 1999.

<sup>99</sup> 'Digital Data Link, GPS to transform airline ops' – Aviation Week & Space Technology, 14 June 1999.

<sup>100</sup> 'Increasing communications capacity' – M Paydar, Integrating Global Air Traffic Management, ISC & ICAO, 1998.

<sup>101</sup> 'ATC datalink – looking beyond CPDLC' – Flight Deck International, April 2000.

<sup>102</sup> 'Inmarsat commits to fourth generation satellite system' – Flight International, 8 December 1999.



However, a new breed of global communications systems, based on constellations of low and medium earth orbit satellites, has been developed. Such satellite systems are planned to use lower orbits, with consequently less power requirements. These communication satellites are designed specifically for mobile communications, offering global coverage for voice and data communications channels. Noting that **Section 4.2.3** contains a current analysis of their implementation status, the following systems have been planned:

- **Globalstar** – with a 1,414 km orbit, this constellation is capable of near-global coverage using the 56 planned satellites, consisting of 48 operational and 8 spares<sup>103</sup>. Bent pipe technology is used, inferring that gateway stations and subscribers must be in view from a particular satellite. Globalstar was planned to initially have non-safety use;
- **ICO Global Communications** – with a 10,390km orbit, this Inmarsat spin-off<sup>104</sup> constellation of 12 satellites (10 operational and 2 spare) has global coverage. It is based on a 12-year design life and has a low gain antenna. ICO needs less satellites than Globalstar due to the higher orbit;
- **Iridium** – with a 780 km orbit and 8-year design life, this constellation consists of 72 satellites (including 6 spare) that offer global coverage, including the Polar Regions<sup>105</sup>. Noting that Iridium has been discontinued, but is included here for completeness, Iridium Aeronautical Services were planned to be compatible with GNSS and intended for use by all aircraft types, from general aviation to airline<sup>106</sup>. A priority, precedence, pre-emption structure was used to ensure that safety, voice, ACARS and ATN communication facilities were enabled, thereby catering for ATC and airline AOC communications. The former includes cockpit voice, CPDLC and ADS messages using ARINC protocols. Inter-satellite calls were possible. Iridium quoted a typical cost, including antenna and installation, of \$75,000, with call charges of ca.\$5 per minute<sup>107</sup>. The weight of a basic unit is 16kg;
- **Orbcomm** – consists of a constellation of Low Earth Orbiting (LEO) satellites orbiting the Earth at a height of 775km. The complete system will consist of 36 satellites and was planned to target AOC communications<sup>108</sup>.

It should be noted that **SkyBridge** and **Teledesic** satellite constellations are also being developed<sup>109</sup>.

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<sup>103</sup> 'Filling the void' – P Lemme. ASK. 4th Air Navigation Conference, Amsterdam. September 1998.

<sup>104</sup> 'The other satcom' – Flight International, 18 November 1998.

<sup>105</sup> 'Satellite Wars' – Regional Airline World, April 1999.

<sup>106</sup> 'Iridium to offer aeronautical service' – S Glenister, Integrating Global Air Traffic Management. ISC & ICAO. 1998.

<sup>107</sup> 'Satcoms become airline standard' – E Kelly, Integrating Global Air Traffic Management. ISC & ICAO. 1998.

<sup>108</sup> 'Global airline operational communications' – Flight Deck International, March 1999.

<sup>109</sup> 'Tomorrow's world' – Air Traffic Technology International 2000.



### 2.3.4 The ATN

The global Aeronautical Telecommunications Network (ATN) is defined by ICAO as "an inter-network architecture that allows different ground, air-ground and avionic data sub-networks to interoperate by adopting common interface services and protocols based on the International Organisation for Standardisation (ISO) Open Systems Interconnection (OSI) reference model." The ATN comprises application entities and communication services that allow interoperation<sup>110</sup>. Automated ATM interaction between fixed ground-based and mobile aircraft-located computer systems will be supported using On-Line Data-Interchange (OLDI). The ATN can be paralleled with the Internet.

Therefore, the ATN is designed to handle data transmissions and provide a protocol suitable for all Aeronautical Administrative Communication (AAC), Aeronautical Operational Control (AOC), Aeronautical Passenger Communication (APC) and Air Traffic Services (ATS) applications. For instance, even though the datalinks mentioned in **Section 2.3.2** use different data transmission techniques, they will all use the same network, the ATN. ICAO has defined VDL as a compliant sub-network of the ATN<sup>111</sup>. It eliminates the need for multiple dedicated communication systems, each of which only providing limited functionality. This provides for their interconnection to other ground-based networks so that the aircraft end of any of these datalinks can be connected to any ground-based system by adopting common interface services and protocols based on the ISO OSI reference model. As such, the choice of the air-ground datalink is, in theory, transparent to the end user.

Under the ATN paradigm, the information provided by each ATC facility should not be first sent to a central system before distribution, but should be transmitted directly to the facility that needs it<sup>112</sup>. Additionally, the ATN makes efficient use of bandwidth, which is a limited resource in air-ground datalinks. It offers flexible and dynamic routing capability that is not available in ACARS<sup>113</sup>. This is critical for CNS/ATM because nodes do fail periodically in a network. ATN's design is such that user communications services can be introduced in an evolutionary manner<sup>114</sup>.

Other operational benefits of the ATN include its facilitation of increased ATM automation through computer-to-computer data interchange. The better clarity of its communications results in less air-ground radio channels, with reduced controller and pilot workload. The ATN is designed for no dependency on any single supplier or

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<sup>110</sup> 'Comprehensive ATN Manual (CAMAL)' – FANS Information Services. January 1999.

<sup>111</sup> 'The rôle of Next Generation Data Link Applications In the Future of Air Traffic Management' – M Hawthorne, FAA. 43<sup>rd</sup> Annual Air Traffic Control Association Conference Proceedings. 1998.

<sup>112</sup> 'Design of a Distributed Air Traffic Control Unit' – K Shiomi & Y Fukuda, Japanese Ministry of Transport. 43<sup>rd</sup> Annual Air Traffic Control Association Conference Proceedings. 1998.

<sup>113</sup> 'Technology & Procedures Report' – Honeywell AATT.

<sup>114</sup> 'The World Market for ATC Equipment' – Jane's Information Group. September 1996.



provider. Additionally, it allows the integration of public and private networks. Failure in any network element should, at worst, cause performance degradation<sup>115</sup>. ATN architecture allows for easy introduction of new applications that have not been developed yet. In addition, advantages of the ATN are that it is designed to provide data communication services specifically for the aeronautical community and its security requirements. The latter are very important, noting the recent spate of hoax ATC controller conversations to flight crew in the UK. Ultimately, it is the reduced need for a multitude of communication systems for AAC, AOC, APC and ATS that will be the main advantage of the ATN.

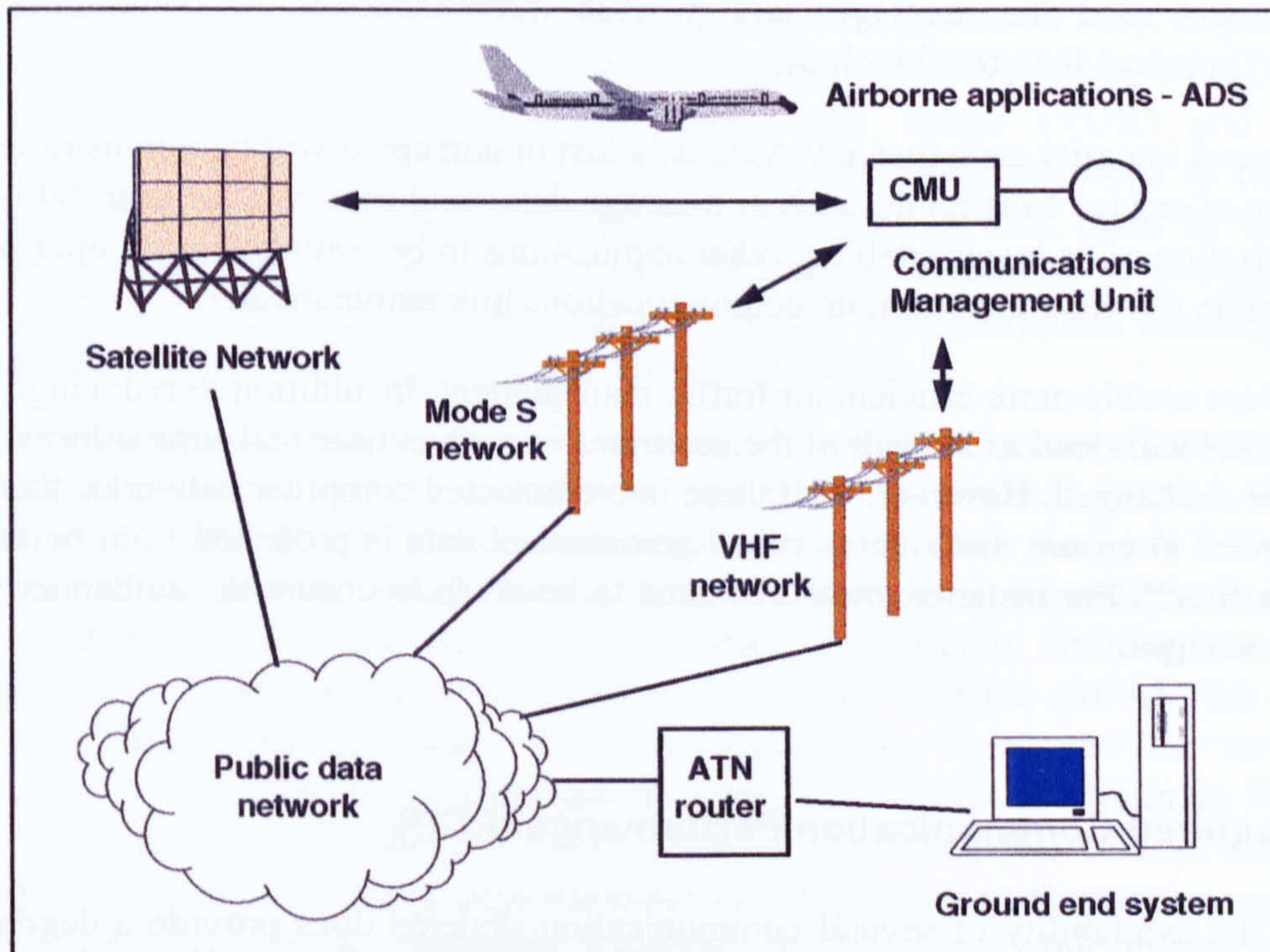


Figure 2.1 - ATN architecture

The ATN will be achieved by using a layered communications architecture, as portrayed in **Figure 2.1**, which consists of the following three basic sub-networks that can be separated as Local Area Networks (LAN) or Wide Area Networks (WAN):

- **Ground network**, which is formed by the AFTN, Common ICAO Data Interchange Network (CIDIN) and airline private networks. It has no limit in message length. Existing Aeronautical Fixed Services (AFS) communications plans detail all facilities required. ATN end systems are capable of communicating with other end systems and/or human machine interfaces;

<sup>115</sup> 'Facilities and Services Implementation Document (FASID) for the North Atlantic Region' - ICAO Doc. 9635. Trial Edition, 1995.



- **Air-ground network** containing data communication via the VHF, Mode S, HF and satellite sub-networks. The latter will carry voice and data using the Aeronautical Mobile Satellite Service (AMSS)<sup>116</sup>. ATN routers will enable the path through the network that is taken to reach the aircraft;
- **Airborne network**, which consists of ARINC data buses and the Communications Management Unit (CMU). The latter provides the interface between airborne systems and the ATN by data formatting and addressing functions<sup>117</sup>. A transition will occur from the character-oriented ACARS to bit-oriented ATN.

ATN's routers send the messages and provide interconnection of communication networks. Technical features<sup>118</sup> include:

- End to end integrity such that any ATC data lost or corrupted will be retransmitted;
- Quality of service constraints, such as message delay and cost, may be user-defined;
- Prioritisation of its levels enabling other applications to be simultaneously operated;
- The ability to select the optimum communications link automatically.

Such services enable more efficient air traffic management, in addition to reducing pilot and controller workload as a result of the accurate, error-free, near real-time information that will be exchanged. However, with these interconnected computer networks, there is a serious need to ensure that safety-critical aeronautical data is protected from potential security threats<sup>119</sup>. For instance, measures need to be taken to ensure the authenticity of datalink messages.

### 2.3.5 Required Communication Performance (RCP)

Although the availability of several communication systems does provide a degree of flexibility to planning and implementation in the different types of airspace, the proliferation of sub-networks will undoubtedly add to the operational complexity of the global ATN. Thus, there is a need to translate all relevant operational requirements in a particular airspace into a series of communication performance parameters.

The concept of Required Communication Performance (RCP) refers to a set of requirements such as availability, capacity, error-rate and transit delay. The RCP will be specified by ICAO for operational scenarios in various airspace environments, indicating that any single communication system, or combination of systems, meeting the set parameters can be considered operationally acceptable.

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<sup>116</sup> 'What is FANS?' – <http://www.iata.com>.

<sup>117</sup> 'Civil Avionics' – *Flight International*, 14 February 1996.

<sup>118</sup> 'CNS/ATM-1 Package SARPs and Guidance Material'. ICAO. Part.V. Version.3.0, August 1995.

<sup>119</sup> 'Information security techniques eventually to apply to aeronautical data communications' – *ICAO Journal*, September 2000.



## 2.4 Current navigation technology

Navigation, which may be defined as the art of directing the aircraft from one place to another, presently uses different ground-based and airborne navigational aids in the following two categories of airspace types:

- **Near or over land with dense traffic:** The Flight Management Computer (FMC) on board the aircraft, part of its Flight Management System (FMS), employs lateral navigation concepts such as Area NAVigation (RNAV) using Non-Directional Beacons (NDB), VHF Omni-directional radio Range (VOR) and Distance Measuring Equipment (DME). Indeed, aircraft are often restricted to flight paths along fixed routes. These are ground-based navigational aids, many of which have been in use for decades. Barometric altimetry is employed to provide vertical navigational guidance. The terminal environment uses Instrument Landing Systems (ILS). Microwave Landing Systems (MLS) also exist;
- **In oceanic and remote areas:** Long Range Navigation Systems (LRNS) are used, which include OMEGA, LORAN C and the self-contained Inertial Navigation System (INS). There has been a navigational trend since the early 1990s to use satellite navigation, which should reduce the required separations due to INS positioning errors that increase with time, consequently limiting the system's accuracy. Although Airborne Collision Avoidance Systems (ACAS) are primarily surveillance facilities, they are increasingly being developed for navigational purposes such as in-trail climbs and descents. The concept of Minimum Navigation Performance Specification (MNPS) airspace, which requires that all flights in a designated region achieve high standards of navigational performance accuracy, is a method of navigational assurance frequently employed in oceanic and remote areas.

Some carriers and countries have started to introduce the Global Positioning System (GPS) as a source of navigation reference. Correspondingly, Inmarsat has placed a set of navigational transponders on its Inmarsat-3 satellites.

With the exception of ACAS, which is covered in **Section 2.6.2**, and barometric altimetry, which is discussed in **Section 3.2.1**, this section analyses the aforementioned technologies and systems, in order to provide an overview of current means of navigation.

### 2.4.1 Area navigational aids

An aircraft's Flight Management System (FMS) is an integrated system, consisting of airborne sensor, receiver and computer with databases, which provides performance indicators and navigational guidance to a display and automatic flight control system.



Based on the flight plans, the FMS provides automated en-route and terminal area guidance using defined procedures, which include SIDs and STARs, holding patterns and procedural turns<sup>120</sup>.

Upon command, the FMS flies directly to a defined waypoint using roll, pitch, speed and thrust steering commands that the system sends to the autopilot and autothrottle. The FMS can compute speed and thrust settings commensurate with a pilot-chosen flight mode and computes predicted arrival times and fuel consumption. It also transmits flight plan, map and position data to the Electronic Flight Instrument System (EFIS) for display of the aircraft's position relative to the flight plan. The FMS selects and tunes the navigation aids automatically, thereby providing the flight path control necessary for navigation.

A Flight Management Computer (FMC), which is part of the aircraft's FMS, has lateral navigation parts called Area NAVigation (RNAV) systems that use one or more sets of signals to get a position fix and navigate based on a series of relative waypoints determined by the FMS. Noting that many ground-based aids are required to achieve high levels of accuracy<sup>121</sup>, the signals can be obtained from VHF Omni-directional radio Range (VOR), Distance Measuring Equipment (DME), VOR TACTical air navigation (VORTAC) or Non-Directional radio Beacons (NDB), thus:

- VOR stations transmit radio beams, termed radials, outward in every direction in the very high frequency range and travel on a line-of-sight basis<sup>122</sup>. Thus, the bearing to/from a station can be determined. However, as mentioned in Section 2.2.1, terrain features and altitude of the aircraft affect the reception range. VOR stations can be connected by specific radials, which form direct routes, or they can act as waypoints to facilitate relative (RNAV) steering by the FMS;
- DME facilities provide an added capability to course guidance, namely distance, up to 199nm from the station. DME, which is also subject to line-of-sight disadvantages, operates by transmitting a signal from the aircraft to a DME ground station and using the time recorded to receive a reply back to compute parameters such as the distance to the station and the aircraft's groundspeed;
- VORTAC provides the same functionality as a VOR or DME based on VOR azimuth and TACTical Air Navigation (TACAN) azimuth/distance information. All components operate simultaneously, albeit at more than one operating frequency;
- NDBs emit low to medium frequency radio signals so that an aircraft can home in on the station using the Automatic Direction Finder (ADF). The signals travel both as ground waves that penetrate obstacles and sky waves that are refracted by the ionosphere. These characteristics enable the waves to travel over great distances, even at low altitudes.

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<sup>120</sup> 'Technology & Procedures report' – Honeywell AATT.

<sup>121</sup> 'Demystifying CNS/ATM' – CANSO. June 1999.

<sup>122</sup> 'Private Pilot Manual' – Jeppesen Sanderson. Chapter 7.



## 2.4.2 Long Range Navigation Systems (LRNS)

Established Long Range Navigation Systems (LRNS) include OMEGA, LORAN C, DOPPLER and the self-contained Inertial Navigation System (INS). thus:

- ❑ **OMEGA** is a network of eight transmitting stations located throughout the world to provide global signal coverage. The signals travel great distances because they are transmitted in the Very Low Frequency (VLF) band. The accuracy of systems depends on the reception geometry and quality of its signals. which leads to its main disadvantage, that a spread of navigational accuracy can occur. However, OMEGA is capable of providing consistent fixing information to an accuracy of  $\pm 2$  nm. OMEGA has been decommissioned in recent years;
- ❑ **LORAN C**'s popularity is based on its capabilities, simplicity of operation and low cost. It obtains its position information from a chain of low frequency transmitters that transmit a synchronised signal in the form of ground and sky waves. Equipment is either certified for en-route/terminal or en-route/terminal/approach. LORAN C may be used as an input to RNAV-based flight management computers in order to facilitate similar operation to inputs from DME or NDB systems;
- ❑ **DOPPLER** radar is a semi-automatic, self-contained dead reckoning navigation system, composed of a radar sensor and computer that is not continuously dependent on information derived from ground-based or external aids. The system employs radar signals to detect and measure ground speed and drift angle using the aircraft's compass system as its directional reference. However, it is less accurate than OMEGA or INS;
- ❑ **INS** is similar to DOPPLER radar systems in that they both measure any change in the aircraft's direction of flight in a precise manner and determines position and speeds accordingly<sup>123</sup>. INS operates by sensing aircraft accelerations with a gyro-stabilised platform to provide output functions such as present position information and navigational data, which includes steering commands, angular pitch, roll and heading. Common practice is to input the aircraft's position prior to departure, when on the ground at a known position. A disadvantage of INS is that its positioning errors increase with time, at a degradation rate of 1 to 2 nm per hour. This consequent limitation of the system's accuracy is one of the reasons for large separation standards being required in oceanic regions. Satellite navigation will augment the systems, but RNAV will still require the route to be defined by waypoints using latitude-longitude. However, it should be noted that Inertial Reference Systems (IRS) are replacing INS, with the navigational trend being to use satellite navigation with the IRS.

One or more of these methods may be coupled with RNAV systems, particularly in oceanic and remote continental regions, where there is a significant lack of ground-based aids.

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<sup>123</sup> 'Fundamentals of Air Traffic Control' – MS Nolan. Wadsworth Publishing Company.



### 2.4.3 Global Navigation Satellite Systems (GNSS)

A Global Navigation Satellite System (GNSS) is a space-based radio positioning, navigation and time-transfer system. It consists of three segments: space, ground and user. GNSS, which is an integral component of the future technologies and procedures, is discussed in **Section 2.5.2** as a planned method of navigation. However, it should be noted that the following two satellite systems are part of the GNSS envisaged by ICAO<sup>124</sup> and are currently available for navigational purposes:

- **Global Positioning System (GPS)** is the US is the Department of Defence constellation of satellites, which is composed of 24 satellites in 6 orbital planes. Navstar is the first GPS system available to civilian users. The satellites operate near-circular 20,200km (10,900nm) orbits at an inclination angle of 55° to the equator. Each satellite completes an orbit in approximately 12 hours. It provides basic signals in space to allow a user to compute their position, velocity and time with a high degree of accuracy. GPS is relatively immune to weather and is very accurate, especially since its Selective/Availability (S/A) was turned off. S/A is the deliberate dithering of either the information used to compute the satellite's time and/or its location. S/A previously reduced GPS's accuracy to ca.100 metres, in contrast with its present sub-10m values. GPS can be employed anywhere on this globe;
- The Russian Federation's **GLONASS** has been deployed for military reasons and became operational in 1996<sup>125</sup>, in order to provide co-ordinate and time information at any point on the globe<sup>126</sup>. Its space segment consists of 24 operational satellites in orbit, with several spare. GLONASS satellites orbit at an altitude of 19,100km with an orbital period of 11 hours and 15 minutes. Eight evenly spaced satellites are arranged in each of three orbital planes, inclined 64.8° and 120° apart. It is similar to GPS, having a Channel of Standard Accuracy (CSA) and a Channel of High Accuracy (CHA).

With reference to **Section 2.2.3**, the Inmarsat-3 satellites carry one navigation transponder each, in order to provide four different services<sup>127</sup>. thus:

- **Integrity monitoring** – there can be a 30 minute delay in GPS and GLONASS satellites warning users of any problems with the system, which could be alleviated by real-time broadcast of information through ground monitoring stations;

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<sup>124</sup> 'The development of satellite navigation systems' – J Ott, *Integrating Global Air Traffic Management*. ISC & ICAO. 1998.

<sup>125</sup> Declaration of the Russian Federation Government dated 29 March 1999 was obtained from <http://mx.iki.rssi.ru/sfcsic/english.html>.

<sup>126</sup> 'GLONASS' – FANS CNS/ATM Starter Kit. IATA & ICAO.

<sup>127</sup> 'Working Paper presented at the First Meeting of the Global Navigation Satellite System Panel' (GNSSP1/-WP/21) – F. Ryan. 1994.

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- **Additional ranging source** – each Inmarsat satellite transponder can receive navigation-related signals from a navigation station on the ground and retransmit the signals at power levels designed to produce approximately the same radio frequency levels as a GPS satellite, with GPS receivers consequently treating the signal as if it emanated from a GPS satellite;
- **Accuracy enhancements** – the Inmarsat navigation package may also be used to transmit wide area differential correction messages to aircraft. Both EGNOS and WAAS (see **Section 2.5.3**) use the navigation transponder on the Inmarsat-3 constellation for trials;
- **Accurate time** – Inmarsat satellites can provide extremely accurate time references, which could be used as common references for worldwide ATC systems.

#### 2.4.4 Approach, landing and departure systems

Landing systems support execution of instrument approaches that are classified as either non-precision or precision<sup>128</sup>, thus:

- A **non-precision instrument approach** procedure uses no electronic guide-slope. Examples include employment of NDB or VOR signals;
- A **precision instrument approach** procedure is a standard instrument approach in which an electronic glide-slope or glide-path is provided. Examples are the Instrument Landing System (ILS), Microwave Landing System (MLS) and Precision Approach Radar (PAR). Different Decision Heights (DH) and Runway Visual Ranges (RVR) apply to the various categories that exist, Category (Cat) I through III, as portrayed in **Figure 2.2** below. Cat II landings must be conducted with a flight director or autopilot for a complete automatic landing. Cat III precision approaches have the added requirement that the aircraft, its systems and the airport's landing aids facilitate roll-out and taxiing of the aircraft also under electronic control.

Category	Decision Height (ft)	Runway Visual Range (m)
I	200	550
II	100	300
IIIa	Below 100	200
IIIb	Below 50	Less than 200
IIIc	-	-

**Figure 2.2 - Decision Heights and Runway Visual Ranges**

<sup>128</sup> 'Technology & Procedures report' – Honeywell AATT.



The following three main types of precision approach and landing systems currently exist:

- **ILS** – is designed to provide an approach path for exact alignment and descent of an aircraft on final approach to a runway. The system may be divided functionally into three parts: guidance information by the localizer and glide-slope; range information by the marker beacon or DME; visual information by approach, touchdown, centreline and runway lights. Both lateral and vertical guidance are displayed on conventional cockpit Course Deviation Indicators (CDI) or incorporated into multipurpose displays. The ground equipment consists of a maximum of three marker beacons along the approach and two highly directional transmitting systems. The latter are known as the localizer and glide-slope transmitters<sup>129</sup>. Radio altimeters measure the actual height of the aircraft above the ground during the final stages;
- **MLS** – is a precision approach and landing system that provides position information and various ground to air data to facilitate navigation guidance for exact alignment and aircraft descent. The position information is provided in a wide coverage sector and is determined by an azimuth angle measurement, an elevation angle measurement and DME/P (Precision) for range measurement<sup>130</sup>. The azimuth navigation guidance is provided by an azimuth station, which also provides data communications associated with the operation of the system and the performance of ground equipment. An elevation station provides the approach elevation. Both lateral and vertical guidance may be displayed on conventional cockpit CDIs or on multifunctional displays. Conventional DME indicators display range information. Advantages of MLS are its flexible descent glide angles and approach paths, with greater immunity from radio interference;
- **PAR** – Precision Approach Radar provides guidance for precision landings to aircraft in conjunction with digital datalinks to relay information on aircraft position and velocity vectors from the ground base radar to the aircraft. A ground-based PAR display includes azimuth, range and elevation information on the aircraft's approach.

Standard Instrument Departure (SID) and Standard Arrival (STAR) routes are established at busy aerodromes. Such systems are deemed forms of air traffic management and are consequently covered in **Chapter 3**.

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<sup>129</sup> 'International Air Traffic Control: Management of the World's Airspace' – A. Field. Pergamon Press.

<sup>130</sup> 'FANS CNS/ATM Starter Kit' – Section 2. IATA/ICAO.



### 2.4.5 Aircraft minimum navigation capability

The concept of Minimum Navigation Performance Specification (MNPS) airspace permits an increased flow of air traffic in an environment constrained by a lack of navigational and communication infrastructure, which is often subject to meteorologically-restrictive operating zones, with consequent reliability hazards<sup>131</sup>. It is implicit in the concept of MNPS airspace that all flights in the region achieve set standards of navigational performance accuracy, with specified aircraft minimum navigation capability.

The rationale and foundation for MNPS is based on a mathematical model that expresses the relationship between collision risk and separation within the appropriate Target Level of Safety (TLS). This Reich collision risk model considers separate risks in lateral, longitudinal and vertical dimensions, with aircraft represented as boxes. A series of procedures for its operations plus continuous monitoring of aircraft navigation accuracy maintain the integrity of MNPS airspace.

Although the aircraft navigation systems used are capable of high standards, an indication of an acceptable means of compliance with specifications in terms of the equipment is required<sup>132</sup>. This method of navigational assurance, which is frequently employed in oceanic and remote areas, ensures that all aircraft in the airspace have the capability to perform based on navigational criteria. Such aircraft are required to meet a minimum navigation performance specification. This is the basis of the Required Navigation Performance (RNP) concept that is discussed in **Section 2.5.5**. Indeed, according to ICAO, existing MNPS airspace will be partially changed to RNP areas with requisite Minimum Aircraft System Performance Specifications (MASPS).

The North Atlantic area is the most pertinent example of MNPS airspace due to its high-density traffic in an oceanic environment with limited communication and navigational aids. To justify consideration for unrestricted operation in its MNPS regions, an aircraft needs to be equipped with two fully serviceable Long Range Navigation Systems (see **Section 2.4.2**), one HF/VHF transmitter and two VHF receivers.

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<sup>131</sup> 'Operating in the North Atlantic MNPS Airspace' – C Whelan, *The Journal of Navigation*, January 1999.

<sup>132</sup> 'Guidance and Information Material concerning Air Navigation in the North Atlantic Region' – ICAO, *Interim 7<sup>th</sup> Ed.*, September 2000.



## 2.5 Future methods of navigation

The objectives of the navigation element of CNS/ATM systems are to enhance coverage and allow for all-weather navigation capability in every airspace, including approach and landing, while maintaining or improving integrity, accuracy and performance in accordance with ATM requirements<sup>133</sup>. It is meant to provide worldwide, accurate, reliable and seamless position determination capability through the introduction of predominantly satellite-based aeronautical navigation.

Ideally, future navigation would be based on a single system that can provide adequate navigation for all phases of the flight, including landing and approach, under all meteorological conditions, enabling aircraft to navigate in all types of airspace all over the world. Although this system still has to be invented, improvements in navigation will occur with the progressive introduction of:

- aRea NAVigation (RNAV) capabilities;
- Global Navigation Satellite System (GNSS);
- Satellite augmentation systems;
- Systems to support approach, landing and departure operations.

Each of the aforementioned components and the concept of Required Navigation Performance (RNP) are described in this section. Additionally, it must be remembered that many of the current navigation technologies will continue to exist in the future CNS/ATM environment.

### 2.5.1 Area Navigation capabilities

With reference to the discussion in **Section 2.4.1**, aRea NAVigation (RNAV) is a method of navigation that permits aircraft to navigate along any desired flight path within the coverage of station-referenced navigation aids or within the limits of self-contained aids. RNAV equipment operates by automatically determining the aircraft's position from one or more of a variety of inputs. The distances along and across tracks are computed to provide estimated times to waypoints.

The main difference between current RNAV and that envisaged in the CNS/ATM system is that future RNAV will operate automatically and will be predominantly satellite-based<sup>134</sup> using datalink facilities. Indeed, Galotti maintains, "Modern aircraft are

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<sup>133</sup> 'Global Air Navigation Plan for CNS/ATM systems' – Volume I, ICAO. 1<sup>st</sup> Ed. 2000.

<sup>134</sup> 'The Future Air Navigation System' – V Galotti. Chapter 4.



being increasingly equipped with RNAV as a system or function of the Flight Management System". Navigation is being revolutionised by the reduced dependence on land-based aids: INS and GNSS are being increasingly employed.

Airworthiness approval and operational requirements are stringent<sup>135</sup>. The common world geodetic reference system, WGS-84, was implemented because of increases in navigation accuracy and the introduction of RNAV, which requires a unique reference system<sup>136</sup>. Maps and airports references had to be changed accordingly.

The application of RNAV techniques in various parts of the world has already been shown to provide a number of advantages over more conventional forms of navigation. According to Galotti, its main intended benefits include:

- Establishment of more direct routes, with consequent reductions in flight distances;
- Creation of dual or parallel routes to accommodate greater flows of en-route traffic;
- Establishment of by-pass routes for aircraft overflying high-density terminal areas;
- Development of contingency and alternate routes on planned and ad hoc bases;
- Facilitation of optimum locations for holding patterns;
- Reduction in the number of ground-based navigational facilities.

In the future CNS/ATM environment, the FMC will periodically download its 4D trajectory and expected routing to allow for the negotiation of flight plans, which can be made available to ATC. Thus, the Required Time of Arrival (RTA) can be sent to the aircraft for acceptance or rejection. ATC and the aircraft can liaise accordingly and determine the optimum profile for the aircraft to adopt in routing towards the airport. In addition, the FMS will also dynamically request information from Flight Information Services (FIS) and deal with CPDLC for automatic route clearances. Flight planning is conducted similar to non-RNAV routings, in a manner approved by the nations whose airspace is being transited.

With reference to the discussion on Required Navigation Performance (RNP) in Section 2.5.5, two types of RNAV are considered in the European context, thus:

- **Basic RNAV, B-RNAV**, with track keeping performance of 5nm 95% of the time (RNP-5). B-RNAV has a minimum requirement of 4 waypoints;
- **Precision RNAV, P-RNAV**, with track keeping performance of 1nm 95% of the time (RNP-1). P-RNAV has a minimum requirement of 10 waypoints.

It should be noted that the following types of RNAV routes exist<sup>137</sup>:

- **Fixed RNAV routes**;
- **Contingency RNAV routes**, which are published ATS routes that can only be made available during specific periods;

<sup>135</sup> 'Area Navigation 1998 Symposium Proceedings' – Eurocontrol & JAA, March 1997.

<sup>136</sup> 'WGS 84 & Mapping' – J Gentleman, UK CAA. SATNAV for GA Seminar, Royal Institute of Navigation. March 1999.

<sup>137</sup> 'Manual of Area Navigation (RNAV) Operations' – ICAO Doc 9573-AN/933. 1991.



- **Random RNAV routes**, which are unpublished routings that may be planned within designated random RNAV areas;
- **Terminal area operations:** RNAV is a potential tool for increasing capacity at congested and/or terrain constrained airports using varied approach and departure procedures based on RNAV techniques<sup>138</sup>.

## 2.5.2 Global Navigation Satellite Systems (GNSS)

**Section 2.4.3** discusses the present satellite constellations in the Global Navigation Satellite System (GNSS), which is a worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers, ground monitor stations and system integrity monitoring devices. According to ICAO, GNSS will be the key feature of the future system and it will evolve from supplemental to sole means of navigation, eventually replacing the current ground-based systems.

The GNSS will provide a high-integrity, high-accuracy and all-weather worldwide en-route and terminal navigation service. GNSS supports accurate RNAV in all airspace types, based on satellite ranging, whereby the position on earth is determined by measuring exactly how far the aircraft is from a series of satellites. The system works by timing how long it takes a radio signal to reach the GNSS receiver and correspondingly calculating the distance. By ranging from four satellites, a position determination can be made.

Three phases are associated with worldwide GNSS implementation in CNS/ATM, thus:

- **Pre GNSS-1:** this current phase consists of the US's Global Positioning System (GPS) and the Russian Federation's GLONASS with, at most, local differential enhancements. GPS and GLONASS are described in **Section 2.4.3**. Both systems have been accepted by ICAO as a means of supporting the evolutionary development of the GNSS. The US has made the standard positioning component of GPS available for public use free of charge, albeit with a minimum guarantee of 6 years' advance termination notice. GLONASS has also been made publicly available and is subject to the two different levels of service cited in **Section 2.4.3**. Inmarsat satellites are also currently available;
- **GNSS-1:** this phase is mainly concerned with enhancing the service capabilities of GPS and GLONASS. **Section 2.5.3** covers geostationary satellite overlay and other augmentation systems such as EGNOS, MSAS, LAAS and WAAS. The continued implementation of GPS and GLONASS systems will enable aircraft to navigate using RNAV in all types of airspace all over the world, offering many nations the possibility of dismantling at least a portion of their aviation ground infrastructures;

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<sup>138</sup> 'Is Area Navigation the solution to capacity constraints?' – era regional report, October 1999.



- **GNSS-2:** Even though the aforementioned augmentation systems are being developed, the US is working on developing a successor to GPS. Correspondingly, the European Union has drafted plans to launch its own constellation of 'Galileo' satellites, which was announced in 1999, allegedly for defence, economic, political, security and strategic reasons. The European Commission and the European Space Agency (ESA) are jointly managing the Galileo project<sup>139,140</sup>. It is anticipated that Galileo will be a constellation of 30 Medium Earth Orbit (MEO) satellites<sup>141</sup> at around 20,000km altitude monitored by a network of ground control stations<sup>142</sup>. Its features will include timing and geodetic model compatibility with GPS. The interoperability of Galileo and GPS, defined<sup>143</sup> as "the level to which satellites from either constellation can be used for aircraft navigation", covers a wide spectrum of design and operational issues. Much synergy will occur in providing two independent GNSSs, but with similar ICAO SARPs<sup>144</sup> and harmonised JAA/FAA certification. However, constraints to the successful outcome of Galileo include the accuracy of GPS, spectrum availability<sup>145</sup>, standards and financing. Additionally, it should be noted that Japan's Multi-functional Transport SATellite (MTSAT) programme will be able to provide GNSS navigation capabilities. With a service life of ten years, operated on a not-for-profit basis, this satellite system will cover most of the Asia-Pacific region. MTSAT will also be used for meteorological purposes.

The successful global implementation of satellite navigation is predicated by the existence of a co-ordinate and procedures database of a very high quality. Accurate satellite navigation is only possible when the ground-derived co-ordinates, calculated co-ordinates and the satellite system-derived co-ordinates use the same geodetic reference system. Therefore, ICAO has adopted World Geodetic System WGS-84 as the common geodetic reference datum for civil aviation. WGS-84 aims to reduce positional discrepancies between different datums. Its implementation has involved the transformation of existing co-ordinates and reference datums to WGS-84. Correspondingly, there is a need to establish aeronautical databases to ensure the quality of position data in terms of accuracy, integrity and resolution. Such databases must be updated on a regular basis using surveys of existing navigation aids, position fixes and runway thresholds, as well as through the design of new routes or approach procedures. This should be done in conjunction with the marine and other industries, noting that the former is presently addressing the need to implement WGS-84 for GNSS navigation<sup>146</sup>.

<sup>139</sup> 'EC launches its Galileo definition phase contracts' – *Air Transport Intelligence*, 10 December 1999.

<sup>140</sup> 'Agreement between the European Community, the European Space Agency and the European Organisation for the Safety of Air Navigation on a European Contribution to the development of a global navigation satellite system (GNSS)' – *Official Journal of the European Communities*, 10.7.98.

<sup>141</sup> 'NAV 2000 – Conference Conclusion' – *Navigation News*, November/December 2000.

<sup>142</sup> 'Galileo: European project on positioning by satellite' – *European Commission brochure*, 2000.

<sup>143</sup> 'GPS and Galileo: best of all possible worlds?' – J Fee, *FAA. 5th Air Navigation Conference*, Amsterdam, September 1999.

<sup>144</sup> SARPs – Standards And Recommended Practices are covered in Chapter 1.

<sup>145</sup> 'Potential interference on the radio spectrum allocated for GNSS service needs urgent attention' – *ICAO Journal*, September 1996.

<sup>146</sup> 'Implications of the use of GNSS and WGS84 for Marine Navigation' – T Moore et al., *The Journal of Navigation*, September 2000.



### 2.5.3 Satellite augmentation systems

To overcome the aforementioned inherent system limitations and to meet performance accuracy<sup>147</sup>, integrity<sup>148</sup>, availability<sup>149</sup> and continuity requirements for all phases of flight, GNSS requires varying degrees of augmentation to support the different phases of flight<sup>150</sup>. The level of GNSS accuracy can vary due to technical problems associated with timing or because of institutional reasons, such as the former GPS degradation. But systems that monitor signal reliability and enhance accuracy to make GNSS suitable for civilian use are still being developed and may be broadly categorised as aircraft-based, ground-based and satellite-based. thus:

- **Aircraft-Based Augmentation Systems (ABAS)**, which is a group of techniques making use of information that already exists within the aircraft<sup>151</sup>. Such systems are either Receiver Autonomous Integrity Monitoring (RAIM), where at least five satellites are continuously assessed for matching positions, with the possibility of determining one that is giving incorrect information, or Aircraft Autonomous Integrity Monitoring (AAIM), which integrates current navigation sensors such as VOR, DME, INS and IRS with GNSS during short periods when the satellite navigation antennas are shadowed by the aircraft during manoeuvres or during periods when insufficient satellites are in view;
- **Ground-Based Augmentation Systems (GBAS)**, which are also referred to as local area systems, involve one or more monitoring stations being at or near an airport where precision operations are desired, with the ability of sending differential correction signals by ground-based datalink to an aircraft within 20nm to provide corrections with a view to increasing the position accuracy locally, along with satellite integrity information;
- **Satellite-Based Augmentation Systems (SBAS)**, which are also termed wide area or regional augmentation systems and enable large area coverage.

Inmarsat-3 satellites, the independent and global satellite based system<sup>152</sup> referred to in **Section 2.2.3**, is designed to complement GPS and GLONASS by having navigational transponders on their Inmarsat-3 satellites that broadcast information concerning the

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<sup>147</sup> Accuracy – the degree of conformance between the aircraft's measured position and its true position.

<sup>148</sup> Integrity – the ability to provide timely warnings that part or all of the system is providing erroneous information and thus should not be used for navigation.

<sup>149</sup> Availability – the probability that, at any given time, the system will meet the integrity and accuracy requirements for a specific flight phase.

<sup>150</sup> 'Global Air Navigation Plan for CNS/ATM systems' – Volume I, ICAO.

<sup>151</sup> 'Demystifying CNS/ATM' – CANSO. June 1999.

<sup>152</sup> 'Someone to watch over me' – F Ryan, *Aeronautical Satellite News*. August-September 1994.



health and performance of GPS or GLONASS. The transponders enhance GPS and GLONASS performance using the ICAO defined GNSS SBAS<sup>153</sup>. Use to date has been for SBAS testing purposes. Based on GPS, Inmarsat and Japanese satellite systems, three SBAS are presently being developed for GNSS-1, thus:

- **Wide Area Augmentation System (WAAS)** in the US, based on an independent large network of monitoring ground stations to augment GPS for civil aviation as a primary means navigation aid from en-route to precision approaches. WAAS will enhance the broadcast of a GPS-like ranging signal and provide integrity broadcasts to permit aviation users to determine when GPS should not be used for various flight phases<sup>154</sup>. WAAS will apply to all phases down to Cat I precision approaches and near-Cat II systems. Indeed, US carriers say that only their domestic operations will benefit from WAAS's limited precision approach capability<sup>155</sup>. It will use Inmarsat satellites' navigation transponders to provide the service. Its planned coverage is very large, extending as far as Iceland and Singapore<sup>156</sup>. WAAS will consist of a network of Wide area Reference Stations (WRS) that receive and monitor GPS signals. Data from these stations will be transmitted to Wide area Master Stations (WMS), where the validity of the signals from each satellite is assessed and wide-area corrections computed. These integrity messages and wide-area corrections are then sent from the WMS to a ground earth station for uplink to geostationary communications satellites for transmission to aircraft on the GPS L1 frequency. "WAAS capable" receivers are required. Unlike standard DGPS, the ground stations for the WAAS system will be equipped with GPS receivers with both L1 and L2 frequencies. Having dual frequency receivers allows the receiver to compute signal delay due to the ionosphere. Ionospheric corrections are critical to any high-accuracy wide area augmentation system for any GNSS;
- **European Geostationary Navigation Overlay Service (EGNOS)** is a GNSS augmentation system similar to WAAS in the US that also uses Inmarsat satellites to provide the augmentation service. EGNOS is expected to use both GPS and GLONASS, in addition to the Inmarsat geostationary satellites, to provide enhanced services with additional ranging sources, integrity information and differential corrections. EGNOS is multi-modal, with use in maritime, road and rail transport sectors in addition to the aeronautical industry<sup>157</sup>. EGNOS is being implemented as a joint effort between the European Commission, the European Space Agency (ESA)

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<sup>153</sup> 'Satellite communication serving the aircraft operator' – L Norrish, Inmarsat. 5<sup>th</sup> Air Navigation Conference, Amsterdam. September 1999.

<sup>154</sup> 'The Future Air Navigation System' – V. Galotti. Chapter 4.

<sup>155</sup> 'UPS claims simple fix for WAAS precision approach problem' – Air Transport Intelligence, 12 January 2001.

<sup>156</sup> 'Implementation of GPS Air Navigation Applications in the USA' – J Fee. 4<sup>th</sup> Air Navigation Conference, Amsterdam. September 1998.

<sup>157</sup> 'EGNOS – the European satellite augmentation to GPS and GLONASS' – E Perrin, European GNSS Secretariat. 4<sup>th</sup> Air Navigation Conference, Amsterdam. September 1998.



and Eurocontrol<sup>158</sup>. The Northern European ADS-B Network (NEAN) trial complements EGNOS<sup>159</sup>;

- **Multi-functional transport Satellite Augmentation System (MSAS) in Japan**, using two MTSAT satellites to provide augmentation cover over the entire Japanese Flight Information Region (FIR), in addition to designated adjacent Asia-Pacific FIRs. The augmentation system will consist of the two GEO satellites, two master control stations, at least six domestic ground-monitoring stations and three monitoring and ranging stations<sup>160</sup>.

The following GBAS, which is faster and cheaper than SBAS, is being developed:

- **Local Area Augmentation System (LAAS) in the US** – LAAS is intended to complement the aforementioned WAAS by providing higher accuracy Cat II or Cat III precision approach and landing phase capability that will not be possible using WAAS. Under this concept, the corrections to the basic GPS signals are broadcast to aircraft within line of sight of a ground reference station<sup>161</sup>. LAAS will facilitate tailored approaches so that obstacles, noise sensitive areas and congested airspace can be avoided. In the case of multiple runway coverage at an airport, one LAAS will suffice. It will also be a potential aid for aircraft surface navigation<sup>162</sup>.

It should be noted that GPS and GLONASS have been proven to be capable of providing adequate redundancy together in order to allow system integrity monitoring and that joint coverage of the two systems appeared to be adequate for receiver autonomous integrity monitoring<sup>163</sup>. Additionally, an investigation of the capabilities and limitations of integrating signals from GPS and GLONASS satellites show significant benefits of having an integrated receiver, which could render the two constellations as supplemental and sole navigational means<sup>164</sup>. Interoperability issues among the augmentation programmes have been considered<sup>165</sup>.

Multi-sensor avionics are expected to supersede the current GPS and GLONASS systems that do not include RAIM capability. Aircraft using multi-sensor navigation systems, such as integrated GNSS/IRS or GNSS/IRS/FMS, may be certified as meeting levels of required navigational capabilities that could not be obtained by use of GPS or GLONASS alone. Correspondingly, it has been shown that a component of Loran-C,

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<sup>158</sup> 'Cost recovery: its relevance to EGNOS and Galileo' – P Le Galbo, ESA. The 5<sup>th</sup> Air Navigation Conference, Amsterdam. September 1999.

<sup>159</sup> 'All change in air traffic control' – Interavia, April 1997.

<sup>160</sup> 'MTSAT: Japan's contribution to the implementation of the ICAO CNS/ATM systems in the Asia/Pacific regions' – ICAO Rio de Janeiro Conference, May 1998.

<sup>161</sup> 'The FAA's implementation of satellite-based navigation systems for aviation' – M Shaw, FAA. The Airline Navigation Conference '95, Amsterdam. September 1995.

<sup>162</sup> 'Swedavia Paper' – J Nilsson. Air Navigation '97 Conference, Amsterdam. September 1997.

<sup>163</sup> Report of the Tenth Air Navigation Conference – ICAO Doc. 9583 AN-CONF/10.

<sup>164</sup> 'Flight Tests of GPS and GLONASS equipment' – The Journal of Air Traffic Control. Jan-Mar 1992.

<sup>165</sup> 'International support for precision approach trials' – Jane's Airport Review, November 1998.



called 'Eurofix', can improve the performance of GPS and/or GLONASS<sup>166</sup>. It is being analysed as a potential inclusion in Galileo<sup>167</sup>.

#### 2.5.4 Approach, landing and departure systems

With reference to the discussion in **Section 2.4.4** on present forms of approach, landing and departure systems, ICAO reported in 1995<sup>168</sup> that it had drafted a 20-year strategy on implementation of all-weather non-visual approach and landing operations, which detailed that the Instrument Landing System (ILS) should be retained as the international standard for the foreseeable future and encouraged limited use of Microwave Landing System (MLS) for precision and landing guidance for those locations where it is operationally required and economically viable. ICAO's global strategy<sup>169</sup> incorporates this by intending to introduce and apply the following standard non-visual aids to precision approach and landing through:

- A continuation of **Instrument Landing System (ILS)** operations to the highest level of service as long as operationally acceptable and economically beneficial;
- Implementation of **Microwave Landing System (MLS)** where operationally required and economically beneficial;
- The promotion of **Multi-Mode Receiver (MMR)** or an equivalent airborne capability, to maintain aircraft interoperability;
- A validation of **Differential GNSS (DGNSS)** use with the requisite augmentations to support terminal operations. DGNSS works on the principle that a receiver is placed at a known location and computes the range to and from the satellites, producing the pseudo-range correction, which is then transmitted via datalink to the aircraft to apply this correction to its own computed pseudo-range. For instance, Differential GPS (DGPS) will use GPS signals as a GPS Landing System (GLS), augmented on a local basis using a Local Area Augmentation System (LAAS), to guide the aircraft on its approach to landing. DGPS can also include a carrier phase to give centimetric accuracy. DGPS is cheaper than ILS<sup>170</sup>. In the US case, the FAA's preferred method of LAAS augmenting DGPS uses Airport PseudoLites (APL), which are ground-based transmitters configured to emit GPS-like signals<sup>171</sup>. GNSS also gives airspace designers a further option to develop procedures that

<sup>166</sup> 'Enhancing GNSS with Loran-C/Eurofix' – *Navigation News*, September/October 1999.

<sup>167</sup> 'Eurofix incorporation in Galileo under study' – *Air Navigation International*, 26 June 2000.

<sup>168</sup> 'ICAO Special Communications/Operations Meeting drafts 20-year strategy for all-weather non-visual approach and landing operations' – *ICAO News Release (PIO 3/95)*.

<sup>169</sup> 'Global Air Navigation Plan for CNS/ATM systems' – Volume I, ICAO. 1<sup>st</sup> Ed. 2000.

<sup>170</sup> 'DGPS approaches' – *Flight International*, 28 February 1996.

<sup>171</sup> 'LAAS Pseudolite Testing' – *SATNAV news*, August 1999.



support low minima, avoid noise sensitive areas and reduce flying time in the terminal area;

- The **Autonomous Precision Approach and Landing System**<sup>172</sup> (APALS) is a completely airborne system that provides functionality similar to an ILS, MLS or DGNSS precision landing system. The unique feature of APALS is that the system requires no ground-based equipment because it uses a combination of an INS and Synthetic Aperture Radar (SAR) to measure the range and range rate errors. The SAR uses the weather radar as the sensor to obtain raw radar returns, which are then processed to form a SAR image that is correlated against stored maps with precisely known references. APALS can determine the exact aircraft location through correlation of sequential scenes along the approach path. Accurate position data from GPS is used to generate conformal runway images in Head-Up Displays (HUD) along with approach azimuth, glide-slope reference and flare cue piloting information. The on-board GPS system can also be used for en-route navigation<sup>173</sup>. APALS is delivered with a database for every runway that an airline expects to serve<sup>174</sup>;
- The **Transponder Landing System** (TLS) is another precision aid, offered by the Advanced Navigation & Positioning Corporation, which has several receivers around the runway that obtain transponder signals from the aircraft and then perform a computation to determine where the aircraft is located. After determining the location, the TLS sends up signals on ILS frequencies that are compatible with existing ILS equipment on board the aircraft<sup>175</sup>. Hence, there is no requirement for any new equipment on the aircraft. The system is designed to allow multiple types of approaches, such as curved and steep angle<sup>176</sup>, which is ideal for small to medium sized airports and those with terrain limitations;
- **Centre TRACON Automation System** (CTAS) is a US project that is developing a facility intended to aid air traffic controllers attain greater runway landing density without any loss in safety. It does so using a ground-based computer to predict optimum descent profiles and approach to the runway.

Head-Up Displays (HUD), which project the aircraft's flight instrument indications onto a transparent screen in front of the pilot's windshield, are felt by many to be the link between future applications and today's systems<sup>177</sup>. It is claimed<sup>178</sup> that "head-up displays and enhanced vision can add significant operational, economic and safety

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<sup>172</sup> Trademark of the Lockheed-Martin Corporation.

<sup>173</sup> 'New approach/landing systems near US certification' – *Interavia*, January/February 1997.

<sup>174</sup> 'APALS at last' – *Air Transport World*, March 1996.

<sup>175</sup> 'Flight trials demonstrate precision approach' – *Jane's Airport Review*, November 1997.

<sup>176</sup> 'New approach/landing systems near US certification' – *Interavia*, January/February 1997.

<sup>177</sup> 'A standard approach to precision landing' – *Jane's Airport Review*, November 1997.

<sup>178</sup> 'Enhanced Vision Systems: an update' – D Haapala, *Air Economics. The Airline Navigation Conference '95, Amsterdam. September 1995.*



advantages.” HUDs increase the precision and safety of flying in the following three ways<sup>179</sup>:

1. HUDs eliminate the need for pilots to transition back and forth between the instrument panel and the exterior view;
2. HUDs present all the information needed to fly the aircraft in such a manner that all parameters can be monitored, thereby enhancing situational awareness;
3. HUDs use two extra information cues, the velocity vector and the flight path acceleration, which allow the aircraft to be flown with greater ease and precision.

HUDs now incorporate Enhanced Vision Systems (EVS), which offer Cat III-equivalent operations on Cat I runways. Using GNSS signals with ILS and MLS, HUD-EVS allows Cat III landings on all runways. They also minimise the chances of experiencing the ‘black hole approach’ effect, whereby pilots find it very difficult to maintain a consistent approach to poorly lit runways at night due to a lack of horizon. HUDs have also been developed for the business and regional aircraft markets<sup>180</sup>, which operate into airports with marginal grounds infrastructure. Ultimately, it is argued<sup>181</sup> that HUD “pays its way in safety benefits alone.”

Due to increased awareness of noise and emissions in the vicinity of the airport, future approaches and landings will employ more Continuous Descent Approach (CDA) procedures<sup>182</sup>, whereby an aircraft is normally at a power setting of idle or near-idle at a final approach fix of around 2,500ft.

### 2.5.5 Required Navigation Performance (RNP)

Similar to the concept of Required Communication Performance (RCP), which is discussed in **Section 2.3.5**, Required Navigation Performance (RNP) recognises that aircraft navigation systems are capable of achieving predictable levels of performance accuracy within a defined airspace. An RNP “type” is based on a value that is expected to be achieved at least 95% of the time by the aircraft population operating within the airspace. RNP types are identified by a single accuracy value expressed in nautical miles for each stage. For example, RNP-10 specifies that all flights must be within 10nm of their intended position for 95% of the total flying time.

Ideally, an airspace would have a single RNP type, but types are mixed within a given airspace. RNP can apply from take-off to landing, for all the different phases of flight. Correspondingly, the RNP types for approach, landing and departure operations are usually different and are defined in terms of the required accuracy, integrity, continuity

<sup>179</sup> ‘A new, safer, way of flying’ – *Interavia*, January-February 1997.

<sup>180</sup> ‘Through the looking glass’ – *Flight International*, 31 January 1996.

<sup>181</sup> ‘Heads up for safety’ – *Air Transport World*, November 2000.

<sup>182</sup> ‘continuous descent approach trials reveal significant improvements in emissions and fuel consumption’ – *era regional report*, November 2000.



and availability of navigation for the particular flight phase. While some types contain accuracy specification of lateral performance only, other types also include lateral and vertical performance specifications.

The RNP type value required for a specific flight phase may be determined by the tunnel concept, which establishes airspace protection criteria based on the occurrence that an aircraft would unintentionally leave a tunnel. The requirement necessary to keep the aircraft in the tunnel is the RNP type translated into accuracy, integrity, continuity and availability parameters. The parameters constitute the probability that the aircraft would leave the tunnel. The tunnel concept applies to all flight phases. Accordingly, airspace infrastructure affects the RNP value. Consideration must therefore be given to regions' airspace collision risk characteristics, which are functions of its communications, navigation, surveillance and air traffic control capabilities. Each route structure's configuration, its traffic density, complexity and forecast traffic demand are other factors that affect the development of new aircraft separation minima based on this concept<sup>183</sup>.

Correspondingly, the level of aircraft equipment sets, or is set by, the RNP value. In theory, any sort of navigation system can be used to provide RNP. The types are presently linked with Basic and Precision-RNAV, as mentioned in **Section 2.5.1**. Indeed, it is expected that most aircraft operating in a future RNP environment will carry some type of RNAV equipment<sup>184</sup>. Given that the use of RNAV facilitates a flexible route system, the RNP concept has been developed to ensure that RNAV navigational equipment will be used in the future system. The RNP concept has been extended from RNAV's en-route operations application to cover all phases of the flight. The RNP concept is similar to the method currently used to indicate required aircraft minimum navigation capability, as discussed in **Section 2.4.5**. Aircraft with lower navigation performance capability will continue to operate in other parts of the airspace regions.

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<sup>183</sup> 'Operating in the North Atlantic MNPS Airspace' – C Whelan, *The Journal of Navigation*. January 1999.

<sup>184</sup> 'Manual on Required Navigation Performance (RNP)' – ICAO Doc 9613-AN/937. 1994.



## 2.6 Current surveillance techniques

Surveillance is the basic tool for the controller to monitor the maintenance of safe separation, manage the airspace efficiently and assist pilots in navigating the aircraft safely. In addition, the pilot needs to be aware of proximate aircraft that may represent a collision risk. The efficiency of Air Traffic Control (ATC) is dependent upon the availability of communications and surveillance capabilities. The following surveillance techniques are presently employed in the respective categories of airspace, thus:

- **Near or over land with dense traffic:** the main means of surveillance by air traffic control in such areas is the use of radar, which is independent of the pilots' co-operation. This is usually Secondary Surveillance Radar (SSR), but Primary Surveillance Radar (PSR) is also still in use. In addition, Airborne Collision Avoidance Systems (ACAS) such as Traffic alert and Collision Avoidance Systems (TCAS) are employed;
- **In oceanic and remote areas:** surveillance methods in such regions, where radar coverage is not available, are usually dependent on co-operation from pilots. Aircraft positioning is determined on board and is transmitted to ATC using HF and/or VHF radio contact, invariably through procedural voice position reporting. Supplemental monitoring is sometimes conducted by ATC using technologies such as Enhanced Traffic Management Systems (ETMS) and Flight Data Processing Systems (FDPS). In addition, aircraft are starting to report positions automatically using datalink technologies.

In all types of airspace, aircraft users are encouraged to place some form of Ground-Proximity Warning System (GPWS) in their avionics. Additionally, systems exist for detecting and avoiding adverse weather conditions.

This section details and analyses the effects of currently available tools.

### 2.6.1 Surveillance radar

As indicated above, surveillance radar coverage may be conducted using Primary Surveillance Radar (PSR) or Secondary Surveillance Radar (SSR), thus:

- **PSR** uses the basic principle of a beam of energy transmitted through an aerial reflected back from any aircraft in its path to provide information on the bearing and distance of the aircraft. It consequently does not require carriage of any equipment by the aircraft and is capable of detecting almost any moving target. The display presented to the controller provides information on the range and azimuth of reflected objects, including aircraft. Thus, primary radars are also currently used for



weather detection, as Airport Surveillance Radars (ASR), and are applied as precision approach radars;

- SSR requires the aircraft to be fitted with a (Mode A or C) transponder<sup>185</sup> that automatically transmits information when interrogated by the controller. In Mode 'A', the aircraft transponder provides identification information, aircraft bearing and distance. In Mode 'C' operation, which employs the use of individual aircraft codes, it has automatic pressure-altitude reporting equipment. Identification is limited to 4,096 codes. The current SSR process is in wide use around the world where terrestrial, line-of-sight surveillance systems are appropriate and possible. Some radar sites are secondary radar equipped only<sup>186</sup>: unlike primary radar, secondary can only "see" those aircraft with operating transponders.

Surface surveillance systems provide coverage of aircraft and vehicles within the airport's designated landside area in order to facilitate confirmation of authorised surface movements, improved movement efficiencies, reduced numbers of surface collisions and to minimise the chance of runway incursions. Airport Surface Detection Equipment (ASDE), which consists of a radar-based detector and display processor/sub-system(s), is currently used at airports. It is possible to present the target's identification on the display.

### 2.6.2 Airborne Collision Avoidance Systems (ACAS)

An Airborne Collision Avoidance System (ACAS) is a technology that enables aircraft to avoid each other in the air. It is, by definition, contained entirely on-board and is not dependent on any ground-based system. The equipment operates as an airborne SSR radar by interrogating (non-Mode A) SSR transponders of other aircraft in its vicinity, analysing the replies by computer using collision avoidance algorithms<sup>187</sup> to see which aircraft represent potential collision hazards and providing appropriate advisory information to the flight crew.

ACAS conducts air-to-air surveillance in one of two modes, according to the type of transponder in the other aircraft under surveillance. If the other aircraft is equipped with a Mode-S transponder, then ACAS is done in Mode-S format; similarly for Mode C<sup>188</sup>. A problem with the latter is that multiple aircraft reply to a single interrogation, which leads to synchronous garble of the replies. In Mode-S, the interrogations are addressed selectively, so that only one aircraft replies to a single interrogation.

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<sup>185</sup> 'Private Pilot Manual' – Jeppesen Sanderson. Chapter 2. Section E.

<sup>186</sup> 'NAT International General Aviation Operations Manual' – North Atlantic Systems Planning Group (NATSPG), 2<sup>nd</sup> Ed.

<sup>187</sup> 'Airborne Collision Avoidance Systems' – ICAO circular 195-AN/118. 1985.

<sup>188</sup> 'TCAS: a system for preventing midair collisions' – The Lincoln Laboratory Journal. Vol. 2, No. 3.



If proximate aircraft are considered to be a potential threat, the ACAS equipment can provide two types of advisories: Traffic Advisories (TA) through position indications of the intruding aircraft on a display and/or aural warnings; Resolution Advisories (RA), which give manoeuvring guidance to maintain or increase separation from threatening aircraft. Generation of these advisories is based on the last three or four interrogations of the nearby aircraft, with a calculation of its projected profile and is not, at present, based on a known intent of intruding aircraft<sup>189</sup>.

Many resolution advisories are experienced in RVSM airspace regions, particularly with earlier TCAS versions<sup>190</sup>. Pilots have reported frequent, long-duration "nuisance" traffic advisories when aircraft climb and descend<sup>191</sup>. Paradoxically, in-trail climb and descents are being made possible with ACAS equipment in the North Atlantic RVSM region. However, care must be exercised because Australia's Bureau of Air Safety Investigation (BASI) claims that, "under certain circumstances, some specific identified design deficiencies, system errors and equipments failures have increased the risk of mid-air collisions."<sup>192</sup>

Traffic alert and Collision Avoidance Systems (TCAS), the US implementation of the ICAO international ACAS standard, has been designed and introduced so that pilots can accurately determine the relative position of other TCAS-equipped aircraft within at least a 10-mile radius. A TCAS system is composed of three major sub-systems for surveillance, collision avoidance and display. Two types of ACAS/TCAS exist, thus:

- **ACAS I = TCAS 1:** provides vertical information only and is intended for General Aviation (GA) aircraft. From the beginning, TCAS 1 was decreed to be a system that would only supply traffic advisories and not resolution advisories<sup>193</sup>. It does not require a Mode-S transponder. TCAS 1 is not recognised in Europe;
- **ACAS II = TCAS 2:** providing approximate horizontal traffic information and vertical resolution, it is presently used on a wide scale. TCAS 2 Change/Version 7 conforms to the ICAO standard and facilitates conflict co-ordination via Mode-S transponders cross-link between aircraft and air-ground. Change/Version 7 reduces nuisance alerts, clarifies warnings, decreases radio frequency congestion<sup>194</sup> and minimises transmission clutter<sup>195</sup>. Indeed, Change/Version 7 contains over 300 improvements to Version 6<sup>196</sup>. An aural command draws the pilot's attention to the display for specific guidance, which provides better graphical messages. Typically, the system records aircraft 30-40nm away and tracks them long before they are displayed. Change/Version 7 is thought to be the last update for TCAS 2<sup>197</sup>.

<sup>189</sup> 'The World Market for ATC Equipment' – Jane's Information Group. September 1996.

<sup>190</sup> 'IFALPA sparks row over use of TCAS in RVSM airspace' – Flight International, 12 March 1997.

<sup>191</sup> 'Two weeks of RVSM confirms pilot fears over TCAS alerts' – Flight International, 16 April 1997.

<sup>192</sup> 'BA, BASI warn of serious TCAS-related faults' – Air Transport Intelligence, 23 September 1999.

<sup>193</sup> 'Collision avoidance for corporate aircraft' – Avionics, September 1992.

<sup>194</sup> 'Eurocontrol monitors Europe's ACAS progress' – Flight International, 7 April 1999.

<sup>195</sup> 'ACAS II approval' – Flight International, 11 August 1999.

<sup>196</sup> 'Carriage clock' – air traffic management, September/October 1998.

<sup>197</sup> 'New TCAS-2 software simplifies operation' – Aviation Week & Space Technology, 10 March 1997.



AlliedSignal, Honeywell and Rockwell Collins offer systems<sup>198</sup>. However, due to the merger of the former two avionics manufacturers, Sextant bought Honeywell's TCAS 2 business<sup>199</sup>. As discussed in **Section 4.6**, Sextant is now part of Thales.

A Traffic and Collision Alert Device (TCAD) is similar to TCAS, but avoids complexity and is small enough to facilitate introduction in GA aircraft. It is a passive device that receives and doesn't transmit. Like TCAS, it uses the reply signals from airborne beacon transponders. TCAD has a display and provides aural warnings. It sounds the alarm when another aircraft penetrates the space with a pseudo-shield that is placed around an aircraft. Dimensions of this shield vary with the operational environment<sup>200</sup>.

### 2.6.3 Procedural voice reporting

To fulfil the need of providing surveillance where radar coverage is not available, procedural voice reporting is employed using HF and/or VHF radio contact. Flights operating in such radar-less environments are controlled on the basis of their flight plans. This necessitates large separations between aircraft due to the slow nature of the process, as described hereunder.

Many Flight Information Regions (FIR) throughout the world rely on procedural systems for controlling air traffic, often with little or no automation support. However, supplemental monitoring is sometimes presently conducted by ATC using technologies such as Enhanced Traffic Management Systems (ETMS) and Flight Data Processing Systems (FDPS), which constantly work out estimates of aircraft locations and alert controllers of any impending conflicts. In addition, aircraft are starting to report positions automatically, using datalink technologies.

The North Atlantic Oceanic region is an area that employs procedural voice reporting, but its Oceanic Area Control Centres (OACCs) use ETMS and FDPS to supplement surveillance. Automatic Dependent Surveillance (ADS) is presently undergoing trials in the region. Even though new technologies have been implemented, lengthy processes are still being conducted: for example, the Shanwick FIR's OACC is located in Prestwick, Scotland and the associated aeradio station at Ballygirreen in Ireland. It can take up to 15 minutes for a pilot to relate the aircraft's position to the OACC because the message must be told over HF radio to Ballygirreen, where it is typed out and sent to the controller in Prestwick.

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<sup>198</sup> 'ACAS II Implementation Progress Update' – Eurocontrol ACAS Programme Steering Group Working Paper, September 1999.

<sup>199</sup> 'AA2000: Sextant nears deal for Honeywell's TCAS' – Air Transport Intelligence, 22 February 2000.

<sup>200</sup> 'New collision avoidance device is based on simple and passive design to keep the cost low' – ICAO Journal, May 1997.



## 2.6.4 Ground-Proximity Warning Systems (GPWS)

Controlled Flight Into Terrain (CFIT) is defined as an accident in which an aircraft, suffering no mechanical difficulties and not subject to adverse weather, is flown under control into terrain without awareness on the part of the crew. CFIT is the greatest cause of air fatalities after flight crew error.

Technical solutions include:

- **Ground-Proximity Warning Systems (GPWS)**, known as Terrain Alerting and Warning Systems (TAWS) in the US, monitor aircraft instruments and trend information from Radio Altimeter (RA), providing audible warnings, but no display, of proximity to the ground. GPWS therefore relies heavily on RA signals<sup>201</sup>;
- **Enhanced GPWS (EGPWS)** use a worldwide digital terrain database, integrated with the RA and linked to the Inertial Navigation System (INS), to provide the alerting functions of GPWS, a visual terrain display and advanced warning of threatening terrain ahead to pilots at least 60 seconds<sup>202</sup> in advance, using a colour code that indicates the level of threat posed. Two alerting envelopes are computed, one that corresponds to a caution-level alert and the other to a warning-level alert<sup>203</sup>. Data can be displayed either on a dedicated weather radar indicator or, if the aircraft is equipped with an Electronic Flight Instrument System (EFIS), the visual map can be superimposed on an electronic Navigational Display (ND). EGPWS is integrated with other avionics warning systems, such as for adverse weather and windshear, in addition to TCAS.

## 2.6.5 Meteorological systems

Meteorological technology includes Airborne Weather Radar (AWR), Storm Scope (SS), Ground Based Weather Radar (GBWR), Automated Weather Observing System (AWOS) and Automated Surface Observation System (ASOS), thus:

- **AWR** – operates like other primary radar systems by scanning the volume of airspace in front of the aircraft from about 45° to either side of the heading. The display unit can usually show storm centres at distances of up to 200 nm;
- **SS** – is an instrument used onboard that detects electrical discharges and displays them relative to the aircraft's heading so that pilots are provided with awareness of dangerous weather;
- **GBWR** – provides high-quality, long-range weather information to the industry;

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<sup>201</sup> 'Enhanced GPWS improves situational awareness and provides more effective protection near terrain' – ICAO Journal, May 1997.

<sup>202</sup> 'Airbus makes EGPWS standard – AlliedSignal' – Air Transport Intelligence, 22 April 1998.

<sup>203</sup> 'Looking ahead with certainty' – Aircraft Technology Engineering & Maintenance, June-July 1999.



- **AWOS** – broadcasts local weather data, at intervals of one minute, to pilots;
- **ASOS** – consists of many individual weather sensors that continually acquire data by sampling and measuring multiple aspects of the ambient environment. Data collection packages then use the raw information and manipulate it as the display or output necessitates.

Current conventional weather forecasting techniques are heavily reliant on the use of Numerical Weather Prediction (NWP) models, which use either a grid point or spectral representation of the wind and temperature fields. Their disadvantages include their accuracy and timelessness<sup>204</sup>, with wind component and temperature accuracies of around 5 m/s and 2°Celsius respectively.

Aircraft operators have only recently been provided with tropical cyclone warnings, which, in conjunction with volcanic ash clouds, are the only meteorological phenomena that can lead to the cancellation of a flight before take-off<sup>205</sup>. Correspondingly, a Volcanic Ash Advisory Centre (VAAC) has been set up in Canada<sup>206</sup>.

Weather Services International (WSI) provides an internet-delivered Pilotbrief service that provides weather and NOTAM data. The pre-flight weather data encompasses radar and satellite images, in addition to turbulence, icing and fog prediction charts<sup>207</sup>.

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<sup>204</sup> 'Improvements in forecasting accuracy may allow a significant increase in en-route capacity' – ICAO Journal, January-February 1997.

<sup>205</sup> 'Flight planning enhanced by implementation of tropical cyclone warning system' – ICAO Journal, January-February 1997.

<sup>206</sup> 'Advanced techniques prove helpful in identifying and forecasting dispersion of airborne volcanic ash' – ICAO Journal, January-February 1997.

<sup>207</sup> 'JMC selects WSI for Internet weather forecasting' – Air Transport Intelligence, 17 February 2000.



## 2.7 Future surveillance methods

The objectives of CNS/ATM systems' surveillance element are to enhance and extend effective surveillance to oceanic and remote areas while improving air traffic situational awareness in the cockpit in accordance with ATM requirements<sup>208</sup>. In addition, it should be increasingly possible to know aircraft position on a continuous basis, with the ability to estimate future positions based on satellite technology. Indeed, aircraft will continuously supply flight path intent information.

It is expected that traditional Secondary Surveillance Radar (SSR) will continue to be used in terminal areas, with the gradual introduction of Mode S (Select) radar in both terminal areas and high-density continental airspace. The major breakthrough, however, will be the implementation of Automatic Dependent Surveillance (ADS).

This section consequently discusses SSR Mode S, ADS, ground movement surveillance methods, the potential systems of Airborne Collision Avoidance Systems (ACAS), cockpit Situational Awareness (SAS) and the concept of Required Surveillance Performance (RSP).

### 2.7.1 Secondary Surveillance Radar (SSR) Mode S

Since the adoption of Secondary Surveillance Radar (SSR) over 20 years ago, a need has arisen for its enhancement. The accuracy, resolution and over-all performance of range and azimuth information is significantly improved by the application of monopulse and other advanced processing techniques. SSR Mode S (Select) is an enhanced mode of secondary surveillance radar that permits the selective interrogation of Mode S transponders, the two-way exchange of digital data between Mode S ground stations and the transponders, in addition to the interrogation of established Mode A/C transponders.

Mode S is a technique that uses a unique address (out of 16 million possibilities) for each aircraft, to improve aircraft identification and provide more aircraft position-related information. Given its high accuracy and reliable surveillance, Mode S is an appropriate surveillance tool in high-density traffic areas. Mode S is also expected to become a medium for routine data communications and may be used as an alternative to other terrestrial and satellite-based datalinks due to its unique address attribute.

Applications for Mode S datalink include communication transfers, altitude assignments, heading and speeds, route changes, Standard Arrival (STAR) routes, emergency communications backup, minimum safe altitude warning, vector delivery,

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<sup>208</sup> 'Global Air Navigation Plan for CNS/ATM systems' – Volume I, ICAO. 1<sup>st</sup> Ed. 2000.



holding instructions, sector hand-off, air traffic advisories, conflict alert, graphic or text weather messages, Automatic Terminal Information Service (ATIS), Pilot REPortS (PIREPS) and NOTices to AirMen (NOTAM). Thus, it is mentioned as a future means of communication in **Section 2.3.2**.

### **2.7.2 Automatic Dependent Surveillance (ADS)**

Automatic Dependent Surveillance (ADS) is the first real application of FANS<sup>209</sup>. ADS may be seen as a beneficial merging of communication and navigation technology: an ADS system automatically transmits current and intended aircraft position-related data, such as four-dimensional position (including heading and speed), from the flight deck via an air-ground datalink to an air traffic service provider. The present position of the aircraft is displayed as on conventional radar screens. The ADS service consists of the airborne ADS function, the air-ground datalink and a ground-based Flight Data Processing System (FDPS).

Although it can transmit other useful information, the main purpose of ADS is to send real-time aircraft information to the ATC ground station periodically or on demand. The ADS reports are requested by the ground station in the form of an ADS contract, which has the following contents: aircraft position (4D), earth reference (track, ground speed), air reference (true heading, Mach speed, vertical rate), MET data (wind speed, direction and temperature), predicted route (next waypoint and its ETA), and aircraft identification. Contracts may be:

- **Periodic**, whereby the aircraft transmits a message at an interval specified by ATS;
- **Event**, under which the aircraft sends the message at specific occasions, such as at an altitude change or crossing a waypoint;
- **On-demand**, which necessitates the aircraft to transmit when asked by the ground.

ADS was originally intended for oceanic operations and those over remote land areas where radar cannot be justified economically<sup>210</sup> or is difficult to implement: the introduction of air-ground datalinks, together with sufficiently accurate and reliable aircraft navigation systems, has presented the opportunity to provide surveillance services in such areas lacking services in the present infrastructure. However, in addition to providing traffic position information in these non-radar areas, ADS has beneficial applications in other areas, including high-density areas, where ADS can serve as an adjunct or backup to Secondary Surveillance Radar (SSR), thereby reducing the need for primary radar. Indeed, ADS may be a substitute for SSR in certain circumstances. Additionally, its applications can include surface movement surveillance at airports.

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<sup>209</sup> 'AA98: Airsys boss backs CNS/ATM despite slow progress' – *Air Transport Intelligence*, 27 February 1998.

<sup>210</sup> 'FANS CNS/ATM Starter Kit' – Section 1. IATA/ICAO.



ADS needs to be supported by avionics equipment that is able to gather aircraft data from on-board systems, format them and direct them to the relevant air-ground datalink. On the ground, the air traffic management system is capable of automating flight data validation, conformance monitoring and automated tracking functions. Software is being developed to allow ground computers to detect and resolve conflicts. Eventually, this could lead to clearances being negotiated between airborne and ground based computers, with little or no human intervention.

The required reporting rate for ADS messages is dependent upon aircraft separation, traffic density, whether an aircraft's altitude or velocity is changing and any emergency situations. Additionally, the air traffic management system itself has an effect on the frequency of reporting. However, direct two-way controller-pilot voice communications are essential for emergency and/or non-routine messages. For instance, a suggested reporting rate in the North Atlantic region is every 5 to 15 minutes, with an emergency mode specified every 64 seconds, thereby aiding search and rescue operations<sup>211</sup>. Indeed, an ADS-based ATC system provides improvement in pilot-controller communications in addition to its surveillance benefits<sup>212</sup>.

### **ADS-B (Broadcast)<sup>213</sup>**

ADS-B is an application of ADS technology that enables a suitably equipped aircraft to broadcast its position, altitude and vector information for display by other aircraft and also by ground users, such as ATS providers. It should be noted that a two-way datalink capability is required for ADS, but that ADS-B only needs a one-way datalink, such as VDL Mode 4, as the information is transmitted in broadcast mode. All users of the latter system have real-time access to precisely the same data, via similar displays, allowing a vast improvement in traffic situational awareness<sup>214</sup> and anti-collision capabilities<sup>215</sup>.

ADS-B information can consequently be used for all phases of flight as a basis for a Cockpit Display of Traffic Information (CDTI), with the potential for pilots to perform conflict detection and resolution. On the ground, it can be implemented as a Flight Information Service - Broadcast (FIS-B) or with ground movement radar and airport surface detection equipment. Even though ADS-B is currently only defined for line-of-sight operations, such as over VHF datalink, it has the potential to complement, and even replace, SSR in terms of coverage for low to medium traffic density.

It is argued<sup>216</sup> that ADS-B is "the cornerstone of any future CNS/ATM ... environment", an enabler for Free Flight and Collaborative ATM. ADS-B is seen as an enabling

<sup>211</sup> 'The ICAO Manual of ATS Datalink applications'. Draft version 0.2, March 1996.

<sup>212</sup> 'Automatic Dependent Surveillance' – ICAO Circular 226-AN/135. 1990.

<sup>213</sup> It should also be noted that ADS-Contract (ADS-C) exists if there is a contract between the ground system and airborne avionics.

<sup>214</sup> 'Talk this way' – *Flight International*, 7-13 February 1996.

<sup>215</sup> 'Crash-free future' – *Flight Deck International*, March 1999.

<sup>216</sup> 'ADS-B: the enabler for Free Flight and Collaborative ATM' – L Lindberg, 4th Air Navigation Conference, Amsterdam, September 1998.



technology for CNS/ATM by both EU and US authorities, and not a concept, because of its potential advantages, which include:

- **Accuracy** – equipped aircraft may be able to report their position to higher accuracy than surveillance radar;
- **Greater information** – aircraft will also be able to report other information such as velocity and intention;
- **Block-to-block operations** – in contrast with the multiple systems presently used, ADS-B systems can provide surveillance reports during any phase of flight;
- **Flexibility** – the reporting rate of ADS-B does not have to be fixed and it can be adjusted to suit the operating phase of flight;
- **Cost** – VDL Mode 4/STDMA ADS-B systems are expected to offer a low cost solution.

### 2.7.3 Ground movement surveillance

There is a need for advanced CNS systems on the ground at busy airports. Surface Movement Guidance and Control Systems (SMGCS) planned in the future CNS/ATM will provide more capability than surface movement radar alone<sup>217</sup>. However, this form of radar, termed airport surface detection equipment, will also be suitable as a future technology<sup>218</sup> because no on-board equipment is required. It is increasingly being accepted that technologies such as Mode S datalink, satellite navigation and ADS techniques can be used for ground movement surveillance without the need for extra avionics.

Indeed, as mentioned in the previous section, ADS-B is intended for surveillance in all air traffic domains, including the airport surface. By equipping the aircraft or surface vehicle with a transponder that continuously broadcasts position and a unique identifier, it will be possible for ATC to receive and display the data<sup>219</sup>. It is envisaged that GNSS/GPS will be used for position determining.

Parallel Runway Monitors (PRM) will provide surveillance for (in)dependent approaches on closely spaced parallel runways to increase approach traffic capacity, even in poor weather conditions. PRMs give aircraft position data with higher accuracy and greater update rates than normal terminal radar.

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<sup>217</sup> 'The Future Air Navigation System' – V. Galotti. Chapter 5.

<sup>218</sup> 'Demystifying CNS/ATM' – CANSO. June 1999.

<sup>219</sup> 'Technology & Procedures Report' – Honeywell AATT.



## 2.7.4 Airborne Collision Avoidance Systems (ACAS)

**Section 2.6.2** discusses the current versions of Airborne Collision Avoidance Systems (ACAS). Even though ACASs were not initially designed or developed as separation-monitoring devices, such systems have the potential to provide, in addition to the avoidance of collisions, other functionalities such as situational awareness and separation assurance. This will be done through the use of conflict detection algorithms and Cockpit Display of Traffic Information (CDTI)<sup>220</sup>. However, this potential must not adversely affect the collision avoidance functionality and is not a substitute for air traffic services.

ACAS III/TCAS 4 is the next generation of ACAS, noting that the US FAA cancelled its TCAS 3 project due to inaccurate bearing measurements that depend on antenna performance. TCAS 4 makes use of accurate (differential) GPS satellite-based position data and air-air datalink using ADS-B to include horizontal resolution based on determined aircraft positions. Each aircraft determines its own position via GPS and broadcasts its position periodically through ADS-B, thereby enabling all aircraft within the vicinity to know each other's location and to calculate relative distances. The system is based on the Mode S ability to transmit longer messages, including position information<sup>221</sup>. Its advantages over TCAS 2 include better detection of conflicts and better selection of resolutions advisories. It is thought that the TCAS 4 software will reduce unnecessary Resolution Advisories by 25-30%<sup>222</sup>.

## 2.7.5 Ground-Proximity Warning Systems (GPWS)

With reference to the discussion on GPWS and EGPWS in **Section 2.6.4**, this section lists future improvements that are planned for Enhanced GPWS (EGPWS)<sup>223</sup>, thus:

- EGPWS currently required a barometric altitude input reference to mean sea level (QNH). Operations using altitudes referenced to airport elevation (QFE) may require disabling the look-ahead alerts and terrain display, unless a barometric altitude source referenced to QNH is available. Radio altitude-based GPWS alerts are still available if EGPWS functions are disabled. AlliedSignal and Boeing have studied alternatives to provide a suitable altitude source for QFE-based operations;
- EGPWS includes provisions for an obstacle database, which will enable it to issue alerts for man-made structures. This capability will be added once the obstacle database has matured, in addition to when display and alerting issues are resolved.

<sup>220</sup> 'Aviation safety enhanced by advanced systems that heighten situational awareness' – ICAO Journal, September 2000.

<sup>221</sup> 'Civil avionics: rising to the challenge' – Flight International, 14 February 1996.

<sup>222</sup> 'New TCAS software to cut unneeded evasive actions' – Aviation Week & Space Technology, 27 January 1997.

<sup>223</sup> 'Enhanced Ground Proximity Warning System' – Airliner, July-September 1997.



## 2.7.6 Cockpit Situational Awareness Systems (SAS)

Situational Awareness Systems (SAS) in the cockpit provide flight crew with enhanced information, which includes graphical and text weather information, situational awareness of surrounding traffic and other types of real-time information. This enhanced awareness supports decision-making capability<sup>224</sup>. SAS is mainly based on differential satellite navigation and air-air or air-ground datalink technologies. Different levels of sophistication can be implemented, which are dependent on the aircraft's primary use, whether airline or general aviation.

A SAS can have the following applications in order to increase safety:

- ❑ **Cockpit Display of Traffic Information (CDTI)** – based on all aircraft broadcasting their position, altitude, time and aircraft identification, with nearby information obtained from the aircraft's own ACAS. CDTI can also be used to track aircraft and ground-based vehicles at an airport;
- ❑ **Wake Vortex Hazard Prediction and Avoidance** – using sensors that provide real-time data on the severity of wake vortices being generated by landing, this technology can enhance the safety of trailing aircraft, but also increase airport capacity for both single and parallel runway approaches;
- ❑ **Synthetic Vision** – this technology assists pilots to perform final approaches and landings in very low visibility conditions by combining images from synthetic vision sensors and displaying them on a Head-Up Display (HUD);
- ❑ **3D terrain and terrain avoidance** – this SAS application does not require datalink, but does need satellite-derived position data, which may be superimposed on a high-resolution digital terrain topology display. **Section 2.6.4** covers the presently available Ground-Proximity Warning Systems (GPWS) and Enhanced GPWS (EGPWS);
- ❑ **Weather awareness** – with reference to the meteorological systems discussed in **Section 2.6.5**, a weather map can be provided to the aircraft using datalink, noting that different meteorological hazards exist at various altitudes. Such maps can be combined with weather information determined on board to display the picture on multi-function displays.

**Section 4.4.6** cites some facts on the implementation of SASs.

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<sup>224</sup> 'Technology & Procedures Report' – Honeywell AATT.



## 2.7.7 Meteorological systems

Current meteorological systems are discussed in **Section 2.6.5**.

Improvements in weather forecasting techniques are necessary to maximise the benefits from future ATM systems<sup>225</sup>. Indeed, meteorological advances are integral parts of the ATM programmes that are being developed. Improvements are being made to the following types of data: temperature, wind, confidence level of forecasted wind, turbulence and anti-icing. A model that was designed to provide more accurate and timely short period forecasts of winds and temperatures has been developed. Known as the Winds Analysed and Forecast for Tactical Aircraft Guidance over Europe (WAFTAGE) model, it can analyse large quantities of observations from several sources such as aircraft, radiosondes, satellites and Doppler radars. Correspondingly, an on-board turbulence detection system, which has been developed by the US FAA and Honeywell, will provide pilots with a direct indication of turbulence severity up to 1,000nm ahead of the aircraft, using a mixture of direct measurements by infrared radar and up-linked forecasts via any of the datalink technologies<sup>226</sup>.

**Section 4.4.7** charts progress with the WAFTAGE model and other developments, noting that instant, up-to-the-minute graphic weather information is considered a priority for the 21<sup>st</sup> century cockpit<sup>227</sup>.

## 2.7.8 Required Surveillance Performance (RSP)

As with the communications and navigational elements of CNS/ATM, although the availability of a plethora of surveillance systems provides planning flexibility, it complicates the harmonisation of surveillance functions. To facilitate the planning, it is necessary to translate the relevant operational requirements into a series of surveillance performance parameters, termed Required Surveillance Performance (RSP). The RSP refers to a set of requirements such as accuracy, availability, capacity, and update rate.

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<sup>225</sup> 'Improvements in forecasting accuracy may allow a significant increase in en-route capacity' – ICAO Journal, January-February 1997.

<sup>226</sup> 'Airborne system to address leading cause of injuries in non-fatal airline accidents' – ICAO Journal, March 2000.

<sup>227</sup> 'At lightning speed' – air traffic management, July/August 1998.



## 2.8 Summary

Although current Air Traffic Control (ATC) systems are based on CNS technologies and ATM procedures that were developed many years ago, their applications have been modified to suit the different types of airspace that exist around the world in order to satisfy the various capacity requirements and specific operating environments. However, the levels of delay now being experienced in many airspace sectors and lack of adequate safety standards in other regions have necessitated further development of these systems, in addition to the implementation of future technologies and procedures, as covered in this chapter.

**Figure 2.3** contains a theoretical summary of the differences between current CNS systems and those envisaged by ICAO in the future system, which may be considered as an aspirational overview of the CNS systems' evolution described in this chapter.

### Communications

- ✗ Very High Frequency (VHF) voice
- ✗ High Frequency (HF) voice

- ✓ VHF voice and data
- ✓ Aeronautical Mobile Satellite Service (AMSS) - voice & data
- ✓ Secondary Surveillance Radar (SSR) Mode S data link
- ✓ Aeronautical Telecommunication Network (ATN)
- ...leading to *Required Communication Performance (RCP)*

### Navigation

- ✗ MNPS
- ✗ Omega & Loran-C
- ✗ Nondirectional Beacon (NDB)
- ✗ VHF Omnidirectional Range (VOR)
- ✗ Barometric altimetry
- ✗ Inertial Navigation System (INS)
- ✗ Instrument Landing System (ILS)

- ✓ Area Navigation (RNAV)
- ✓ Global Navigation Satellite System (GNSS)
- ✓ Barometric altimetry
- ✓ GNSS altitude
- ✓ Inertial Navigation System (INS)
- ✓ GNSS landing system
- ...leading to *Required Navigation Performance (RNP)*

### Surveillance

- ✗ Primary Radar
- ✗ Secondary Surveillance Radar (SSR)
- ✗ SSR Mode A/C
- ✗ Voice position reports

- ✓ Automatic Dependent Surveillance (ADS)
- ✓ ADS-B (Broadcast)
- ✓ SSR Mode A/C or Mode S
- ...leading to *Required Surveillance Performance (RSP)*

**Figure 2.3** - CNS system evolution according to ICAO

Ultimately, the degree of systems introduction in a country will be heavily dependent on the nation's and region's current status in terms of economic prosperity, its propensity to change and the level of extra capacity that is presently required. **Chapter 4** assesses the degree to which the technologies and systems covered in this chapter, in addition to the Air Traffic Management (ATM) concepts in **Chapter 3**, have been implemented to date.



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## CHAPTER 3

# ATM CONCEPTS

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### 3.1 Introduction

In order to harmonise the world's airspace regions, it is essential to implement enhanced Air Traffic Management (ATM) procedures using concepts based on the Communications, Navigation & Surveillance (CNS) technologies described in **Chapter 2**. Noting that many of the current ATM methods will still be utilised at the start of the next decade, this chapter assesses both present and future ATM.

Different ATM concepts will be applied with various CNS components to the multitude of airspace types that exist around the world. Together, the CNS/ATM solutions aim to alleviate the inherent problems associated with present Air Traffic Control (ATC) systems. In addition to those that are derivatives of current methods, future ATM will be based on principles and guidelines developed by ICAO and other aviation stakeholders. Many such systems have already been, and are currently being, implemented.

Due to the fragmented nature of ATC between countries, different systems and standards have resulted in poor harmonisation between adjacent units. The consequent lack of common air to ground data interchange systems means that current ATM is still based on a multitude of traditional methods. This is manifested by inflexible fixed route structures, which result in demand exceeding capacity levels, air traffic delays and increased operating costs for users. Coupled with poor ATC infrastructure in many nations, there are many Flight Information Regions (FIR) that are considered unsafe.

The future CNS/ATM concepts aim to alleviate such problems by introducing an interoperable, seamless system, with full global coverage for safe ATM, whereby ATM should dictate the operational requirements for CNS systems and their functionality. However, many delays with the implementation of new ATM concepts have occurred to date and it can consequently be difficult to accurately predict the introduction timeline of the future systems. Nonetheless, **Chapter 4** discusses the planned implementation timelines of the new CNS/ATM systems and assesses the experiences to date.

The analyses in **Chapter 4** and those in the second part of this dissertation draw on the descriptions of current and future ATM concepts given in this chapter: following a section on current ATM procedures, this chapter provides a contrast to the present systems with a discussion on the objectives, benefits and design of future ATM. The chapter then covers the following three main emerging ATM concepts, which have been developed to date, that aim to avert ATM gridlocks:

- ICAO's global ATM;
- Europe's initiatives, which are encompassed in the ATM Strategy for 2000+;
- The US alternative approach, Free Flight.

It should be noted that Europe's ATM Strategy for 2000+ and the US Free Flight operational concepts are based on the ICAO CNS/ATM systems concept.



## 3.2 Current ATM

The current Air Navigation System (ANS) provides international Air Traffic Services (ATS) based on the availability of Communications, Navigation and Surveillance (CNS) technology and Air Traffic Control (ATC) systems. The agency responsible for safe and orderly ATS operations at a worldwide level is the International Civil Aviation Organisation (ICAO). As mentioned in **Chapter 1**, ICAO has developed international Standards And Recommended Practices (SARPs) that are classified as Annexes of the ICAO Convention. **Appendix 3.1** contains a list of the ICAO Annexes.

Annexes 2 and 11 detail the rules of the air and ATS respectively, which are the basis of ATM<sup>228</sup>. Rules of the air and ATS are also covered in a 'Procedures for Air Navigation Services' (PANS) document. Even though all countries produce their own ATM legislation based on Annex 2's rules, the adoption of the SARPs by all ICAO contracting countries means that ATM around the world uses the same language (English), the same navigation aids (as described in **Chapter 2**) and the same procedures. This section considers current procedures.

ATS providers expedite the safe and orderly flow of air traffic by offering ATC coverage, a Flight Information Service (FIS)<sup>229</sup> and an alerting service<sup>230</sup>. The rôle of ATC<sup>231</sup>, which accounts for the greatest percentage of ATS on a global level, is to:

- Prevent collisions between aircraft in the air by physical separation;
- Expedite and maintain an orderly flow of air traffic;
- Provide advice and information useful for safe and efficient conduct of flights;
- Notify the appropriate organisations regarding aircraft in need of Search And Rescue (SAR) aid.

The air traffic controller's job consists of complex tasks demanding a high degree of skill and active application of unique cognitive abilities such as spatial perception, information processing, reasoning and decision-making. Controllers must know where all aircraft under their responsibility are, in addition to being able to determine how and when to take action so that they remain separated from each other, while also seeing to their requests and needs for actions such as take-off, departure, climb and descent<sup>232</sup>.

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<sup>228</sup> *International Air Traffic Control – Management of the World's Airspace* – A Field, Pergamon Press.

<sup>229</sup> FIS is provided for the purpose of giving advice and information useful for the efficient and safe conduct of flight.

<sup>230</sup> Alerting services are provided to notify the appropriate organisations regarding aircraft in need of Search & Rescue aid and to assist such organisations as required.

<sup>231</sup> *International Standards and National Regulations* – R Fewings, Air Transport Group, Cranfield University, 1995.

<sup>232</sup> *Demystifying CNS/ATM* – CANSO, June 1999.



The ATC service is further divided into aerodrome control at the airport, approach control in the vicinity of the airport and area control for en-route flights. Such services apply to both Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) traffic. ATC control centres employ AirSpace Management (ASM) and Air Traffic Flow Management (ATFM) to provide Air Traffic Management (ATM). Ultimately, ATM is conducted through strategic and tactical planning from months in advance, in addition to monitoring and control of flights.

It should be noted that the world is divided into many lower and upper airspace Flight Information Regions<sup>233</sup> (FIR) for the purpose of providing ATS. Some only occupy small volumes of airspace because FIR boundaries are usually defined by national borders or by agreed lines of demarcation over water. However, the FIRs can span the boundaries of more than one nation. Each country's Civil Aviation Authority (CAA) puts together its own ATS system, which is sometimes in conjunction with one or more other nations. ICAO Air Navigation Plans (ANP) present, in general terms, the provision of facilities, services and procedures required for air navigation around the world. Spanning the globe, they are produced for specific regions. Additionally, ICAO requires that every country publish manuals, termed Aeronautical Information Publications (AIP), describing their ATM systems and any differences from ICAO standards.

Controlled airspace regions are manifested as Terminal control Areas (TMA), inter-connecting airways and area-type control areas. The latter two are further divided into ATC sectors. Other than the aforementioned types of controlled airspace and Control zones (CTR), which facilitate the separation of aircraft operating within the vicinity of busy airports, the airspace within FIRs is usually uncontrolled. Airspace is categorised into different classes, the exact composition being determined by each nation. Civil and military airspace regions are usually distinct, under separate control. However, Special Use Airspace (SUA) is increasingly being employed to share the resource.

The ATM procedures within an FIR are based on the types and densities of air traffic, the CNS technology that is available, in addition to the topography and economic conditions of the country involved. Clearance deliveries must be obtained prior to entering the airspace. Thus, similar to the applications of the various types of CNS technology in the different categories of airspace cited in Chapter 2. ATM is presently based on procedures and separation standards that vary with operating environment. The following types have been identified and are discussed in this section:

- Near or over land with dense traffic;
- In oceanic and remote areas;
- In the terminal area.

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<sup>233</sup> 'Air Traffic Control' – G Duke. 2<sup>nd</sup> Edition, 1986.



### 3.2.1 ATM near or over land with dense traffic

ATM in these situations uses ATC strips, based on the aircraft's flight plan, which are colour-coded to denote the direction of the aircraft. Strips incorporate information about the flight such as its timings, desired route level and radar code. The controller places the strip on a flight progress board in geographical and time order. After taking the requirements of all other traffic in the sector airspace at that time and in the immediate future, the controller plans a safe Flight Level<sup>234</sup> (FL) and route for the aircraft using an ATS route structure of Upper Airways (UA). The exact altitude of the FL is dependent on the magnetic heading of the track, whether between 0° and 179° or between 180° and 359°. Aircraft use the area navigation techniques covered in **Chapter 2** to fly the route. Trunk routes have aRNA NAVigation (RNAV) designators that integrate with previous upper airway route systems rather than replace them. When segments of new trunk routes are superimposed on conventional airways, the authorities maintain a double designator, which allows the routes to be used by both RNAV and non-RNAV equipped aircraft.

Vertical navigation is based on the science of measuring vertical distances in the atmosphere, altimetry. Low altitude aircraft set their altimeter, which is a barometer that indicates altitude based on the fact that air pressure decreases as height increases, to the current pressure setting of the local or regional ATC centre<sup>235</sup>, thus ensuring that all aircraft using the area have the same pressure setting. At higher altitudes, pressure altitude is employed, which is the height above the International Standard Atmosphere (ISA) pressure datum. The change to pressure altitude occurs above a country's transitional height, which is dependent on the highest mountain in the nation, where aircraft are not as concerned about their actual height above the ground, but more aware of their relative separation from other aircraft. In addition, the pressure altitude method is used at high altitudes because aircraft travel at higher speeds and migrate through many sectors. Hence, they would have to change their regional pressure setting too frequently. For example, the transition level in the US is 18,000ft, but in the UK, it is 3,000ft<sup>236</sup>.

Separation standards near or over land with dense traffic, where there is a high presence of ground aids, are usually lower than in oceanic and remote areas. The exact separation criteria, whether stated in time or distance intervals, vary in each country and within FIRs. The separation typically consists of lateral and longitudinal horizontal elements, in addition to the vertical component. Standards are determined using a collision risk equation that has the following variables: assigned airspace dimensions, traffic complexity, exposure duration, communications capability, blunder detection capability and correction.

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<sup>234</sup> Each cruising altitude is known as a Flight Level, which is stated using digits that represent hundreds of feet. Therefore, the actual height in feet has the final two zeros omitted.

<sup>235</sup> 'Fundamentals of Air Traffic Control' – MS Nolan, Wadsworth Publishing Company.

<sup>236</sup> 'The Air Pilot's Manual: Air Navigation' – T Thom. 2<sup>nd</sup> Edition. Airlife Publishing.



Historically, vertical separation between FLs was 1,000ft below FL290 and 2,000ft above FL290 due to the inherent inaccuracies of altimeters above this height<sup>237</sup>. However, regions over and near land are in the process of reducing this separation standard from 2,000ft to 1,000ft above FL290. Such programmes, termed Reduced Vertical Separation Minima (RVSM), are being implemented. Horizontal separation minima, which are split into longitudinal (along the track) and lateral (across the track) components, vary and are dependent on the availability of ground-based navigational aids and radar surveillance. Longitudinal horizontal separation is stated in distance terms, whilst lateral horizontal separation can be based on time or distance.

Central Flow Management Units (CFMU), such as that operated by Eurocontrol in Brussels and the Central Flow Control Facility operated by the US Federal Aviation Administration (FAA) in Washington DC, facilitate co-ordination of flights. Based on the flight plans given by airspace users, they employ the services of Initial Flight Plan Processing Systems (IFPS), which provide dynamic pictures of the complete air traffic situation, and Traffic Prediction Load Devices (TPLD), which foresee situations arising where too many aircraft will be put through a specific ATC sector.

The Eurocontrol CFMU undertakes Air Traffic Flow Management (ATFM) in three phases, thus:

- *Strategic ATFM* – from several months until two days before a flight;
- *Pre-tactical ATFM* – during the two days prior to operation;
- *Tactical ATFM* – carried out on the day of operation.

Similarly, Eurocontrol operates an upper (airspace) area control centre in Maastricht, which is Europe's first international ATC centre. It provides multi-national Air Traffic Services (ATS) in the upper airspace of Belgium, Germany, Luxembourg and the Netherlands<sup>238</sup>. A data processing system collects, processes and stores the information needed to establish and maintain a real-time synthetic picture of the air traffic situation for the entire airspace. This Maastricht Data Processing and Display System (MADAP) uses filed flight plans, radar target reports from a multitude of radar stations and weather data as its main data sources. Flight Data Processing (FDP) employs information received from the IFPS at Eurocontrol's CFMU in Brussels. The system automatically exchanges data with neighbouring ATS units using the Eurocontrol On-Line Data Interchange (OLDI). Similar efforts, such as Eurocontrol's Free Route Airspace Project (FRAP), which offers users direct routes through the upper airspace of 8 European nations, are currently adding capacity to ATM systems.

ATC presently enables automated functions such as short-term conflict alert, trajectory prediction, flight progress monitoring and medium-term planning conflict alert. In the

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<sup>237</sup> 'International Air Traffic Control – Management of the World's Airspace' – A Field. Pergamon Press.

<sup>238</sup> 'Austria to host ATC centre' – *Flight International*, 10 February 1999.



US, Air Route Traffic Control Centres (ARTCC) provide the en-route portion of the National Airspace System (NAS), which includes the following services<sup>239</sup>:

- **Flight planning** – provision of in-flight weather information prior to departure;
- **Advisory** – special use airspace, traffic and flight following services;
- **Separation** – including aircraft ground, obstacle and weather avoidance;
- **Flight assistance and monitoring** – includes emergency assistance;
- **Capacity and demand management** – traffic flow assessment, planning and management are provided on a local basis, in addition to co-ordination of services on a national basis;
- **Guidance** – navigation, landing and take-off guidance is provided.

An Enhanced Traffic Management System (ETMS) is installed in the ARTCCs of the NAS to provide Aircraft Situation Display (ASD), which depicts all aircraft in the NAS for either the present scene or some time in the future<sup>240</sup>. The Monitor Alert (MA) function of ETMS provides warnings of predicted overloads of key NAS resources. The Estimated Departure Clearance Time (EDCT) programme is also part of the ETMS.

### 3.2.2 ATM in oceanic and remote areas

A lack of present aircraft position information due to absence of radar technology means that flights are controlled using procedural ATC methods in oceanic and remote areas. These methods use very large separation criteria, similar in concept to the aforementioned vertical and horizontal standards, which result in low system capacity and poor availability of efficient flight profiles. Additionally, flight tracks are based on route structures that are not necessarily the desired routings of aircraft.

In oceanic regions that have large amounts of traffic condensed into short time frames, such as the Pacific Ocean and North Atlantic airspace areas, Oceanic Area Control Centres (OACC) are the authorities. Designated OACs are run by nations that lie adjacent to the oceans in order to provide safe ATM for trans-oceanic traffic, even though the aircraft may not land in the controlling countries. The OACs are responsible for maintaining separation between aircraft and for allocating changes to their routings.

The OAC contacts the aircraft if it must change its assigned Mach number or if responding to a tactical adjustment from a pilot, such as a cruise climb to another Flight Level. In the case of the North Atlantic OAC, two types of controller exist for the Organised Track Structure (OTS): the Entry planner, who deals with the clearance delivery requests and slot allocations in the tracks; the En-route planner, who regulates the traffic and deals with any in-track changes that may be required<sup>241</sup>. The OTS is devised twice daily, accommodating the predominantly westbound transatlantic traffic

<sup>239</sup> 'Technologies & Procedures Report' – Honeywell AATT.

<sup>240</sup> 'Enhanced Traffic Management System' – publication from Department of Transportation, FAA.

<sup>241</sup> 'Operating in the North Atlantic MNPS Airspace' – C Whelan, *Journal of Navigation*. Jan 1999.



at one period during the day and eastbound at night. The OTS consists of a set of tracks that are located based on meteorological and user preferences bases. The number of tracks offered is directly proportional to the amount of traffic expected. Operators file their flight plan stating their preferred tracks. It should be noted that random tracking is also frequently conducted and is sometime required for Extended Twin-engine Operations (ETOPS) reasons. The aircraft are assigned slot entry times to a track and told to fly at a specific speed, to facilitate the application of the Mach Number Technique (MNT), whereby the aircraft are spaced according to their relative speeds. The aircraft must obtain oceanic clearances in order to enter the track structure. This clearance is based on a list of routes to be followed in the form of cleared Flight Levels and waypoints. As stated in **Chapter 2**, clearances are now being requested by datalink.

Reduced Vertical Separation Minima (RVSM) were successfully introduced in the North Atlantic in 1997-1998 and are presently being implemented in the Pacific. The latter region facilitates Dynamic Airborne Re-routing Procedures (DARP), whilst the former will soon implement direct routing and Reduced Horizontal Separation Minima (RHSM). **Chapter 4** contains a more detailed evaluation of the situation in oceanic and remote regions.

### **3.2.3 ATM in the terminal area**

With reference to the discussion in **Section 2.4.4**, approach control is a terminal ATC facility that uses radar and non-radar capabilities to provide control services to aircraft arriving, departing or transiting airspace controlled by the facility. Guidance is sometimes given by ATC using radar vectors, but routes are also created for navigation using the ground-based VOR radio navigation facilities. These Standard Instrument Departure (SID) and Standard Arrival (STAR) routes are established at busy aerodromes to ensure that traffic departs and arrives at an airport in a safe, orderly and expeditious flow. SID and STAR routes link with significant points of ATS en-route tracks and are designed to take account of noise abatement procedures.

The higher traffic densities, and greater complexity of traffic flow in the terminal area than in en-route airspace, necessitate greater levels of surveillance. This complexity is compounded by the fact that aircraft of different performance characteristics have to operate together. Correspondingly, strict noise abatement and environmental procedures impose further restrictions in the terminal area. Hence, frequent delays are experienced in the final phase of flight at many airports around the world. Thus, many ATM programmes, such as staggered, dual runway approaches, attempt to maximise the approach capacity of slot-restricted airports.

Separation is maintained between aircraft in such a manner that wake vortices from larger aircraft do not affect the flight of other aircraft. Every aircraft in flight trails an area of unstable air behind it that is known as wake turbulence, which is partly caused by the pair of counter-rotating vortices from the wing tips. These wake vortices are a by-product of the lift produced by the wing. Their strength is governed by the weight, speed



and shape of the wing. Maximum vortex generation occurs when the generating aircraft is heavy and slow, thus when the aircraft is taking off or landing<sup>242</sup>.

Given that other aircraft encountering the forces may lose control, sufficient separation is needed between take-offs and landings. Correspondingly, lighter aircraft rotate on take-off before the point of rotation of the preceding aircraft and touch down after the point of rotation on landing. Nonetheless, a controversial<sup>243</sup><sup>244</sup> strategy to Land And Hold ShOrt (LAHSO) is operated, whereby two intersecting runways are used at the same time, with normal operations on one and landings on the other, on condition that the landing aircraft stops short of the intersection<sup>245</sup>. However, contentions in the US over this procedure were reduced in 1999<sup>246</sup>, even though controllers say that LAHSO reduces capacity<sup>247</sup>. Additionally, it should be noted that laser-based analysis of aircraft wake-vortices suggests that problems exist with increasing runway capacity by reducing separations<sup>248</sup>. It is believed that real-time provision of vortex information to controllers could assist with tactical ATC.

Holding patterns are used whenever insufficient airspace exists in the approach and terminal control environments. Vertical separation in holding patterns is applied by clearing aircraft to hold either above or below other holding aircraft, thereby creating a stack. Adequate lateral horizontal separation is applied by ensuring that the airspace reserved for the holding aircraft does not overlap the airspace reserved for other aircraft.

The airport surface movement area can also compound delays. Ground control is conducted through radar or visual means, with no automation support at many aerodromes. Coupled with a lack of adequate co-ordination between ATC and ramp agents, the present ATM on the ground often affects the On-Time Performance (OTP) of aircraft.

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<sup>242</sup> 'Fundamentals of Air Traffic Control' – MS Nolan, Wadsworth Publishing Company.

<sup>243</sup> 'LAHSO threat' – air traffic management, November/December 1998.

<sup>244</sup> 'IFAPLA backs US pilots in refusing LAHSO participation' – Air Transport Intelligence, 29 May 2000.

<sup>245</sup> 'Curing LAHSO fever' – air traffic management, January-February 2000.

<sup>246</sup> 'US FAA, pilots and airlines agree on revised LAHSO procedures' – Air Navigation International, 22 February 1999.

<sup>247</sup> 'LAHSO restrictions adding to delays, controllers say' – Air Navigation International, 4 October 1999.

<sup>248</sup> 'Wake analysis shows little hope of growing capacity' – Flight International, 22 March 1995.



### 3.3 Future ATM

Based on current activity around the world regarding future ATM, the expected status of ATM during this, and the next, decade varies for different regions, but will ultimately be the result of many capacity-enhancing programmes. The fragmentation of airspace structures will be simplified, in order to provide seamless systems with greater capacity. It should be noted that, in contrast with the CNS technologies that are increasingly becoming available, there is no readily available piece of ATM equipment, other than certain automation and radar data processing systems, which can be seen as revolutionary.

It is the evolutionary implementation of CNS elements and their orchestrated interaction that will form the backbone of the future integrated ATM system. Future ATM will encompass all of the elements traditionally associated with ATS<sup>249</sup>, as described in **Section 3.2**. Indeed, according to ICAO, "ATM is used to describe the airspace and air traffic management activities carried out in a co-operative manner by the aeronautical authorities concerned with planning and organising the effective use of the airspace and air traffic flows within their area of responsibility". Therefore, ATM is a set of rules and procedures.

In order to assess the changes to ATM over the next 15 years or so, this section discusses the limitations of the current system, the objectives of future ATM, its potential benefits and the ATM design considerations that exist. It should be noted that three subsequent sections of this chapter cover the ATM operational concepts that have been drafted to date.

#### 3.3.1 Limitations of the present system

With reference to the explanation of today's ATM system in **Section 3.2**, it has many limitations that result in lack of safety in certain regions, delays in others and operational problems in most, with aircraft invariably not flying their optimal routes in terms of fuel consumption and flight time. All of these restrictions can apply to en-route operations, terminal control zones and airport surface areas.

Limits on the amount of traffic that Air Traffic Control (ATC) systems can handle in the en-route phase, without increasing levels of automation to assist with conflict detection and resolution, are large due to:

- Conventional airspace organisation of Flight Information Regions (FIR) with their supporting infrastructure of ATS routes and ground-based facilities or services;

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<sup>249</sup> 'Global Air Navigation Plan for CNS/ATM systems' – Volume I, ICAO. 1<sup>st</sup> Ed. 2000.



- ❑ Fragmentation of airspace and a diversity of national systems that prevent optimum use of airspace;
- ❑ Lack in uniformity of ATM procedures due to differences and limitations in ATM capabilities<sup>250</sup>;
- ❑ Inconsistent separation standards in radar and non-radar airspace because a lack of co-ordination among countries in developing their ground ATM systems exists;
- ❑ Saturated information flow within and between ATC units, in addition to between ATC units and aircraft;
- ❑ Poor data and procedures for surveillance, prediction and optimisation of the air traffic flow from the ground, noting that the airborne element is often more sophisticated;
- ❑ Aircraft position is only known to ATC, meaning that other aircraft do not know actual intent of aircraft trajectory<sup>251</sup>;
- ❑ Difficulty, due to a variety of reasons, to implement current CNS systems and operate them in a consistent manner in large parts of the world;
- ❑ Poor propagation limitations of current line-of-sight systems;
- ❑ Limitations of voice communications and the lack of digital air-ground data interchange systems to support automated systems in the air and on the ground.

Thus, with low capacity levels in airspace regions, aircraft must plan their flights along inflexible ATS route structures and be channelled in order for ATC systems to keep aircraft safely separated from each other. It is often the case that concentrations of traffic flows occur at major intersections, which can lead to a reduction in the number of optimum flight levels being available.

Similarly, in the terminal control phase of flight, current separation standards prevent full use of available capacity and render inflexible, indirect routings for aircraft. Even on the ground, there is a distinct lack of harmony with aircraft operations, hindering the path to trouble-free gate-to-gate operations. Additionally, runway capacity constraints exist at airports and many are slot restricted.

Although ATM limitations are not present in all countries and regions, their effect hinders the progression towards a uniform worldwide ATM system.

### 3.3.2 Objectives of future ATM

The overall objective of the future system should be to enhance the level of ATM service provided, in order to maximise operational benefits, through the exploitation of current and developing technologies. Improved efficiency of air traffic should be achieved with the same or higher safety level of the present system based on cost-effective operations adaptable in as near 4-dimensional freedom (space and time) as the

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<sup>250</sup> 'Demystifying CNS/ATM' – CANSO, June 1999.

<sup>251</sup> 'ADS-B: the enabler of Free Flight and Collaborative Air Traffic Management' – L Lindberg et al, Generic CNS/ATM Development Consortium. 4<sup>th</sup> Air Navigation Conference, September 1998.



systems' capability will permit. While the future CNS/ATM system planning aims to satisfy the demand of all airspace users on a continuous basis, it would not be practical to provide for excessive peak levels of air traffic demand. Consequently, the major aim should be to optimise and maximise airspace capacity, in addition to minimising safety-critical happenings.

Thus, the concept of future ATM is to provide enhanced levels of service delivery by the progressive implementation of reduced separation standards and increased aircraft flexibility. In addition to maximising enhanced versions of current methods, future ATM intends to fully exploit the new CNS technologies through international harmonisation of ATM procedures and standards. According to ICAO<sup>252</sup>, the objectives to be reached through the envisaged, evolutionary global ATM system include:

- Meet evolving air traffic demand;
- Support a safe and orderly growth of international civil aviation;
- Enhance safety, regularity and efficiency;
- Minimise delays
- Provide greater flexibility by accommodating user-preferred flight profiles;
- Improve the provision of information to users;
- Organise airspace in accordance with ATM provisions and procedures;
- Optimise benefits through global integration;
- Enhance economy of commercial air transport.

Heijl<sup>253</sup> maintains that, "in order to reach these objectives, it is necessary to manage the ATM system evolution with a view to obtaining progressive and incremental enhancements, functional compatibility of all system elements, including flight operations and, ultimately, a global system". Thus, an integrated, global ATM system will only be possible after the standards and recommended practices, procedures and guidance material are developed, adhered to and implemented by countries<sup>254</sup>.

Indeed, attaining the goal of an integrated, global ATM system requires harmonisation and standardisation of national and regional systems' technologies and procedures. It remains to be seen whether such a system will ever exist, but the strategy framework that is developed in this dissertation's **Chapter 5** considers the potential of ICAO's international harmonisation and standardisation planning mechanisms. ICAO's consequent development of Standards and Recommended Practices (SARPs) for ATM is also referred to in **Section 3.4, Chapter 4** and in the analyses of this dissertation's second part.

With all these ideals in mind, the aforementioned shortcomings in terms of technical, operational, procedural, economic and implementation nature cited in **Section 3.3.1** should be remembered.

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<sup>252</sup> 'Global Air Navigation Plan for CNS/ATM systems' – ICAO. 1<sup>st</sup> Edition, 2000.

<sup>253</sup> 'CNS/ATM road map for the future portrays an evolutionary process' – M Heijl. ICAO Journal, May 1994.

<sup>254</sup> 'The Future Air Navigation System' – V Galotti, Chapter 6. 1997.



### 3.3.3 Potential benefits from future ATM

CNS systems and emerging technologies should be seen as tools that will enable ATM enhancements and result in benefits for both airspace users and providers of services. The advances in CNS technologies will serve to support ATM. In addition, the future ATM system must accommodate all users, with their various levels of avionics equipage. Therefore, benefits must exist for airlines and General Aviation (GA) users alike. More accurate and reliable navigation systems will allow aircraft to navigate in all types of airspace, including reduced separation minima and more dynamic routings. Thus, carriers should have a greater chance of obtaining optimal profiles.

The GA community should find increasing access to avionics equipment that will allow them to use ATM for operations in flight conditions that would normally have been prohibitive because of the operating cost and associated requirements<sup>255</sup>. Furthermore, as a result of implementing CNS/ATM systems that enable use of future ATM, GA aircraft will have access to many remote areas that are presently inaccessible due to GA's inability to communicate or navigate safely in such airspace regions. Nonetheless, technical considerations will remain prohibitive factors due to the long distances from suitable diversion airfields.

Countries should also benefit from the future ATM system, with a reduction in cost of operation and maintenance of ground infrastructures. However, evidence in **Section 4.6.2** demonstrates that savings in this decade may not be too significant. Accordingly, it is expected that many current ATM systems on the ground will become obsolete due to the increased use of satellite systems. Therefore, implementation of CNS/ATM provides a timely opportunity for developing nations with very poor CNS equipment to enhance their infrastructure so that they may handle additional traffic with minimal investment (see **Chapter 6**). Indeed, it is essential that the ATM systems of all countries are improved if CNS/ATM is to be implemented on a global basis.

The introduction of the future CNS technologies described in **Chapter 2** will enable the evolution of more sophisticated ATM. This particularly applies to technologies that facilitate automatic sending of aircraft position data. ATM should consequently dictate the operational requirements for CNS systems and their functionality. Hence, optimum benefits from CNS systems will only be obtained through an evolutionary-derived integrated, global ATM system.

The combined benefits from advances in the aforementioned CNS technologies will serve as tools to support improved ATM. Execution of ATM calls for close integration of ground and airborne parts through well-defined procedures<sup>256</sup>. The benefits should result in improved flow management that should alleviate some of the present

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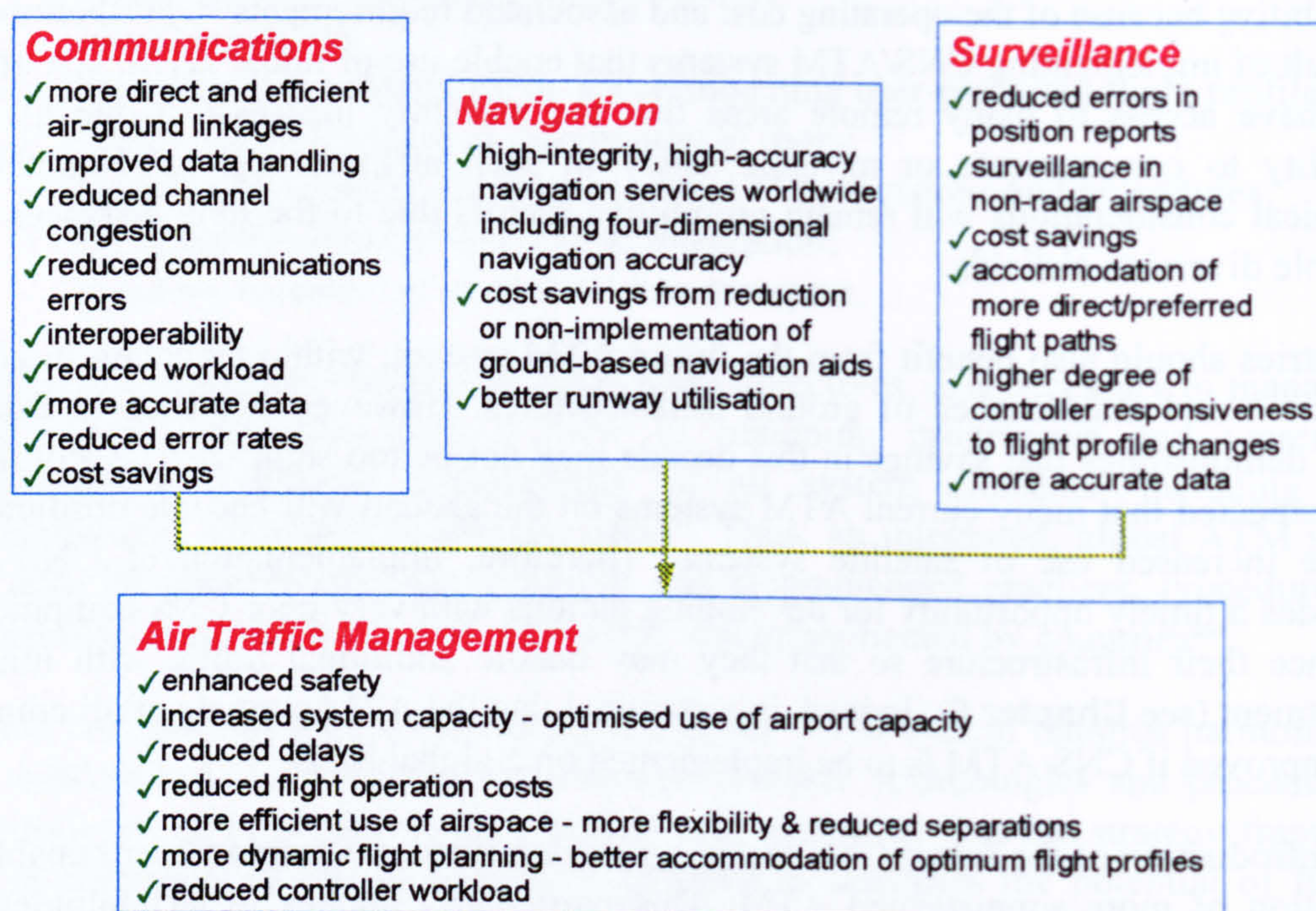
<sup>255</sup> 'The Air Traffic Management System – present and future' – V Galotti, Chapter 10. *Developing the Future Aviation System*, R Baldwin. 1998.

<sup>256</sup> 'Hybrid Air Traffic Management Plan for the North Atlantic region' – NATIMG (Ver.0.1), May 1996.



congestion. This applies to both en-route and terminal ATM functions, which must be integrated to provide smooth traffic flow into and out of terminal areas. Indeed, ICAO states that the integrated benefits and technical attributes of CNS technology will amalgamate to improve ATM, as portrayed in **Figure 3.1**. As a result, the ATM system should be better able to accommodate an aircraft's preferred flight profile and help aircraft operators to achieve reduced flight operating costs and delays.

The ultimate expectation is that accuracy can be improved through the rapid calculations associated with automation. Conflict prediction and detection, based on advanced computational methods, should allow more direct routings. These systems will be introduced in an evolutionary manner, with their rate of implementation determining the standard of ATM procedures next decade. Within this timeframe, the controller will undoubtedly still play a pivotal rôle, using skills such as spatial perception, information processing, reasoning and decision making, which are all presently employed.



**Figure 3.1** - Overall ICAO CNS/ATM systems benefit  
**Source** – adapted from ICAO's Global Air Navigation Plan for CNS/ATM systems (1<sup>st</sup> Ed. 2000)

**Appendix 3.2** depicts ICAO's view of the relationship between the future ATM's procedures and the aforementioned benefits, based on CNS components and automation enhancements in the following airspace types<sup>257</sup>:

- Oceanic/continental en-route airspace with low-density traffic;
- Oceanic en-route airspace with high-density traffic;

<sup>257</sup> 'Global Air Navigation Plan for CNS/ATM Systems' – Volume I, ICAO. 1<sup>st</sup> Ed. 2000.



- Continental en-route airspace with high-density traffic;
- Terminal area with high-density traffic;
- Terminal area with low-density traffic.

It is possible to observe that the benefits vary with airspace type and that each CNS aspect is improved by the envisaged system. Specifically, the advantages of future ATM should be manifested by increased airspace capacity and improved utilisation. In the en-route phase, aircraft should obtain more direct routings and user-preferred flight profiles, mainly due to better conflict prediction and resolution. In the terminal environment, improved sequencing and flight profiles should lead to better trajectory planning.

### 3.3.4 Future ATM system design

ATM systems must be designed in order to overcome the aforementioned limitations of the present system, in addition to accommodating future growth, so that the best possible service is offered to all airspace users. As mentioned in the previous two sections, the basic need is to provide airspace users with maximum convenience when selecting a flight path, which invariably means increased capacity. The CNS/ATM material and technical resources allocated for the development of a system must also be incorporated<sup>258</sup>. Hence, the air traffic management solutions that apply to the multitude of airspace regions around the world are not identical. Correspondingly, the optimum systems are not the same for the different phases of flight.

**Chapter 2** and sections in this chapter refer to the different scenarios and their answers. This section, however, discusses elements of ATM design that should be considered when drafting the solutions, thus:

- **Use of flight plans** – the future ATM system should use flight plans, similar to current methods, to represent users' most preferred and easily accommodated trajectories, given the ATM constraints. The plans should result from negotiations between the ATM system and users;
- **Airspace particulars** – traffic flow patterns, penalties for aircraft not cruising at their optimum Flight Level, meteorological forecasts and geographical criteria are factors that should be considered by the designers. Additionally, separation standards have significant impacts on the capacity and functioning of ATM systems. Thus, the future ATM system must use reliable methods for determining separation standards applicable to new technologies and procedures, noting that a prerequisite to the implementation of any reduction in separation minima is the continuation or improvement of safety levels. Furthermore, flexibility must be considered<sup>259</sup> and

<sup>258</sup> 'Basic areas of research in the development of a future ATM system' – Dr TG Anodina, ICAO Bulletin, December 1989.

<sup>259</sup> 'FANS Starter Kit – Guide to implementation' – IATA & ICAO.



capacity should be maximised through methods such as use of dynamic sector boundaries, which allow for more user-preferred routings and reduced controller workload<sup>260</sup>;

- **Aircraft position and manoeuvre intent** – optimum use of airspace requires an efficient airspace structure that permits collaboration planning between aircraft and the ground-based ATM system. Airspace structures should therefore be capable of dynamically adapting to changing circumstances, which necessitates real-time position and intent information. Additionally, improved communications are required to expedite immediate data or voice conversations between pilots and controllers;
- **International harmonisation** – ATM procedures and standards need to be uniform throughout the world. Therefore, designers of future ATM should adhere to internationally developed criteria. Correspondingly, every effort should be made by nations for improved infrastructure and information flow links through ATS Inter-facility Data Communications (AIDC) with neighbouring, regional and other countries: greater levels of automated and seamless ATS co-ordination must exist to enhance interoperability. Additionally, centralised Air Traffic Flow Management (ATFM) that is based on inter-regional co-operation and the application of strategic/tactical ATFM planning should be encouraged. Hence, it is essential to ensure that adjacent systems and procedures are able to interface in such a way that boundaries are transparent to airspace users. This should be done in an evolutionary manner, with minimum transitional periods possible;
- **Consideration of all users** – the effects of design decisions on all airspace users, including general aviation and military, must be taken into account. For instance, the performance of differing aircraft types has an impact on the separation standards of a particular airspace type;
- **ATM automation** – the future ATM system should be based on more automated processes for transfer of information and intent, but should also use decision support tools for trajectory planning, flight progress monitoring and short/long-term conflict detection or resolution. Such processes need to be at least as flexible and adaptive as controllers. Indeed, one of the most significant advances should be the introduction of software that performs some of the cognitive tasks presently conducted by the controller. The justification for implementation of these systems is that the controller is not always capable of determining exactly when and/or where aircraft would conflict with each other. This can lead to separation of airspace blocks rather than of individual aircraft, which consequently results in less than optimum use of an airspace region<sup>261</sup>. The expectation is that greater degrees of accuracy could be

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<sup>260</sup> 'Recent analysis indicates dynamic ATC sectors could improve efficiency and reduced delays' – ICAO Journal, March 1998.

<sup>261</sup> 'ICAO working to establish an integral global air traffic management system' – V Galotti & M Heijl, ICAO Journal, May 1996.



achieved by the rapid calculations associated with automation<sup>262</sup>, particularly if automation is initially used to assist controllers. Correspondingly, effective human-machine interfaces should exist to permit interaction between the controller, pilot and ground automation. Human factor considerations provide designers of all ATM-related infrastructure, including the flight-deck, with opportunities and challenges<sup>263</sup>:

- **En-route operations** – many en-route regions require more capacity and efficient use of ATFM. This should be possible through in-trail climbs and parallel routes<sup>264</sup>. Correspondingly, ATM system design should employ decision support tools and improved flows of information. The tactical management process should monitor aircraft movements to assure conformance with flight plans, in addition to identifying and resolving problems such as imminent separation violations and aircraft incursions into special use airspace;
- **Oceanic and remote operations** – the future ATM system in these regions should be based on different considerations than for en-route operations over land, but with the same overall goal to make operations as flexible as possible in accommodating users' preferred trajectories. Concepts include flexible routing and dynamic modifications to aircraft routes, which are necessary due to changes in weather and traffic conditions. The use of Automatic Dependent Surveillance (ADS), digital communications, satellite navigation, Collaborative Decision Making (CDM) and aviation weather system improvements facilitate this;
- **Terminal navigation operations** – increased levels of capacity are required in terminal airspace, which must be accommodated by the ATM procedures. Use of curved approaches, in addition to improved sequencing and spacing using automated metering devices, may eliminate some of the constraints imposed by the present centre-line approaches, such as the effects of wake vortices' turbulence. The issue particularly applies to the approach separation for the new Very Large Aircraft (VLA), such as the Airbus A380<sup>265</sup>. The procedural improvements in the approach phase are particularly beneficial at airports that are slot restricted and those aerodromes that are in close proximity to each other. ATFM should constantly monitor capacity resources to implement flow management in terminal airspace;
- **Airport operations** – increased airport capacity should be a major objective of the future ATM system because there is little point in maximising the capacity of the skies if bottlenecks are only going to occur on the ground. It is argued, however, that greater levels of runway capacity are presently available<sup>266</sup>. Nonetheless, the hubbing

<sup>262</sup> 'Demystifying CNS/ATM' – CANSO, June 1999.

<sup>263</sup> 'Displaying progress' – *Flight International*, 7 March 2000.

<sup>264</sup> 'Eurocontrol support to MFF operational requirements definition' – A Vink, Eurocontrol. 6<sup>th</sup> Air Navigation Conference, October 2000.

<sup>265</sup> 'AA98: A3XX approach separation worries Airbus' – *Air Transport Intelligence*, 24 February 1998.

<sup>266</sup> 'Increasing capacity, reducing delays and improving safety' – D Gleave, Aviation Hazard Analysis. 5<sup>th</sup> Air Navigation Conference, Amsterdam. September 1999.



concept used by carriers can drastically affect capacity of the terminal area<sup>267</sup>. Irrespectively, design planners must consider techniques, procedures and technologies that fully utilise capacity resources. Correspondingly, increased levels of collaboration between users and ATM providers should create a more realistic picture of airport departure and arrival demand, allowing users to make scheduling and flight planning decisions<sup>268</sup>. Thus, automation should become more prevalent in the airport environment to aid the increased levels of collaboration. ATM design should maximise the use of technologies such as Advanced Surface Movement Guidance and Control Systems (A-SMGCS), and ADS-Broadcast (ADS-B). Routing, guidance, surveillance and control of aircraft and vehicles on the airport surface should be accommodated in order to maintain acceptable movements rates under all weather conditions, while improving the required level of safety. **Chapter 4** details efforts such as the US Federal Aviation Administration's systems to display runway status, tag surface-movement-radar returns with aircraft identity and to advise the ground controller on runway use. Accordingly, NASA is looking at systems that could increase airport capacity in its Terminal Area Productivity (TAP) project. TAP's aims include the automation of terminal ATM, the reduction of spacing between aircraft on final approach and the faster movement of aircraft off the runway to the terminal<sup>269</sup>. Systems include Roll-Out and Turn-Off (ROTO), which provides braking commands to the crew to minimise runway occupancy times; Taxi-Navigation And Situational Awareness (T-NASA), which provide the crew with airport maps, taxi guidance and collision warning<sup>270</sup>; and a Dynamic Runway-Occupancy Measurement (DROM) system, which determines the spacing between landing aircraft.

With reference to the aforementioned different elements of ATM design, it is currently possible to introduce many airspace enhancements that increase capacity and flexibility. Certain steps must be taken to ensure that acceptable levels of safety are maintained<sup>271</sup>. In order to demonstrate this, consider the following ATM concept programmes that are being implemented around the world:

- **Routings requiring conventional functionalities** – routes requiring a Real Time Navigation (RTN) capability and existing navigational aid infrastructure;
- **Routings requiring CNS/ATM functionalities** – fixed and flexible routes, in addition to Dynamic Aircraft Routing Procedures (DARP) and satellite-based RTN routes, necessitate many different airborne functions and ground-based services;

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<sup>267</sup> 'Airports key to Free Flight' – *Orient Aviation*, November 1999.

<sup>268</sup> 'The Air Traffic Management System – present and future' – V Galotti, Chapter 10, *Developing the Future Aviation System*, R Baldwin. 1998.

<sup>269</sup> 'Working to capacity' – *Flight International*, 5 June 1996.

<sup>270</sup> 'Hitting the ground running' – *air traffic management*, March-April 2000.

<sup>271</sup> 'Reduction in aircraft separation minima requires an airspace safety management plan' – *ICAO Journal*, May 2000.



- **En-route vertical separation reductions** – Reduced Vertical Separation Minima (RVSM) programmes usually implement 1,000ft vertical separation between FL290 and 410, using certification and operational approval functions in conjunction with height monitoring practices<sup>272</sup>;
- **En-route longitudinal separation reductions** – the separation standards between successive aircraft along routes in non-radar environments have been lowered over the years. Termed Reduced Horizontal Separation Minima (RHSM) longitudinally, they are dependent on the availability of aircraft functions and ground services. Reductions are stated in terms of distance or time;
- **En-route lateral separation reductions** – similar to the aforementioned longitudinal RHSM situation, lateral separation standards are also progressively lowered through lateral RHSM, with improved aircraft functions and ground services. Such separation standards, which are listed in units of distance, are implemented in both non-radar and radar environments;
- **Flexible Use of Airspace** – the FUA concept, whereby airspace is considered as one continuum and allocated according to user requirements. Any necessary airspace segregation is temporary and based on real-time usage within specific time periods. Such Conditional Routes allow shorter paths with consequent fuel and time savings. The efficient application of FUA depends on civil-military co-ordination capability<sup>273</sup>.

In contrast, future airspace ATM designers will be able to employ, among others, two methods of improving capacity and enhancing flexibility, thus:

- **ATM Trajectories** – trajectories used in current systems are limited to 3-dimensional (3D) accuracy<sup>274</sup>. Indeed, controllers can now view airspace in 3D<sup>275</sup>. There are, however, Flight Management Systems (FMS) in use that can generate and fly 4D trajectories with extremely accurate guidance. Graphical representation is provided on Cockpit Displays of Traffic Information (CDTI). If all aircraft had known 4D trajectories, it would be possible to allow direct and free routing (see hereunder) for user-preferred trajectories, with increased safety and reduced controller workload. However, it is not yet possible to conduct deconfliction, which makes use of altitude and route separation rather than time separation of crossing aircraft. This leads to the use of separation by in-trail sequencing. Once the ATM system enables the FMS to transmit 4D data to other sub-systems, conflict detection and deconfliction will become possible. Other ATM functions such as trajectory negotiation management and runway sequencing will also occur:

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<sup>272</sup> 'Reduced Vertical Separation Minimum' – *Airliner*, July/September 1996.

<sup>273</sup> 'Area Navigation 1998 Symposium Proceedings' – Eurocontrol & JAA, March 1997.

<sup>274</sup> 'User Preferred Trajectories and the Known Trajectory Environment' – I Wilson, Eurocontrol. *Air Traffic Management: Prospects for Free Flight SMI Conference*, London, 1999.

<sup>275</sup> 'Adding that extra dimension' – *air traffic management*, November-December 1999.



□ **Free routing** – Free routing is an ATM operational concept that is considered to minimise ground control and maximise aircraft operators' freedom<sup>276</sup>. However, it has only been tested in low-density airspace regions and will undoubtedly reap higher benefits in such environments. For instance, consider the following three free routing concepts:

1. **Air Traffic Management Partnership (ATMP)** – this US proposal involves equipped aircraft being responsible for resolution of potential conflicts within their own surveillance range. Similar to Traffic Collision Avoidance Systems (TCAS), but longer range, aircraft act according to conflict resolution advisories. ATC retains control of non-equipped aircraft and controls area zones around airports;
2. **Free-Route Experimental Encounter Resolution (FREER) Autonomous Aircraft Operations** – this Eurocontrol study gives suitably-equipped aircraft access to defined Free Flight Airspace, away from airports, in which they operate under Extended Flight Rules (EFR). The latter allow aircraft to operate without ATC clearance, with the pilot responsible for maintaining separations using ASAS equipment onboard;
3. **Programme for Harmonisation of ATC Research in Eurocontrol (PHARE)** – this Eurocontrol concept enables pilots to propose their ideal trajectory to ATC and negotiate an agreed path via datalink. ATC retains responsibility for ensuring separation by re-negotiation of agreed trajectories in order to resolve potential conflicts.

Each of the three concepts contains differences regarding the airspace régime, freedom to initiate action, the responsibility for separation assurance, responsibility for conflict resolution and the demand capacity balancing with airspace allocation. Ultimately, the free routing concept should not require a large amount of interventions. Otherwise, the aircraft could end up flying a route that is longer than today's. Correspondingly, controller and pilot workload could be higher than at present. Nonetheless, the concepts have been proven.

The design of the future ATM system must incorporate the transition and integration from current systems because it takes several years to develop and evolve to new systems. The design should provide a well-understood, manageable, cost-effective sequence of improvements that keep pace with users' needs and culminate in a system meeting the safety, capacity, efficiency, regularity and environmental demands<sup>277</sup>.

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<sup>276</sup> 'Free routing – where and when it applies' – A Turner, *The Smith Group. Air Traffic Management: Prospects for Free Flight SMI Conference, London. 1999.*

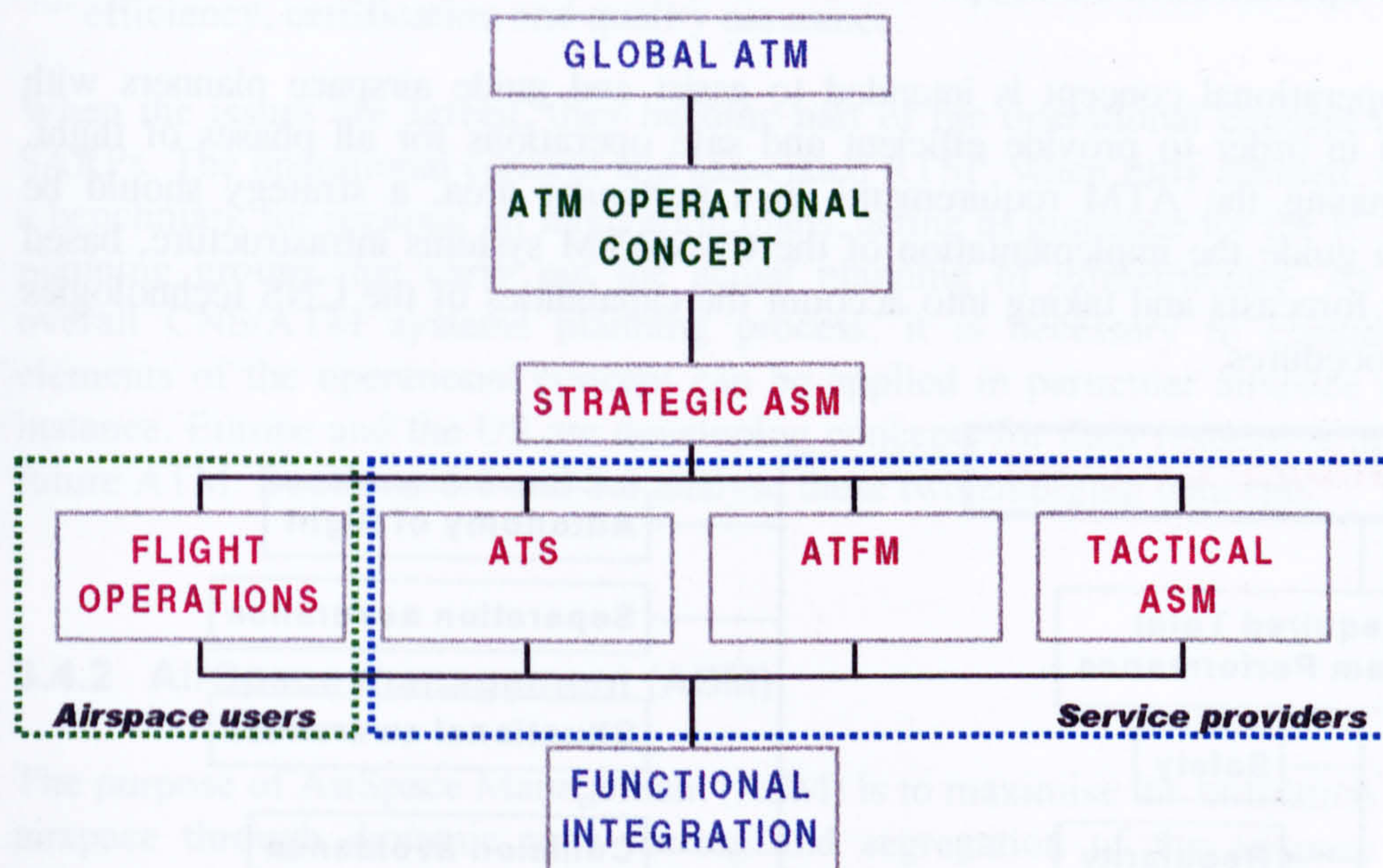
<sup>277</sup> 'Demystifying CNS/ATM' – CANSO, June 1999.



### 3.4 ICAO's global ATM plan

In order to optimise the flow of air traffic around the world, the capacity and efficiency of its air traffic operations must be improved, as discussed in **Section 3.3.4**. The providers of Air Traffic Services (ATS), the system's users and other stakeholders are currently working, both together and in conjunction with ICAO, to draft and implement suitable future amendments to today's situation. As mentioned in **Chapter 1**, ICAO and its regional groups are responsible for the global integration of CNS/ATM<sup>278</sup>.

Indeed, ICAO considers CNS/ATM to be the most far-reaching aviation project ever undertaken<sup>279</sup>. Thus, this section analyses the Air Traffic Management (ATM) component of ICAO's CNS/ATM at a worldwide level, as described in the ICAO 'Global Air Navigation Plan for CNS/ATM systems' (1<sup>st</sup> Ed. 2000). This discussion complements the analysis of this concept's CNS technologies in **Chapter 2**, in addition to the synopses of the European and US regional ATM concepts in **Section 3.5** and **Section 3.6**. It should be noted that the latter two concepts are derivatives of the Global Plan in that they are their regions' respective CNS/ATM blueprints.



**Figure 3.2** - Structured approach to global ATM

**Source** - ICAO's Global Air Navigation Plan for CNS/ATM systems (1<sup>st</sup> Ed. 2000)

ICAO's global ATM model highlights ATM methods of alleviating the limitations cited in **Section 3.3.1**. **Figure 3.2** portrays ICAO's structured approach to global ATM,

<sup>278</sup> 'Global air navigation plan is blueprint for next major step in CNS/ATM systems implementation, Secretary General tells ATCA' – ICAO Journal, October 1997.

<sup>279</sup> 'Down to Business' – ICAO Journal, January/February 1998.



which consists of the ATM Operational Concept and elements of the future ATM system. These elements include:

- AirSpace Management (ASM);
- ATM-related aspects of flight operations;
- Air Traffic Services (ATS);
- Air Traffic Flow Management (ATFM).

Noting that ICAO wishes the inter-operability of these components to functionally integrate into a total system, yielding a synergy of operations that does not presently exist, each element is discussed in this section under its own heading, prior to an analysis of their functional integration. The initial development of ATM systems is concentrated primarily on ATS and ATFM<sup>280</sup>. Performance capabilities are used to determine airspace design in terms of separation minima, route spacing, sectorisation, required instrument procedures and the capability requirements for ATC intervention. The following parts of this section discuss the various components of this structured approach to global ATM.

### 3.4.1 ATM operational concept

The ATM operational concept is intended to assist and guide airspace planners with ATM design in order to provide efficient and safe operations for all phases of flight. After determining the ATM requirements in a particular area, a strategy should be developed to guide the implementation of the CNS/ATM systems infrastructure, based on air traffic forecasts and taking into account the capabilities of the CNS technologies and ATM procedures.

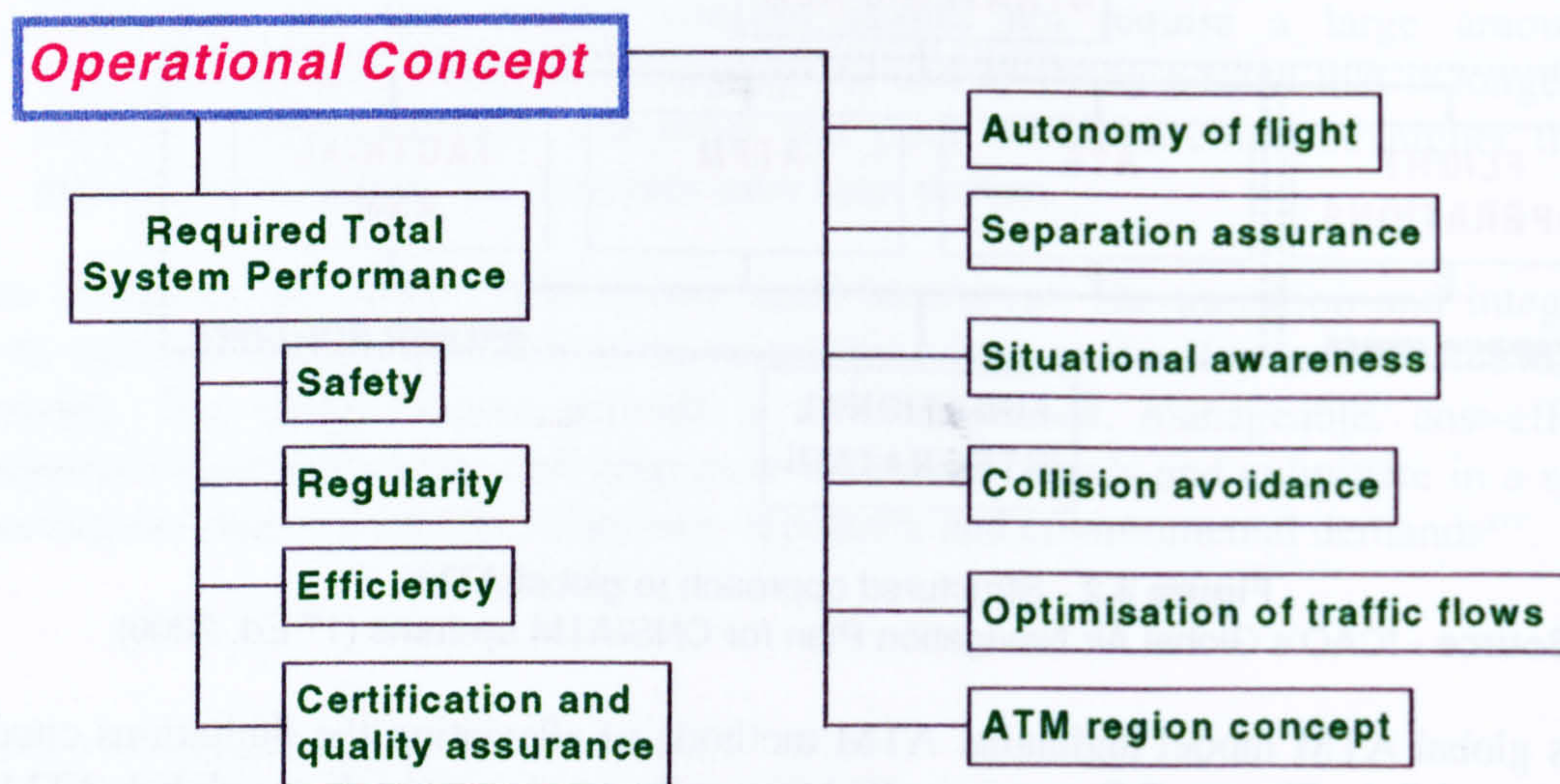


Figure 3.3 - ATM operational concept

Source - ICAO's Global Air Navigation Plan for CNS/ATM systems (1<sup>st</sup> Ed. 2000)

<sup>280</sup> 'Demystifying CNS/ATM' – CANSO, June 1999.



With reference to **Figure 3.3**, ICAO's basis for developing the standards necessary for harmonisation and integration of ATM is an operational concept. The concept clarifies benefits, in addition to giving countries and industry objectives for designing and implementing the ATM systems. Work on the concept aims at obtaining consensus on the following objective issues:

- ❑ *Autonomy of flight;*
- ❑ *Separation assurance;*
- ❑ *Situational awareness;*
- ❑ *Collision avoidance;*
- ❑ *Optimisation of traffic flows;*
- ❑ *ATM regional concept* of providing services over greater geographic areas that encompass several Flight Information Regions (FIR);
- ❑ *Required Total System Performance (RTSP)*, which is necessary because a target level of safety has been developed for some airspace regions, but not at a global level. In the absence of agreed criteria for airspace and airport capacity, there is no common basis for efficiency and regularity worldwide. Indeed, there is no assurance that the future traffic demand can be met. Thus, the whole system must be viewed in its entirety, using RTSP. According to **Figure 3.3**, RTSP specifies criteria that should be met by the entire ATM system in the areas of safety, regularity, efficiency, certification and quality assurance.

When the issues are agreed, they become part of the operational concept that leads to SARPs. The operational concept and associated RTSP, when fully defined, will serve as a benchmark for regional air navigation plans, acting as guidance for the ICAO regional planning groups that carry out the actual planning of infrastructure. As part of the overall CNS/ATM systems planning process, it is necessary to consider how the elements of the operational concept can be applied in particular airspace regions. For instance, Europe and the US are developing concepts for their respective approaches to future ATM: **Sections 3.5** and **3.6** analyse these two emerging concepts.

### **3.4.2 AirSpace management (ASM)**

The purpose of AirSpace Management (ASM) is to maximise the utilisation of available airspace through dynamic time-sharing and segregation of the airspace among the various user categories, based on short-term needs. ASM has traditionally been recognised as involving a dynamic sharing of airspace by civil and military users. However, ASM will not just be limited to tactical aspects of airspace use, but will also be employed as a strategic planning function of airspace infrastructure and flexible use of airspace. Thus, the future ASM has two main parts, tactical and strategic. Tactical ASM, which is based on calculations, already exists. Strategic ASM may be considered to consist of two elements, infrastructure planning and the corresponding determination of ATM requirements for CNS equipment, which both affect the air navigation infrastructure.



Infrastructure planning is based on the operational requirements and planning criteria for airspace organisation, services and facilities to support global ATM. The objective of this methodology is to facilitate the optimal use of airspace, organised to provide efficient service with improved safety levels. For instance, risk assessment modelling derives safe separation minima in given airspace regions based on given traffic volumes and airborne capabilities, in addition to facilities and services.

Implementation options are developed for ground-based facilities and airborne systems to achieve the required functionality, adhering to the stated guidelines. Thus, infrastructure planning is based on defined ATM requirements for CNS, which may each be discussed as follows:

- **ATM operational requirements for communication** – referring to the air-ground and ground-ground systems discussed in **Chapter 2**, the Required Communication Performance (RCP) concept will govern the development of SARPs, procedures and guidance material for communication system performance and aircraft equipment requirements;
- **ATM operational requirements for navigation** – will specify aRea NAVigation (RNAV) capability of aircraft, noting the trend towards Global Navigation Satellite Systems (GNSS) that should lead to a reduction in numbers of ground-based navigational aids. Statements will consist of Required Navigation Performance (RNP) guidelines that are described in **Chapter 2**;
- **ATM operational requirements for surveillance** – noting that additional radars and Automatic Dependent Surveillance (ADS) technologies are given pre-requisites in accommodating future demand, the ATM surveillance requirements will specify criteria for ADS and radar coverage. This will include statements on Required Surveillance Performance (RSP), as mentioned in **Chapter 2**, which will guide countries and industry with design, development and implementation of surveillance components, both in the air and on the ground, that are based on the CNS/ATM concept.

### 3.4.3 ATM aspects of flight operations

ATM-related aspects of flight operations are integral to harmonised CNS/ATM systems because carriers must equip their aircraft with specified avionics that are required for the future situation. For instance, datalinks are necessary to enhance ATM. As discussed in **Chapter 2**, much of the communications presently accomplished by voice will be carried out using automatic transmission of data<sup>281</sup>. Similarly, automated systems on the ground will be able to assist the controller with conflict detection and resolution, based on information derived from the aircraft's Flight Management Systems (FMS).

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<sup>281</sup> 'The Future Air Navigation System' – V Galotti, Chapter 6. 1997.



The help of aircraft operators is also needed to bring about collective gate-to-gate efficiency of flights. The gate-to-gate concept is heavily dependent on flight scheduling and planning, in addition to apron area manoeuvring management. Correspondingly, given that the future system will attempt to let all airspace users have access to airspace using the Flexible Use of Airspace (FUA) concept, rather than an ATM based on strict segregation of airspace, close co-ordination of all users is required.

Flight planning in the future will incorporate data for three or four-dimensional flight profiles, which must be shared between the FMSs and the ground-based ATC systems. Users will consequently have more collaborative rôles based on shared information such as status of Special Use Airspace (SUA) and traffic flow requirements. FMSs will have requirements to automatically notify the ground ATC system as soon as deviations from agreed flight profiles occur. The limits of such deviations should be determined by the traffic situation and the aircraft's capability.

#### 3.4.4 Air Traffic Services (ATS)

Air Traffic Services (ATS) will continue to be the primary component of ATM in the future, still split into Air Traffic Control (ATC), Flight Information Services (FIS) and alerting services, thus:

- ❑ **ATC's** main objectives are to prevent collisions between aircraft (and obstructions) and to expeditiously maintain a safe, orderly flow of air traffic. Ideally, ATC will enable aircraft to fly direct routes at their optimum Flight Levels to avoid increasing their Direct Operating Costs (DOC) by having higher trip distances and consuming more fuel;
- ❑ The purpose of the **FIS** will still be to provide advice and information, for the safe and efficient conduct of flights, in the form of up-to-date information for the flight deck. The availability of datalinks will enable the provision of meteorological and operational flight information to be performed in a more efficient manner by allowing direct access to the databases. **Chapter 2** covers the various meteorological systems that are being planned for the future CNS/ATM. Facilities and services will include routine weather information, forecasts and SIGMET information;
- ❑ The **alerting service** will remain responsible for notifying the appropriate organisations of aircraft in need of Search And Rescue (SAR) aid. No fundamental changes are foreseen in the present rôle of ATS in this respect. The service should be improved with the introduction of satellite-based systems. States should ensure the availability of rescue co-ordination centres or Sub-Centres on a 24-hour basis. Neighbouring states should enter into mutual assistance agreements to promote greater efficiency and economy. This pooling of resources should aim to provide comprehensive coverage.



The ATC service currently maintains air traffic flow by applying separation between aircraft and by issuing clearances to individual flights as close as possible to their preferred profiles. In the future, however, the following rôles are envisaged for ATC:

- ❑ *Avoidance of in-flight collisions*: ATC's primary function, it will exist under the three distinct strategic, tactical and short-term phases of conflict resolution;
- ❑ *Area control service*: provided on a 24-hour basis in all controlled airspace, it will be used by international flights on their en-route and terminal phases;
- ❑ *Ensuring optimum efficiency for the operation of each aircraft in flight*: ATC should strive to achieve this objective by responding in an optimal way to the intentions specified in the filed flight plan and those arising during the flight;
- ❑ *Assistance to aircraft in emergency*: procedures should be designed to make optimum use of developments in CNS automation in the NAT region;
- ❑ *AFTM-related activities*: to meet AFTM objectives, ATC units will have to share forecast and real-time traffic data as well as details of specific capacity constraints;
- ❑ *Real-time relay of special information to aircraft in flight*: the provision of HF communications will continue to be required.

According to ICAO's global plan, the future ATS system will include a network of routes, established so that aircraft may operate along, or near to, their preferred flight path in both horizontal and vertical planes. Where possible, ATS routes will be great circles between significant points. Whenever circumstances warrant, airspace organisation should be designed to support the ultimate goal of allowing each aircraft to fly its own optimised flight path, with conflict resolution by tactical intervention, thereby including the possibility for flight-planned cruise climbs and variable schedules.

The division of airspace regions should conform with the major worldwide route axes, so that the different regional interface problems may be removed. This could therefore be the foundation of new airspace structures that would ensure efficient flows of air traffic. In addition, the procedures for progressive reductions in separation minima should involve verification trials and determinations of suitable target levels of safety.

Airspace sectorisation involves dividing a given control area into small volumes to keep controller workload within reasonable limits. Division is by vertical and geographical methods, but dependent on traffic patterns, their density, the predominance of whether in level, ascending or descending flight and any inherent changes. An optimum scenario will be safe and keep the co-ordination workload to a minimum. Flexibility in sectorisation should be encouraged.

Significant improvement in ATS will only be achieved through the development of powerful decision support software tools. System safeguards will exist so that the failure of any component will not lead to the ATC service being adversely affected. Humans will remain the ultimate decision makers, with their intervention minimised and ergonomics optimised. However, automation is essential and will assist in ensuring optimum efficiency by employing appropriate algorithms.



Automation systems will possess precise information on the present and predicted future position of aircraft, supported by an accurate, up-to-date meteorological database using data common to all users. This will permit the best use of information available to controllers, for:

- ❑ **Conflict prediction:** a dynamic function whose aim is to progressively reduce the required length of the conflict free path in order to increase airspace capacity and improve flight economy;
- ❑ **Conflict resolution:** this function will be capable of determining those modifications to flight profiles which result in the least overall penalties for the aircraft involved. Alternatives should be offered where possible;
- ❑ **Clearance compliance:** ability to verify that the current flight plan's contents are identical to the flight being flown. Information regarding the latter will be contained in the extended ADS message. Any discrepancy should be pointed out to the controller. It is envisaged that automated assistance, available to both operators and ATS providers, will enable the more timely input of filed flight plans;
- ❑ **Conformance monitoring:** essential for the reduction of separation minima, this function will report when an aircraft deviates from its cleared profile;
- ❑ **Traffic monitoring:** traditionally achieved by the use of flight progress strips, and radar displays where available, monitoring should improve on these tools using modern display technology.

### 3.4.5 Air Traffic Flow Management (ATFM)

The objective of Air Traffic Flow Management (ATFM) is to ensure an optimum flow of air traffic to or through areas during times when demand exceeds the available capacity of the ATC system<sup>282</sup>. A major catalyst for efficient ATFM is the cost of fuel<sup>283</sup> and the penalty for having to carry greater fuel loads. Thus, an ATFM system should reduce delays to aircraft in flight and on the ground, in order to prevent an overload of the system. The order of sequencing is very important. In essence, ATFM and Air Traffic Services (ATS) will merge into a single, seamless system.

ATFM assists ATC in meeting its objectives and achieving the most efficient utilisation of available airspace and airport capacity, while keeping delay costs to a minimum<sup>284</sup>. Indeed, ATFM should also ensure that safety is not compromised by the development of unacceptable traffic congestion levels, and that unnecessary flow restrictions should not be applied.

<sup>282</sup> 'Global Air Navigation Plan for CNS/ATM systems' – Volume I, ICAO. 1st Ed. 2000.

<sup>283</sup> 'The dynamics of arrival flow management' – BG Sakkappa, *Journal of ATC*. April – June 1987.

<sup>284</sup> 'Air Navigation Plan for the North Atlantic Region' – ICAO Doc. 9634. Part V. Trial Edition, 1995.



Similar to ATS, two categories of ATFM processes exist, thus:

- **Strategic** – seeks to accommodate traffic through preplanning, such as the use of traffic routing schemes for particular areas or during particular seasons. Additionally, pre-determined acceptance rates for specific points over a flight's route or at an airport may be prescribed on a strategic basis. Acceptance rates are normally enforced through the issuance of departure slot allocation times:
- **Tactical** – monitors the progress of individual aircraft and intervenes in their flight paths when required to meet ATM constraints on a flexible, real-time basis. It will make extensive use of automation: in the event that a flight plan amendment is required, for instance, the aircraft's flight management system will negotiate with the ground-based tactical management system. The process will also operate in the opposite direction.

Integrated ATM systems require real-time flow management tools to assimilate information and offer flow strategies that avail themselves of changing conditions. Models that accurately predict congestions are being developed to formulate real-time strategies to cope with excess demand. Solutions are obtained by interrelating the available capacity with delays<sup>285</sup>. Bottlenecks must incorporate airports and airspace sectors<sup>286</sup>. The algorithms and associated dynamic programming can be optimised in many ways, such as by assigning the correct ground-holding times, namely how long the take-off of a particular flight should be delayed for ATFM purposes<sup>287</sup>. Such algorithms are beyond the scope of this dissertation.

Different types of airspace regions should be interfaced in manners that enhance harmonisation. ATFM should cater for flights to and from adjacent FIRs using proactive and reactive systems: the former requires dynamic interaction with strategic planning of traffic flows; reactive ATFM considers the short-term contingencies, providing the controller with information quickly. Users must interface with the flow management process to negotiate trajectories that best suit their needs.

Correspondingly, worldwide standardisation of functionality is required to ensure global compatibility of regional ATFM systems as part of the integrated ATM in the future. ICAO is undertaking this through the development of functional specifications and procedures to ensure global integration of ATFM systems that will facilitate optimal air traffic flows.

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<sup>285</sup> 'Air route flow management – problems and research efforts' – V. Tošić and O. Babić, *Transportation Planning and Technology*, Vol 19, 1995.

<sup>286</sup> 'Some models and algorithms for en-route air traffic flow management' – V. Tošić, O. Babić, M. Čangalović and D. Hohlačov, *Transportation Planning and Technology*, Vol 19, 1995.

<sup>287</sup> 'Ground-holding strategies for ATC flow control' – M Terrab, AR Odoni and OL Deutsch, *American Institute of Aeronautics and Astronautics*, 1989.



### 3.4.6 Functional integration

In order to develop an integrated, global ATM system, the elements and procedures of regional and national systems must be harmonised and standardised. The future ATM system must be compatible with ATM developments around the world. Thus, ICAO continues to develop new Standards and Recommended Practices (SARPs) for the pertinent technologies, which are referred to in **Chapter 2**. Nations and industry use these standards as a guide in the development and implementation of ATM systems.

The global model is assembled using functional integration that ensures maximum levels of harmonisation and synergy. The functional integration of the ATM system elements is the key to success. Indeed, according to ICAO, an integrated global ATM system should fully exploit the introduction of new CNS technologies through international harmonisation of standards and procedures. Hence, SARPs, procedures and guidance material necessary for the functional integration of airborne and ground-based systems are being developed.

In order to ensure safe and efficient movement of aircraft during all flight phases, the required airborne and ground portions of ATM must have the functional capability to interface with one another. For instance, with reference to the analysis in **Section 4.6**, increasing numbers of aircraft are being equipped with CNS systems, such as the FANS-1 or FANS-A suites of avionics. Communications aspects of FANS-1/A are based on a harmonised protocol, ARINC 622. Correspondingly, ICAO is advocating and developing a global infrastructure for communications through the Aeronautical Telecommunications Network (ATN), as discussed in **Section 2.3.4**.

Furthermore, the various elements of the overall ATM system must be designed to work together effectively to ensure that a homogeneous, continuous and efficient service is provided to the user on a gate-to-gate basis. This invariably necessitates international harmonisation. However, current ATS systems usually do not permit optimum flight trajectories in most airspace regions, so the capabilities of airborne and ground-based systems cannot be fully exploited, due to the absence of functional integration. The evaluation in **Chapter 4** observes when ICAO predicts that functional integration of airborne systems with ground systems will occur.



### 3.5 European ATM initiatives

Historically, the planning and execution of ATM in Europe has been carried out mainly on a national basis, with varying degrees of co-ordination via organisations such as the European Civil Aviation Conference (ECAC), Eurocontrol and ICAO. But, as cited throughout this dissertation, many ATC delays exist in the region. Indeed, these problems were recognised in the late 1980s: in 1989, due to the level of delays, the Association of European Airlines (AEA) published a document<sup>288</sup>, which highlighted the severity of the future situation.

Additionally, the transport ministers of the ECAC States adopted the 'En-route ECAC Strategy for the 1990s'. To achieve its objectives, the European Air Traffic Control Harmonisation and Integration Programme (EATCHIP) was developed<sup>289</sup>. According to Eurocontrol, EATCHIP, which was launched in 1990, has delivered increased airspace capacity through the harmonisation of existing air traffic control systems. However, the escalation of delays during the 1990s indicates that EATCHIP was not too successful or, certainly, that its objectives were not sufficient. It therefore became apparent that, in the long run, its harmonisation and integration measures would not suffice to keep pace with the projected increase of traffic demand. Hence, the European Air Traffic Management Programme (EATMP) became EATCHIP's successor.

In fact, EATMP incorporates the final phase of EATCHIP, the future European ATM System (EATMS)<sup>290</sup> concept. The EATMP was developed in parallel with a new approach<sup>291</sup>, the 'ATM Strategy for 2000+', which was drafted in close consultation with all stakeholders, namely the Eurocontrol national civil aviation authorities, service providers, military, other airspace users, the manufacturing industry and the European Commission (EC), in addition to many international and professional organisations. The Strategy obtained its approval at the ECAC States<sup>292</sup> Directors General of Civil Aviation to the Ministers of Transport at their meeting in January 2000<sup>293</sup>.

Eurocontrol defined the 2000+ Strategy, which is in accordance with ECAC's Institutional Strategy and ICAO's CNS/ATM developments, at the request of the ECAC transport ministers. Thus, this section describes Europe's approach to developing a future ATM system by discussing the emerging concept, 'ATM Strategy for 2000+'. It

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<sup>288</sup> 'Toward a single system for Air Traffic Control in Europe' – Association of European Airlines, 1989.

<sup>289</sup> 'Development of the European air traffic management systems (EATMS)' – paper presented at the 37<sup>th</sup> meeting of ICAO's European Air Navigation Planning Group, 1995.

<sup>290</sup> The mission statement of EATMS is to allow all airspace users the maximum freedom of movement, subject to the needs for safety, cost-effectiveness, environmental aspects and national security requirements.

<sup>291</sup> 'One Sky for Europe' – Eurocontrol, October 1997.

<sup>292</sup> The ECAC member nations are listed in Appendix 3.3.

<sup>293</sup> 'European Transport Ministers act on Air Traffic Management' – ECAC/Eurocontrol joint press release, 28 January 2000.



should be noted, once again, that the success to date of the Strategy and the previous European CNS/ATM projects are evaluated in **Chapter 4**. Additionally, given the fact that the 2000+ Strategy is only starting to be implemented now, the analysis in **Chapter 4** includes the intended milestones of this programme.

### 3.5.1 Introduction to the 'ATM Strategy for 2000+'

Noting the aforementioned serious levels of delay being experienced in the European region, the 'ATM Strategy for 2000+' aims to create capacity in order to constantly meet demand. The capacity applies to airport and airspace congestion, with the Strategy viewing ATM as "a network with airport and airspace users as integral parts of the gate-to-gate environment"<sup>294</sup>. Other than ATC systems and their performance shortfalls, the main areas in need of change in European ATM identified in the Strategy include:

- ❑ **Organisation and use of airspace**, which is a major obstacle to providing more en-route capacity in Europe, is invariably due to a lack of cross-border airspace agreements between nations that impose ATM constraints. A major thrust of the Strategy is to achieve one, uniform European airspace. However, every country will continue to have complete and exclusive sovereignty over the airspace above its territory, in accordance with international conventions (the framework in **Part 2** of this thesis demonstrates how this is feasible);
- ❑ **Safety**, noting that the maintenance of safety levels with increased traffic has an effect on capacity and operational efficiency because delays are imposed to maintain safe separation between aircraft;
- ❑ **Limits of human capabilities**, with ATC processes relying heavily on the cognitive skills of the air traffic controllers. Reliance on the human element alone will lead to a critical imbalance between capacity and demand within a few years;
- ❑ **Management practices**, to ensure that projects meet time, budgetary and performance requirements. The Strategy realises that economic and financial considerations are recognised as being among the main drivers that will determine the future EATMS.

Eurocontrol has defined the overall objective of its 'ATM Strategy for 2000+' and the EATMP, thus: "For all phases of flight, to enable the safe, economic, expeditious and orderly flow of traffic through the provision of ATM services, which are adaptable and scaleable to the requirements of all users and areas of European airspace. The services shall accommodate demand, be globally inter-operable, operate to uniform principles, be environmentally sustainable and satisfy national security requirements".

The Strategy defines guiding principles and major goals for meeting the objective through the establishment of a uniform ATM network in Europe. The focus is on the

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<sup>294</sup> 'ATM Strategy for 2000+' document – Volume I, Eurocontrol, 1998.



progressive introduction of operational improvements that keep pace with traffic increases, while providing early benefits for the airspace users whenever possible<sup>295</sup>. The Strategy defines strategic targets and objectives that the new ATM system must meet to satisfy air transport needs. It also defines the path for change and identifies those measures that will deliver early, lasting benefits for airspace users.

Given the severity of the situation in many European regions, the systems approach of the 'ATM Strategy for 2000+' is thought to be the most practical path forward. By 2005, the Strategy hopes to adopt general use of best current practice and, by 2010, it aims to integrate ATM information so that current and future positions of aircraft are known. The Strategy's present timeframe is up until 2015, but it provides a strategic planning framework past that date.

### 3.5.2 Principles and objectives of the Strategy

The main objective of the Strategy is to ensure that European ATM is capable of providing the required services in the future. With reference to this and the overall objective cited previously, this section considers the strategic principles that will be systematically applied throughout the European ATM system and the specific objectives of the future ATM Strategy.

#### Strategic principles

The following strategic principles apply to the European 'ATM Strategy for 2000+':

- *One airspace* – the airspace of the ECAC States shall, for the ATM purposes of the Strategy, be considered as a continuum that is not constrained by national boundaries. Indeed, certain programmes that remove boundaries already exist;
- *Safety* – uniform safety standards and risk management practices shall be based on established and monitored safety performance;
- *Economy* – ATM activities shall be economically sustainable for the users;
- *Freedom of movement and service quality* – all airspace users shall have maximum operational freedom within the scope of the other principles and shall receive services that satisfy their requirements, based on defined performance targets;
- *Sovereignty* – every country shall continue to have complete and exclusive sovereignty over the airspace above its territory in accordance with international conventions;
- *National security and defence requirements* – the ATM network shall satisfy national security and defence requirements;

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<sup>295</sup> 'The Air Traffic Management System – present and future' – V Galotti. Chapter 10. *Developing the Future Aviation System*, R Baldwin. 1998.



- *Environment* – the environmental impact of aircraft noise and gaseous emissions shall be taken into account when defining operational ATM improvements.

### **Strategic objectives**

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The strategic performance objectives of the future ATM network must be tailored to reflect regional and local differences. The Safety Regulation Commission (SRC), which is independent of Eurocontrol, but reports to its Council, is drafting safety guidelines. In a similar manner and with comparable status, the Performance Review Commission (PRC) is setting performance level targets. **Chapter 7** analyses the results of the PRC so far. The objectives of the future ATM system should be considered in the context of the relevant safety and performance levels for each regional and local application under the following headings<sup>296</sup>:

- *Safety* – to improve safety levels by ensuring that the number of ATM-induced accidents and serious or risk bearing incidents does not increase and, where possible, that they decrease. However, a further objective is to ensure that safety levels are achieved in the most efficient and economic way, with minimum adverse effect on operational conditions. To accomplish this, harmonised ATM safety policies, performance measurement and evaluation methodologies must be introduced within the ECAC States;
- *Economics* – to reduce the direct and indirect ATM-related costs per unit of aircraft operations, which means that the operating costs of ATM systems must also be lowered. Two frameworks exist for cost reduction: a performance-driven approach that uses price, quality and quantity service indicators; a business-driven approach using economic regulation or service-level policies (both are covered in **Part 2** of this thesis);
- *Capacity* – to provide sufficient capacity to accommodate the demand in typical busy periods without imposing significant operational, economic or environmental penalties under normal circumstances. This particularly applies to delays, predictability of flight operations and increased flexibility, in addition to including airports being able to maximise their airside capacity potential and users being able to get fair access to airspace;
- *Environment* – to work with ICAO and its member nations to mitigate the impact of aviation on the environment through the use of new ATM technologies, systems and procedures;
- *National security and defence requirements* – to determine new mechanisms, criteria and structures to enhance civil-military co-operation and co-ordination. Additionally, the Strategy should ensure access to airspace for military purposes, through the implementation of special procedures where necessary:

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<sup>296</sup> According to Volumes I and II of the 'ATM Strategy for 2000+' document, Eurocontrol. 1998.



- *Uniformity* – to ensure that ATM operations are compliant with ICAO CNS/ATM plans, provide a seamless service to the user at all times and operate on the basis of uniformity throughout the ECAC area. Thus, the Strategy aims to apply common ATM rules and procedures across all European airspace, in addition to adopting common standards and enabling inter-operability between the different aircraft and airport ATM systems;
- *Quality* – to foster, promote and enhance the use of recognised quality management standards in the provision of gate-to-gate ATM services. **Chapter 7** deals with this;
- *Human involvement and commitment* – to ensure that the change to future ATM is supported by staff within their operational and technical capabilities. **Appendix 3.4** details the key evolutions of the changing rôles and responsibilities that pilots, controllers and aircraft operators should witness in the lifetime of the Strategy. It is interesting to note the expected increase in involvement of the aircraft operators in dynamic route changes of their aircraft by 2010. Accordingly, the Strategy's prediction that pilots will conduct aircraft separation in free route airspace after 2010 is a controversial claim that is already facing opposition from air traffic controllers.

The simultaneous satisfaction of all user requirements and the fulfilment of all the aforementioned strategic objectives is unrealistic. Conflicts of interest are inevitable. Hence, the approach adopted in the Strategy is to make sure that the different trade-offs supported by the various types of airspace user are explicit, and that, wherever possible, the optimum solutions are selected for all affected airspace users. The following trade-offs have been identified:

- Capacity versus costs;
- Free routes versus structured routes;
- Individual versus collective benefit of performance;
- Mandating versus incentive for equipment.

### **3.5.3 The operational concept**

With reference to the discussion on ICAO's ATM Operational Concept in **Section 3.4.1** and the fact that "ICAO's basis for developing the standards necessary for harmonisation and integration of ATM is an operational concept," the future ATM needs in Europe have led to the definition of an operational concept that focuses on providing extra capacity and improving ATM services. The new approach to providing ATM services that is detailed in the Strategy is embodied within a target operational concept in order to provide network-wide benefits.

The Operational Concept Document (OCD)<sup>297</sup> discusses the main operational and functional options available to meet the aforementioned objectives and principles. It

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<sup>297</sup> The latest available OCD by Eurocontrol is Edition 1.1, dated 4<sup>th</sup> January 1999.



also describes the types and scope of ATM services needed through the target concept statement, as outlined in **Appendix 3.5**. The main concept options range from between a managed ATM environment based on traffic structuring, greater traffic predictability, longer planning horizons and extensive automated support, to a free flight environment based on free routings and autonomous aircraft separation. In practice, the target concept will have to contain elements of most options in order to meet the varying requirements of all airspace users and the different regional traffic conditions.

The OCD supports the ATM Strategy for 2000+. Indeed, the application of the Strategy is interrelated with the operational and functional options described in the OCD. It should be noted that Eurocontrol has also assembled a User Requirements Document (URD)<sup>298</sup>, which contains the ATM Stakeholders' needs, as expressed by the aviation community at two consultations workshops in 1994 and 1998.

The following principal characteristics aim to fulfil the objectives of the Strategy and its operational concept:

- ❑ **Flight management from gate-to-gate** – flights will be managed continuously within the ATM network throughout all phases of flight, including pre- and post-flight activities. This will improve planning and reactions to real-time events and make better use of resources, including those at airports;
- ❑ **Enhanced flexibility and efficiency** – the trajectory of a flight will be managed to reflect the best balance that can be achieved at any moment between the aircraft operators' needs to operate as closely as possible to their preferences and the prevailing flight or ATM circumstances. This will enhance the efficiency of both individual flights and total fleet utilisation, while improving the management of traffic;
- ❑ **Collaborative Decision Making (CDM)** – decisions will be made by those best positioned to take them, based on the sharing of validated real-time information<sup>299</sup>. This will provide the means for greater efficiencies on a network-wide and individual flight basis. Improved information management will provide a foundation for dialogue between the various parties (ATM, aircraft operators' operations centres, airport operations and pilots) in real time, during all phases of flight;
- ❑ **Responsive capacity management to meet demand** – the available capacity will be adapted to meet demand through flexible ATC sectors, improved planning and capacity management, which will provide operational and cost efficiencies;
- ❑ **Collaborative Airspace Management (CAM)** – changes in ATM rôles will shift the emphasis from tactical to planning activities in enlarged airspace regions. This will lead to a collaborative airspace planning and management mechanism, based

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<sup>298</sup> The latest available URD by Eurocontrol is Edition 2.0, dated 5<sup>th</sup> January 1999.

<sup>299</sup> 'A gate-to-gate, seamless European Air Traffic Management System for the Years 2000+' – *International Airport Review*, Winter 1999.



on the flexible use of airspace, involving both civil and military authorities to ensure that the whole airspace is used in a dynamic manner;

- **Extended levels of automation and communication support** – future operational improvements will require the support of more sophisticated computer assistance tools and Human-Machine Interfaces (HMI) able to exploit air-ground data communications, higher quality trajectory prediction data and the exchange of data between ground units. This will increase ATC productivity and enhance safety nets.

Progressive improvement in these areas will also contribute to enhanced safety, extend the principles of uniformity and seamless services and help reduce aviation-related environmental pollution.

### 3.5.4 Lines of action

The target ATM operational concept describes the available operational options that are expected to satisfy the strategic objectives for European ATM until 2015: a timeline is given in **Chapter 4**. However, the concept also proposes lines of action to achieve the target concept, which comprise a series of complementary and stepped operational improvements in the core ATM processes. In addition, system-wide information management and technical integration affect the lines of action.

#### Operational improvements

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Noting that the weakest element of the ATM network adversely affects the whole system, the following operational improvements are planned in four core processes, thus:

- *Airspace organisation and management* – the main objective is to optimise the structure of the entire ECAC airspace with flexible route structures that must be designed at European and national levels. Programmes such as Reduced Vertical Separation Minima (RVSM), Flexible Use of Airspace<sup>300</sup> (FUA) and aRea NAVigation (RNAV) techniques<sup>301</sup> will provide the cornerstones for progressive improvement in the manner that the airspace is managed. Airspace structure optimisation, route network optimisation and terminal control area re-organisation will also enhance the airspace organisation and management. Airspace regions' complexity will be split into three categories, thus: High ATC, Medium or Low ATC and Very Low ATC;
- *Flow and capacity management* – changes will centre on moving from flow management based on regulating mechanisms to collaborative management of

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<sup>300</sup> FUA shares military airspace with civil operations, thereby providing extra airspace capacity.

<sup>301</sup> Free routes based on RNAV operations will be introduced by 2002, starting in the upper airspace.



capacities. Improved rerouting, enhanced tactical ATFM using Central Flow Management Unit (CFMU) services and collaborative flight planning will lead to optimised capacity management. This means that the emphasis will migrate from managing demand to managing the capacity of the ATM network;

- *En-route and terminal Air Traffic Control (ATC)* – increased automated support to the controller, a redistribution of some control tasks and the implementation of air-ground co-operation will reduce risks of aircraft collisions and provide greater capacity in the system, which will facilitate the consequent designation of some ‘free flight’ airspace in the en-route environment. Improvements in Radar Data Processing Systems (RDPS) will provide enhanced safety net capabilities. Sequencing and metering of landing aircraft, in addition to automated arrival and integrated departure management tools, will improve terminal ATC;
- *Airport ATC* – some capacity gains will be seen with improved management of arriving and departing aircraft based on the gate-to-gate concept. Optimisation of wake turbulence effects will be introduced. ATM operational planning initiatives at airports and efficient use of the available surface movement areas will bring capacity and efficiency gains in terms of reduced ground waiting times.

The operational improvements will need to be implemented in tandem with the essential ongoing modification of airspace control sectors, which is currently the primary method of enhancing sector capacity.

### **System-wide information management**

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ATM increasingly depends on system-wide information management and on services such as Aeronautical Information Services (AIS) and aviation METeorological services (MET), as discussed earlier in this chapter. Some ATM activities, such as trajectory prediction, sequencing and Collaborative Decision Making (CDM), require that all parties have access to the same, real-time information. Aeronautical information and charting systems, including 4D displays, will be integrated with a comprehensive reference database for the ECAC area. New specifications for electronic aeronautical data, including terrain and vertical obstruction information, will be developed. The Strategy therefore wishes that all information be collected, collated, stored and distributed through a network system. This will be performed by systems already in place using an integrated digital environment. Hence, a system-wide information management strategy will be established. The aim, within the framework, will be to move to a system that provides on-line quality aeronautical information to users in real time.

### **Technical integration**

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Enablers can be defined as elements necessary to achieve required operational improvements of ATM systems. They are split as technical and other enablers. A large proportion of the technical enablers are elements defined and produced under the aegis



of CNS. Examples include RNAV equipment and datalinks. These and other CNS technologies, such as those described in Chapter 2, will form the backbone of Europe's ATM network. Some 'ECAC ATM Strategies for the 1990s' achieved harmonisation and integration of ATM, but much fragmentation of the systems still exists.

The evolution of CNS systems in Europe must use CDM and be benefit-driven. Indeed, the rôle of the CNS infrastructure is to support and enable the operation of ATM. Improvements in ATM can often only be realised when supported by improvements to one or more of the CNS components. CNS developments are not only driven by ATM needs, but also by the general evolution of technology. CNS infrastructures need to be compliant with operational and general requirements. In Europe's case, different strategies for communications, navigation and surveillance exist, thus:

- *Communication strategy* – provision of data and voice communications services through the Pan-European Fixed Network Services (PENS) and the Mobile Network Services (MNS);
- *Navigation strategy* – achievement of a total RNAV environment that facilitates the 'free routes' concept, with implementation of some 4D-RNAV operations using the increased availability of satellite services;
- *Surveillance strategy* – using technologies such as Secondary Surveillance Radar (SSR) Mode S and Automatic Dependent Surveillance (ADS), in addition to its Broadcast derivative (ADS-B).

In order to maximise the efficiency of the transition to new CNS systems, the rule-making process needs to adopt the European Notice of Proposed Rule-Making (ENPRM), which is referred to in the next section. Additionally, the frequency spectrum must have sufficient spectra available and better management of the allocated frequencies is needed. In a similar manner, an efficient ground communication infrastructure is essential.

### 3.5.5 Management of change

The aim to convert the Strategy's objectives into practical implementation actions, in conformance with the strategic principles, requires management guidelines, which consist of:

- *Institutional framework* – is included in the revised Eurocontrol Convention, which is the legal instrument of the ECAC ATM Institutional Strategy, adopted by Ministers in 1997. Within this framework, rules and standards will be produced, which may be transposed by further legal instruments into regulations that are applied in each country. The content of rules or standards will range from general objective setting to detailed provisions;
- *Divisions of responsibility* – between Eurocontrol's General Assembly, Council and the agency, in addition to the airspace users and service providers;



- *Decision-making, commitment and follow-up* – which are integral to the implementation process of the future ATM system;
- *Rule-making and regulation* – common operational concepts at European level require definition and agreement, followed by implementation on the part of the users and service providers. European Notice of Proposed Rule-Making<sup>302</sup> (ENPRM) attempts to ensure the latter, whereby the level of uniformity achieved in European ATM is determined by the application of common rules. **Appendix 3.6** considers the rule-making process in more detail;
- *Organisational aspects and enlarged partnership* – to implement the future European ATM system, the Eurocontrol organisation needs a more flexible management structure. The systematic approach of the Strategy necessitates the enhanced involvement of all stakeholders in the decision-making process. This includes the users, ATM service providers, airports, the military and the manufacturing industry. Correspondingly, collaboration is essential between industry and Eurocontrol in terms of Research & Development (R&D) of systems that are inter-operable and based on jointly agreed standards (see hereunder). Eurocontrol believes that its rôle is to guide the market by defining agreed high-level requirements and specifications;
- *Maintenance of a dynamic strategic planning process* – whereby additions can be made to this Strategy in the future, that take it after 2015;
- *Projects of common interest* – countries are encouraged to adopt common project involvement where synergies exist;
- *Research & Development* – which must focus its activities on developing the Strategy's aims by validating the future procedures and technologies against quantified system performance objectives, noting that the Strategy relies on the progressive introduction of innovations rather than the continuation of traditional solutions;
- *Economics and financial arrangements* – that can either be performance or business driven approaches. The former is covered in **Chapter 5**; the latter pertains to Cost-Benefit Analysis (CBA), which notes that the level of benefit received by organisations making investments should be commensurate with the investment amount. Both airspace users and ATM service providers must make investments. However, cost-benefit assessments should also be considered at the overall ATM network level. CBA, which is also discussed in **Chapter 5** of this dissertation, must also consider the economic case.

Remembering that the Strategy is Eurocontrol's aspiration for future ATM in its region, **Chapter 4** mentions how the European Commission is attempting to guide and manage the process.

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<sup>302</sup> 'eurocontrol notice of proposed rulemaking (enprm)' – era regional report, December 1999.



### **3.5.6 Summary of Strategy – its initiatives**

Thus, in order to accommodate the aforementioned changes that are needed, Eurocontrol's 'ATM Strategy for 2000+' document cites the following new initiatives at European level that will be implemented:

- ❑ The management and use of ECAC member countries' airspace as a gate-to-gate continuum for ATM purposes, not constrained by national boundaries;
- ❑ Enhanced uniform safety standards, practices and safety regulations;
- ❑ A regulatory framework to provide effective and timely common rules governing ATM service application and provision by all States;
- ❑ Cost-effective seamless ATM services tailored to users' requirements and allied to monitored performance targets;
- ❑ Cost reduction through improved operational efficiency and the optimising of the structure and organisation of service provision;
- ❑ Concurrent enhancement of the capacity of air traffic control, airspace and airports as elements of a complex integrated network;
- ❑ Collaborative decision-making involving all partners based on improved information management and data communications;
- ❑ An effective management structure and process to fulfil in a co-ordinated way both Pan-European and local implementation needs;
- ❑ Recognition of the importance of the environmental impact of aviation;
- ❑ Decision-making processes and incentive options for delivering early and lasting ATM performance improvements;
- ❑ Early encouragement of the effective contribution and commitment of people in all aspects of ATM as one of the key factors for change;
- ❑ Measures to strengthen and further enhance civil-military co-operation.



### 3.6 ATM activities of the US

The US has been concerned about its Air Traffic Control (ATC) system for many years, even though assessments have categorised it as safe, because the number of delays and the poor reliability of its en-route portion affect the efficiency of air traffic movements<sup>303</sup>. Indeed, the US Federal Aviation Administration (FAA) was accused in the 1990s of not having a technical master plan to modernise ATC systems<sup>304</sup>. Even the FAA's current administrator, Jane Garvey, cited concerns that the administration would be unable to meet its mandate and modernise the ATC system by 2005<sup>305</sup>.

However, the Garvey administration has realised that industry co-operation is necessary to swiftly improve Air Traffic Management (ATM) in the US. Other ATM players have echoed this<sup>306</sup>. Hence, the FAA started working, during the 1990s, in conjunction with the industry technical standards committee, the Radio Technical Commission for Aeronautics (RTCA). The RTCA is a non-profit company that was formed to "advance the art and science of aviation and aviation electron systems for the benefit of the public". It functions as an advisory committee to the US government and develops consensus-based recommendations.

The FAA and RTCA believe that working in partnership with all airspace users to develop Air Traffic Services (ATS) will ensure that all requirements are identified, analysed and implemented when appropriate<sup>307</sup>. Together, they stress that a collaborative approach must be adopted towards re-evaluation of the US National Airspace System (NAS) and its Enhanced Traffic Management System (ETMS). It was previously thought that the ETMS and its automated features were sufficient for the needs of the US's traffic management system<sup>308</sup>. Similar to its European counterparts, the US has realised the limiting effects of the present rigid route structures and is attempting to increase levels of capacity and flexibility in the ATC system. Correspondingly, the FAA has also acknowledged that ATM is replacing the concept of ATC.

They have consequently developed short-term and long-term plans. Thus, this section initially details some short-term improvements that have been developed and suggested, then follows with a discussion on US Free Flight, the FAA's guiding vision, mission and operational concept that is based on the CNS/ATM systems concept. It should be noted that Free Flight per se is also part of the future European ATM strategy, which is

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<sup>303</sup> 'US en route ATC system unreliable, but safe' – *Flight International*, 31 January 1996.

<sup>304</sup> 'FAA Structural Problems Impede ATC Upgrades' – *Aviation Week & Space Technology*, 10 February 1997.

<sup>305</sup> 'Garvey: ATC modernization is art of the possible' – *Air Transport Intelligence*, 11 February 1998.

<sup>306</sup> 'Teamwork key to US airspace system upgrade – ARINC' – *Air Transport Intelligence*, 25 February 1998.

<sup>307</sup> According to the report of the RTCA Board of Directors' Select Committee on Free Flight.

<sup>308</sup> 'Advanced Traffic Management System Automation' – MF Medeiros, *Proceedings of the IEEE*, Vol 77 No. 11, November 1989.



covered in the previous section. However, given that the FAA is instrumental in advancing and improving air traffic management concepts, it is considered pertinent to analyse the US approach to Free Flight separately. It should also be noted that the Global Air Traffic Management (GATM) system refers to the US military requirements for the future CNS/ATM environment<sup>309</sup>.

### 3.6.1 Methods of ATM improvements in the short-term

Near-term improvements to the US ATC system are focusing on reducing air traffic restrictions, implementing procedures that increase user flexibility and system capacity<sup>310</sup>. There is also an emphasis on increasing operational economics<sup>311</sup>. The following two programmes, in particular, are attempting to act accordingly:

- *National Route Programme* – the NRP uses procedural changes to allow pilots flying above predetermined flight levels to choose their own flight paths. These user-preferred routes are based on the FAA and users' real-time exchange of operational information that influences ground delay programmes and improves airline efficiency;
- *Pacific Oceanic Programme* – satellite voice and data communications are being used over the Central Pacific to provide faster and more reliable transmission to facilitate reductions in vertical, lateral and longitudinal separation, in addition to more direct flight tracks and faster altitude clearances.

Ultimately, the NAS aims to become a predominantly Free Flight environment, which is discussed in **Section 3.6.2** and **Section 3.6.3**. However, it should be noted that Free Flight now encompasses all current ATM improvements because the FAA realises that incremental improvements are necessary to provide increased levels of capacity and flexibility, where possible, immediately. Therefore, such improvements can be seen as early benefits of Free Flight. Thus, prior to covering the Free Flight concept, consider the following RTCA Task Force 3 recommendations on ATM procedural changes that, it believes, should be implemented in the short term<sup>312</sup>:

1. The FAA, in co-operation with the users, must develop new procedures that use airplane RNAV capabilities to reduce congestion over waypoints. Such procedures should be expedited at the top 50 airports.
2. Institute a process to quickly develop the standards, criteria, procedures and training programmes necessary to expand implementation of procedures for the use of

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<sup>309</sup> 'Navigating the Airways' – *Aerospace Review*, No. 67.

<sup>310</sup> 'Free Flight – Introduction' – <http://www.faa.gov/freeflight>.

<sup>311</sup> 'Free Flight – an airline perspective' – KA Stover, *The Dawn of Free Flight Conference*. Washington DC, April 1997.

<sup>312</sup> In its 'Free Flight Implementation' final report, dated 1<sup>st</sup> November 1995.



RNAV equipment capabilities, including vertical guidance, to increase capacity and operating efficiency in terminal areas.

3. Review existing ATC procedures to identify changes for increased use of RNAV routes below FL180.
4. The planned expansion of the National Route Programme (NRP) to FL290 should be continued.
5. Where appropriate, decrease the existing 200nm radius restriction for NRP filing.
6. Develop mechanisms to provide pre-departure feedback to the flight planners on potential impacts of requested flight plans, changes to requested flight plans and systems constraints causing those changes.
7. Implement rationing-by-schedule during ground delay programmes.
8. Establish more flexible ground delay programme procedures that support the Decision Support System.
9. Establish a co-ordinated effort among military, FAA and NAS users to define the information and capabilities necessary to improve civil use of Special Use Airspace (SUA) when not being utilised.
10. An operational trial in one or more SUA should be conducted to demonstrate how improved information exchange on the status of SUA can improve civil use of SUAs when not being utilised.
11. Develop and implement real-time SUA notification between the Department of Defence, the FAA and the flight planners. A programme is needed in the near-term.
12. Streamline the FAA certification process to reduce time and costs for approval and fielding of new and emerging technologies.

In contrast, the Honeywell Advanced Air Transportation Technologies group (AATT) has identified the following procedural changes<sup>313</sup> that can be made to ATM to help alleviate some of the inefficiencies in the existing US air transport system:

- *Curved DGPS precision approach* – this alternative for executing a precision approach differs from the straight path required by ILS and is applicable at airports that do not have sufficient space for ILS, due to terrain or other airport factors. Curved Differential GPS (DGPS) offers capacity enhancements and increased efficiency for aircraft, with a shorter path for landing. In this procedure, the aircraft is constantly calculating its position using differential corrections and the signals generated by GPS. **Section 2.5.4** analyses DGPS;
- *Runway hold short procedure* – this procedure allows landing traffic and crossing traffic to simultaneously use runway resources. Depending on the aircraft type and its separation requirements from other aircraft, simultaneous operations may be conducted on the runways. Visual Flight Rule (VFR) conditions are needed;

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<sup>313</sup> 'Technology & Procedures Report' – Honeywell AATT.



- *Reduced Vertical Separation Minima (RVSM)* – noting that it is covered in **Section 3.3.4**, RVSM allows for more efficient use of airspace by lowering vertical separation standards from the 2,000ft worldwide average. Aircraft must have accurate altimeters;
- *No speed restriction airspace* – to help the expeditious flow of traffic, this programme would be particularly effective in the terminal area where departing aircraft could rapidly gain altitude;
- *Use of VFR climb and descent in upper airspace* – allowing aircraft to operate in more efficient manners when the weather supports Visual Flight Rules (VFR) operations by performing their own overtaking manoeuvres and not being reliant on ATC's vectors;
- *CDTI separation on final* – the capacity of runways could be enhanced using Cockpit Display of Traffic Information (CDTI) for reduced Instrument Flight Rules (IFR) separation on final approach. Thus, pilots would be more in charge of their own separation from other aircraft;
- *GPS approaches for light and STOL aircraft* – GPS can be used as the principal means of landing aid at airports that currently do not have instrument approaches. This may also apply at larger airports that have SIDs and STARs, where the GPS approaches for light and Short Take-Off and Landing (STOL) aircraft could exist in parallel with existing ILS routes;
- *First come, first served interpretation* – aimed at helping improve traffic flow at major airports when IFR conditions exist, this procedure applies to the whole ATM system and is not a case of an aircraft just turning up at an airport and expecting to land.

It should be noted, also, that many of the aforementioned programmes or suggestions could be suitably applied around the globe to improve worldwide ATM.

### **3.6.2 Introducing the US 'Free Flight' concept**

Free Flight, the US's emerging ATM operational concept, aims to provide the airspace system flexibility and capacity required in the US for the next 50 years. In theory, the concept will enable optimum dynamic flight paths for all airspace users through the application of certain CNS technologies referred to in **Chapter 2** and the establishment of ATM procedures that maximise flexibility, while assuring positive separation of aircraft. Its precept is to remove airways, allowing aircraft to fly the most efficient routes, whether in terms of minimised flight time or fuel burn. But Free Flight, similar to its European interpretation, will not be an uncontrolled operation<sup>314</sup>.

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<sup>314</sup> 'Free Flight – An Airline Perspective' – K Stover, Delta Airlines. *The Dawn of Free Flight Conference*, Washington DC, April 1997.



The primary difference between today's direct route clearance and Free Flight will be the pilot's ability to operate the flight without specific route, speed or altitude restrictions. Whenever practical, pilots will be able to choose their own route<sup>315</sup> and file a flight plan that will be available to the ATS provider to assist with flow management, but will no longer be the basis for separation. The FAA maintains that "it is possible, and highly desirable, to shift from a concept of strategic (flight path based) separation to one of tactical (position and velocity vector based) separation". There may even be situations where separation assurance lies in the cockpit, but Free Flight will have limited pilot flexibility in certain situations.

Free Flight will evolve as a function of available technologies, procedural changes, aviation requirements and increases in airspace system capacity to accommodate all users. It will incorporate new CNS/ATM technologies and procedures to improve conflict identification and resolution, in addition to data transmission and display. The intention is that Free Flight will be benefits driven and not mandatory: this ATM concept is aimed at adding levels of autonomous flight. It is a provocative idea because the concept appears to be at odds with ATC and management practices of the last three decades<sup>316</sup>. Free Flight requires a different way of thinking<sup>317</sup>, with new forms of collaboration between airspace users and air traffic management providers<sup>318</sup>. The revolution of thinking is needed every bit as much as the new technology<sup>319</sup>.

However, RMB Associates believes<sup>320</sup> that the aviation industry cannot throw technology at the problem of Free Flight implementation. Indeed, they say that "datalink, like GPS and other advanced avionics, are not requirements for Free Flight, they potentially allow the safe reduction of the size of the protected area by increasing the accuracy of position and the speed of communication." The task, they add, is to define the minimum information, and its display methodology, required in a Free Flight environment.

### 3.6.3 Description of Free Flight

The RTCA Free Flight Task Force 3 defined Free Flight in 1995<sup>321</sup> as "a safe and efficient flight operating capability under Instrument Flight Rules (IFR) in which the operators have the freedom to select their path and speed in real time. Air traffic restrictions are only imposed to ensure separation, to preclude exceeding airport capacity, to prevent unauthorised flight through Special Use Airspace (SUA) and to

<sup>315</sup> 'Free Flight – Introduction' – [www.faa.gov/freeflight](http://www.faa.gov/freeflight).

<sup>316</sup> 'Free Flight sparks international debate' – *Aviation Week & Space Technology*, 31 July 1995.

<sup>317</sup> 'Cultural shift key to new concept' – *Aviation Week & Space Technology*, 31 July 1995.

<sup>318</sup> 'Free Flight: a new concept in Air Traffic Management' – Dr. Atef Ghobrial, *Civil Aviation*.

<sup>319</sup> 'A European view of the benefits and challenges of introducing Free Flight operations' – J Meredith, *The Dawn of Free Flight Conference*, Washington DC, April 1997.

<sup>320</sup> 'Automated Conflict Identification – Free Flight's Missing Link' – RMB Associates, 1 December 1995.

<sup>321</sup> 'Free Flight' – *The National Air Traffic Controllers Association*, Vol 1, No. 2.



ensure safety of flight. Restrictions are limited in extent and duration to correct the identified problem. Any activity which removes restrictions represents a move towards Free Flight.

“This suggests that each user is granted both maximum flexibility and guaranteed safe separation. The goal is not only to optimise the system, but to open the system for each user to self-optimize. Self-optimization is the key to understanding the extent of Free Flight’s reach as well as Free Flight’s challenges. Free Flight is not limited to airspace – its spatial constraints are chock-to-chock, but Free Flight reaches into a flight’s pre-history by providing increased flexibility in flight planning.” Accordingly, it is said that “Free Flight is a set of operational goals as defined by the RTCA Task Force 3 and adopted by the FAA”<sup>322</sup>. Ultimately, Free Flight encompasses all ATM improvements that remove restrictions. It therefore includes all flight phases<sup>323</sup> and is based on technologies from SSR Mode S datalink to GPS navigation.

Free Flight is an evolutionary concept that is benefits-driven and time phased. The objective is to provide benefits to airspace users and providers immediately and over time as Free Flight is further developed. The RTCA Task Force 3 report developed the overall guiding principles of Free Flight, which are<sup>324</sup>:

- ❑ Ensure that transitioning to Free Flight will not compromise safety;
- ❑ Expand the Free Flight definition to include strategic flight planning and ground phases of operation;
- ❑ Emphasise initiatives that give users a high return on investment;
- ❑ Transition to Free Flight should be benefits driven;
- ❑ Emphasise the need for collaborative planning and decision making;
- ❑ Emphasise procedural improvements with proven technology;
- ❑ Consider end-to-end impact and benefits when planning improvements;
- ❑ Address human factor issues during all stages of development;
- ❑ Assess benefits, when possible, prior to implementation;
- ❑ Use modelling and analysis to anticipate operational impacts on users and providers;
- ❑ Accommodate users with various levels of equipage during the transition to Free Flight.

In the full Free Flight concept, each aircraft flies a dynamic, optimum flight path, making full use of the onboard systems. Position and short-term intent information is sent to the ATS provider, who performs separation monitoring and prediction functions. The ATS provider intervenes to resolve any detected conflicts, with short-term restrictions used only when two or more aircraft are in contention for the same airspace. This is known as dynamic re-routing. In normal situations, it is thought that aircraft manoeuvring will be unrestricted, based on enhanced separation assurance. Ultimately, however, there will be clear-cut lines of authority between the pilot and the controller.

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<sup>322</sup> ‘Technology and Hardware for CNS/ATM and ATN’ – T Littlejohn, AlliedSignal. *The Dawn of Free Flight Conference*, Washington DC, April 1997.

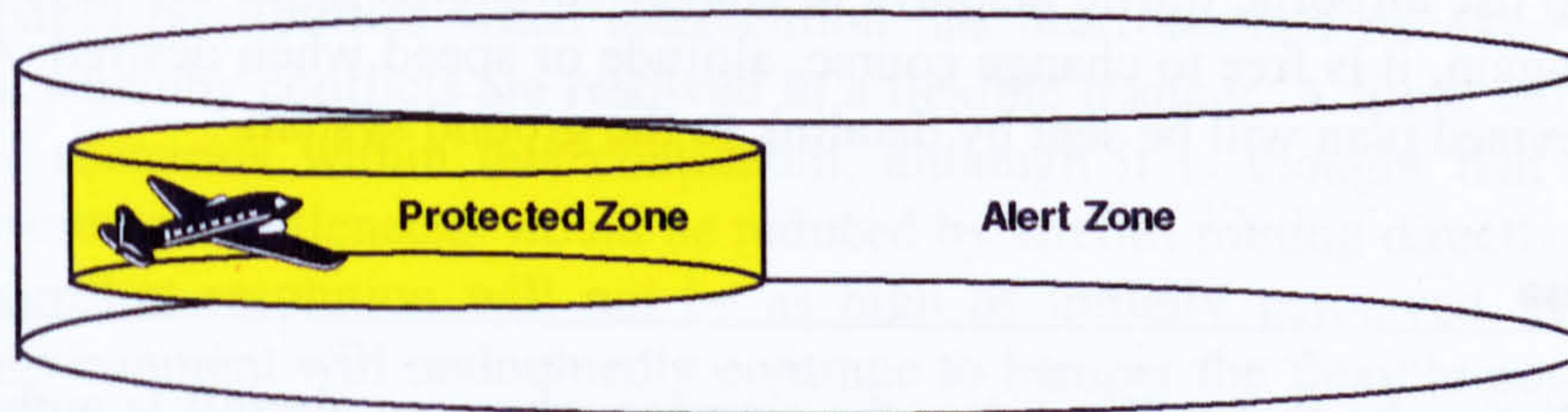
<sup>323</sup> ‘The cost of Free Flight’ – *Flight International*, 11 June 1997.

<sup>324</sup> ‘Free Flight – Guiding Principles’ – <http://www.faa.gov/freeflight>.



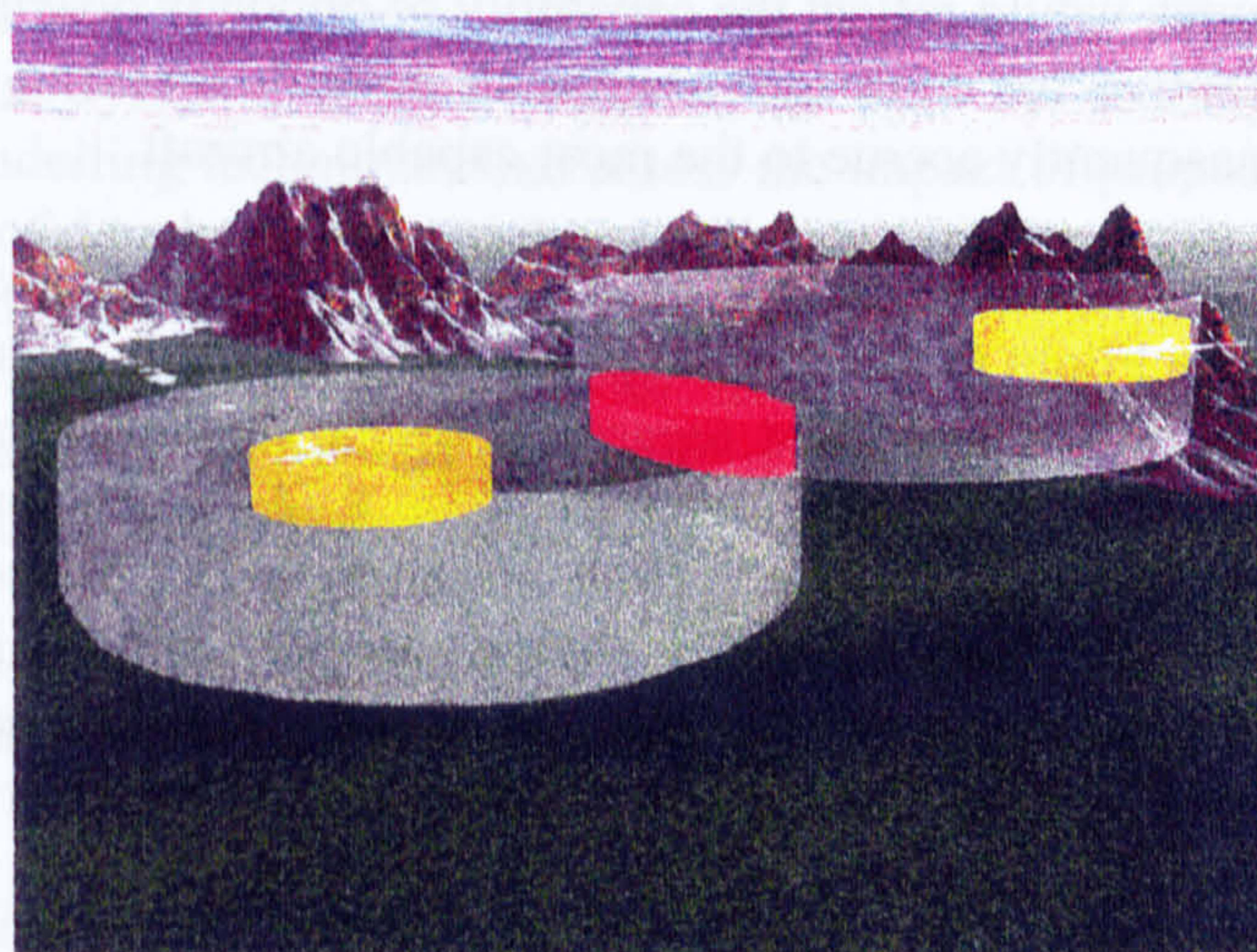
In addition, technology will not replace humans or their reasoning process, but will allow them to do their job better.

Central to the Free Flight concept is the principle of maintaining safe airborne separation<sup>325</sup>. This principle is based on two airspace zones, the protected and alert zones, as shown in **Figure 3.4**. The sizes of the zones are based on the aircraft's speed, performance characteristics and available CNS equipment. The alert zone is much larger than the protected. Aircraft with different CNS performance capabilities will have alert and protected zones of varying sizes. The protected zone of one aircraft can never meet that of another.



**Figure 3.4** - Free Flight 'protected' and 'alert' zones  
Source - US FAA

If alert zones do touch, as portrayed in **Figure 3.5**, a controller may provide one or both pilots with course corrections or restrictions to ensure separation. The ATM system will assess the potential for conflict and issue preventative advisories or resolution instructions as necessary. Highly accurate aircraft position and velocity information, in addition to advanced automation, will allow the shift to near-term conflict identification and resolution.



**Figure 3.5** - Free Flight Aircraft zones  
Source - US FAA @ <http://www.faa.gov/freeflight>

<sup>325</sup> 'Free Flight: ATC model for the next 50 years' - *Aviation Week & Space Technology*, 31 July 1995.



Restricting the flexibility of an aircraft may also be necessary when:

- Potential manoeuvres may interfere with other aircraft operations and/or Special Use Airspace (SUA);
- Traffic density at airports or in congested airspace precludes Free Flight operations;
- Unauthorised entry of a SUA is imminent;
- Safety of flight restrictions are considered necessary by the air traffic controllers.

Thus, CNS/ATM technology must be able to identify conflicts and rapidly communicate actions between the aircraft and controller via datalink or using voice communications. Additionally, satellites and aircraft avionics will, with the concurrence of controllers, allow pilots to use airborne traffic displays to choose solutions. Once the aircraft's alert zone is clear again, it is free to change course, altitude or speed when desired. After any change, the revised plan will be sent by datalink to the ground system.

### **Conflict probe**

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It is the conflict probe that will monitor the airspace where an aircraft is authorised to manoeuvre without prior clearance. As previously mentioned, it will use the aircraft's position and intent to project its path forward and determine if the aircraft's protected area would overlap that of another aircraft in a defined period of time. In practice, it would compute the probability of a separation loss happening in a 5 to 20 minute time horizon and take appropriate action to avoid the loss of separation from occurring.

The system could allow controllers to monitor random tracks and ensure conflict-free routes. However, the pilot could also be in the decision loop, which would necessitate a move from ground ATC being totally in charge of separation assurance, with the added requirement that all aircraft be fitted with similar datalink technologies. The magnitude of resolution manoeuvres would reflect the capability of onboard systems, which should provide a benefit incentive for equipage. Maximum benefit, meaning least flight path disruption, would consequently accrue to the most capable aircraft.

Indeed, RMB Associates<sup>326</sup> believe that the only new technology required to accomplish the task of en-route Free Flight is the conflict probe, which already exists in the form of a human air traffic controller, and "that regardless of the display, the human conflict probe will never be able to assure separation in a 4-Dimensional Free Flight environment based on the display alone." Thus, automation is required in the form of computerised conflict probes. However, Bill Cotton, former United Airlines' Manager for Air Traffic and Flight Systems, disagrees<sup>327</sup> by arguing that this applies to the en-route phase only and that it "by no means is it an all-encompassing operations concept."

RMB Associates also maintain<sup>328</sup> that, "given an accurate computerized 4D conflict probe, the number of required conflict resolutions will actually decrease." This has been

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<sup>326</sup> 'Free Flight – Rapid Implementation' – RMB Associates, 1 July 1995.

<sup>327</sup> 'Diverging courses' – Air Transport World, March 1997.

<sup>328</sup> 'Automated Conflict Identification – Free Flight's Missing Link' – RMB Associates, 1 December 1995.



reinforced through findings by the Dutch National Aerospace Laboratory, which concluded that workload does not increase when a pilot is given responsibility for separation assurance in a Free Flight environment<sup>329</sup>. Correspondingly, Cotton believes that the inclusion of pilots in the decision-making loop is essential to ensure success with the automation aspects of Free Flight. The National Air Traffic Control Association (NATCA) has eliminated the notion that separation assurance will be the pilot's responsibility.

### **Free Flight continuum**

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Thus, two extremes of the Free Flight continuum will be traditional strategic separation with inflexible possibilities when intervention has been deemed necessary to tactical separation, whereby conflicts are resolved in a flexible manner. A flight will experience a range of scenarios within this continuum, although it is thought that the present, artificially-created bottlenecks would be reduced by aircraft routing directly and that the need for conflict resolution will not be as high as initially perceived. However, the terminal environment will undoubtedly continue to hamper the flexible possibilities for aircraft. Indeed, airport capacity will affect the full realisation of Free Flight's benefits.

The essential factors affecting conflict rate in both the en-route and terminal airspace are traffic density, complexity of flow<sup>330</sup> and separation standards. When considered together, they are termed the dynamic density, which consequently controls the conflict rate. When the dynamic density approaches the limits of available automation, controller workload will increase and restrictions will then be applied to keep the controller's workload at an acceptable level. The situation is aggravated in multiple-conflict scenarios. Thus, it is essential that highly sophisticated automation systems be developed.

In time, Traffic Flow Management (TFM) will become the determination of points where changes in dynamic density occur. This will be accomplished with better prediction and modelling techniques that assess the impact of proposed routes and flight times in advance of developing situations. Analytic capabilities will make use of current and future data on flights, the traffic delays and weather information. TFM will employ automation and dynamic interaction with users to provide features of projected problems in the system. TFM will also employ the Flexible Use of Airspace (FUA) concept, as mentioned in the previous section.

One of the benefits which is touted for Free Flight is that it will be safer<sup>331</sup>. However, affirmations of safety must be regarded with appropriate caution.

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<sup>329</sup> 'Free Flight study finds pilots' workload is not increased' – *Flight International*, 20 May 1998.

<sup>330</sup> Complexity of flow refers to factors such as crossing or manoeuvring flight paths, performance differences, mixing departure/arrivals or closely located airports that may produce conflicts.

<sup>331</sup> 'Developing a safe system for Free Flight' – S Matthews, *Flight Safety Foundation. The Dawn of Free Flight Conference, Washington DC, April 1997.*



### 3.7 Summary

This chapter discusses the issue of Air Traffic Management (ATM) under the auspices of CNS/ATM. Specifically, given that it forms part of the worldwide CNS/ATM evaluation, the chapter analyses current ATM methods followed by contrasting assessments of future ATM. The latter are mostly considered in terms of their potential and aspirational characteristics. A section also details possible design elements for an ATM system.

Noting that the European ATM Strategy for 2000+ and US Free Flight operational concepts are their respective regions' answers to the ICAO CNS/ATM systems concept, the chapter covers these three ATM concepts as the only available examples of future ATM that have been developed to date, with analyses in the following order:

- ICAO's global ATM;
- Europe's initiatives, which are encompassed in the ATM Strategy for 2000+;
- The US alternative approach, Free Flight.

Therefore, in addition to providing an overview of current ATM procedures, this chapter discusses how authorities intend to optimise the flow of air traffic in the world's airspace regions using ATM concepts that are designed to increase capacity and enhance flexibility. CNS/ATM systems should be able to meet the requirements of all civil aircraft operations based on predicted traffic loads and should be sufficiently adaptable to safely accommodate multiple aircraft operational characteristics from those exhibited by supersonic aircraft to balloons.

However, as discussed in **Chapter 4**, this will only materialise if the aforementioned ATM operational concepts are adhered to. Indeed, the European and US approaches are actually quite similar, in that they aim to sort out existing delays over the next 5 years and then develop the new CNS systems, which are discussed in **Chapter 2**, to support improved ATM. There remains, however, the issue of whether CNS/ATM can be simultaneously developed elsewhere in order to create the seamless worldwide concept that is needed.

Many aspects of future ATM are highlighted in this chapter, ranging from the fact that airspace is a finite resource and, based on the expected growth of air traffic, must be managed more efficiently to the fact that capacity at airports must also be increased to provide a comprehensive gate-to-gate improvement in ATM. Correspondingly, a balance must be achieved between the ATM requirements and the implementation costs involved. In addition, better harmonisation and increased integration of existing services will provide a transparent service to users.

It should be noted that the International Air Transport Association (IATA) has also developed a CNS/ATM implementation plan, which overviews the users' preferred options regarding the introduction strategy of future technologies and procedures. It is presented in this dissertation as part of the current CNS/ATM implementation status evaluation in **Section 4.5.5**.



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## CHAPTER 4

# STATUS OF CNS/ATM IMPLEMENTATION

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## 4.1 Introduction

According to Dr. Kotaite, President of the ICAO Council, "our present air navigation system is reaching the saturation point in many parts of the world. CNS/ATM systems are the best guarantee we have that civil aviation can continue to grow and to support the economic and social development of nations." Such CNS/ATM systems are based on the technology and procedures described in **Chapter 2** and **Chapter 3** respectively.

As mentioned in **Chapter 1**, the CNS/ATM concept already has some of its elements in place. However, the extent to which all the components of CNS/ATM have been globally integrated has not yet been assessed by an independent study. Therefore, this chapter completes the first of this dissertation's two objectives by analysing the success to date with worldwide implementation of CNS/ATM systems. This is conducted by evaluating the integration status of CNS technologies and ATM procedures described in the previous two chapters. The current expectations of future introductions are also incorporated and therefore constitute a realistic assessment of the present situation, which also facilitates development of the framework in the second part of this research.

The implementation status of each CNS component is described in separate sections, followed by a section that appraises ATM procedures. This latter section, **Section 4.5**, compares and contrasts the authorities' ATM concept visions with the reality so far, by covering the integration plans of ICAO, Europe and the US that are described in **Chapter 3**. In addition, it contains an overview of the implementation plans drafted by the International Air Transport Association (IATA). In order to ensure that the CNS/ATM programmes around the world are comprehensively assessed, **Section 4.6** covers the progress of manufacturers and their equipment, while **Section 4.7** details the endeavours of various nations and regions by discussing the current status of their programmes. The analyses draw from a multitude of information sources, thereby enhancing the impartiality of the results.

When considered in light of the present technologies and procedures in the previous two chapters, the contents of this chapter additionally highlight the significant changes that are being developed in terms of design and implementation of all aspects required for the provision of air traffic management. It should be noted that this chapter does not usually review the applications and definitions of CNS/ATM systems, which are contained in the previous two chapters, but rather concentrates on their integration status and timelines. Accordingly, it should also be noted that it is sometimes necessary to refer to a technology or programme in more than one section because it may affect different aspects of CNS/ATM. Correspondingly, it should be remembered that the aim is not to determine the obstacles to complete introduction, which are dealt with in the second part of this dissertation, nor to predict the future CNS/ATM environment. However, reference is frequently made to reasons affecting progress and how the technologies or procedures will figure in the future CNS/ATM arena.



## 4.2 Communications integration status

This section assesses the present situation regarding CNS/ATM communication systems by analysing the implementation situations to date of:

- Analogue VHF;
- Datalink applications;
- Satellite-based communication facilities;
- The ATN;
- Required Communications Performance.

It should be noted that ICAO has been developing Standards And Recommended Practices (SARPs) for communications aspects of CNS/ATM since 1995. Therefore, each aspect of communications described hereunder mentions the status of SARPs, where relevant.

### 4.2.1 Analogue VHF

With reference to the discussion in **Section 2.3.1**, analogue VHF continues to be used as the primary medium of voice communications, but there are numerous current problems. In addition to developing alternative communications technologies, the air transport industry is presently maximising analogue VHF's efficiency by:

- **Dealing with the threat of insufficient spectrum availability** due to losing aeronautical radio communications frequencies to mobile telecommunications operators. This remains a serious concern to the industry and protection of this spectrum has become a high priority issue. Intensive lobbying has been conducted by IATA<sup>332</sup>, ICAO<sup>333</sup> and other air transport associations such as the Airports Council International (ACI), the Air Transport Action Group (ATAG) and the Civil Air Navigation Service Organisation (CANSO)<sup>334</sup> to retain a large segment of the spectrum, if only until the next World Radio Conference (WRC) in 2003<sup>335</sup>. Aviation managed to hold on to its crucial spectrum at the 2000 WRC<sup>336</sup>. The group has also initiated a long-term action strategy plan. The threat particularly applies to communication satellite bands and GNSS frequencies<sup>337,338</sup>. This is crucial because,

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<sup>332</sup> 'Securing Adequate Spectrum for Future Aviation Growth and Safety' – J White, IATA. 5<sup>th</sup> Air Navigation Conference, Amsterdam. September 1999.

<sup>333</sup> 'Aviation Coalition optimistic over radio spectrum battle' – Air Transport Intelligence, 15 March 2000.

<sup>334</sup> 'Aviation industry unites on frequency protection issue' – Flight International, 21 March 2000.

<sup>335</sup> 'Long-term radio strategy urged' – Flight International, 13 June 2000.

<sup>336</sup> 'GPS radio spectrum appears safe from poaching threat' – Air Transport Intelligence, 10 May 2000.

<sup>337</sup> 'IATA warns over threat to radio spectrum' – Air Transport Intelligence, 21 September 1999.

<sup>338</sup> 'Making waves' – air traffic management, November-December 1999.



if there is spectrum sharing, then GNSS will not be permitted for use by safety-critical services<sup>339</sup>;

- **Increasing infrastructure usage with bandwidth reduction**, thereby creating more channels. Carriage of the requisite equipment to deal with a 8.33kHz frequency spacing, which was reduced from 25kHz, became mandatory in the ICAO European region for flights above FL245 during October 1999<sup>340</sup>. Due to several implementation delays<sup>341,342</sup>, operators were threatened with severe penalties if they were non-equipped. France will lower the area of applicability to FL195 in October 2001. It has been noted, however, that little new capacity was created<sup>343</sup>. Bandwidth reduction will soon be necessary in other parts of the world, such as the US;
- **Maximising provision of VHF facilities**, which includes increasing VHF coverage through installation of new terrestrial sites and deployment of communication buoys in the sea<sup>344</sup>. An example of the latter implementation has been the Gulf of Mexico, noting that the systems have been designed to incorporate ADS-B/CPDLC receivers in the future.

Even though these three measures are being taken, there is an urgent need to maximise the use of VHF's data capabilities, with standards developed for a Time Division Multiple Access (TDMA) radio as the medium-term solution to spectrum congestion and enhanced air-ground services. The US Next Generation Air-Ground Communications System (NEXCOM) is an FAA initiative to increase capacity and spectral efficiency of air-ground voice<sup>345</sup>, given that frequency shortage in the US is imminent<sup>346</sup>. NEXCOM will also cut radio interference and create a platform for future datalink communications. The system will use VDL Mode 3 protocol<sup>347</sup> (see Section 2.3.2) and begin operational capability testing in 2001, with initial operating capability due by August 2002. 36,000 multi-mode digital radios will be installed across the US<sup>348</sup>. NEXCOM aims to jump directly to a fully digital system, bypassing the more cautious approach underway in Europe<sup>349</sup>. Additionally, other improvements continue to be developed for VHF<sup>350</sup>.

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<sup>339</sup> 'The spectrum challenge' – *Flight International*, 16 December 1998.

<sup>340</sup> 'Euro capacity plans sought for 8.33kHz success' – *Flight International*, 22 December 1999.

<sup>341</sup> 'Doubts grow over European 8.33kHz deadline' – *Air Transport Intelligence*, 5 March 1999.

<sup>342</sup> 'Eurocontrol to put back radio update deadline' – *Air Transport Intelligence*, 10 June 1998.

<sup>343</sup> 'Europe's new radio rules create little new airspace capacity' – *Air Transport Intelligence*, 25 February 2000.

<sup>344</sup> 'Domesticating the Gulf' – *air traffic management*, September/October 2000.

<sup>345</sup> 'A Proposed Capability Demonstration for Next Generation Digital Air-Ground Voice Communications' – T Kabaservice, Harris Corporation. 43<sup>rd</sup> Annual ATCA Conference Proceedings. 1998.

<sup>346</sup> 'An overview of NEXCOM' – *Journal of ATC*, July-September 2000.

<sup>347</sup> 'Is three a crowd?' – *air traffic management*, November/December 1998.

<sup>348</sup> 'FAA requests proposals to overhaul VHF radio network' – *Air Transport Intelligence*, 7 November 2000.

<sup>349</sup> 'Technology for a new millennium: digital communications' - *AVflash*, 18 January 2001.

<sup>350</sup> 'FAA plans for VHF broadcast weather service' – *Flight International*, 5 May 1999.



## 4.2.2 Datalink applications

In 1992, it was observed<sup>351</sup> that “it is perhaps surprising that in the field of air traffic operations, automatic air-ground data communications has not been implemented much earlier”. How far has datalink progressed since then? Noting that the future datalink systems are described in **Section 2.3.2**, much activity has taken place in the worldwide datalink arena during the last few years, such that many datalink applications will soon become the norm. However, traditional HF, VHF and SATCOM networks will certainly be responsible for most communications for at least another 5 years. Indeed, the North Atlantic region has planned that HF will still play a rôle in 2010.

Correspondingly, **Chapter 2** cites numerous examples of datalink currently being used for ATC purposes that will continue throughout this decade. With reference to the different types, the following summarises the present implementation situation:

- **VDL Mode 1** – VDL Mode 1 has been used for Airline Operational Control (AOC) purposes since the late 1970s and has been declared unsuitable for ATC purposes. Its ICAO SARPs have been established;
- **VDL Mode 2** – ICAO SARPs have been established for VDL Mode 2, which is the form of VHF-based CNS/ATM datalink that is nearest to implementation: it is thought that ACARS will be phased out for “VDL-2” in 2004, which will be ready for use in Europe (as part of the PETAL II programme: see **Appendix 4.2**) during 2001 and the US in 2002<sup>352</sup>. Tests were recently completed<sup>353</sup>. However, VDL Mode 2’s ATC applications are limited since it does not support time-critical communications, which is a capability requirement for most ATM systems. Other problems include the absence of certified avionics and the fact that Mode 2 does not facilitate spectrum sharing<sup>354</sup>. Nonetheless, given that ACARS supports AOC and ATS functions, it is believed that VDL Mode 2 can facilitate an early introduction of ATS applications. Airlines recognise the need for swift introduction of VDL Mode 2 to provide capacity for increased AOC traffic growth. Interestingly, carriers also view ACARS and VDL-2 with potential to enhance their customer services, such as timely schedule information<sup>355</sup> and in-flight telephony. ARINC and SITA will offer VDL Mode 2: their situation is discussed below;
- **VDL Mode 3** – Mode 3 has been proposed by the FAA to ICAO versus the European lobby for VDL Mode 4 STDMA (see hereunder)<sup>356</sup>. In its present design, Mode 3 requires timing from ground stations and is consequently of little use over more than 70% of the world’s airspace. SARPs were due to be completed in 1999, but have not been published yet. VDL Mode 3 is not expected before 2008:

<sup>351</sup> ‘Air Ground Data Communications’ – T Tapsell, UK NATS. Datalinks Civil Aircraft Royal Aeronautical Society Conference, London. November 1992.

<sup>352</sup> ‘ARINC datalink trial clears way for launch’ – *Flight International*, 28 November 2000.

<sup>353</sup> ‘SITA tests pave way for global digital comms’ – *Flight International*, 31 October 2000.

<sup>354</sup> ‘Question marks over VDL Mode 2’ – *Flight Deck International*, April 2000.

<sup>355</sup> ‘JetBlue sees ACARS as customer service aid’ – *Air Transport Intelligence*, 16 December 1999.

<sup>356</sup> ‘Drawing a line’ – *Flight International*, 22 April 1998.



- **VDL Mode 4** – although its SARPs have not been developed yet, Mode 4 has gained approval from ICAO<sup>357</sup>, with publication of SARPs due at the end of 2001<sup>358</sup>. Mode 4 has been demonstrated to work through extensive research in Europe, where its main proponents are. The EU-sponsored FARAWAY, NAAN, NEAN and SUPRA projects have established VDL Mode 4/STDMA ground stations<sup>359</sup> (see **Appendix 4.2**). In addition, the North European ADS-B Network Update Programme (NUP) has shown datalink's use for transmitting ADS-B signals<sup>360</sup>. Even though the US is more interested in VDL Mode 3, the FAA has set up an STDMA (Mode 4) test programme, in order to evaluate STDMA for ADS-B, GNSS ground augmentation and uplink of traffic information. Indeed, the Europeans argue that only Mode 4 offers the possibility of providing the necessary CNS/ATM functionality required to achieve the goals of Free Flight<sup>361</sup>. ICAO refers to VDL Mode 4 as STDMA VHF datalink. There is no timetable for Mode 4;
- **SSR Mode S datalink** – SARPs became applicable in 1996<sup>362</sup>, but SSR Mode S datalink is not expected to be operational before 2005, although it may be integrated by 2010. Raytheon Systems have conducted trials on operating Secondary Surveillance Radar (SSR) Mode S with datalink, as part of the Pre-Operational European Mode S Station (POEMS)<sup>363</sup>. The objective of POEMS was to provide an evaluation of Mode S ground stations' future rôle in Europe. They found that overall Mode S probability of detection for track updates was 99.6%;
- **HFDL** – ICAO SARPs for HF DataLink (HFDL) were adopted in April 1998 and published in 1999. ARINC has started operational HFDL service for transpolar flights using its GLOBALink HFDL network<sup>364</sup>. The HFDL portion is activated when VHF is not available and when reliability of HF does not warrant integration of the satellite service. HFDL coverage is now worldwide, having recently completed the chain with two new HFDL ground stations in the North Polar area<sup>365</sup>. It can be used for AOC or ATS purposes<sup>366</sup>. HFDL will undoubtedly continue to be employed at the end of this decade, but not beyond that because it has no voice capability and may not be acceptable for ADS<sup>367</sup>;
- **Gatelink** – Eurocontrol is developing a wireless Gatelink called Wireless Airport Communication System (WACS)<sup>368</sup>. ARINC<sup>369</sup> and SITA<sup>370</sup> have become part of separate consortia that are in the testing phase.

<sup>357</sup> 'Take off for VDL Mode 4' – *Flight Deck International*, October 2000.

<sup>358</sup> 'VDL Mode 4 recommended for ICAO standardisation' – *Air Navigation International*, 17 April 2000.

<sup>359</sup> 'Swedavia Paper' – J Nilsson. *Air Navigation '97 Conference*, Amsterdam. September 1997

<sup>360</sup> 'Link to the future' – *Flight International*, 28 April 1999.

<sup>361</sup> 'ADS-B – the Enabler of Free Flight and Collaborative Air Traffic Management' – L Lindberg, L Kilchert & K O'Neill. 4<sup>th</sup> *Air Navigation Conference*, Amsterdam. September 1998.

<sup>362</sup> 'Aeronautical Mobile Communications: status and standardisation of air-ground datalink in progress' – ICAO Rio de Janeiro Conference, May 1998.

<sup>363</sup> 'The Pre-Operational European Mode-S Station (POEMS): Operating Mode-S with datalink', D Spalding, Raytheon Cossor. *Air Traffic Management: Prospects for Free Flight SMi Conference*, London. 1999

<sup>364</sup> 'ARINC breathes new life into HF communications' – *Air Transport Intelligence*. 14 April 1998.

<sup>365</sup> 'ARINC steps out of satellite footprints' – *inflight*, January 2001.

<sup>366</sup> 'Old technology finds a welcome new lease of life' – *Jane's Airport Review*, November 1998.

<sup>367</sup> 'Aer Lingus Satcom Plans' – F Ryan, Aer Lingus Consultant. *Inmarsat Aero Conference*. May 2000.

<sup>368</sup> <http://www.eurocontrol.be>



It would appear, therefore, that numerous types of datalink and their SARPs have been, and are presently being, developed. For instance, ICAO is presently formally adopting SARPs for VHF datalink Modes 3 and 4<sup>371</sup>. This disguises the aforementioned debate over the competing datalink technologies: European airlines and manufactures are in support of VDL-4, while the US wishes VDL-3 to become standard. Additionally, airlines have requirements for other facilities, such as passenger telephony, which must also be considered. Indeed, carriers have VDL implementation constraints based on aircraft hardware and support of existing airline datalink applications. Correspondingly, it has been noted that the introduction of datalink progresses slowly because it must be integrated with other ATC tools<sup>372</sup>. Although implementation of datalink is seen as necessary in Europe due to expected voice-frequency capacity limits being reached by 2006, it is difficult to see how datalink will work as efficiently as VHF voice in the central part of the region.

Apart from the evolution and standardisation of particular types of datalink, the interoperability issue of whether to develop the ATN or FANS-1/A as the platform for datalink is another contentious issue<sup>373</sup>. Most of the aforementioned datalinks use different data transmission techniques, but as an individual network through the ATN, they all use the same network access protocol in accordance with the ISO OSI reference model (see **Section 2.3.4** and **Section 4.2.4**). However, as discussed in **Section 4.6**, FANS-1 has been established since the mid-1990s: Controller-Pilot DataLink Communications (CPDLC) are in operation in the South Pacific for FANS-1 aircraft and are currently being tested in the North Atlantic region using FANS-1/A<sup>374</sup>, noting that the ICAO regional authority has stated<sup>375</sup> that “SARPs-compliant [CPDLC] systems using the ATN remain the end goals ... [and that] ... it is intended to ensure that the transition ... will be seamless to users.” Accordingly, Airbus Industrie’s A340 testbed has demonstrated datalink communications between pilots and air traffic controllers as part of global FANS-A avionics trials<sup>376</sup>. Therefore, should FANS-1/A become the main worldwide standard instead of ICAO’s ATN? Using the North Atlantic region example, ICAO says that FANS-1/A is being accommodated because it already exists<sup>377</sup>.

Hence, there are many factors that must be solved before a definitive assessment of the future datalink position can be made. These questions together form a large bottleneck to comprehensive introduction of CNS/ATM. Urgent action is consequently necessary, similar to that by ARINC, the EU, SITA and the US, who are actively developing VDL Mode 2 and its associated technologies.

<sup>369</sup> 'ARINC, Concourse partner for wireless airport venture' – *Air Transport Intelligence*, 31 October 2000.

<sup>370</sup> 'More carriers show interest in wireless Gatelink system' – *Flight International*, 10 October 2000.

<sup>371</sup> 'ICAO to adopt vital new datalink standards' – *Air Transport Intelligence*, 3 April 2000.

<sup>372</sup> 'Implementation of datalink applications in modern ATC systems comes with challenges' – *ICAO Journal*, April 1999.

<sup>373</sup> 'In search of a strategy' – *ICAO Journal*, March 1998.

<sup>374</sup> 'Canadian teams test CPDLC over the Atlantic' – *air traffic management*, March-April 2000.

<sup>375</sup> 'FANS-1/A ADS Waypoint Reporting Trials. Interim Results for Shanwick OCA' – J Coulson, NATS. Inmarsat Aero Conference, May 2000.

<sup>376</sup> 'FANS-A datalink tested on A340-300' – *Flight International*, 14 March 2000.

<sup>377</sup> 'ADS on the North Atlantic' – H Martin. NavCanada. Inmarsat Aero Conference, May 2000.



## The ARINC-SITA saga

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As mentioned in Section 2.2.1, ARINC's GLOBALink and SITA's AIRCOM offer similar services. The two providers are presently competing to obtain maximum share of the current and future air-ground datalink market, with both rivals trying to get airlines to equip for VDL-2 even though ACARS messages can initially be converted to use VDL-2 infrastructure. Historically, ARINC monopolised the VHF datalink service market in the US, its home base, and SITA held most of the rest of world, with total dominance in Europe. Indeed, noting that half of the global datalink market is in the US, ARINC has the US FAA contract to develop VDL Mode 2 for air-ground AOC<sup>378</sup>.

However, SITA recently became the US FAA's FANS-1 datalink service provider for ATC on oceanic areas<sup>379</sup>. SITA had requested that the FAA separate the datalink-service element from provision of equipment<sup>380</sup>. SITA obtained vital frequencies to provide datalink in the US during 1998<sup>381</sup> and has contracted a US company to provide the ground stations for its VDL-2<sup>382</sup>; by 2003, SITA plans to have around 1,000 ground stations installed globally, with around 400 in North America. However, it has warned CAAs against venturing into its business, noting that Brazil, China and Thailand already have. SITA claims that its CPLDC applications are financially supported by its AOC activities<sup>383</sup>.

In contrast, ARINC is aggressively penetrating into SITA's European home territory. ARINC supports the efforts of Eurocontrol and the FAA, who are trying to implement CPDLC using VDL Mode 2 (see below): ARINC and the Dutch NLR have demonstrated use of VDL-2<sup>384</sup>; and ARINC is presently developing an ATN-compliant VDL Mode 2 sub-network and ground infrastructure to support AOC and ATS applications, noting that all aviation stakeholders use ARINC's networks<sup>385</sup>. It should also be noted that smaller airlines are no longer prohibited from using ARINC's ACARS for AOC purposes due to cost reasons, because ARINC has developed an Internet-based system<sup>386</sup>.

## EU/US CPDLC activities

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Universal CPDLC is the next phase of the industry's datalink programme, albeit with varying degrees of CPDLC usage in different ATM circumstances: CPDLC will certainly not be used for urgent messages. Use of CPDLC to date has not been too successful, mainly due to the cultural shift from voice to data systems<sup>387</sup>. However, there is a distinct need for CPDLC, which is acutely recognised by the EU and the US. Noting that ATC datalink implementation schedules are very long, with claims that

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<sup>378</sup> 'Major software releases mark US CPDLC milestones' – *Air Transport Intelligence*, 29 February 2000.

<sup>379</sup> 'SITA surprises with FAA oceanic datalinking win' – *Air Transport Intelligence*, 7 October 1999.

<sup>380</sup> 'SITA hopes to modify FAA oceanic deal' – *Air Transport Intelligence*, 7 June 1999.

<sup>381</sup> 'SITA US breakthrough sets scene for datalink wars' – *Air Transport Intelligence*, 13 August 1998.

<sup>382</sup> 'SITA picks Harris for datalink revolution' – *Air Transport Intelligence*, 7 June 1999

<sup>383</sup> 'SITA hands stern warning to CAAs over datalink' – 16 June 2000.

<sup>384</sup> 'ARINC goes Dutch for datalink navigation demonstration' – *Flight International*, 26 May 1999

<sup>385</sup> 'Communications and a whole lot more' – *Air Transport World*, November 1998.

<sup>386</sup> 'AOC over the Internet' – *Flight Deck International*, October 2000.

<sup>387</sup> 'ATC datalink – looking beyond CPDLC' – *Flight Deck International*, April 2000.



comprehensive CPDLC implementation in US and Europe could take 10 years<sup>388</sup>, the EU and the US are trying to initially introduce CPDLC using VDL Mode 2. Indeed, an ATN-compliant VDL Mode 2 sub-network is being developed. Therefore, the following detail the current status of the CPDLC's integration in the EU and the US, thus:

- In Europe, the aforementioned PETAL II's final report is due in 2002, with CPDLC expected through ATN/VDL-2 by 2003<sup>389</sup>. Many CPDLC test flights by numerous airlines have occurred in the PETAL II programme trials<sup>390</sup>. The programme is scheduled to begin conducting datalink trials using the ATN as a medium in 2001;
- In 1997, the US FAA created a government-industry CPDLC programme team, as part of the country's National Airspace System (NAS) modernisation plan, to develop, with industry, the evolution and implementation of Aeronautical DataLink (ADL)<sup>391</sup>. They envisage that CPDLC avionics, which are already active in the Pacific Ocean region, and the VDL-2 air-ground network, will be implemented by 2005, with an emphasis on shared ownership. The FAA team is in partnership with ARINC<sup>392</sup>, Boeing, the European PETAL II Interoperability Team and Rockwell Collins. Boeing, given its FANS-1 system, supports the ACARS to VDL-2 migration and hopes for trial aircraft implementation by the end of 2001<sup>393</sup>. American Airlines will be the first user of the CPDLC technology when it equips aircraft during the operational evaluation phase, 'Build 1', which is due to begin in June 2002<sup>394</sup>. US national deployment will begin in 2004, with completion slated for the end of 2005<sup>395</sup>. Successful tests were recently conducted<sup>396</sup>. Accordingly, three key software components, which will form the backbone of the ATN, have already been delivered<sup>397</sup>. The on-time delivery of the ATN router software keeps the CPDLC programme on track, but US budget cuts could allegedly jeopardise its timing<sup>398</sup>. US carriers are pressing the FAA to keep a high priority on deploying CPDLC because of its promises for near-term relief from flight delays<sup>399</sup>. Indeed, there is a feeling in the US that CPDLC has "got to succeed"<sup>400</sup> and that it will provide the greatest cost-benefits possible by sharing the VDL Mode 2 infrastructure for AOC and ATC datalinking. Correspondingly, the FAA revealed that nearly 30% of all controller operational errors are caused by readback/hearback or misunderstanding communications errors and want CPDLC to be implemented immediately<sup>401</sup>.

<sup>388</sup> 'Aligning ATC Datalink Requirements with Airline Requirements' – P Clinch, SITA. *Air Traffic Management: Prospects for Free Flight SMI Conference*, London. 1999.

<sup>389</sup> 'Demystifying CNS/ATM' – CANSO, 1999.

<sup>390</sup> 'PETAL trial sees surge in controller-pilot datalink use' – *Air Transport Intelligence*, 11 August 2000.

<sup>391</sup> 'FAA Datalink Program' – D Reimold, FAA. 5<sup>th</sup> Air Navigation Conference, Amsterdam. September 1999.

<sup>392</sup> 'FAA selects ARINC to develop datalink' – *Flight International*, 8 September 1999.

<sup>393</sup> 'Don't look for CNS/ATM silver bullet: Boeing' – *Air Transport Intelligence*, 30 September 1999.

<sup>394</sup> 'American calls for datalink, NAS to be investment-efficient' – *Air Transport Intelligence*, 2 March 2000.

<sup>395</sup> 'CPDLC under scrutiny' – *air traffic management*, July/August 2000.

<sup>396</sup> 'Rockwell Collins demonstrates first successful CPDLC transactions' – [www.airfax2000.com](http://www.airfax2000.com), 6 December 2000.

<sup>397</sup> 'Delivering datalink' – *air traffic management*, March-April 2000.

<sup>398</sup> 'Next-generation datalink held up' – *Flight International*, 15 December 1999.

<sup>399</sup> 'On-time software keeps FAA datalink on track' – *Flight International*, 7 March 2000.

<sup>400</sup> 'US industry to fight CPDLC budget threat' – *Air Transport Intelligence*, 8 December 1999.

<sup>401</sup> 'CPDLC is needed for improved safety efficiency: FAA' – *Air Transport Intelligence*, 9 December 1999.



### 4.2.3 Satellite-based communication facilities

Noting that **Section 2.2.3** describes the Inmarsat constellation and that **Section 2.3.3** covers the low and medium orbit neo-geostationary satellites systems, this section assesses their current implementation and use.

It is generally acknowledged that the level of satellite-based Airline Administrative Communications (AAC), Airline Operational Communications (AOC) and Airline Passenger Communications (APC) traffic has grown and is very active<sup>402</sup>, but that a lack of appropriate en-route systems presently reduces the scope for Air Traffic Service (ATS) satellite communications. Captain Fintan Ryan recently said<sup>403</sup> that “in the year 2000 ... pilots still cannot use satcom in most airspace to get an air traffic control service”, although an informal list of telephone numbers is published for ATC contacts, should the need arise to contact ATS centres by voice. The Inmarsat system is the only satellite constellation approved for ATC datalink or CPDLC<sup>404</sup> and their charges have been reduced in latter years<sup>405</sup>. Indeed, it is ironic that passengers are sitting in the back of the aircraft talking in a crystal-clear manner to people on the ground, while the cockpit crew is practically unable to hear ATC transmissions due to poor HF quality. It is even more ironic that over 80% of the global wide-body fleet is now satcom equipped<sup>406</sup>.

Nonetheless, some of the aforementioned datalink systems that are used for ATS purposes are increasingly employing satellite-based facilities for part of the communications network. For instance, ACARS via Inmarsat satellite is being used extensively in oceanic and remote regions. The latest enhancement to ACARS has been the addition of ATC functionality and a link to the FMS via FANS-I/A systems, which channel satellite voice through the Audio Control Panel (ACP). It is therefore evident that the Inmarsat constellation of satellites is already in use for ATS purposes. Indeed, the oceanic ATS communications started in 1995, using Inmarsat's aeronautical system<sup>407</sup>. By 1997, Inmarsat's network of global satellites was providing satcom service to 2,000 long-haul aircraft<sup>408</sup>. The Inmarsat Aero-H system is used operationally by many airlines<sup>409</sup>. According to Inmarsat, many airlines have seen a return on their investment. In addition to satcom use in cockpit and passenger communications, airlines have used the technology for other applications, such as ground operations, maintenance purposes and freight handling. The next generation of Inmarsat satellites, Inmarsat-4s,

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<sup>402</sup> 'Virgin starts ground-to-air calls' – *Flight International*, 11 July 2000.

<sup>403</sup> 'Aer Lingus Satcom Plans' – F Ryan, *Aer Lingus Consultant*. Inmarsat Aero Conference, May 2000.

<sup>404</sup> 'Whither Free Flight?' – *Flight Deck International*, September 1999.

<sup>405</sup> 'Inmarsat brings down satcom costs' – *Flight International*, 24 March 1999.

<sup>406</sup> 'Passenger quality communications on the flight deck' – *Flight Deck International*, September 1999.

<sup>407</sup> 'FANS – the future is here' – *Aeronautical Satellite News*, June/July 1996.

<sup>408</sup> 'Satcoms become airline standard' – E Kelly, *Integrating Global Air Traffic Management*. ISC & ICAO, 1998.

<sup>409</sup> 'High Life' – *Via Inmarsat*, April 1997.



are scheduled to enter service in 2004<sup>410</sup>. However, Inmarsat plans to allow some customers to test the new satellites' capabilities before 2004<sup>411</sup>.

The Japanese geostationary MTSAT programme, which will have communications capabilities, was dealt a severe blow when the first satellite, MTSAT-1, was destroyed in an aborted launch during November 1999. It is being replaced by MTSAT-1R<sup>412</sup>, which is due to be delivered in 2002.

Noting that they weren't manufactured solely for the CNS/ATM market<sup>413</sup>, but that they could theoretically also be used for navigation payload purposes<sup>414</sup>, the new neo-geostationary constellations of Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) satellites have not had overly successful integrations to date, thus:

- **Globalstar** – the full constellation of 56 satellites was supposed to be completely implemented by the end of 1999. Forty-four satellites were up by end of 1998, but a malfunction led to the last 12 being lost. The company filed for Chapter 11 bankruptcy in 2000, but now has funds to survive until 2002<sup>415</sup>. The In Flight Network (IFN) used Globalstar satellites in 2000 to send and receive email on board<sup>416</sup>;
- **New ICO** – formerly called ICO Global Communications<sup>417</sup>, the first launch was due in June 1999<sup>418</sup>, but was lost in a March 2000 sea launch failure. It was expected that 12 satellites would be in orbit by the end of 2000, with plans to offer aeronautical service from 2003. However, even though Inmarsat has a 10% stake in the company, in addition to helping ICO market and distribute its services, financial problems were experienced during 1999<sup>419</sup>: ICO entered bankruptcy, but was saved temporarily by Teledesic<sup>420</sup>: their merger was recently shelved<sup>421</sup>;
- **Iridium** – All 72 have been launched since the first launch in May 1997. Iridium had started service in November 1998<sup>422</sup>, but ceased commercial operations in March 2000 due to financial problems<sup>423</sup>, even though its charges were lower than Inmarsat's<sup>424</sup>. Plans to de-orbit the satellites were started later in 2000<sup>425</sup>. Arnav Systems, a US company, has allied with Globalstar to substitute Iridium's service<sup>426</sup>;

<sup>410</sup> 'Beyond 64 Kbits/sec' – A Howell, Inmarsat. Inmarsat Aero Conference, May 2000.

<sup>411</sup> 'Customers to test capabilities of Inmarsat 4 ahead of 2004 launch' – Flight International, 23 May 2000.

<sup>412</sup> 'Japan orders replacement for lost ATC satellite' – Air Transport Intelligence, 27 March 2000.

<sup>413</sup> 'Mobile satellites move into high gear' – Interavia, May 1997.

<sup>414</sup> 'The case for augmenting GPS/GLONASS using navigation capability on communication satellites' – Ryan, Inmarsat. ATM in Europe: the business case for CNS/ATM conference. London, 1997.

<sup>415</sup> 'Globalstar payment freeze buys it time' – Flight International, 23 January 2001.

<sup>416</sup> 'Test flights show Globalstar allows Internet browsing: IFN' – Air Transport Intelligence, 23 June 2000.

<sup>417</sup> 'Hughes in New ICO satellite win' – Flight International, 19 September 2000.

<sup>418</sup> 'License to roam' – inflight, March 1999.

<sup>419</sup> 'Globalstar tally increases as ICO changes business plan' – Flight International, 27 October 1999.

<sup>420</sup> 'Satellite companies to be merged after \$1.2bn bankruptcy rescue' – Flight International, 23 May 2000.

<sup>421</sup> 'Satcom specialists shelve merger as stock prices fall' – Flight International, 27 March 2001.

<sup>422</sup> 'Satellite Wars' – Regional Airline World, April 1999.

<sup>423</sup> 'Iridium sinks under debts of \$4.4 billion' – Flight International, 28 March 2000.

<sup>424</sup> 'The other satcom' – Flight International, 18 November 1998.

<sup>425</sup> 'Iridium re-entry' – Flight International, 26 September 2000.

<sup>426</sup> 'Arnav and Globalstar to fill satcom gap' – Flight International, 31 October 2000.



- **Orbcomm** – similar to the other satellite constellations, Orbcomm has had financial difficulties<sup>427</sup>.

Given that the Aeronautical Mobile-Satellite Service (AMSS) is an integral component of ICAO's CNS/ATM system, panels have been developing Standards And Recommended Practices (SARPs) for AMSS, which were incorporated into ICAO Annex 10 in late 1995. These SARPs are based on Inmarsat's aeronautical satellite system design and take issues such as systems design, airborne antennae types, spectrum conservation and data integrity into account. Since then, other SARPs have been adopted, such as those for Inmarsat's Aero-I, which started service towards the end of 1998. Correspondingly, ICAO is developing SARPs for the neo-geostationary satellite constellations that allow for inter-satellite links, datalink and the ATN.

#### 4.2.4 The ATN

Since the 1980s, tests and extensive Research & Development (R&D) have been conducted to demonstrate the feasibility of this global digital telecommunications network<sup>428</sup>, the Aeronautical Telecommunications Network (ATN), which is discussed in Section 2.3.4. This section charts the happenings since the early 1990s.

In 1993, ICAO's Air Navigation Commission established the ATN Panel (ATNP) to develop SARPs for the ATN. The first set of SARPs, commonly called the CNS/ATM-1 package, was finalised in 1996<sup>429</sup> and produced in 1998<sup>430</sup>. Issues such as end-user data types, dialogue characteristics, message delivery and Quality of Service parameters were addressed<sup>431</sup>. ATN systems management and security provisions issues are only now being adopted, meaning that a complete set of SARPs is available from March 2001<sup>432</sup>. SARPs cover ATN communications services and application in terms of<sup>433</sup>:

- **Air-ground applications** such as Context Management<sup>434</sup>, Automatic Dependent Surveillance (ADS), Controller Pilot DataLink Communications (CPDLC) and Flight Information Service (FIS);
- **Ground-ground applications**, which include Air Traffic Service (ATS) Message Handling Services (ATSMHS) and ATS Inter-facility Data Communications (AIDC).

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<sup>427</sup> 'Orbcomm is latest satellite operator in financial crisis' – *Flight International*, 26 September 2000.

<sup>428</sup> 'Digital network could improve aircraft links to operations & ATC' – *Aviation Week & Space Technology*, 20 November 1989.

<sup>429</sup> 'Comprehensive ATN Manual (CAMAL)' – *FANS Information Services*, January 1999

<sup>430</sup> 'ATN: system status and standardization in progress' – *ICAO Rio de Janeiro Conference*, May 1998.

<sup>431</sup> 'Manual of the Aeronautical Telecommunication Network (ATN)' – *ICAO Doc 9578-AN/935*, 1991.

<sup>432</sup> 'Evolutionary approach to transition now focused on detailed vision of how to exploit technologies' – *ICAO Journal*, September 2000.

<sup>433</sup> 'The ATN SARPs: Introduction and System Level Requirements' – *FANS Information Services*, 2<sup>nd</sup> Edition.

<sup>434</sup> Context Management – an ATN application that provides a log-on service allowing initial aircraft introduction into the ATN and a directory of all other datalink applications on the aircraft. It also includes the functionality to forward addresses between ATS units.



However, the CNS/ATM-1 SARPs do not contain provisions for interconnection gateways of the ATN with other non-ICAO networks, such as ACARS: work is in progress to develop further enhancements to the CNS/ATM-1 package. Indeed, many components of the package are still being developed, with efforts made by the two main aircraft manufacturers to allow existing non-ICAO standardised data communication systems, such as ACARS, to avail of new, more efficient bit-oriented ATM applications that are part of the ATN. With reference to the discussion in **Section 4.2.2**, it is argued<sup>435</sup> that ACARS equipment should evolve to VDL Mode 2 and HFDL avionics.

Nonetheless, the transition to the ATN has started<sup>436</sup>. For instance, helicopters servicing the offshore Norwegian oilrigs are equipped with a modified ADS system that sends ADS reports via Inmarsat satellite systems and a local ATN network to ATC centres, where the data is presented to controllers on combined radar and ADS displays. Correspondingly, the satellite portion of ARINC's GLOBALink communications system, which uses Inmarsat satellites, supports the ARINC 622<sup>437</sup> Application Gateway as a transition to the ATN<sup>438</sup>. Airservices Australia successfully conducted live ATN flight trials using VDL Mode 2 datalink<sup>439</sup>. Eurocontrol recently conducted the first test flight of an ATN-equipped aircraft as part of its Preliminary Eurocontrol Test of Air-ground Datalink (PETAL II) project<sup>440</sup>. Validation of the first ATS applications on ICAO-compliant ATN and VHF networks is due to occur in 2001.

Airlines presently use a combination of standards and protocols through International Aeronautical Communication Service Providers (IACSP). Under the auspices of IATA, which backs the ATN<sup>441</sup>, they have developed a set of airline-preferred OSI profiles, the Aeronautical OSI Profile (AOP), which is available to be used over the ATN. An addressing plan has been established for the ATN that meets the needs of a variety of aeronautical data communication user groups, including ATS providers, airspace users and the IACSP.

The FAA and eleven US carriers have established the consortium, ATN Systems Incorporated, to develop ATN-based air traffic control services. ATN Systems has become a focal point for ATN development in the US from ARINC 622 protocols to ATN. It reports that high-speed data transmission exists worldwide, with the first of three router software phases for the ATN introduced in 1999<sup>442</sup>. It should be noted that a US Radio Technical Commission for Aeronautics (RTCA) Free Flight report, referred to in **Section 3.6**, recommended that the ATN is a critical element in the transition to Free Flight.

<sup>435</sup> 'CNS/ATM-GATM Transition taking off' – D Helgeson, Rockwell Collins. Air Navigation Conference, Amsterdam. 1998.

<sup>436</sup> 'The transition to Free Flight – Airspace and Avionics Perspective' – D Helgeson, Rockwell Collins. Air Traffic Management: Prospects for Free Flight SMI Conference, London. 1999.

<sup>437</sup> Interim protocol developed that enables digital data to be converted into characters for transmission over the teletype-style ACARS datalink.

<sup>438</sup> <http://www.arinc.com>

<sup>439</sup> 'World premiere: Airservices Australia performs ATN flight trials using VDL Mode 2' – CANSO News, September 2000.

<sup>440</sup> 'First ATN-equipped aircraft test-flies as part of PETAL II' – Flight International, 7 November 2000.

<sup>441</sup> 'The role of ATN within the new CNS/ATM systems' – IATA FANS FACTS, 1999/2.

<sup>442</sup> 'Digital data network software progresses' – Flight International, 14 July 1999.



**Section 4.6** contains discussions on Boeing's FANS-1 package and Airbus' FANS-A. It is claimed that the ATN provides advantages over FANS-1/A, such as bandwidth being used more effectively and routing protocols providing more efficient establishment and use of paths between the aircraft and ATS provider. However, the use of FANS-1/A in the interim period while the ATN is under development has served as a useful step towards early introduction of future ATM applications. Indeed, as previously mentioned, speculation has occurred about whether FANS-1/A should become the preferred platform. Nonetheless, the ATN and its associated ATM applications are the ultimate end-state that are defined and standardised by ICAO.

Sofréavia have conducted projects in Europe based on the ATN, which have proven that it is currently possible to derive benefits from air-ground data communications. The company completed a programme in 1999 on the Downlinking of Aircraft Derived Information (DADI), whose purpose was to use technologies such as the ATN and Mode-S to get information from airborne systems, thereby offering significant ATM benefits. They stress that a lot of effort must be put into the Human-Machine Interface (HMI) design to provide operational acceptance and automated assistance to users. It is thought that ATN development will still be ongoing in Europe during 2005, but should then be complete in the North Atlantic. Indeed, both Airbus and Boeing agree<sup>443</sup> that the ATN will not be "available until after 2003."

Provisions have been made so that existing AFTN infrastructure can be used together with ATN gateways during the transition period. Therefore, there is a need to provide a clear transition path to the ATN that provides backward compatibility with existing applications and also allows full ATN-compatible avionics to operate over the same ground infrastructure, thereby reducing costs<sup>444</sup>. ICAO has produced a document that states the essential guidelines for migration<sup>445</sup>. Correspondingly, improvements continue to occur with ground-ground communications, such as use of the Air traffic services Data EXchange Protocol (ADEXP) for exchanging flight plan information in a user-friendly text format<sup>446</sup>.

In order to ensure that information routed through the ATN is of good quality and completely protected, Annex 15 of the ICAO Convention was recently amended, stating that nations must introduce a comprehensive quality system within their Aeronautical Information Service (AIS)<sup>447</sup>. Indeed, international action is needed to standardise the presentation and distribution of such information in electronic format as CNS/ATM systems become more widely used<sup>448</sup>.

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<sup>443</sup> 'FANS commitment' – *Flight Deck International*, April 2000.

<sup>444</sup> 'VDL Mode 2 and HF Data Link: Next Generation Data Link' – G Lake, ARINC. *Air Traffic Management: Prospects for Free Flight SMi Conference*, London, 1999.

<sup>445</sup> 'ATFN migration to ATN' – *Air Traffic Technology International* 2001.

<sup>446</sup> 'Copenhagen ATC first to use new flight plan link' – *Air Transport Intelligence*, 7 December 2000.

<sup>447</sup> 'Standards for licensing of AIS/MAP personnel go hand-in-hand with technological change' – *ICAO Journal*, May 1999.

<sup>448</sup> '1990s have witnessed revolution in processing and presentation of aeronautical information' – *ICAO Journal*, May 1999.



#### **4.2.5 Required Communication Performance (RCP)**

New proposed operational concepts are not yet defined into the details required to make a selection between alternative communication technologies: even the transition from voice to data communication to support the traditional way of providing ATS has to overcome various misunderstandings among operational and technical experts. This is due, in part, to the non-completion of certain technologies' SARPs to date.

Technologies that have been used since the beginning of ATC are no longer adequate to express operational requirements in the new environment. Therefore, work still needs to be done to ascertain the requirements from the operational concepts and incorporate them as the Required Communications Performance (RCP) parameter in the Target Level of Safety (TLS) for airspace regions, which is presently mainly determined by navigational performance.



### 4.3 Progress with Navigation

This section assesses the present status of CNS/ATM's navigation systems by analysing the integration of:

- Area navigation capabilities;
- Global Navigation Satellite System (GNSS);
- Satellite augmentation systems;
- Approach, landing and departure systems;
- Required Navigation Performance.

It should be noted that ICAO has been developing Standards And Recommended Practices (SARPs) for navigation systems. Thus, each aspect of navigation described hereunder mentions the status of relevant SARPs, where applicable. Correspondingly, the common world geodetic reference system, WGS-84, was implemented due to required increases in navigational accuracy, which necessitated a unique reference system: WGS-84 is now the absolute positional reference system in civil aviation since its introduction on the 1<sup>st</sup> of January 1998, even though transition challenges continue with some countries<sup>449</sup>.

#### 4.3.1 Area navigation capabilities

**Section 2.5.1** details the future of Area Navigation (RNAV) and its applications. The principle of RNAV has been around for many years, but improved RNAV procedures and RNAV approaches using Flight Management System (FMS) technologies continue to be developed and implemented. For instance, more so-called 'FANS routes' are being defined using CNS/ATM systems.

Noting that direct routes have been permitted where possible for many years, Basic-RNAV (B-RNAV) was introduced to RNP-5 in the European region during 1998, from FL95 up in most cases, even though the implementation process was not too smooth<sup>450</sup> and there were last minute postponed deadlines<sup>451</sup>. The first B-RNAV based route structure was implemented in Scandinavia, where the airspace was optimised for capacity and shortest distance for the en-route portion of major traffic flows<sup>452</sup>, with more direct routes<sup>453</sup>. The net result was that capacity improved in the en-route segment, but, interestingly, that the overall operational system efficiency decreased. Thus,

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<sup>449</sup> 'Recent implementation of WGS-84 supports evolution of a worldwide satellite-based navigation system' – ICAO Journal, May 1999.

<sup>450</sup> 'Europe's B-RNAV plans in chaotic mess' – Flight International, 27 August 1997.

<sup>451</sup> 'IATA plea leads to delay of B-RNAV' – Flight International, 19 November 1997.

<sup>452</sup> 'Gate-to-Gate ADS-B based CNS/ATM concept' – L Lindberg, Avtech Sweden. 5<sup>th</sup> Air Navigation Conference, Amsterdam. September 1999.

<sup>453</sup> 'Advances in navigation lead to more direct routes' – Jane's Airport Review, September 1997.



capacity needs to be generated in the whole system, including the terminal phase. The latter is accomplished through use of RNAV-based Procedure Design Tools (PDT)<sup>454</sup>. In addition, evolutionary introduction means that there is a mixture of equipped and non-equipped aircraft, whereby RNAV trunk routes interface with non-RNAV routes. This also adversely affects the system's efficiency and capacity. However, even old aircraft can be made B-RNAV compliant, through the installation of GPS receivers<sup>455</sup>. It is thought that GPS is the only viable RNAV option for general aviation. Earliest implementation of European Precision-RNAV (P-RNAV), which will bring radical benefits<sup>456</sup>, is expected in 2005 or later<sup>457</sup>. This may be mandatory specification. In 2005, B-RNAV will become known as RNP-5 and P-RNAV as RNP-1.

### 4.3.2 Global Navigation Satellite System (GNSS)

With reference to the discussion on the components of the Global Navigation Satellite System (GNSS) in **Section 2.5.2**, it should be noted that ICAO States have endorsed satellite navigation as the primary system for aviation, with the ultimate aspiration that aircraft will be able to circumnavigate the globe using a single suite of avionics. The ICAO GNSS Panel recommended a first set of draft SARPs for GNSS operation in 1999, with a view to incorporating them in Annex 10 of the Convention in 2000.

However, the future GNSS remains a major issue with users, due to present uncertainty regarding many financial, legal and operational aspects of the systems. The current situation is that many aviation stakeholders question whether the present GPS/GLONASS system with GNSS-1 augmentation is sufficient; others ask if GNSS-2 is necessary. Thus, also given recent technical problems that plague spatial endeavours, it is not possible to accurately predict the future of the GNSS at the moment. Nonetheless, noting that the next section covers the present implementation status of augmentation systems, the following summarises the current situation with GNSS components:

- **Pre GNSS-1:** GPS's Selective/Availability was removed in May 2000<sup>458</sup>. GPS is not a universal sole means form of navigation, even though a report by John Hopkins University in early 1999 controversially claimed that augmented GPS is sufficient for all the US's navigation needs<sup>459</sup>. But, a debate ensued about fears of signal jamming<sup>460</sup>: interference, whether intentional or not, is a very significant issue<sup>461</sup> relating to the reliability of GPS. Canada's satellite navigation chief recently said that accidental or deliberate interference remains a big question over GPS's use<sup>462</sup>. The US has since announced plans to improve GPS performance by adding two civil

<sup>454</sup> 'Go GATM – the fight for airspace continues' – *Flight Deck International*, September 1999.

<sup>455</sup> 'Eurocontrol solves B-RNAV problem for ageing aircraft' – *Flight International*, 26 March 1997.

<sup>456</sup> 'AA98: Europe finalises B-RNAV plans' – *Air Transport Intelligence*, 23 February 1998.

<sup>457</sup> 'Area Navigation 1998 Symposium Proceedings' – Eurocontrol & JAA, March 1997.

<sup>458</sup> 'More power to the people: Selective Availability is switched off' – *Navigation News*, May/June 2000.

<sup>459</sup> 'GPS adequate for 'sole means': report' – *Air Transport Intelligence*, 30 January 1999

<sup>460</sup> 'FAA faces criticism over GPS report' – *Flight International*, 24 February 1999.

<sup>461</sup> 'GNSS Interference management as a problem in aviation security' – J Brading, Raytheon Systems. 6<sup>th</sup> Air Navigation Conference, October 2000.

<sup>462</sup> 'Interference is biggest threat to satnav: Nav Canada' – *Air Transport Intelligence*, 15 June 2000.



frequencies, scheduled for introduction in 2003 and 2005, which will increase GPS's accuracy significantly and reduce potential interference threats. Its consistency is still affected by weak signals and shadowing/masking<sup>463</sup>. The low signals levels may be solved through satellite link enhancers<sup>464</sup>. However, many operators are using GPS for supplemental en-route (26 countries approved in 1998<sup>465</sup>) and non-precision approach operations<sup>466</sup>. For instance, GPS is presently being used as a primary means of navigation in the North Atlantic region Minimum Navigation Performance Specification (MNPS) airspace, noting that approvals require operators to retain traditional avionics and service providers to retain ground aids. The integration of GPS and the Inertial Navigation System (INS) may be seen as a step in the progression towards GNSS integration. In contrast, although GLONASS satellites are currently operational, little international use is being made of the constellation. Indeed, there is little faith in GLONASS now, even though the integration of GPS and GLONASS was thought possible for many years<sup>467</sup>. Nonetheless, the President of the Russian Federation offered GLONASS to the international community as its input to the GNSS<sup>468</sup> and made the Russian Space Agency responsible for development of GLONASS in the interests of civil users<sup>469</sup>. Noting that only 9 of the full complement of 24 satellites were active<sup>470</sup>, the agency recently launched three new GLONASS satellites<sup>471</sup>;

- **GNSS-1:** ATS providers have created a number of GNSS-based RNAV routes, in addition to terminal routings and procedures for suitably equipped aircraft (see **Section 4.3.4**). An added bonus in these cases is that non-equipped aircraft also have increased freedom due to the absence of the equipped aircraft, which lessens competition for optimum flight levels on busy routes. However, it is now widely accepted that GPS and GLONASS require augmentation: **Section 4.3.3** covers the progression to date of systems such as EGNOS, MSAS, LAAS and WAAS;
- **GNSS-2:** The new generation of GPS satellites should be implemented by 2015, noting that the present constellation has to be replaced in its entirety before the second-generation performance can be realised<sup>472,473</sup>. Accordingly, the timing of the EU's Galileo programme is uncertain due to present political wrangling within the European Commission about the project's cost, financing, management and overall viability. Availability of spectra is also an issue<sup>474</sup>. In contrast with the European

<sup>463</sup> 'GPS: the Holy Grail?' – J Spaans. *The Journal of Navigation*, May 2000.

<sup>464</sup> 'Weak links' – *Flight Deck International*, April 2000.

<sup>465</sup> 'Satellite Navigation Program Update' – J Fee, FAA. 4<sup>th</sup> Air Navigation Conference. Amsterdam. September 1998.

<sup>466</sup> 'Something for everyone' – *Air Transport World*, March 1998.

<sup>467</sup> 'Capability and performance make GLONASS suitable for navigation in all phases of flight' – *ICAO Journal*, November 1997.

<sup>468</sup> 'Russia offers GLONASS share' – *Flight International*, 28 October 1998.

<sup>469</sup> Declaration of the Russian Federation Government dated 29 March 1999 was obtained from <http://mx.iki.rssi.ru/sfcsic/english.html>.

<sup>470</sup> 'From Galileo to ... Galileo – European Community strategies for the development of a satellite navigation system' – *Aerogram*, June 2000.

<sup>471</sup> 'GLONASS launch' – *Flight International*, 24 October 2000.

<sup>472</sup> 'Global radionavigation: next 50 years and beyond' – J Beukers. *The Journal of Navigation*. May 2000.

<sup>473</sup> 'L5 signal should be operational by 2013' – *Air Navigation International*, 15 May 2000.

<sup>474</sup> 'European ministers move on Galileo studies' – *Flight International*, 30 June 1999.



Geostationary Navigation Overlay Service (EGNOS)<sup>475</sup>, Galileo does not have commitment from European transport ministers, but the study phase has recently been cleared<sup>476</sup>. The final decision is due in April 2001<sup>477</sup> and the European Space Agency very recently committed to providing \$180 million to the project<sup>478</sup>. The US does not want Europe to develop its own, independent system<sup>479</sup>, but the Russians are interested in becoming involved with Galileo<sup>480</sup>. Co-operation is still very much an option. The definition phase of Galileo finished in November 2000<sup>481</sup>, with theoretical timeline plans for deployment in 2007 and initial operational capability in 2008. However, transition to a fully-fledged GNSS-2 could realistically be 15-20 years. It has been said<sup>482</sup> that Europe and the US are making policies while most of the world is sitting back doing nothing, adopting a wait and see approach. Nonetheless, it is important from many perspectives that there be at least two independent GNSS-2 constellations, not only for the EU and US, but also for all other nations. On that note, the Japanese geostationary MTSAT programme, which will have navigation capabilities, was dealt a blow when the first satellite, MTSAT-1, was destroyed in an aborted launch during November 1999. Initial service was expected in 2001 with MTSAT-1<sup>483</sup>. It is being replaced by MTSAT-1R<sup>484</sup>, which is due to be delivered in 2002. MTSAT-2 is scheduled for launch in 2004. Succeeding satellites will follow at five-year intervals. It should also be noted that China recently launched its own, domestically built navigation position satellite, the Beidou Navigation Test Satellite (BNTS-1) that is mostly aimed at other transport modes<sup>485</sup>.

Most existing ground-based navigational aids will be eventually withdrawn, offering significant savings. However, at the moment, reliability of GPS and GNSS-1 limits the withdrawal of infrastructure: LORAN-C was due to be shut down at the end of 2000, but will now remain operational until at least 2008<sup>486</sup>. Indeed, it is argued that aids such as LORAN-C will be beneficial as back-ups to satellite systems<sup>487</sup>. Ultimately, the US FAA expects that a sufficiently long period of dual ground and satellite system operation will exist. Given that the primary navigation system of the future will be satellite-based, the US FAA has set up the Satellite Navigation Implementation Office<sup>488</sup> and the EU has created the European equivalent, which both co-ordinate GNSS initiatives. Nonetheless, terrestrial-based systems will be here for a long time yet.

<sup>475</sup> 'EU transport ministers back EC satnav plan' – *Air Transport Intelligence*, 17 March 1998.

<sup>476</sup> 'European Space Agency to launch Galileo study phase' – *Flight International*, 27 February 2001.

<sup>477</sup> 'Galileo – European satellite navigation system' – *Flight Deck International*, February 2001.

<sup>478</sup> 'Galileo funding' – *Flight International*, 27 March 2001.

<sup>479</sup> 'USA warns Europe against GNSS-2 satnav system' – *Air Transport Intelligence*, 29 January 1999.

<sup>480</sup> 'Satellite-based navigation systems' – R Schnabel, *Air & Space Europe*. Vol. 1 No. 1, 1999.

<sup>481</sup> 'Galileo gets go-ahead (?)' – *Navigation News*, November/December 2000.

<sup>482</sup> 'Outlook for navigation aids' – D Last, *University of Wales. RIN '98: Safety of Navigation seminar*, Manchester. March 1998.

<sup>483</sup> 'Augmentation – Improving GNSS accuracy and Integrity' – A Paylor, *Integrating Global Air Traffic Management. ISC & ICAO*. 1998.

<sup>484</sup> 'Japan orders replacement for lost ATC satellite' – *Air Transport Intelligence*, 27 March 2000.

<sup>485</sup> 'China launches 1<sup>st</sup> navigation satellite' – *Navigation News*, November/December 2000

<sup>486</sup> 'Loran-C reprieved as USA gets timetable for move to sole GPS' – *Flight International*, 24 March 1999.

<sup>487</sup> 'LORAN-C for civil aviation' – *Flight Deck International*, April 2000.

<sup>488</sup> 'FAA Headquarters and regional SATNAV air traffic initiatives' – J Williams, *FAA & T Meyer, AMTI. 43<sup>rd</sup> Annual Air Traffic Control Association Conference Proceedings*. 1998.



### 4.3.3 Satellite augmentation systems

While basic satellite service has been shown as suitable for some applications, it must be augmented through improvements in its integrity, availability and accuracy in order to realise its full potential as a primary means of navigation and landing guidance. The many satellite augmentation systems that are at concept and development stages are discussed in **Section 2.5.3**. It is thought that Ground-Based Augmentation Systems (GBAS) and Satellite-Based Augmentation Systems (SBAS) meeting ICAO standards will become operational by 2005. This section analyses their rate of progression, thus:

- **Wide Area Augmentation System (WAAS)** – continues to experience budgetary<sup>489</sup> and integrity/stability technical setbacks<sup>490</sup>, such as the whole system shutting down for 90 minutes<sup>491</sup>: in 1994, it was thought that WAAS would be available by 1997<sup>492</sup>; in 1995, it was thought<sup>493</sup> that “WAAS is expected to achieve an initial operating capability in 1998, with the end-state system being completed in 2001”; in 1999, it was claimed that the initial operational capability of WAAS should be expected in 2000<sup>494</sup>. Even the removal of GPS’s selective availability had no positive impacts on its integration. However, the FAA demonstrated part of WAAS’s precision capabilities in 1998<sup>495</sup>/1999<sup>496</sup>, with its certification date now set for 2002<sup>497</sup> and expecting “robust WAAS by 2007”<sup>498</sup>. WAAS signals are finally available now, but only for increasing situational awareness during VFR flight. Thus, the airline community is challenging WAAS over high costs and unresolved cost recovery mechanisms that have raised doubts over the system’s cost effectiveness: it is claimed to be an extravagant exercise<sup>499</sup>. Nonetheless, carriers are desperate for CNS/ATM improvements and want WAAS introduced as soon as possible<sup>500</sup>. Airlines are starting to equip<sup>501</sup>. They claim that, if WAAS contributes to the future sole use of GNSS for en-route and terminal operations, then it may prove to have been justified. An independent review board was consequently set up

<sup>489</sup> ‘Expert analysis drains FAA’s WAAS programme funds’ – *Air Transport Intelligence*, 28 March 2000.

<sup>490</sup> ‘FAA WAAS report acknowledges GPS signal jamming concerns’ – *Flight International*, 18 February 1998.

<sup>491</sup> ‘Raytheon details WAAS signal integrity problems, fixes’ – *Air Transport Intelligence*, 9 March 2000.

<sup>492</sup> ‘Global Navigation Satellite System: the future of precision navigation’ – R Hartman, Honeywell, Landing and Approach Systems ’94 Conference, Geneva, October 1994.

<sup>493</sup> ‘The FAA’s implementation of satellite-based navigation systems for aviation’ – M Shaw, FAA, The Airline Navigation Conference ’95, Amsterdam, September 1995.

<sup>494</sup> ‘GPS and Galileo: best of all possible worlds?’ – J Fee, FAA, 5<sup>th</sup> Air Navigation Conference, Amsterdam, September 1999.

<sup>495</sup> ‘North Atlantic Global Navigation Satellite System (GNSS) augmentation flight demonstration’ – *Journal of ATC*, January-March 1999.

<sup>496</sup> ‘FAA introduces WAAS to Asia with Singapore flight trials’ – *Flight International*, 19 May 1999.

<sup>497</sup> ‘WAAS OK for 2002, but Cat I uncertain’ – *Navigation News*, March/April 2000.

<sup>498</sup> ‘Reality check’ – *Flight International*, 22 February 2000.

<sup>499</sup> ‘Is WAAS worth it?’ – *Jane’s Airport Review*, June 1997.

<sup>500</sup> ‘Users’ summit to shape FAA’s WAAS operational timetable’ – *Air Transport Intelligence*, 9 March 2000.

<sup>501</sup> ‘UPS to fit freighter fleet with satellite navigation systems’ – *Flight International*, 11 January 2000.



in 2000 to evaluate WAAS<sup>502</sup>. WAAS is presently employing the Inmarsat service for trials<sup>503</sup> and still has its same ultimate goal, to provide Cat I precision approach capability across the US<sup>504</sup>. Nonetheless, it is thought that “WAAS was over-sold and over-promised”<sup>505</sup>;

- **European Geostationary Navigation Overlay Service (EGNOS)** – with an initial capability down to Cat I precision landing due in 2002<sup>506</sup>, it is expected that EGNOS will be fully operational in 2005<sup>507</sup>. The programme is presently using Inmarsat satellites for testing purposes. The UK’s National Air Traffic Services (NATS) has demonstrated accurate automatic guidance during all flight phases<sup>508</sup>. The EGNOS Operators and Infrastructure Group (EOIG) has not worked out cost recovery aspects: indeed, there is still debate whether EGNOS is needed at all, if the EU eventually decides to implement Galileo as part of GNSS-2. Correspondingly, airlines claim that EGNOS should not be implemented based on the US experiences with WAAS<sup>509</sup>. They are also concerned that they may be paying for the development costs of EGNOS<sup>510,511</sup>;
- **Multi-function transport Satellite Augmentation System (MSAS)** – as cited in **Section 4.3.2**, the Japanese geostationary MTSAT programme, which will have augmentation capabilities, will not be operational until at least 2002 when the replacement MTSAT-1 should be launched. MTSAT-2 is scheduled for 2004;
- **Local Area Augmentation System (LAAS)** – in 1994, the US FAA awarded a LAAS contract to examine the technical feasibility of using satellite-based systems for Cat II and Cat III precision approaches. It was completed during 1995 and provided data for developing LAAS. However, Cat III LAAS precision landings will not be available for a few years<sup>512</sup> (latest official estimate of certification date is 2004/5), even though the initial deployment of publicly available LAAS Cat I is due in 2002<sup>513</sup>. LAAS is part of the Capstone project in Alaska, which is evaluating advanced flight technology and procedures<sup>514</sup> (see **Section 4.5.4**). Indeed, the FAA is considering whether LAAS would be a better way of achieving Cat I approach capability than using WAAS<sup>515</sup>. Project Newark, which is described in **Section 4.3.4**, portrays the evolutionary approach that is being adopted towards LAAS. It

<sup>502</sup> 'Review board formed to monitor WAAS progress' – 20 June 2000.

<sup>503</sup> 'WAAS guides FAA to new approach' – *Flight International*, 28 March 2000.

<sup>504</sup> 'Raytheon pins down cause of persistent WAAS alarms' – *Flight International*, 14 March 2000.

<sup>505</sup> 'New WAAS-based approach procedures mooted' – *Air Navigation International*, 3 April 2000.

<sup>506</sup> 'EGNOS: project status overview' – J Benedicto et al, ESA. *Air & Space Europe*. Vol. 1 No. 1, 1999.

<sup>507</sup> 'EGNOS – the European satellite augmentation to GPS and GLONASS' – E Perrin, European GNSS Secretariat. 4<sup>th</sup> Air Navigation Conference, Amsterdam. September 1998.

<sup>508</sup> 'EGNOS-based coupled approaches demonstrated' – *Air Navigation International*, 15 May 2000.

<sup>509</sup> 'The Airspace Users View on EGNOS & GNSS' – V De Vroey, AEA. 4<sup>th</sup> Air Navigation Conference. Amsterdam. September 1998.

<sup>510</sup> 'AEA asks Kinnock to crack down on CAAs' EGNOS fees' – *Air Transport Intelligence*, 2 March 1999.

<sup>511</sup> 'do we really need egnos?' – *era regional report*, november 1998.

<sup>512</sup> 'Reality check' – *Flight International*, 22 February 2000.

<sup>513</sup> 'Chicago airports sign up for LAAS approach technology' – *Air Transport Intelligence*, 30 August 2000.

<sup>514</sup> 'LAAS, WAAS and Capstone to benefit Alaska together: FAA' – *Air Transport Intelligence*, 30 August 2000.

<sup>515</sup> 'FAA looks at LAAS to replace Cat I WAAS' – *Flight International*, 4 April 2000.



should also be noted that the LAAS architecture may consist of Airport PseudoLites (APL) that function just like GPS satellites, but would be located on the ground to enhance the availability of LAAS service by providing an additional ranging source that originates from the local airport<sup>516</sup>. APLs are referred to hereunder as part of Differential GPS system trials. The FAA expects to finish deployment of LAAS equipment at US airports in 2006<sup>517</sup> if the aforementioned operational deployments in 2002 and 2005 are successful. SARPs for LAAS are expected in 2001;

□ **Differential GNSS (DGNSS) – discussed hereunder in Section 4.3.4.**

It should be noted that the SBAS Worldwide Availability Tool (SWAT) has been developed to predict the ability of the GNSS and its enhancement (whether GBAS or SBAS), to support navigation and landing functions<sup>518</sup>. This has the dual benefit of estimating the augmentation resources required to achieve a specified level of performance and to enable operational personnel to plan action in the event of the GNSS or its augmentation system failing.

Regarding Aircraft-Based Augmentation Systems (ABAS), current aircraft navigational systems, combined with increasing RAIM/AAIM coverage through the GPS and/or GLONASS receiver, satisfy most en-route performance requirements.

#### **4.3.4 Approach, landing and departure systems**

Section 2.5.4 describes the various precision approach, landing and departure systems that figure in the future CNS/ATM system. However, it should be noted that GNSS and RNAV are already being used for non-precision approaches:

- **GNSS** – General aviation has led the way in using GPS Landing System (GLS) non-precision approaches. Airlines exploit the capability of GPS for such approaches, particularly at airports with geographical and other problems that prevent the use of ILS. For instance, many airports are using GPS for non-precision approaches in the US. Indeed, Fiji has been conducting GPS-based landings for many years;
- **RNAV** – GPS/Flight Management System (FMS) overlay procedures for SIDs and STARs, which include GPS/FMS transitions to final approach for all landing directions, have been operational at Frankfurt and Munich airports in Germany since 1998<sup>519</sup>. This is the result of a study, the NESS project on new SID and STAR procedures, conducted by Lufthansa Airlines and the German air navigation service provider, DFS<sup>520</sup>. Other DFS GPS-based departures have been developed<sup>521</sup> and

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<sup>516</sup> 'US Wide Area Augmentation System (WAAS) update' – 6<sup>th</sup> Air Navigation Conference, October 2000.

<sup>517</sup> 'FAA selects joint LAAS developers' – Air Transport Intelligence, 5 April 1999

<sup>518</sup> 'Global GPS navigation – resource planning and performance modeling' – Air Traffic Technology International '99.

<sup>519</sup> 'NESS Project' – B Rockel, DFS. 43<sup>rd</sup> Air Traffic Control Association Conference Proceedings, 1998.

<sup>520</sup> 'GPS-FMS/RNAV – an operational necessity towards ATM' – J Schadt, Lufthansa. 4<sup>th</sup> Air Navigation Conference, Amsterdam, September 1998.

<sup>521</sup> 'Germany tests GPS in bid to reduce departure noise' – Flight International, 31 October 2000.



Lufthansa has reapplied these approach techniques in Russia<sup>522</sup>. Correspondingly, RNAV approach and departure operations, such as Alaska Airlines', have been conducted since the early 1990s. It should be noted that there is an emphasis to implement FMS-based Vertical NAVigation (VNAV) procedures to ensure stabilised non-precision approaches, thereby reducing Controlled Flight Into Terrain (CFIT).

Software for designing, simulating and testing new non-precision GNSS and RNAV-based approach procedures has been undergoing development trials with European ATS providers<sup>523</sup>: Wavionix Innovative Solutions International's 'Precision-Ware' gathers all pertinent airport and terrain data within 30 nautical miles, prior to generating routes within a matter of seconds, which highlight the relevant Minimum Descent Altitudes (MDA), Minimum Sector Altitudes (MSA) and descent gradients. It is then tested and verified for different aircraft types through simulation. Additionally, many other simulation tools are becoming increasingly available<sup>524</sup>.

This section also assesses the current situation with precision aids, thus:

- **Instrument Landing System (ILS)** – as per the ICAO 20-year strategy, ILS continues to be used as the primary, standard non-visual aid to precision approach and landing after over 50 years<sup>525</sup>, although many runways around the world are not equipped for Cat III operations<sup>526</sup>. Indeed, an inventory survey of navigation aids at European airports in 1999 indicated that less than 50% of airports have ILS in some countries, such as Greece, Portugal, Iceland and Norway<sup>527</sup>. The good weather in the former two nations may be the reason in their cases. There were predictions that ILS's withdrawal would have commenced by now, in particular due to its susceptibility to interference from Frequency Modulation (FM) broadcasts. However, this problem was solved and ICAO mounted a concerted effort to get airlines to re-equip with FM-protected ILS receivers. Indeed, ILS systems are still being bought in bulk<sup>528</sup>. Other incidents have occurred over the last few years, with ILS sending false signals as apparently normal to the cockpit<sup>529</sup>;
- **Microwave Landing System (MLS)** – MLS has been operational for many years, but has only had limited introduction, even though it was previously envisaged that MLS would have replaced ILS at busy airports by 1998-2000. Even though a Mobile MLS (MMLS) was available in 1993, in addition to the fact that MLS was mature and standardised to Cat III after 25 years of development by 1994, implementation has been limited. It is only employed at a few airports where local topography warrants MLS. In 1994, the FAA position<sup>530</sup> on ILS versus MLS was

<sup>522</sup> 'Lufthansa to use GPS in Russia' – *Flight International*, 12 September 2000.

<sup>523</sup> 'Software programme helps designers to devise and verify new GNSS-based approach procedures' – *ICAO Journal*, September 2000.

<sup>524</sup> 'Integrated tools' – *Air Traffic Technology International* 2001.

<sup>525</sup> ILS was first adopted by ICAO as the standard aid to approach and landing in 1949.

<sup>526</sup> 'Reach for the ground' – *Flight International*, 12 March 1997.

<sup>527</sup> 'European Airport Infrastructure' – R Fewings, Cranfield University. *Proceedings of the 1<sup>st</sup> Forum on Air Transport in Europe's Remote Regions*, June 1999.

<sup>528</sup> 'FAA renews instrument landing systems acquisition' – *Air Navigation International*, 17 April 2000.

<sup>529</sup> 'Near-accidents warn pilots of potential for ILS trap' – *Flight International*, 7 November 2000.

<sup>530</sup> 'Precision Approach Systems: a future outlook' – M Shaw, FAA. *Landing and Approach Systems '94 Conference*, Geneva. October 1994.



that it would adhere with ICAO's plan for "full-scale implementation of MLS for international operations starting 1998 and the discontinuance of ILS by 2000." However, the US FAA, ICAO and others have moved away from their strict endorsement of MLS. At the time, Airbus Industrie argued<sup>531</sup> that "ILS works well and [integration] of MLS would divert aviation funds that would be better used to improve the approach service elsewhere." Indeed, Potocki said that Airbus Industrie had had no requests from airlines to install MLS, although they now offer it as part of the FANS-A package. British Airways has contributed an MLS-equipped Boeing 757 to the UK's MLS certification programme for many years, since 1988<sup>532</sup>. Indeed, MLS enjoyed a resurgence of interest in the late 1990s<sup>533 534</sup>, when the Netherlands, the UK and others opted for MLS due to the anticipated degradation of ILS signals<sup>535</sup>. It has also been claimed recently that Heathrow and Schiphol will start MLS operations in the near future. Business aircraft operators and regional airlines highlight MLS's high installation airborne and ground costs, in addition to the fact that such aircraft users need precision landing capabilities at more airports than currently have them. Correspondingly, they are against MLS and seek total independence from ground facilities for landing operations (see hereunder):

- **Multi-Mode Receiver (MMR)** – Given the view in 1994 that "several landing systems will be in service (including ILS, GPS/GNSS and MLS)"<sup>536</sup>, it was decided to develop a Multi-Mode Receiver (MMR) for landing that operates in a similar manner to an ILS receiver. A 1998 milestone was created to have it standardised, certified and produced. The two main aircraft manufacturers incorporate MMRs as part of their FANS packages (see Section 4.6.1). In addition, a Cat III Pilot's Landing System (PLS) that is integrated in the MMR can be used in low visibility conditions with PLS's FogEye, a sensor on the aircraft that scans for runway lights, which emit ultraviolet signals. GPS/ILS/MLS remain as integrity monitors<sup>537</sup>.
- **Differential GNSS (DGNSS)** – much work has been completed on approach, landing and departure DGNSS, in particular with Differential GPS (DGPS). DGPS has been developed and tested since the early 1990s, when the US FAA thought that "early in 1998, WAAS will enable the use of GPS for Cat I precision approaches." The previous section, Section 4.3.3, details the delays associated with WAAS, but the following successes have been experienced with DGNSS/DGPS:
  - In 1994, Project DFW tested DGPS in the US, which included the first successful GNSS auto-land;
  - In 1995, flight tests using DGPS demonstrated better than Cat III lateral and longitudinal accuracy, with greater than Cat I vertical accuracy<sup>538</sup>. However,

<sup>531</sup> 'An airframe manufacturer's view of ILS replacement' – P Potocki, Airbus Industrie Landing and Approach Systems '94 Conference, Geneva October 1994

<sup>532</sup> 'MLS development: the British Airways experience' – A Fisher BA Landing and Approach Systems '94 Conference, Geneva, October 1994.

<sup>533</sup> 'Europe plans MLS purchase' – Jane's Airport Review, September 1997

<sup>534</sup> 'MLS products are back in business' – Jane's Airport Review, November 1997

<sup>535</sup> 'A standard approach to precision landing' – Jane's Airport Review November 1997

<sup>536</sup> 'The Multi-Mode Landing Receiver (MMR): a reality' – J Hettyei, Thomson-CSF Landing and Approach Systems '94 Conference, Geneva, October 1994.

<sup>537</sup> 'Cat III compatibility' – Flight Deck International '98

<sup>538</sup> 'DGPS appears feasible for CAT III landings, FAA says' – CNS Outlook September 1995



commercially available GPS-based Cat III landing systems are still not on the market. At the time, the US FAA acknowledged that additional investigation was needed regarding the availability, certification, continuity and integrity of DGPS as an operational system:

- In 1997, the UK's Project Boscombe<sup>839</sup> achieved real-time DGNSS positioning to Cat I standard for LAAS and integration of GNSS positioning with the FMS for aircraft guidance in all flight phases using the autopilot. Straight-in and curved approaches using GNSS guidance were tested in 2000<sup>840</sup>;
- Project Newark was the first effort to install, test, validate and certify a DGNSS landing system<sup>841</sup>; with the main objective being to increase capacity at Newark airport in the US, which experiences record levels of delays. Continental Airlines has been working with the FAA and others since 1993 to introduce a Special Cat I (SCAT-I) GLS facility at their New Jersey hub airport. The SCAT-I process also provides a means of gaining operational approval prior to LAAS being fully defined for DGPS. Many aircraft have been equipped with the requisite MMR equipment since the first certified GLS approach and landing were made in September 1998<sup>842 843</sup>. Continental has decided to equip all new aircraft with GPS receivers capable of making use of this technology<sup>844</sup>. The FAA commented that the performance of the GLS appeared to be superior to that of an ILS Cat III. The Project Newark team converted the ground station at Newark to transmit LAAS correction signals at the end of the evaluation phase. Project Newark sparked the creation of the US Government Industry Partnership (GIP) to certify Cat I LAAS, with a team consisting of an airline, airport, avionics manufacturer, ground station manufacturer and the US FAA;
- As part of the gate-to-gate demonstrations of the North European ADS-B Applications Project (NEAP), it was proven that DGNSS is possible through the integration of ADS-B and VDL Mode 4<sup>845</sup>;
- LAAS-augmented DGPS tests using Airport PseudoLites (APL) have shown that the GPS-like signals did not cause any reduction in receiver performance<sup>846</sup>;
- Airbus Industrie, having conducted trials using an A340 aircraft, think that Cat I DGNSS precision landings will be available soon<sup>847</sup>;
- UPS Aviation Technologies' GPS-based precision approach system, which includes a mechanism for ensuring the integrity of WAAS signals, is expected to be certified in late 2001<sup>848</sup>;

<sup>839</sup> 'Project Boscombe' – P Daly, D Walsh (University of Leeds) & A McGregor, DERA. Global Navcom '97 Symposium & Exhibition, Mexico, June 1997.

<sup>840</sup> 'UK tests auto guidance system' – Flight International, 16 May 2000.

<sup>841</sup> 'Project Newark – the pathway to LAAS' – D Diehl, Continental Airlines. 3<sup>rd</sup> Air Navigation Conference, Amsterdam September 1997.

<sup>842</sup> 'Project Newark: GLS landing trials' – J Ariens, Continental Airlines. 4<sup>th</sup> Air Navigation Conference, Amsterdam, September 1998.

<sup>843</sup> 'Satellite precision landings are operational at last' – Jane's Airport Review, November 1998

<sup>844</sup> 'Project Newark: Certification of the first Satellite Landing System' – D Diehl, Continental Airlines Airline Navigation '96 Conference, Amsterdam, October 1996.

<sup>845</sup> 'Seamless services' – Air Traffic Technology International 2000.

<sup>846</sup> 'LAAS Pseudolite Testing' – SATNAV news, August 1999.

<sup>847</sup> 'AIM-FANS business process' – Airbus Industrie, January 2000.

<sup>848</sup> 'Precision approaches for small airports' – AVflash, 18 January 2001.



- **Autonomous Precision Approach and Landing System (APALS)** – Flight demonstrations were conducted in 1996<sup>549</sup>, based on proof-of-concept trials in late 1994<sup>550</sup>. An ILS Cat I-equivalent capability<sup>551</sup> of 1m<sup>552</sup> has been demonstrated, achieving lateral and vertical accuracy performance exceeding published Cat IIIb requirements. Cat II certification was achieved in mid-1997, with Cat III due at the end of 1997<sup>553</sup>. Cat II APALS is the lead product for the US market, whilst Cat III is more suited in Europe, where the need for a new system is pressing and augmented GNSS is some way off. Similar to APALS, Sweden's SAAB has developed the New Integrated Navigation System/New Integrated Landing System (NINS/NILS), which enables precision approaches without ground nav aids<sup>554</sup>.
- **Transportation Landing System (TLS)** – The FAA has approved the TLS<sup>555</sup>, noting that it is capable of exceeding specifications for Cat I ILS approaches.

Head-Up Displays (HUD) are becoming more prominent in commercial carrier operations. For example, Delta Airlines recently made a decision to equip the bulk of its fleet with HUDs<sup>556</sup>. BAE Systems' Marconi Avionics is targeting European Boeing 737NG operators, noting that half of all 737NGs come off the production line with HUDs fitted. In addition, the HUD-Visual Guidance System (VGS) has recently become available to the market<sup>557</sup>; certification for Boeing aircraft will occur from the latter half of 2002<sup>558</sup>. HUDs with Enhanced Vision Systems (EVS) have been proven to greatly assist in the execution of GLS approaches to airports not equipped with vertical guidance. In addition, Marconi says that "as well as improved landing capability, ... [it has] capability ... to provide take-off guidance."<sup>559</sup> HUD also facilitates Surface Guidance Systems (SGS), which are expected to achieve certification in 2003<sup>560</sup>. SGS will benefit from differential GPS, CPDLC and ADS-B<sup>561</sup>.

In summary, the long-term future of ground-based landing aids is being drastically impacted by the arrival of operational terminal satellite-based systems. Countries will have two main options: transfer directly from ILS to differential satellite-based systems; or, replace ILS with MLS and then migrate to a satellite-based system. Broadly speaking, the US favours the first approach and the UK the second. Undoubtedly, however, ILS will continue for quite a while at many airports and the aviation community will embrace whichever reliable technology comes first.

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<sup>549</sup> 'Lockheed Martin tests pre-production APALS' – *Flight International*, 17 January 1996

<sup>550</sup> 'Landing by radar' – *Flight International*, 7 February 1996.

<sup>551</sup> 'APALS at last' – *Air Transport World*, March 1996

<sup>552</sup> 'System Briefing: APALS' – O Dieffenbach, *Lockheed Martin The Airline Navigation Conference '95*, Amsterdam, September 1995.

<sup>553</sup> 'New approach/landing systems near US certification' – *Interavia*, January/February 1997

<sup>554</sup> 'No strings attached' – *air traffic management*, November/December 1998

<sup>555</sup> 'FAA certifies TLS as Cat I aid; developer eyes China effort' – *ATC Market Report*, 11 June 1999

<sup>556</sup> 'Heads up for safety' – *Air Transport World*, November 2000

<sup>557</sup> 'Assembly-line VGS wiring for 737-800s starts this month' – *Air Navigation International* 12 June 2000

<sup>558</sup> 'FI2000: Boeing timetables new flightdeck nav display technologies' – *Air Transport Intelligence*, 27 July 2000.

<sup>559</sup> 'Marconi Systems sees European HUD sale soon' – *Air Transport Intelligence* 6 January 2000

<sup>560</sup> 'Advanced avionics put the accent on safety' – *Flight International*, 17 October 2000

<sup>561</sup> 'FI2000: surface guidance system flight-tests to start in 2002' – *Air Transport Intelligence* 27 July 2000



### 4.3.5 Required Navigation Performance (RNP)

The Required Navigation Performance (RNP) concept is discussed in Section 2.5.5.

RNP is quite well established, certainly more so than its associated RCP and RSP concepts. Introduction of RNP-10 occurred in the North and Central Pacific during 1998. Similarly, with reference to Section 2.5.1, the use of Basic Area Navigation (B-RNAV) in Europe since 1998 is equivalent to RNP-5 airspace standards. Correspondingly, RNP types are being used by planners to determine airspace utilisation potential, in addition to defining route widths and traffic separation requirements. RNP is therefore fundamental in determining safe separation standards.

However, the transition to RNP is a complex matter and is taking longer than had been envisioned. In contrast, however, RNAV routes are widespread. Noting that ICAO approval and guidelines are required, it is working to facilitate the process<sup>662</sup>. By 2010, the navigational requirements for some airspace environments will be stated in RNP terms by ICAO. Indeed, according to ICAO, "the RNP concept is currently being developed and implemented as an essential element of the global future air navigation system."

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<sup>662</sup> 'RNP implementation demands commitment and careful consideration of many issues' – ICAO Journal, March 1998.



## 4.4 Surveillance success

It is argued that surveillance is the key to beneficial CNS/ATM. This section assesses the present status of CNS/ATM's surveillance systems by analysing the integration of:

- Secondary Surveillance Radar Mode S;
- Automatic Dependent Surveillance;
- Ground Movement Surveillance;
- Airborne Collision Avoidance Systems;
- Ground-Proximity Warning Systems;
- Cockpit Situational Awareness Systems;
- Meteorological systems;
- Required Surveillance Performance.

Over the next 5 to 10 years, it is expected that both Primary and Secondary Surveillance Radar (PSR and SSR) will continue to be used, with the gradual introduction of Mode S (Select) SSR radar in both terminal areas and high-density continental airspace. Mode S SSR will be used in high-density airspace to provide high accuracy and reliable surveillance. In contrast, Automatic Dependent Surveillance – Broadcast (ADS-B) will also be introduced. More advanced versions of Airborne Collision Avoidance Systems (ACAS), such as TCAS 2 Version 7, will be standard by 2005. Additionally, many of the old radars are being upgraded with new signal and data-processor technology<sup>563</sup>.

It should be noted that ICAO has been developing Standards And Recommended Practices (SARPs) for surveillance systems. Thus, each aspect of surveillance discussed hereunder mentions the status of relevant SARPs, where applicable.

### 4.4.1 Secondary Surveillance Radar Mode S

Noting that technical SARPs exist, **Section 2.7.1** illustrates technical details and applications of SSR Mode S, which is increasingly being used for surveillance in high-density airspace<sup>564</sup>. Mode S is already in operation in some dense traffic areas for surveillance and TCAS purposes, but not for datalink examples. It is currently not used as a general datalink service like VHF and SATCOM, but future implementation of Mode S Aircraft DataLink Processor (ADLP) will allow Mode S transponder to be connected to any airborne computer to provide general-purpose datalink service for all onboard avionics.

In Europe, the programme for Mode S implementation, POEMS, aims to provide operational services in 2001. A contiguous volume of airspace, within which Air Traffic Services' (ATS) use of Mode S Enhanced Surveillance is feasible, is expected to be

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<sup>563</sup> 'Low-cost upgrades to in-service radars' – *Air Traffic Technology International '98*.

<sup>564</sup> 'The Future Air Navigation System' – V. Galotti. Chapter 5.



available from 2003. Carriage and operation of Mode S airborne equipment has been mandatory in airspace for IFR flights using new aircraft from the beginning of 2001 and for all aircraft from the start of 2003<sup>565</sup>. British Airways, which was commissioned by Eurocontrol to execute a study into the airborne impact of Mode S Enhanced Surveillance and Down-linked Aircraft flight Parameters (DAP), recommends that all capable aircraft in Europe be equipped with Mode S DAP by 2005<sup>566</sup>. Airlines, however, are sceptical of Mode S's value, thinking that technologies such as ADS-B may make Mode S obsolete<sup>567</sup>. Indeed, the US is not as convinced by Mode S, although it is expected on that side of the Atlantic after 2008<sup>568</sup>. Consequently, there are questions being asked about Mode S's long-term future in global CNS/ATM<sup>569</sup>.

#### 4.4.2 Automatic Dependent Surveillance

Automatic Dependent Surveillance (ADS), which is described in **Section 2.7.2**, has been implemented in some areas, but is still presently being tested in others, thus:

- ADS is operating beyond radar limits in Asia-Pacific en-route oceanic and remote regions: ADS with CPDLC through ACARS via Inmarsat satellites commenced as part of FANS-1 during 1995 in the South Pacific and has since spread into Asia and the North Pacific<sup>570</sup>;
- In the North Atlantic (NAT) region, ADS underwent pre-operational checks in 2000<sup>571</sup>, followed by CPDLC trials<sup>572</sup> and fully operational in 2001<sup>573</sup>. The latter will co-ordinate with other datalink trials in 2001<sup>574</sup>. ADS trials began in July 1999<sup>575</sup>, involving more than 50 FANS-1 equipped Boeing 747-400 and 777 aircraft, which account for 15% of aircraft on transatlantic routes. The ADS trial phases in the NAT region are using Inmarsat satellites<sup>576</sup>. FANS-A trials were due to begin in October 2000. ADS is online at the London ATC centre (LATCC) to monitor NAT traffic. Trials of waypoint position reporting are currently underway in Gander and Shanwick FIRs. HF will be dropped for aircraft that log on directly to ADS. A fully operational ADS system in the Shanwick OCA was expected in July 2000<sup>577</sup>, but it was postponed following technical problems with the

<sup>565</sup> 'Basic and Enhanced Surveillance with SSR Mode S' – JAA CNS/ATM Steering Group Working Paper, 28 July 1999.

<sup>566</sup> 'The airborne impact of Mode S enhanced surveillance and down-linked aircraft parameters' – A Rose, British Airways. The 6<sup>th</sup> Air Navigation Conference, October 2000.

<sup>567</sup> 'Modernising with Mode-S' – air traffic management, May/June 2000.

<sup>568</sup> 'Go GATM – the fight for airspace continues' – Flight Deck International, September 1999.

<sup>569</sup> 'Mode S: will it be worth the effort?' – air traffic management, March/April 1997.

<sup>570</sup> 'Asia/Pacific leads global modernization demand' – Aviation Week & Space Technology, 27 January 1997.

<sup>571</sup> 'ADS on the North Atlantic' – H Martin, NavCanada. Inmarsat Aero Conference, May 2000.

<sup>572</sup> 'Nav Canada aims for North Atlantic ADS datalink trials' – Flight International, 21 March 2000.

<sup>573</sup> 'North Atlantic ADS goes from trial to live' – Flight International, 6 February 2001.

<sup>574</sup> 'Automatic transmission' – air traffic management, May/June 2000.

<sup>575</sup> 'Atlantic ADS' – Flight International, 7 July 1999.

<sup>576</sup> 'Meeting the demand' – Aircraft Engineering and Aerospace Technology, Vol 68 No. 6, 1996.

<sup>577</sup> 'FANS-1/A ADS Waypoint Reporting Trials. Interim Results for Shanwick OCA' – J Coulson, NATS. Inmarsat Aero Conference, May 2000.



infrastructure<sup>578</sup>. In another part of the Atlantic region, the Spanish Airport and Navigational Authority, Aena, has tested ADS datalink for CPDLC in the Canary Islands as part of its SACCAN FANS-1/A system<sup>579</sup>. Studies in the North Atlantic area have shown that changing from a procedural to an ADS environment would create airspace capacity gains of between four and five times<sup>580</sup>;

- ADS is also currently being tested over dense land areas: authorities such as the UK's National Air Traffic Services (NATS) started ADS trials in the early 1990s as part of the ADS Europe project, whose objective was to validate some key ICAO SARPs<sup>581</sup>. NATS used the ATN as the communications system;
- Norway's M-ADS for North Sea helicopters, which uses a local ATN, was installed in 1996<sup>582</sup>. The Norwegian CAA has made M-ADS mandatory for all commercial helicopter operators in the Norwegian Sea since 1999<sup>583,584</sup>.

With SARPs complete<sup>585</sup>, the introduction of ADS is dependent upon the availability of aircraft airborne equipment, air-ground datalink, ATC Flight Data Processing System (FDPS) and controller situation display. Some states would be capable of effecting track monitoring today, but the procedures associated with the use of ADS for separation purposes have not been developed yet. Software is currently being developed that will allow ADS data to be used directly by ground computers to detect and resolve conflicts.

### **ADS-B (Broadcast)**

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The arrival of ADS-Broadcast (ADS-B) has had the unfortunate consequence that implementation processes have been slowed while decision makers attempt to determine which technology is best. Several operational concepts are in progress, but consensus must still be reached on ADS-B datalink technology. It is important to develop the most suitable concept, noting that ADS-B provides the same data for the controller and pilot, which are needed for future ATM<sup>586</sup>. There is a lot of synergy among ADS-B's communications and surveillance functional capabilities. Accordingly, ADS-B ties in the three required system performance parameters: Required Communication Performance (RCP) through datalink, Required Navigation Performance (RNP) through satellite-based navigation and Required Surveillance Performance (RSP) through radar.

ADS-B SARPs have been completed, but the technology will most likely not be available by 2005. Nonetheless, ADS-B could be in service soon thereafter, based on the following successful ADS-B concept demonstrations that have occurred:

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<sup>578</sup> 'Technical problems delay North Atlantic ADS debut' – *Air Transport Intelligence*, 14 August 2000.

<sup>579</sup> 'SACCAN Automatic Dependent Surveillance in the Canary Islands' – Aena, 1999.

<sup>580</sup> Coote, Schraw and Schwab. 1993.

<sup>581</sup> 'Innovations in aerospace satcoms' – *Aircraft Engineering and Aerospace Technology*, Vol 68 No. 6. 1996.

<sup>582</sup> 'Eyes over the sea' – *Flight International*, 29 January 1997.

<sup>583</sup> 'North Sea helicopter operations made safer with M-ADS' – *Air Traffic Technology International* '99.

<sup>584</sup> 'Norway's M-ADS implementation slips to April' – *Air Navigation International*, 25 January 1999.

<sup>585</sup> 'Surveillance systems' – *ICAO Rio de Janeiro Conference*, May 1998.

<sup>586</sup> 'Implementation of ATM for the airline operation' – N Brandt, Lufthansa. *The Airline Navigation Conference '95, Amsterdam*. September 1995.



- There was a live demonstration of ADS-B at the ICAO ATN panel in 1999<sup>587</sup>;
- As part of the Eurocontrol Free Route Experimental Encounter Resolution (FREER)-3 programme, a European team demonstrated air-air and air-ground data exchange in all flight phases using ADS-B as part of establishing the European ADS-B network<sup>588</sup>, which involved flying aircraft towards one another<sup>589</sup>. Implementation has proceeded in Germany and Sweden. FREER showed that ADS-B and VDL Mode 4 can be used as an Airborne Separation Assurance System (ASAS)<sup>590</sup>;
- The US Cargo Airline Association ADS-B programme, which is part of the FAA Safe Flight 21 (see **Section 4.5.4**), started in 1996 as a method to gain conflict avoidance and CDTI operational benefits from ADS-B<sup>591</sup>. Phase 1 of the ADS-B systems' operational evaluation occurred during 1999 in Ohio Valley<sup>592,593</sup>: both operators and regulators were involved to demonstrate improved terminal operations in low-visibility conditions; enhanced en-route air-to-air operations; improved capability to navigate airport taxiways; and improved capability to see and avoid adjacent traffic<sup>594</sup>. The second, 'OpEval 2', phase was completed in October 2000: it indicated that ADS-B has great potential on the ground and in the air to give pilots a displayed view of traffic around them<sup>595</sup>. The final phase, 'OpEval 3', will be completed in mid-2001<sup>596</sup>. The cargo carrier, UPS, hoped to have 90 aircraft equipped by the end of 2000<sup>597</sup> and all of its 230 aircraft by the end of 2002<sup>598</sup>. Its subsidiary company, UPS-Aviation Technologies, is developing the ADS-B system that was tested in Ohio Valley<sup>599</sup>. Indeed, its ADS-B recently received certification that allows the company to produce and sell units<sup>600</sup>. Although the Cargo Association prefers ADS-B to TCAS as an ACAS, its airlines will be implementing the latter technology by 2005, as discussed in **Section 4.4.4**;
- The datalink aspect of ADS-B is also presently under evaluation as part of the US FAA's Safe Flight 21 programme. Three candidate datalinks were tested during the aforementioned US cargo carrier trials. The FAA will make a decision before the end of 2002<sup>601</sup>;

<sup>587</sup> 'What's New' – *Aerospace International*, July 1999.

<sup>588</sup> 'SAS team shows get-to-gate CNS/ATM' – *Flight International*, 17 February 1999.

<sup>589</sup> 'Broadcast and avoid' – *air traffic management*, January-February 1999.

<sup>590</sup> 'European Free Flight demonstrated in Berlin' – *Flight International*, 21 October 1998.

<sup>591</sup> 'Datalink pioneers hope to avoid international split' – *Air Transport Intelligence*, 22 September 1999

<sup>592</sup> 'US cargo carriers ready to launch ADS-B tests' – *Flight International*, 7 July 1999.

<sup>593</sup> 'ADS-B: transition is the end state' – *Journal of ATC*, October-December 1999.

<sup>594</sup> 'FAA gives go-ahead for ADS-B trials' – *Flight International*, 21 April 1999.

<sup>595</sup> 'OpEval 2 ADS-B trial produced very positive results: FAA' – *Air Transport Intelligence*, 1 November 2000.

<sup>596</sup> 'FAA pursues next phase of flight evaluation for ADS-B' – *Flight International*, 7 November 2000.

<sup>597</sup> 'UPS primes 90 aircraft for ADS-B implementation' – *Flight International*, 4 April 2000.

<sup>598</sup> 'UPS to equip entire fleet with ADS-B by 2002' – *Air Transport Intelligence*, 10 March 2000.

<sup>599</sup> 'A near-term, incremental approach to ADS-B for transport category and General Aviation aircraft' – *K Shapero*, 6<sup>th</sup> Air Navigation Conference, October 2000.

<sup>600</sup> 'UPS wins conflict-alerting certification for ADS-B' – *Air Transport Intelligence*, 12 October 2000.

<sup>601</sup> 'Surveillance Success' – *Flight International*, 28 July 1999.



- Also in the US, a paired approach concept has been developed to increase IFR capacity to closely spaced parallel runways using TCAS and ADS-B<sup>602</sup>. These two independent methods of surveillance are employed to ensure separation under Electronic Flight Rules (EFR);
- Areas of Alaska in the US have installed equipment for participation in the Capstone (see **Section 4.5.4**) ADS-B evaluations of advanced flight technology demonstration<sup>603</sup>, with the view of eventually using ADS-B on a wide scale throughout the US<sup>604</sup>. The first flight using ADS-B occurred recently<sup>605</sup> after tests concluded that the aircraft position-reporting performance of ADS-B is better than that provided by radar<sup>606</sup>;
- The Southern Ring Air Routes programme, which aims to examine introduction of ADS-B in Kazakhstan, Azerbaijan, Tajikistan, Turkmenistan, Georgia, Armenia, Kyrgyzstan, Uzbekistan, Moldova and Mongolia, is starting trials in March 2001<sup>607</sup>. The Russian Federation aims to make ADS-B the basis for air traffic surveillance using VDL Mode 4 datalink<sup>608</sup> by 2005.

#### 4.4.3 Ground Movement Surveillance

Due to an ever increasing number of runway incursion incidents (the number rose by 69% in the US over the period from 1993 to 1998<sup>609</sup>), interest in Surface Movement Guidance and Control System (SMGCS) has increased in latter years<sup>610</sup>, thus:

- The Darmstadt SMGCS, developed in partnership with Frankfurt Airport, has shown that it is perfectly feasible to taxi around “blind” using the screen display, with other traffic displayed<sup>611</sup>;
- NASA has developed Situation Awareness Virtual Environment (SAVE), which uses headsets and computer-generated images to augment reality for controllers<sup>612</sup>;
- The UK’s NATS has commissioned a new system to measure runway capacities and monitor surface movement delays, the Airport Monitoring And Capacity System (AMACS)<sup>613</sup>;

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<sup>602</sup> 'Work on ADS-B in the US' – R Stone, United Airlines. Airline Navigation Conference '96.

<sup>603</sup> 'Pilots applaud ADS-B after human factors evaluation' – Flight International, 1 December 1999.

<sup>604</sup> 'First large-scale airborne ADS-B test imminent' – Air Transport Intelligence, 8 July 1999.

<sup>605</sup> 'ADS-B on ice: system goes live in Alaska' – www.avweb.com, 4 January 2001.

<sup>606</sup> 'FAA concludes ADS-B positional technology beats radar' – Air Transport Intelligence, 8 December 2000.

<sup>607</sup> 'Azerbaijan, Georgia to host region's first ADS-B demo' – Air Transport Intelligence, 15 January 2001.

<sup>608</sup> 'Russia becomes first major ADS-B customer' – Flight International, 2 January 2001

<sup>609</sup> 'Runway Incursion Reduction Program: Increasing safety by improving situational awareness' – Journal of ATC, July-September 1998.

<sup>610</sup> 'New ground designs' – Jane's Airport Review, November 1998.

<sup>611</sup> 'New displays key to safer flying' – Interavia, May 1997.

<sup>612</sup> 'X-ray spectacle' – air traffic management, January-February 2000.

<sup>613</sup> 'NATS commissions airport capacity monitor' – air traffic management, March-April 1999.



- Swedavia conducted Advanced-SMGCS (A-SMGCS) trials at Stockholm Arlanda airport using an ADS-B system with VDL Mode 4 datalink, whereby ground vehicles and aircraft determined their positions by GNSS receivers and transmitted this information to others in the vicinity of the airport<sup>614</sup>;
- UPS also believes that ADS-B is useful on the ground and is testing accordingly<sup>615</sup>;
- The FAA is developing the Airport Movement Area Safety System (AMASS)<sup>616</sup>, which employs Airport Surface Detection Equipment (ASDE)-3 radars located at heavily laden airports as a ground equivalent of the conflict alert used with en-route radars. The \$100m contract for development of a lower-cost alternative to ASDE-3, ASDE-X, was awarded recently, with full fielding of AMASS expected by the end of 2002<sup>617</sup>. NASA's Runway Incursion Prevention System (RIPS) combines GPS and ADS-B with AMASS to help navigation at busy airports in low visibility<sup>618</sup>;
- Additionally, two different Parallel Runway Monitors (PRM) technologies based on SSR reply transmissions are being tested in the US<sup>619</sup>;
- Also in the US, Orincon has developed its Ground Safety Tracking And Reporting System (GSTARS), which can detect unauthorised movements by vehicles or aircraft and alert the tower controller<sup>620</sup>. GSTARS is an inexpensive system that the USAF rates as very useful in low-visibility operations<sup>621</sup>;
- Surface Guidance Systems (SGS), which use Head-Up Display (HUD) technology, are expected to achieve certification in 2003<sup>622</sup>. Rockwell Collins unveiled its SGS in 2000<sup>623</sup>.

#### 4.4.4 Airborne Collision Avoidance Systems

With reference to the discussion of current Airborne Collision Avoidance Systems (ACAS) in **Section 2.6.2**, TCAS 2 has been mandatory in US airspace for many years on aircraft seating more than 30 passengers<sup>624</sup> and its Change/Version 7<sup>625</sup> became requisite for aircraft with Maximum Take-Off Weights (MTOW) greater than 15 tonnes flying in Europe at the beginning of 2000<sup>626</sup>, noting that a transitional period<sup>627</sup> for

<sup>614</sup> 'Using satellite systems for navigation and control of ground vehicles' – *Integrating Global Air Traffic Management*, ISC & ICAO, 1998.

<sup>615</sup> 'Not just for the birds' – *air traffic management*, March-April 2000.

<sup>616</sup> 'No trespassing' – *Air Transport World*, March 2000.

<sup>617</sup> 'Sensis wins deal for runway safety device' – *Flight International*, 16 January 2001.

<sup>618</sup> 'Preventing incursions' – *Flight International*, 7 November 2000.

<sup>619</sup> 'New approach procedures using PRM promise reduced arrival delays' – *Journal of ATC*, January-March 1999.

<sup>620</sup> 'System uses embedded sensors to track and report on airfield ground movements' – *ICAO Journal*, May 2000.

<sup>621</sup> 'Low-cost runway incursion system under test' – *Flight International*, 16 May 2000.

<sup>622</sup> 'Advanced avionics put the accent on safety' – *Flight International*, 17 October 2000.

<sup>623</sup> 'Rockwell reveals guidance system' – *Flight International*, 18 July 2000.

<sup>624</sup> 'AlliedSignal wins FAA ACAS II certifications' – *Air Transport Intelligence*, 29 July 1999.

<sup>625</sup> 'Crash-free future' – *Flight Deck International*, March 1999.

<sup>626</sup> 'Safety net' – *Flight International*, 22 December 1999.



those with exemptions will end on March 31<sup>st</sup> 2001. However, it was recently announced that many operators will be unable to meet this deadline<sup>628</sup>. Business aircraft operators must install ACAS II/TCAS 2 by 2005. Aircraft not fitted with the system in Europe face being refused entry into dense airspace areas or being grounded for not meeting airworthiness requirements<sup>629</sup>. It is thought that TCAS 2 Change/Version 7 will be standard in 2005. Indeed, the US FAA recommends that airlines conducting Reduced Vertical Separation Minima (RVSM) operation should install the Change/Version 7<sup>630</sup> because it has modifications for compatibility with RVSM<sup>631</sup>.

US cargo carriers will comply with their December 2002 deadline to fit collision avoidance equipment, but will ensure that the system has ADS-B capability<sup>632</sup>. Indeed, the US Cargo Airlines Association (CAA) would prefer it if its members' aircraft were equipped with ADS-B systems instead of TCAS 2<sup>633</sup>. However, even though they believe that ADS-B (see **Section 2.7.2**) could fulfil the situational awareness requirement, as presently conceived, it does not provide resolution advisories to avoid collisions<sup>634</sup>. Thus, TCAS 2 is to be installed in cargo aircraft, similar to their passenger counterparts<sup>635</sup>. It should be noted that Honeywell launched its new TCAS in 2000, which provides a 100nm range and is capable of supporting ADS-B<sup>636</sup> and Mode S<sup>637</sup>.

Other regions around the world are being actively encouraged to enforce ACAS implementation on flight decks: Argentina, Australia, India, Japan and Oman have also mandated ACAS II. ICAO has placed a January 2003 implementation date for ACAS II systems on large aircraft used for international operations and January 2005 on small<sup>638</sup>.

ACAS III/TCAS 4, which is described in **Section 2.7.4**, is still a long way off due to difficulty with developing horizontal conflict escape manoeuvres. Indeed, there have been some serious incidents from false TCAS advisories<sup>639</sup>. ICAO and the US FAA had hoped to have TCAS 4 ready for 2000<sup>640</sup>. However, ACAS cannot generate Resolution Advisories (RA) against aircraft that don't have altitude reporting SSR transponders<sup>641</sup>.

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<sup>627</sup> 'Separate Values' – *Flight International*, 3 February 1999.

<sup>628</sup> 'Collision course' – *Flight International*, 13 March 2001.

<sup>629</sup> 'Eurocontrol wants ACAS delay' – *Flight International*, 12 August 1998.

<sup>630</sup> 'Pacific heights' – *air traffic management*, September-October 1999.

<sup>631</sup> 'Maximizing minima' – *air traffic management*, September/October 1998.

<sup>632</sup> 'Surveillance Success' – *Flight International*, 28 July 1999.

<sup>633</sup> 'Pilots applaud ADS-B after human factors evaluation' – *Flight International*, 1 December 1999.

<sup>634</sup> 'No reason to delay' – *Regional Airline World*, September 1999.

<sup>635</sup> 'FAA to push TCAS II for US freighters' – *Flight International*, 14 March 2000.

<sup>636</sup> 'Swissair, Virgin, SAS sign for new Honeywell TCAS' – *Air Transport Intelligence*, 28 July 2000.

<sup>637</sup> 'Honeywell extends TCAS capability' – *Flight International*, 25 July 2000.

<sup>638</sup> 'CNS/ATM systems & the reduction of CFIT accidents' – *ICAO Rio de Janeiro Conference*, May 1998.

<sup>639</sup> 'Shattered faith' – *air traffic management*, November-December 1999.

<sup>640</sup> 'Airborne Collision Avoidance Systems' – *ICAO Rio de Janeiro Conference*, May 1998.

<sup>641</sup> 'More than collision avoidance' – *Flight International*, 3 September 1997.



#### 4.4.5 Ground-Proximity Warning Systems

With reference to the discussions in **Section 2.6.4** and **Section 2.7.5**, this section lists the implementation situation to date for GPWS and EGPWS, thus:

- **GPWS** was developed in the 1970s and improved in the 1980s. It was mandated in 1974 for larger commercial passenger aircraft certificated by the US FAA. ICAO made a recommendation in 1979 for carriers to install GPWS. Even though GPWS is not mandatory around the world, countless airlines have embarked on GPWS programmes, with numerous success stories<sup>642</sup>. By 1997, all but 200 aircraft of the then 12,000 commercial jets operating worldwide had a GPWS<sup>643</sup>. For smaller, regional aircraft, US legislation means that imperative introduction of GPWS will not occur before 2005 for retrofits<sup>644</sup> and all air carrier turbine aircraft;
- **EGPWS** was developed by AlliedSignal (now part of the Honeywell group) in the 1990s. It was approved for use in commercial passenger aircraft during 1996<sup>645</sup>. EGPWS is in service, with production availability on all Boeing aircraft and standard on all Airbus airplanes since 1999<sup>646</sup>. Honeywell is still the only provider<sup>647</sup>. It is presently becoming available for general aviation aircraft<sup>648</sup>. In 1997, the major US airlines announced their plan to install EGPWS in all their aircraft<sup>649</sup>. The US FAA was preparing a Notice of Proposed Rule Making (NPRM) for the carriage of EGPWS in 1999<sup>650</sup>, stating that “commercial aircraft with 6 or more seats must have Terrain-Awareness Warning Systems (TAWS) by 2005<sup>651</sup>. Australia’s Civil Aviation Safety Authority (CASA) brought in legislation during 1999 requiring operators to install GPWS by October 1999 or EGPWS by January 2001<sup>652</sup>. The UK CAA is pre-empting expected JAA regulations from the start of 2003<sup>653</sup>. ICAO announced a planned addition to its Annex 6 (Operations) in 1999 to require commercial aircraft to be fitted with “a predictive terrain hazard warning function” such as EGPWS. It would apply to new aircraft above 15t from 2001 and retrofits from 2003<sup>654</sup>.

<sup>642</sup> 'New GPWS policy combined with training initiative proves successful in changing crew attitudes' – ICAO Journal, March 1997.

<sup>643</sup> 'Enhanced Ground Proximity Warning System' – Airliner, July-September 1997.

<sup>644</sup> 'Waiting for TAWS' – Air Transport World, April 1999.

<sup>645</sup> 'Enhanced GPWS improves situational awareness and provides more effective protection near terrain' – ICAO Journal, May 1997.

<sup>646</sup> 'Airbus makes EGPWS standard – AlliedSignal' – Air Transport Intelligence, 22 April 1998.

<sup>647</sup> 'Making sense' – Flight International, 18 July 2000.

<sup>648</sup> 'AlliedSignal launches general aviation EGPWS' – Flight International, 19 May 1999.

<sup>649</sup> 'US airlines move to install EGPWS' – Flight International, 19 November 1997.

<sup>650</sup> 'Looking ahead with certainty' – Aircraft Technology Engineering & Maintenance, June-July 1999.

<sup>651</sup> 'FAA makes TAWS compulsory' – Flight International, 4 April 2000.

<sup>652</sup> 'Australia to require GPWS from October' – Air Transport Intelligence, 28 July 1999.

<sup>653</sup> 'navigation and communications reference timetable' – era regional report, october 1999.

<sup>654</sup> 'ICAO leads way with enhanced proximity warning proposals' – Flight International, 17 March 1999.



#### 4.4.6 Cockpit Situational Awareness Systems

Situational Awareness Systems (SAS) are discussed in **Section 2.7.6**. Situational awareness is enhanced by Cockpit Display of Traffic information (CDTI) and other applications of certain CNS technologies.

CDTI was commercially proven by the Scandinavian airline, SAS, in 1996<sup>655</sup>, using ADS-B. Additionally, a CDTI traffic situation display, which aids conflict resolution advisory services, was developed by Boeing and integrated into its navigation display<sup>656</sup>.

Airborne Collision Avoidance Systems (ACAS) associated with ADS-B are similar to TCAS. The implementation status of ACASs is discussed in **Section 4.4.4**. In addition, it should be noted that the previous section assesses the introduction to date of Ground-Proximity Warning Systems (GPWS) and Enhanced GPWS (EGPWS), both of which improve pilots' situational awareness.

#### 4.4.7 Meteorological Systems

With reference to the discussion in **Section 2.7.7** on the Winds Analysed and Forecast for Tactical Aircraft Guidance over Europe (WAFTAGE) model, it should be noted that Eurocontrol and the European Commission have adapted WAFTAGE to the terminal area. A programme that provides a forecast confidence level for WAFTAGE and Numerical Weather Prediction (NWP) models was being conducted in 1997<sup>657</sup>. Also in 1997, NASA tested technology that aims to minimise the effects of deteriorating weather on airport capacity and potential ground collisions. The Low Visibility Landing And Surface Operations (LVLASO) system has the following three elements<sup>658</sup>:

- *Roll-Out and Turn-Off (ROTO)*, to help pilots locate and use high-speed exits;
- *Taxiway Navigation And Situational Awareness (T-NASA)*, designed to provide taxi guidance and traffic information;
- *Dynamic Runway Occupancy Measurement System (DROMS)*, to help ATC determine approach spacing.

Satellite images provide useful information on the location of clouds, weather systems and some adverse weather conditions that can affect aircraft in flight. An imaging system that transmits such data directly to the cockpit was being developed in 1997<sup>659</sup>. Real-time satellite information and resources are becoming increasingly available to operators<sup>660</sup>. The World Area Forecast System (WAFS)<sup>661</sup>, which provides en-route

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<sup>655</sup> 'Reaching for Free Flight' – *Flight International*, 22 January 1997.

<sup>656</sup> 'Boeing CNS/ATM Status' – D Allen, Boeing. 5<sup>th</sup> Air Navigation Conference, Amsterdam. 1999.

<sup>657</sup> 'Improvements in forecasting accuracy may allow a significant increase in en-route capacity' – *ICAO Journal*, January-February 1997.

<sup>658</sup> 'Beating the weather' – *Flight International*, 24 September 1997.

<sup>659</sup> 'Advances in computing and communications could revolutionise delivery of weather data to cockpit' – *ICAO Journal*, January-February 1997.

<sup>660</sup> 'Satellite images provide valuable information supplement to the aviation meteorologist' – *ICAO Journal*, March 2000.

<sup>661</sup> 'World area forecast system – meeting the global demand for aviation weather information' – *Air Traffic Technology International* '99.



weather forecasts around the globe, has been developed using satellite broadcasts. Work was also being conducted at the time on the ability to accurately forecast inflight icing conditions<sup>662</sup>. This is essential because the present approach to inflight icing problems is based on subjective information that the pilot is usually unable to obtain. Aircraft icing aloft is especially dangerous for single-engine and small, twin-engine aircraft due to the average operating altitude. Correspondingly, research is under way to improve the forecasting of freezing drizzle<sup>663</sup>.

Additionally, airborne trials recently demonstrated the uplink of real-time graphic weather data through the concept of an Aviation Weather Information Network (AWIN)<sup>664</sup>. The AWIN system is an on-board avionics application that integrates existing textual meteorological airmen's reports, terminal area forecasts, aircraft present positions and flight plan information into a single-source pilot workstation in the cockpit. It was scheduled for certification in September 2000<sup>665</sup>. NASA is presently sponsoring a programme that aims to develop a satellite-based graphical weather information service, which will provide worldwide, real-time weather data to aircraft displays when requested<sup>666</sup>. Versions superimposed on moving map displays exist<sup>667</sup>.

A windshear and turbulence warning system that provides real-time hazardous weather information and can issue 12-hour forecasts was installed at Hong Kong's Chek Lap Kok (CLK) airport when it opened<sup>668</sup>. In addition, the Fronts and Atlantic Storm Tracks Experiment (FASTEX), conducted in 1997, involved sending aircraft into the eyes of storms over the North Atlantic and facilitated the gathering of large amounts of data. A new generation of stormscope is becoming available, with the ability to show impending thunderstorms on moving map displays<sup>669</sup>. However, it is presently very difficult to predict the occurrence of Clear-Air Turbulence (CAT) in flight, but a system involving an infra-red laser aperture mounted on aircraft nose will facilitate avoidance of this phenomenon<sup>670</sup>. The Specific CAT Risk (SCATR) index, which provides a probability measure of CAT occurrence in a region, is currently being used<sup>671</sup>.

#### 4.4.8 Required Surveillance Performance

ICAO has not yet specified the Required Surveillance Performance (RSP) concept of an operational scenario for a given airspace. When RSP is complete, any single system or combination of surveillance systems meeting the set parameters can be considered operationally acceptable.

<sup>662</sup> 'Icing problem is a serious threat for which the best solutions may be years away' – ICAO Journal, January-February 1997.

<sup>663</sup> 'Meteorological research focuses on ways to improve forecasting of icing conditions aloft' – ICAO Journal, January-February 1997.

<sup>664</sup> 'Outlook becoming brighter' – air traffic management, November-December 1999.

<sup>665</sup> 'AWIN weather system ready September 2000: Boeing' – Air Transport Intelligence, 7 January 2000.

<sup>666</sup> 'Rockwell to lead NASA weather-by-satcom effort' – Air Transport Intelligence, 28 January 2000.

<sup>667</sup> 'Foundation for safer skies – the promise of 4D flight displays' – Flight Deck International, March 1999.

<sup>668</sup> 'Automatic windshear warning system designed to enhance flight safety and operational efficiency' – ICAO Journal, January-February 1997.

<sup>669</sup> 'Lightning detection system – a new look at thunderstorms' – Flight Deck International '98.

<sup>670</sup> 'Phantom menace' – air traffic management, July-August 1999.

<sup>671</sup> 'Technology's impact on weather for free flight' – Air Traffic Technology International '98.



## 4.5 ATM procedures in place

With reference to the discussions in **Chapter 3**, this section evaluates how certain aspects of future ATM have progressed prior to detailing timeframes and appraising the success to date with implementation of the following three ATM concept blueprints:

- ICAO's Global Plan;
- Europe's ATM Strategy 2000+;
- US Free Flight.

These three concepts aim to ensure that the extra capacity needed is provided to meet the projected growth in civil air traffic over the coming years. Additionally, the greater flexibility that they hope to facilitate will attempt to bring savings in time and fuel to aircraft operators. Correspondingly, the concepts incorporate many of the technological and procedural advances that exist, which are covered in **Chapter 2** and **Chapter 3**. In addition, the many national and regional programmes that are referred to in **Section 4.7** contain inherent elements of ICAO's Global Plan.

However, it is imperative to note that these operational concepts represent solutions and that many countries/regions around the world have not developed CNS/ATM plans for the future: hence the need to develop a framework, as conducted in this dissertation's **Part 2**. It should also be noted that the concepts invariably refer to the future and that it is consequently difficult to accurately assess the success with which they are being introduced. Nonetheless, the objective of this chapter is to analyse the current situation of CNS/ATM implementation plans. On that note, IATA's CNS/ATM implementation plans are covered in **Section 4.5.5**.

### 4.5.1 Future ATM

This section analyses the current situation regarding migration from the present ATC methods towards the future ATM system that is discussed in **Section 3.3**. Whilst the many issues raised in **Section 3.3.2** on the objectives of future ATM and **Section 3.3.3** on the potential benefits from future ATM are very important in terms of progressing towards a future ATM system that accommodates all traffic in a flexible manner, they are quite idealistic and the current situation is far from perfect. In many regions, capacity remains below required levels and severe delays continue to occur. It is therefore assumed that the objectives and potential benefits have not yet been realised. This section consequently concentrates on assessing ATM and its procedures, noting that their associated operational concepts are dealt with in subsequent sections.

Progress has been slow because ATM is an amalgamation of CNS equipment, automation capabilities and modified or new ATC service procedures. Many nations have updated their ATC systems, but the technology employed varies. ATM procedures have not been drastically altered in most countries, with use of paper strips still not



replaced by electronic techniques<sup>672</sup>, although thermal printers bring benefits<sup>673</sup>. Indeed, the transition to CNS/ATM systems is difficult because all types of traffic must be accommodated. Until the aircraft population reaches a critical mass in terms of its ATM capability, only those ATC units that dedicate specific resources to CNS/ATM aircraft, such as in oceanic regions, will lead the way. Correspondingly, more units will comply when system specifications are agreed globally through Standard And Recommended Practices (SARPs). Furthermore, aircraft operators that have taken a decision to invest at an early stage expect corresponding benefits.

However, it is looking increasingly likely that an internationally based ATM system can be constructed<sup>674</sup>, but it is difficult to evolve from one system to another in timeframes of less than several years. Thus, long transition periods can be expected, which place a heavy burden because the new and old systems must be operated simultaneously. This also amplifies the problem of aircraft having to operate in mixed environments where the population has different levels of CNS/ATM capability. In a similar manner, a seamless ATM system must be open and adhere to international standards<sup>675</sup>. Thus, airlines must exchange information with each other, with ground systems at ATM facilities and with airline operation centres in a consistent, standard manner, regardless of operating region.

Many airspace regions throughout the world are still using outdated separation criteria due to deficient infrastructures. However, interim measures such as Flexible Use of Airspace (FUA) and Reduced Horizontal/Vertical Separation Minima (RHSM/RVSM) have been implemented to increase airspace capacity, resulting in improvements that do not require many technological changes. RVSM has been successfully introduced in the North Atlantic region, with present implementation in Australia, Europe, the Pacific Ocean, in addition to the West and South Atlantic Ocean<sup>676</sup>. China is assessing RVSM<sup>677</sup>. This programme is one of the more effective means of increasing airspace capacity<sup>678</sup>, but the importance of vigilant monitoring has been demonstrated, even after introduction<sup>679</sup>. In addition, spurious TCAS alerts and undesirable wake turbulence effects have been experienced<sup>680</sup>.

A large number of ATM procedures now account for Extended Twin engine OperationS (ETOPS<sup>681</sup>), mainly with Airbus A330, Boeing 757-767 and Boeing 777 aircraft. ETOPS started in the North Atlantic region in 1985 and in the Pacific Oceanic area during the 1990s. The Boeing 777 has 180-min ETOPS, which means that aircraft can

<sup>672</sup> 'Stripping away' – air traffic management, September/October 1998.

<sup>673</sup> 'New printers for Prestwick' – Air Traffic Technology International '98.

<sup>674</sup> 'A Guide to CNS/ATM', Philip Butterworth-Hayes, February 1999.

<sup>675</sup> 'Considerations for inserting CNS/ATM technologies into ATM solutions' – B Culbertson, Lockheed Martin. 43<sup>rd</sup> Annual Air Traffic Control Association Conference Proceedings. 1998.

<sup>676</sup> 'RVSM to extend to South and West Atlantic' – Air Transport Intelligence. 4 July 2000.

<sup>677</sup> 'Making room with RVSM' – air traffic management, September/October 2000.

<sup>678</sup> 'UK reveals big success with North Atlantic RVSM' – Air Transport Intelligence. 30 September 1997.

<sup>679</sup> 'Rogue RVSM flights cause concern' – Flight International, 1 October 1997.

<sup>680</sup> 'Two other problem areas identified' – Air Navigation International, 8 October 1997

<sup>681</sup> ETOPS flights are those conducted over a route that contains a point further than one hour flying time at the approved one engine inoperative cruise speed (under standard conditions in still air) from an adequate diversion airport.



fly from virtually anywhere in the US to Asia. Indeed, Boeing wants 180+15% minutes to ensure that all destinations may be served in the event of alternate unavailability<sup>682</sup> and so that Polar Routes may be used. Airbus, however, does not agree with the extension<sup>683</sup>, citing the potentially very low alternate airfield temperatures. Airbus does offer the four-engine A340, which is similar in seating capacity to its twin-engine A330. There is, however, very poor provision of diversion airfields in the Polar region.

Accordingly, it is evident in **Section 4.7** that some regions have begun to implement CNS technologies, with resultant ATM improvements. For instance, RNP-10 has been introduced in the North Pacific, with partial implementation on the Pacific Organised Track System and the US to Hawaii corridor. Basic aRea NAVigation (B-RNAV), which is similar to RNP-5, has been implemented in Europe: the amalgamation of the Flight Management Computer and RNAV has led to more efficient use of airspace, with resultant reductions in flight times and fuel consumption. GPS routes are being flown daily in the Caribbean. The Dynamic Aircraft Route Planning System (DARPS) has started on the main South Pacific routes<sup>684</sup>. In-Trail Climbs (ITC) have been performed in oceanic airspace using TCAS since the early 1990s<sup>685</sup>. In addition, as mentioned in **Section 4.6**, several routes have been developed for aircraft with FANS-1/A avionics capable of providing ADS reports and routinely communicating with ATC units via CPDLC. This has consequently reduced congestion on conventional routes and increased overall capacities in the relevant regions. Indeed, early experience suggests that ADS and CPDLC may form a satisfactory tactical system in certain airspaces and could serve as a strategic system in other, more congested airspace regions<sup>686</sup>.

Separation standards in the terminal approach environment are also being altered through many capacity-increasing programmes, which are being conducted. Eurocontrol and the US's NASA/FAA have started programmes to provide flight crews, airline operators and air traffic managers with automation aids to increase capacity in en-route and terminal areas<sup>687</sup>. Visualisation tools that enable controllers to keep converging runways open have been developed<sup>688</sup>. NASA and Honeywell have completed development of a flight-path management and conflict-detection concept, the Airborne Information for Lateral Spacing (AILS), for closely spaced parallel approaches<sup>689</sup>. Frankfurt Airport has analysed the effects of wake vortices on final approach in order to enhance capacity by optimising separation<sup>690</sup>. NASA has developed a ground-based system for accurately predicting wake turbulence, the Aircraft VOrtex Spacing System (AVOSS)<sup>691</sup>. In addition, a Pan-European vortex reporting scheme, ETWIRL, has been

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<sup>682</sup> 'Boeing looks for ETOPS rule change for 777 operations' – *Flight International*, 10 March 1999.

<sup>683</sup> 'Airbus and Boeing set to clash over longer ETOPS' – *Air Transport Intelligence*, 7 May 1999.

<sup>684</sup> 'Fans fails to pay the bills' – *Jane's Airport Review*, June 1997.

<sup>685</sup> 'FAA weighs expanding in-trail climb program' – *Aviation Week & Space Technology*, 12 December 1994.

<sup>686</sup> 'Signs of progress are notable despite some questions and still some unresolved issues' – L Desmarais, *ICAO Journal*, November/December 1999.

<sup>687</sup> 'Future air traffic management: technology, operations and human factors implications' – *Air & Space Europe*, Vol 1, No. 1, 1999.

<sup>688</sup> 'Seeing ghosts' – *air traffic management*, May/June 2000.

<sup>689</sup> 'On the rails with AILS' – *air traffic management*, January-February 2000.

<sup>690</sup> 'Cleared for two-six left' – *air traffic management*, July-August 1999.

<sup>691</sup> 'NASA's wake vortex system promises increased capacity' – *Flight International*, 1 August 2000.



established<sup>692</sup>. Correspondingly, the need for additional airport capacity is continuously addressed, with Eurocontrol, ICAO and others looking at technical solutions<sup>693</sup>. In the meantime, noting that airport congestion is already a serious problem, unused capacity at lesser airports can shoulder some of the burden. Additionally, airspace and airport designers are aware of the environmental impact of aircraft noise and gaseous emissions when defining operational ATM improvements<sup>694</sup>.

Ground-based ATM infrastructures vary greatly between regions. Systems must interoperate with one another: On-Line Data Interchange (OLDI) technology has revolutionised the operational transfer of data between area control centres. Also on the ground, oceanic ATM is being improved through new Flight Data Processing Systems (FDPS2)<sup>695</sup> that process data from sources such as ADS and CPDLC to provide tools for the controller, which support future ATM concepts. However, the capability of present-day software to run automated processes is being questioned<sup>696</sup>, even though there is a need for greater exchange of information between ATM units with differing levels of ATM automation<sup>697</sup>.

Nonetheless, some success is evident, such as the 'Direct-To' tool, which automatically searches for aircraft eligible for shorter trajectories to downstream fixes<sup>698</sup>. Since software completion in 1999, it has been operating in shadow mode. The new Canadian Automated Air Traffic System (CAATS), which offers a paper-free environment with functions such as 4-D conflict probe and clearance validation, is also an example of advances in automated systems<sup>699</sup>. Correspondingly, The Australian Advanced Air Traffic System (TAAATS), which became fully operational in 2000, incorporates new technology (ADS, CPDLC) that links ground ATM automation systems with airborne avionics computers, thereby increasing flight path flexibility and providing more time for decision making<sup>700</sup>. In addition, authorities are investigating the potential of retinal-scan display technology in future ATC<sup>701</sup>: Eurocontrol is testing a prototype head-worn display that uses Retinal Scanning Display (RSD) technology, which is expected to be available in mid-2001<sup>702</sup>.

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<sup>692</sup> 'Tackling turbulence' – *air traffic management*, November/December 1998.

<sup>693</sup> 'ecac investigates airport capacity' – *era regional report*, November 2000.

<sup>694</sup> 'ACI Europe approves EC noise and ATC initiatives' – *Air Transport Intelligence*, 16 February 2000.

<sup>695</sup> 'An alternative procurement for the Future Oceanic Air Traffic Management System' – C Gibson, EDS. *Air Traffic Management in Europe: The business case for CNS/ATM Conference*, London, 1997.

<sup>696</sup> 'Are software and air traffic control incompatible?' – *Jane's Airport Review*, September 1999.

<sup>697</sup> 'CNS/ATM-GATM Transition taking off' – D Helgeson, Rockwell Collins. *Air Navigation Conference*, Amsterdam, 1998.

<sup>698</sup> 'The straight goods' – *air traffic management*, May/June 2000.

<sup>699</sup> 'Automated ATC system passes Nav Canada acceptance tests' – *Air Transport Intelligence*, 7 December 2000.

<sup>700</sup> 'Air-ground datalinks bring enhancements to Australian air traffic management' – *ICAO Journal*, May 2000.

<sup>701</sup> 'Eurocontrol studies retinal display aid for tower controllers' – *Air Transport Intelligence*, 20 December 2000.

<sup>702</sup> 'Eurocontrol considers Nomad display for air traffic' – *Flight International*, 2 January 2001.



## 4.5.2 ICAO's Global Plan

With reference to **Section 3.4**, the ICAO CNS/ATM system aims to create a unified strategy to support a seamless, global air traffic management system that improves present safety levels, enhances regularity and increases efficiency of airspace or airport operations, in addition to increasing the availability of user-preferred flight profiles and minimisation of the different equipment requirements between the regions. At a macro level, the system is made up by **Chapter 3's** concept and associated components using many of **Chapter 2's** CNS technologies.

The aforementioned advances in CNS technologies should serve to support future ATM, which is much more than just ATC because, as cited in **Chapter 3**, ATM's components include Air Traffic Services (ATS), Air Traffic Flow Management (ATFM), AirSpace Management (ASM) and the ATM-related aspects of flight operations. An integrated global ATM system should fully exploit the introduction of new technologies through international harmonisation of standards and procedures. This should enable aircraft to fly in preferred trajectories that can be dynamically adjusted in a cost-efficient manner.

When the ICAO Assembly initially endorsed the CNS/ATM concept and produced the 'Global Co-ordinated Plan for Transition to ICAO CNS/ATM Systems' document in the early 1990s, ICAO thought that ATC systems would evolve, as follows, in this decade:

- ❑ **2000-2005:** full CNS/ATM services available in parallel with existing systems so that appropriately equipped aircraft can have maximum operating benefits from CNS/ATM;
- ❑ **2005-2010:** the international terrestrial system not required for the CNS/ATM systems progressively dismantled<sup>703</sup>;
- ❑ **2010:** the CNS/ATM systems are the sole means for international use.

Thus, the target date for global FANS CNS/ATM implementation set by ICAO was 2010. However, it was soon realised that more concrete plans would be required. The 'Global Air Navigation Plan for CNS/ATM Systems' was consequently produced in 2000. The Global Plan contains approximate indications of CNS/ATM system implementation timeframes at a global level for each of the four components, namely Communications, Navigation, Surveillance and Air Traffic Management. The CNS/ATM implementation charts in the Global Plan, which are reproduced in **Appendix 4.1**, overview the aspirational timing of ICAO's solution at a global level.

Although the charts in the appendix show the implementation status of various technologies and systems, it must be remembered that there is still no integrated plan on a worldwide scale<sup>704</sup>. Even the regional Air Navigation Plans have not been produced. In addition, since the chart was developed, the implementation of specific programmes has not adhered to the timelines cited and certain aspects of the solution have already been postponed. Indeed, ICAO acknowledges that the exact integration dates in the Global Plan will be subject to change. Nonetheless, the diagrams provide indicative

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<sup>703</sup> 'Potential impact of FANS far-reaching and positive' – ICAO Journal, December 1991.

<sup>704</sup> 'Boeing FANS chief Ekstrand warns on slow progress' – Air Transport Intelligence, 9 March 2000.



guidelines and it is considered essential to show the aspirations of aviation's governing body. It is for these reasons, among others, that the analyses contained in **Part 2** of this dissertation aim to improve worldwide integration of CNS/ATM.

The fact that countries are starting to draft their own strategies, independent of the ICAO process, means that ICAO's Global Plan may never be comprehensively integrated. Success of the Global Plan depends on the degree to which regional cooperation and integration develop. An example of this evolution is the issue of FANS-1/A versus the Aeronautical Telecommunications Network (ATN), as previously mentioned. ICAO presently says that its recent acceptance of FANS-1/A is only as a stepping-stone to the ATN, but adoption of the ATN by carriers and providers in the future is not certain.

Therefore, ICAO still has a lot of work to do before its Global Air Navigation Plan is complete. For instance, the future ATM operational concept has yet to be clearly defined<sup>705</sup>. When complete, the concept should clarify the benefits of global ATM and give ICAO regional planning/implementation groups, States and industry a clearer objective for designing and implementing ATM systems than is presently available. The RCP, RNP, RSP and RSTP concepts aim to comprise the essential attributes of the CNS/ATM systems and should characterise operations in a given airspace. The concepts will provide the means to quantify and assure performance in terms of safety, efficiency and regularity. But, the operational and RTSP concepts are nowhere near completion.

Accordingly, the ICAO Planning and Implementation Regional Groups (PIRG) are still assessing regional situations and details. With most regions presently amending their Air Navigation Plans (ANP) to incorporate the new CNS/ATM system, **Section 4.7** discusses their particular solutions. ICAO is using the opportunity to alter the structure of ANPs and develop new-generation electronic aeronautical information databases with the ANPs and their Facilities and Services Implementation Document (FASID)<sup>706</sup>. ICAO's ALLPIRG<sup>707</sup>, its interregional co-ordination mechanism and advisory group, represents the PIRGs and aviation stakeholders. The ALLPIRG is currently active with the implementation of the ATN as the CNS/ATM-1 package.

ICAO believes that the benefits of new ATM systems will not be realised unless common international specifications are reached<sup>708</sup>. The Air Traffic Management operational Concept Panel (ATMCP) was therefore set up in 1998 to develop the necessary SARPs, procedures and guidance material for the Global Plan<sup>709</sup>. In addition, the panel is charged with developing the ATM requirements needed for CNS/ATM implementation<sup>710</sup>, which is dealt with as part of **Part 2**'s framework strategy. Thus, although progress appears to have been slow since ICAO's landmark Rio de Janeiro CNS/ATM conference in 1998, momentum may finally be gathering pace.

<sup>705</sup> 'Signs of progress are notable despite some questions and still some unresolved issues' – ICAO Journal, November 1999.

<sup>706</sup> 'ICAO air navigation planning database to support several initiatives' – ICAO Journal, May 1999.

<sup>707</sup> 'A forum for action' – Integrating Global Air Traffic Management, ISC & ICAO, 1998.

<sup>708</sup> 'ATM commonality crucial' – Orient Aviation, November 1999.

<sup>709</sup> 'Airborne separation to feature on new ICAO panel agenda' – air traffic management, May-June 1999.

<sup>710</sup> 'Panel strives to set out operational concept for a global ATM system' – ICAO Journal, May 2000.



### 4.5.3 Europe's ATM Strategy 2000+

**Section 3.5** details Europe's ATM initiatives, which are mainly encompassed in Eurocontrol's 'ATM Strategy for 2000+'<sup>711</sup>. The Strategy, which was endorsed in January 2000<sup>712</sup>, draws heavily on earlier Eurocontrol projects, such as the Programme for Harmonised Air Traffic Management Research (PHARE), which ran from 1989 to 1999. Therefore, current Eurocontrol projects are listed in **Appendix 4.2**, which also contains a summary of past and present European CNS/ATM projects that are of particular relevance to this dissertation. This section, however, appraises the 3-staged timeline planned by Eurocontrol, which is summarised in **Appendix 4.3**, in addition to discussing the European Union's involvement in the current European ATM situation.

#### Implementation of Eurocontrol's 'ATM Strategy 2000+'

With reference to the analysis of regional CNS/ATM in **Section 4.7**, it may be observed that Eurocontrol orchestrates the ATM implementation plans of the region's western part, while ICAO helps the other (Eastern European and Soviet) States. Thus, this section is concerned with ATM in Western Europe, although it should be noted that the interface with the Eastern region is acutely relevant. Indeed, the new Central European ATS (CEATS) Centre near Vienna<sup>713</sup>, which has a planned in-service date of 2007<sup>714,715</sup>, will cover a large area of the Eastern States' airspace<sup>716</sup> and hopes to bring a reduction in fees and delays<sup>717</sup>. When introduced, CEATS and Maastricht will control a large element of Europe's upper airspace above FL290.

The timing of the ATM Strategy 2000+ plan in **Appendix 4.3** lists the operational improvements and their associated period of introduction that the strategy aims to adopt. The short-term objectives, until 2005, predominantly try to increase capacity, with some improvement in flexibility. The aspirations of this Step 1 are quite realistic because they were mostly developed in previous programmes. Indeed, EATCHIP, which allegedly extracted 40% extra capacity from existing ATM facilities<sup>718</sup>, may be seen as the start of the integration of ATC systems. Accordingly, airlines and decision makers realise the severity of the present situation and consequently try to adhere to the schedule. It should be noted that the whole aviation community was consulted in the preparation of the Strategy<sup>719</sup>, although some argue that the Strategy is too theoretical<sup>720</sup>.

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<sup>711</sup> 'ATM Strategy for 2000+' document – Volume I & Volume II, Eurocontrol, 1998.

<sup>712</sup> 'European Transport Ministers act on Air Traffic Management' – ECAC/Eurocontrol Joint Press Release, 28 January 2000.

<sup>713</sup> 'New initiative revives hopes for central European ATC unity' – *Flight International*, 14 May 1997.

<sup>714</sup> 'Jane's Air Traffic Control' – 6<sup>th</sup> Edition, 1999-2000.

<sup>715</sup> 'Seamless system' – *Flight International*, 4 April 2000.

<sup>716</sup> Countries include Austria, Bosnia-Herzegovina, Croatia, the Czech Republic, Hungary, Italy, Slovakia and Slovenia.

<sup>717</sup> 'CEATS moves a step closer' – *Jane's Airport Review*, September 1999.

<sup>718</sup> 'Air traffic management for the 21<sup>st</sup> century' – *era yearbook*, 1999.

<sup>719</sup> 'Shaping Europe's future' – *Jane's Airport Review*, October 1997.

<sup>720</sup> 'Airlines express their concerns over Eurocontrol ATM strategy' – *Flight International*, 26 November 1997.



In order to evaluate the current situation of Step 1's implementations, consider the following synopsis:

- **B-RNAV** – Basic-RNAV has been introduced in Europe since August 1998<sup>721</sup>, which was initially set as the deadline for Precision-RNAV (P-RNAV). Even though many carriers were not ready, B-RNAV was started because others had equipped and, according to a Eurocontrol study, capacity gains of 30% are achievable through uniform application of B-RNAV. It has permitted more efficient use of the Flexible Use of Airspace (FUA) concept and allowed a redesigned ATS route network. By 1997, the FUA concept had been implemented in most Eurocontrol States<sup>722</sup>. P-RNAV is expected to be mandatory in 2005<sup>723</sup>;
- **RVSM** – Reduced Vertical Separation Minima are expected in January 2002 over 38 European States, between FL290 and FL410<sup>724,725</sup>. It was initially thought that some States could apply RVSM in specific areas from March 2001<sup>726</sup>, but this was subsequently declined<sup>727</sup>. Due to participation in North Atlantic RVSM, Ireland and the Northern UK FIR are exceptions and will introduce RVSM in April 2001<sup>728</sup>. The height monitoring equipment has been installed<sup>729</sup>. It is thought that the task is more difficult in Europe than over the North Atlantic, given its airspace structure<sup>730</sup> and number of countries<sup>731</sup>. Similar to the North Atlantic implementation, corporate users are sceptical<sup>732</sup>. Indeed, it was recently announced that implementation delays could be expected due to poor aircraft equipage rates, readiness of States and developing a safety case in time<sup>733</sup>. In addition, Eurocontrol is concerned about just over 2,000 aircraft, for which an RVSM solution has not yet been developed<sup>734</sup>. Aircraft such as the BAe-146 may be banned<sup>735</sup>. Therefore, BAe is considering a new CNS/ATM cockpit programme<sup>736</sup>;
- **Mode S transponder** – entered operational validation on the 1<sup>st</sup> of January 2000 for new aircraft and will be requisite in Basic form at the start of 2003 for all other IFR aircraft or start of 2005 for all VFR airplanes<sup>737</sup>. Enhanced Mode S is expected in 2005. It should be noted that Germany is the only nation to have committed to the Basic Mode S 2003 in-service date. Airlines are sceptical of Mode S's value,

<sup>721</sup> 'Eurocontrol extends B-RNAV deadline' – *Navigation News*, May/June 1998.

<sup>722</sup> 'An investigation of the EATCHIP concepts of the Flexible Use of Airspace (FUA), Area Navigation (RNAV) and Reduced Vertical Separation Minima (RVSM) with particular reference to the Dublin-UK routes' – D Hamill, Cranfield University MSc thesis, September 1997.

<sup>723</sup> 'navigation and communications reference timetable' – *era regional report*, October 1999.

<sup>724</sup> 'Eurocontrol firms up separation plans in bid to beat congestion' – *Flight International*, 27 January 1999.

<sup>725</sup> 'Taking to new heights: RVSM in Europe' – *Navigation News*, July/August 1999.

<sup>726</sup> 'Eurocontrol ACG meeting: new RVSM deadline set' – *era regional report*, April 1999.

<sup>727</sup> 'Eurocontrol turns down plan for early RVSM' – *Air Transport Intelligence*, 8 September 1999.

<sup>728</sup> 'UK and Ireland ready for early RVSM launch' – *Flight International*, 11 July 2000.

<sup>729</sup> 'RVSM height monitoring system implemented' – *Flight International*, 21 November 2000.

<sup>730</sup> 'New levels' – *Flight International*, 3 February 1999.

<sup>731</sup> 'Making room with RVSM' – *air traffic management*, September/October 2000.

<sup>732</sup> 'EBAA concerned on European RVSM' – *Flight International*, 6 May 1998.

<sup>733</sup> 'Risks stack up for Europe's reduced separation plan' – *Flight International*, 5 December 2000.

<sup>734</sup> 'No RVSM solution for many airlines: Eurocontrol' – *Air Transport Intelligence*, 14 November 2000.

<sup>735</sup> 'Ban on airliners failing to meet RVSM standards' – *Flight International*, 19 September 2000.

<sup>736</sup> 'BAe 146 cockpit upgrade offers Cat 3 capabilities' – *Flight International*, 25 July 2000.

<sup>737</sup> 'Eurocontrol to present Mode S business case' – *Flight International*, 14 April 1999.



thinking that technologies such as ADS-B may make Mode S obsolete<sup>738</sup>. It is for such reasons that Eurocontrol has decided to use Mode S as a test case for its Eurocontrol Notice of Proposed RuleMaking (ENPRM) system<sup>739</sup>. Indeed, it should be noted that Eurocontrol published details of its NPRM at the end of 2000<sup>740</sup>;

- **8.33 kHz** – this voice channel frequency spacing above FL245 was introduced in October 1999. It will probably extend to other levels after 2003<sup>741</sup>;
- **ACAS type II** – became requisite for aircraft with Maximum Take-Off Weights (MTOW) greater than 15 tonnes flying in Europe at the beginning of 2000, noting that a transitional period for those with exemptions ends on March 31<sup>st</sup> 2001. Business aircraft operators must install ACAS II/TCAS 2 by 2005. Aircraft not fitted with the system face being refused entry into dense airspace areas or being grounded for not meeting airworthiness requirements<sup>742</sup>;
- **VHF DataLink (VDL)** – the whole issue of which datalink to adopt is still being assessed. The decision for Controller Pilot DataLink Communications (CPDLC) using the ATN, VDL Mode 2 or VDL Mode 4 is tied in with ICAO SARPs developments. Progress is presently being made with VDL-2. It should be noted that the Eurocontrol project, FREER, has shown that datalink is technically feasible<sup>743</sup>.

Therefore, it appears that the majority of Step 1's objectives are being fulfilled. The European Union (EU) has made considerable funding available through its 4<sup>th</sup> and 5<sup>th</sup> Research Framework Programmes. However, noting that Europe has been plagued by delays<sup>744,745</sup> and poor punctuality, the region is still debating many other issues, such as its strategy for Global Navigation Satellite System (GNSS)<sup>746</sup>, which includes EGNOS and Galileo, as discussed in **Section 4.3**. Correspondingly, a lot of airspace redesign is being conducted: for instance, reorganisation of some UK airspace in 1999 increased capacity<sup>747</sup>. In a similar manner, some European airports are thought to be committing to Microwave Landing Systems (MLS) for greater flexibility and associated capacity increases in the terminal area.

In addition, Eurocontrol hopes to increase capacity through its Free Route Airspace Project (FRAP), which aims to offer operators direct routes through the upper airspace regions of eight EU States, from their point of entry to exit, without having to follow a fixed route structure. FRAP started in 1999<sup>748</sup> as part of the 2000+ Strategy, with free routings expected from 2002<sup>749</sup>. Responsibility for separation will remain with the

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<sup>738</sup> 'Modernising with Mode-S' – air traffic management, May/June 2000.

<sup>739</sup> 'European airlines question Mode S surveillance system' – *Flight International*, 25 April 2000.

<sup>740</sup> 'Eurocontrol prototypes rule-making proposals' – *Air Navigation International*, 2 October 2000.

<sup>741</sup> 'navigation and communication reference timetable' – era regional report, may 2000.

<sup>742</sup> 'Eurocontrol wants ACAS delay' – *Flight International*, 12 August 1998.

<sup>743</sup> 'FREER: a solution for European Free Flight implementation?' – V Duong, Eurocontrol. 3<sup>rd</sup> Air Navigation Conference, Amsterdam. September 1997.

<sup>744</sup> 'Eurocontrol warns of French and Swiss ATM disruptions' – *Flight International*, 24 February 1999.

<sup>745</sup> 'NATO attacks force Eurocontrol re-jig' – *Air Transport Intelligence*, 29 March 1999.

<sup>746</sup> 'Euro Satnav' – *Flight International*, 22 February 2000.

<sup>747</sup> 'Airspace changes will cut flight delays' – CAA News Release, 21 January 1999.

<sup>748</sup> 'Eurocontrol launches the 8-States Free Route Airspace Project' – *ATC Network*, August 1999.

<sup>749</sup> 'Integrating Air Traffic Management – the European experience' – *Integrating Global Air Traffic Management*, ISC & ICAO, 1998.



controllers. FRAP should be beneficial to Europe's fragmented ATC system, which consists of 49 ATC centres, 31 national systems, 18 suppliers of hardware, 22 operating systems and 30 programming languages<sup>750</sup>. Accordingly, iterative improvements in traffic flow were agreed in 1999 by enhancing co-operation between Area Control Centres (ACC)<sup>751</sup>.

Hence, much effort is being placed on gaining short-term capacity and some flexibility improvements during the period until 2005<sup>752</sup>. Indeed, Eurocontrol asked its Member States in 1999 to provide data on their capacity enhancement plans until 2005<sup>753</sup>. The outcome of this first step will impact greatly on the subsequent two steps until 2015, which are also covered in **Appendix 4.3**. In these latter two stages, some European air traffic specialists doubt whether Free Flight will ever work in Europe's high-density environment<sup>754</sup>. Correspondingly, it was realised in 1995 that European ATC would continue to depend heavily upon direct human input for the foreseeable future<sup>755</sup>, even though EATCHIP was supposed to have introduced "extensive automation"<sup>756</sup>. On that note, authorities are concerned about the shortage of controllers in Europe<sup>757</sup>. However, it remains to be seen whether the transfer of responsibility for separation will migrate to the cockpit after 2010, as mentioned in **Appendix 3.4**. Emphasis is also being placed on maximising available capacity through the Collaborative Decision Making (CDM) concept, which will be introduced in the Strategy 2000+ Step 2 (2005 to 2010)<sup>758</sup>.

Ultimately, noting that the US FAA has given its support to Eurocontrol's ATM endeavours<sup>759</sup>, the latter is adopting a multilateral approach to improving the region's ATM, using different methods to accommodate demand for increased capacity<sup>760</sup>. For instance, it is targeting the area control centres that have been highlighted in recent performance review reports (see **Part 2** of this thesis) as having created many ATC delays. Specific improvements in the ATM procedures of such centres should bring benefits and reduce delays: Eurocontrol estimates that it can eliminate the delays by 2008<sup>761</sup>. Additionally, Eurocontrol is planning to re-run its future ATM profile model to meet capacity shortfalls from 2002 to 2005. It is also developing an Enhanced Tactical Flow Management System (ETFMS) that provides a continuously updated real positional data. The contract for ETFMS was awarded in 2000<sup>762</sup>. However, Eurocontrol's actions using its present powers may not suffice and it is for this reason that the EU Commission is attempting to increase co-operation of States.

<sup>750</sup> Association of European Airlines (AEA) – Yearbook, 1999.

<sup>751</sup> 'Eurocontrol settles on remedies to increase capacity' – *Flight International*, 28 July 1999.

<sup>752</sup> 'Eurocontrol Provisional Council discusses important issues' – *ATC Network*, August 1999.

<sup>753</sup> 'Eurocontrol delays steps to taking regulatory powers' – *Flight International*, 21 July 1999.

<sup>754</sup> 'Free Flight sparks international debate' – *Aviation Week & Space Technology*, 31 July 1995.

<sup>755</sup> 'The future's controller' – *Flight International*, 11 October 1995.

<sup>756</sup> 'How Eurocontrol will harmonise Europe's ATC system' – P Stalpers, Eurocontrol. Air Traffic Control '91 conference, Maastricht. February 1991.

<sup>757</sup> 'European shortfall in air traffic controllers' – *Air Transport Intelligence*, 27 November 2000.

<sup>758</sup> 'Collaborative decision making' – *Air Traffic Technology International* 2001.

<sup>759</sup> 'USA backs Eurocontrol ATM' – *Flight International* 9 June 1999.

<sup>760</sup> 'Recent initiatives serve to modernize and increase capacity of European airspace' – *ICAO Journal*, March 1998.

<sup>761</sup> 'Eurocontrol moves to cut delays' – *Flight International*, 12 December 2000.

<sup>762</sup> 'The global picture' – *Air Traffic Technology International* 2001.



## The EU Commission's single sky

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The European Commission (EC) is very concerned about the level of delays in recent summers and the expected worsening situation over the coming five years. Therefore, its first initiative is to ensure that the immediate impact of delays is reduced in the first half of this decade. The Commission claims that responsibility for the delays rests with operators, airports and the saturation of airspace. Indeed, it is argued that the airlines' wishes for more services, with greater use of regional jets<sup>763</sup>, have added to the problem. According to the EC, the latter is due to "Europe's lack of inter-operable ATM infrastructures and segregated airspace regions based on political frontiers".

The second major emphasis of the Commission's efforts is the reform of Europe's ATM. It wishes to work with Eurocontrol and the Community's member countries to create a single sky. The EC believes that more work is needed, so that Europe can implement the objectives of the 'ATM Strategy for 2000+'. However, the Commission believes that this cannot be conducted solely using technical and operations solutions, that collective management is needed, which must make for substantial reorganisation of ATC sectors and airspace regions. Thus, airspace management must occur irrespective of borders and be under a central organisation that has full responsibility at strategic and tactical levels.

Hence, the Commission believes that the following short-term actions are needed:

- Eurocontrol must draw up and use emergency plans to cope with crises;
- Eurocontrol must also come up with alternative routes and put them in practice when the need arises;
- Set up a uniform body that organises and plans European ATM, with representation of all stakeholders and Eurocontrol. The EC has noted Eurocontrol's lack of powers, even since its revised Convention of 1997. Therefore, the Commission created a high-level group to examine the reform of Europe's ATM<sup>764</sup>. The group recently delivered its final report<sup>765</sup>, which says that the EU should develop a more active rôle as the key arbiter of European air traffic regulation by 2005, while detailed implementation and monitoring of the new ATM system would be undertaken by an autonomous regulator. It is thought that, under the proposed guidelines, Eurocontrol would have an advisory rôle as a support body: Eurocontrol is arguing against this regulator, claiming that it should have more power. However, Eurocontrol claims that the political dispute between Spain and the UK over Gibraltar is holding up plans to accept the EU as a member of the organisation<sup>766</sup>. The report says that the Commission will work with Eurocontrol and the national air traffic authorities to put structures in place by 2005 that will enable creation of a single European airspace<sup>767</sup>.

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<sup>763</sup> 'A revolution stumbled' – *Aerospace International*, December 2000.

<sup>764</sup> 'Communication from the Commission to the Council and the European Parliament – The creation of the single European sky' – 29 November 1999, Brussels.

<sup>765</sup> 'Rewriting the rules on ATM' – *Airline Business*, January 2001.

<sup>766</sup> 'Gibraltar row still blocking EU's Eurocontrol entry' – *Air Transport Intelligence*, 27 November 2000.

<sup>767</sup> 'Report prompts EC to launch air traffic reform effort' – *Air Transport Intelligence*, 18 December 2000.



Similarly, EU governments will have to adopt new laws and try to reach consensus with the non-EU Eurocontrol Member States.

However, the Commission is aware that success is dependent on the involvement and collaboration of many players. Hence, new decision-making mechanisms are needed, which require:

- Use of Eurocontrol's 'Medium Term Capacity Planning' measure;
- Creation of a regulatory framework for the provision of air traffic services that applies common rules;
- Development of new incentives to support voluntary equipage;
- Generation of a fund for financing common projects, which are essential to the performance of the European network.

Aviation stakeholders also consider that a unified system would, among other solutions, solve many of Europe's ATM problems<sup>768,769,770</sup>. IATA produced a five-point action plan in 1999 for improving European ATM<sup>771</sup>, thus:

1. Adopt the ATM 2000+ Strategy in full;
2. Give Eurocontrol and the EU the necessary regulatory powers and processes;
3. Establish a permanent European-wide capacity planning process;
4. Liberalise the provision of Air Traffic Services (ATS);
5. Develop incentives for ATS.

Correspondingly, the Civil Air Navigation Services Organisation (CANSO) has called for the following changes with its Recommendation Plan<sup>772</sup>:

1. Adopt the ATM 2000+ Strategy in full;
2. Service provision should be freed from political control and states should make available, to service providers, appropriate resources such as airspace and spectrum, free from constraints of national boundaries;
3. Service providers should be made accountable for the safety and performance of the ATM system since they have the most direct control over meeting and developing the service;
4. Change the current charging mechanism for ATM so as to introduce appropriate incentives for service providers to perform in terms of service value and safety;
5. Establish separate regulatory authority to protect the interests of consumers by, wherever possible and appropriate, encouraging competition whilst maintaining firm adherence to safety standards.

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<sup>768</sup> 'Airports and airlines join forces over ATC delays' – *Airline Business*, January 2000.

<sup>769</sup> 'Commissioner urges action over inefficient ATS' – *Flight International*, 8 December 1999.

<sup>770</sup> 'Boeing sees European governments fixing ATC' – *Air Transport Intelligence*, 14 September 1999.

<sup>771</sup> 'ATC in Europe: An IATA action plan for the new millennium' – IATA, 1999.

<sup>772</sup> 'ATS Provision – a way forward' – CANSO, October 1999.



#### 4.5.4 US Free Flight

**Section 3.6** discusses the US approach to CNS/ATM, 'Free Flight'. The US RTCA maintains<sup>773</sup> that "any activity which removes restrictions is a move towards Free Flight", a view reiterated by RMB Associates, the vocal proponents for Free Flight, who believe that it will be an ever-evolving concept<sup>774</sup>. Thus, Free Flight has already started with the methods of ATM improvements in the short-term described in **Section 3.6.1** and aspirations of previous 'National Airspace System Plans' that describe the facilities, equipment, associated development and other capital needs.

Correspondingly, in contrast with the aspirational notion that Free Flight enables an aircraft to fly in whatever trajectory that it wishes, avoiding conflicting traffic where necessary, Free Flight consists of a multitude of capacity and flexibility enhancing methods, which will be implemented in the short and long term. Free Flight does not consist of a single solution that will be implemented overnight. So, in order to clarify the future of CNS/ATM in the US, this section deals with the planned integration of Free Flight and the success to date: even though Free Flight was first analysed in the US as part of a 1981 study, 'Operation Free Flight', which tested direct-route flight paths, it was not until the RTCA became the co-ordinating body for Free Flight with the FAA that all key players in the US were represented. Since then, Free Flight has been, and continues to be, developed, tested and incrementally implemented by the FAA and the aviation community through the RTCA.

The US attaches great importance to the condition of its ATM: outgoing US president Bill Clinton recently issued an executive order directing the FAA to create a performance-based organisation to manage the operation of air traffic services<sup>775</sup>. In a similar manner, Boeing is preparing an unsolicited proposal for mid-2001 to lead development of a new GPS-based ATM system<sup>776</sup>. The avionics giant, Honeywell, told the US Congress recently that its technology solutions could help curb the delays<sup>777</sup>. In addition, American Airlines is starting to alter its schedules to accommodate increased delays: for instance, American Airlines (AA) has isolated its Chicago hub from the rest of its network<sup>778</sup>. It should be noted that AA and other carriers believe that airlines should not shoulder all of the blame for delays<sup>779</sup>, which are getting worse<sup>780</sup>, apparently due to increased airspace congestion<sup>781</sup>. Saturation of US airspace is the result of many factors, including the high adoption of regional jets in the region<sup>782</sup>, although the Regional Airline Association denies that this is the cause<sup>783</sup>.

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<sup>773</sup> 'Free for all' – *Airline Business*, November 1999.

<sup>774</sup> 'Free Flight – Rapid Implementation' – *RMB Associates*, 1 July 1995.

<sup>775</sup> 'FAA to reform ATC unit' – *Air Transport World*, January 2001.

<sup>776</sup> 'Boeing offers to solve US congestion problems' – *Flight International*, 31 October 2000.

<sup>777</sup> 'Honeywell tells Congress it has answers to delays' – *Air Transport Intelligence*, 3 October 2000.

<sup>778</sup> 'American Airlines reveals plans to combat delays' – *Flight International*, 19 September 2000.

<sup>779</sup> 'Airlines not solely to blame for delays: Carty' – *Air Transport Intelligence*, 28 June 2000

<sup>780</sup> 'US ATC delays soar again' – *Airline Business*, August 2000.

<sup>781</sup> 'FAA outlines full extent of LaGuardia delay horror story' – *Air Transport Intelligence*, 9 November 2000.

<sup>782</sup> 'Jam tomorrow' – *air traffic management*, March-April 1999.

<sup>783</sup> 'RAA fights notion that RJs jam up US ATC system' – *Air Transport Intelligence*, 6 November 2000.



Since its resurrection in the 1990s, many different opinions have been cited regarding the integration timeline of Free Flight and whether it is feasible at all. In 1996, the FAA developed a Free Flight action plan and a government-industry Free Flight Steering Committee was formed to establish an implementation strategy and to identify new Free Flight implementation opportunities<sup>784</sup>. This Committee worked with ICAO's CNS/ATM committees and co-ordinated activities with Eurocontrol in order to define Free Flight because problems existed<sup>785</sup>.

In 1998, the FAA produced a blueprint for Free Flight<sup>786</sup>. In essence, it was a modernisation plan for the US National Airspace System (NAS). Indeed, a Modernisation Task Force of the aforementioned RTCA developed it in conjunction with the whole aviation community. The blueprint adopted a phased approach to modernisation, ultimately leading to the goal of Free Flight. The FAA acknowledged in the blueprint that ground-based aids will be needed indefinitely as backups to a satellite-based system due to concerns over jamming of GPS signals<sup>787</sup>. The FAA further revised its blueprint NAS Architecture plan in 1999<sup>788</sup> to bring early user benefits by reducing the costs and risks, noting that operators are reluctant to incur the cost of equipping their fleet with new technologies. The 1999 NAS Architecture (Version 4) lays out a plan, with the transition split into three phases, thus:

- **Phase 1 (1998 – 2002):** The FAA and the RTCA have agreed the elements, which include the implementation of limited Free Flight prototypes. This is purely ground-based and involves making existing, but not widely used, ATM capabilities quickly available to the airlines without the need to re-equip with expensive avionics. For instance, the present system is continually being improved in this phase through higher levels of automation aids. The Standard Terminal Automation Replacement System (STARS) is expected to enable NAS efficiency improvements<sup>789</sup>, but has experienced considerable delays<sup>790</sup>. Initial deployment of STARS workstations has occurred<sup>791</sup>. The FAA planned to integrate its longstanding National Route Program (NRP) into the overall Free Flight concept by phasing in altitude and geographic distinctions during Phase 1. Additionally, it aimed to open up Special Use Airspace (SUA), deploy the Wide Area Augmentation System (WAAS) and increasingly employ aRea NAVigation (RNAV) routes. A Free Flight Phase 1 programme office was established in October 1998 to serve as the single point of accountability within the FAA for Phase 1 issues<sup>792</sup>;
- **Phase 2 (2003 – 2007):** This phase begins the transition to Free Flight per se, which aims to deploy the next generation of CNS equipment together with automation upgrades, to bring decision-support systems for ATM. For instance, Phase 2 will

<sup>784</sup> 'Free Flight – Introduction' – [www.faa.gov/freeflight](http://www.faa.gov/freeflight).

<sup>785</sup> 'The cost of Free Flight' – *Flight International*, 11 June 1997.

<sup>786</sup> 'Transition Planning' – *Flight International*, 28 October 1998.

<sup>787</sup> 'FAA free flight programme to retain existing ground navaids' – *Flight International*, 7 October 1998.

<sup>788</sup> 'FAA upgrades NAS modernisation plan' – *Air Transport Intelligence*, 9 March 1999.

<sup>789</sup> 'FAA/DoD partnership flourishes via Standard Terminal Automation Replacement System (STARS)' – *Journal of ATC*, October-December 1999.

<sup>790</sup> 'Raytheon wins \$270m STARS final design mod work' – *Air Transport Intelligence*, 3 May 2000

<sup>791</sup> 'STARS in service at second site' – *Air Navigation International*, 7 February 2000.

<sup>792</sup> 'Free Flight Phase 1' – <http://ffp1.faa.gov>.



assume responsibility for joint FAA-industry efforts to implement CPDLC technology<sup>793</sup>. The FAA also aims to complete WAAS during this phase, so that precision instrument approaches are facilitated. In addition, the FAA aims to install Automatic Dependent Surveillance (ADS): the Safe Flight 21 programme includes an analysis of the technology and procedures<sup>794</sup> that may be augmented through the use of ADS-Broadcast (ADS-B)<sup>795,796</sup>. In essence, it is designed to test the Free Flight concept in a working environment with GPS receivers, ADS-B transceivers and CDTI. There will consequently be a greater need for changes to avionics, although the enabling technologies have yet to be concretely decided;

- **Phase 3 (2008 – 2015):** the FAA aims to complete the required infrastructure and integration of new automation to enable limited Free Flight operations. This phase should see NAS-wide information sharing among users and service providers, in addition to 4-dimensional profiles that enable greater flexibility and planning.

Interestingly, there is no plan for RVSM in the Eastern US, the busiest airspace in the world: this is because airlines could not afford the fleet modification costs and some aircraft could not be technically upgraded.

The timeline shows how Free Flight Phase 1 (FFP1) has been in operation since 1998 and that it is still the current phase. The FAA claims adherence to its schedule<sup>797</sup>. According to Charlie Keegan, FAA Director of FFP1<sup>798</sup>, Phase 1 is concentrating on increasing the NAS capacity through deployment of some core capabilities, which “were selected to provide near-term measurable improvements in operational freedom to users, consistent with ... long-term plans for NAS modernisation”. Implementation of the core capabilities, which are FFP1’s enabling technologies, emphasise co-operation between the FAA and the users. They may be described and their integration timing listed as follows:

- **Surface Movement Advisor (SMA)** – facilitates the sharing of aircraft arrival information to airlines to augment decision-making regarding the surface movement of aircraft. It commenced in 1999 and was completed on schedule<sup>799</sup>;
- **Collaborative Decision Making (CDM)** – provides airline operations centres and the FAA with real-time access to NAS status information<sup>800</sup> in the departure phase

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<sup>793</sup> 'FAA names Free Flight Phase 2 programme overseer' – *Air Transport Intelligence*, 11 May 2000.

<sup>794</sup> The operational enhancements to be demonstrated by Safe Flight 21 include bringing weather and other information into the cockpit; reducing CFIT; improving approaches in low-visibility conditions; delegating aircraft separation authority to pilots; improving pilots' ability to navigate airport taxiways; enhancing the capability to see and avoid adjacent traffic; improving controllers' tools for managing aircraft and other surface traffic; providing surveillance coverage in non-radar airspace; and improved separation standards.

<sup>795</sup> 'Free Flight Collaboration: The Politics and Pain of Change from the Perspective of the National Air Traffic Controllers' Association' – K Grundman, NATCA. *Air Traffic Management: Prospects for Free Flight SMi Conference*, London, 1999.

<sup>796</sup> 'Safe Flight 21: government and industry partnerships enhancing aviation' – *Journal of ATC*, July-September 1999.

<sup>797</sup> 'USA's air traffic control update is 'on track'' – *Flight International*, 1 August 2000.

<sup>798</sup> 'Overview of the USA's Free Flight Position' – C Keegan, FAA. *Air Traffic Management: Prospects for Free Flight SMi Conference*, London, 1999.

<sup>799</sup> 'Lessons learned during Free Flight Phase 1 technology transfer' – *Journal of ATC*, April-June 2000.

<sup>800</sup> 'Collaborative Decision Making in Aviation' – *Journal of ATC*, April-June 1998



of flight. CDM is due to start in mid-2001 and is ahead of schedule. It has been demonstrated through SMART<sup>801</sup> and by one of its components, CDMnet, the communications network over which airlines send their latest schedule updates<sup>802</sup>;

- **User Request Evaluation Tool (URET)** – enables controllers to manage user requests in en-route airspace during the cruise phase by identifying potential conflicts. URET is projected to be implemented in late 2002, noting that a conflict probe and related decision aids based on URET have been successfully tested<sup>803</sup>;
- **Traffic Management Advisor (TMA) Single Centre (SC)** – provides en-route controllers with the capability to develop arrival sequence plans while the aircraft is still in the cruise. Integration of TMA is expected in late 2001. It should also be noted that the FAA has introduced a Departure Spacing Programme (DSP)<sup>804</sup>;
- **Passive Final Approach Spacing Tool (pFAST)** – maximises take-offs and landings by helping controllers sequence aircraft and assign runways when the aircraft is in the final approach phase. The integration of pFAST is planned for the end of 2001, although it has been operational at the Dallas-Fort Worth TRACON since 1999<sup>805</sup>.

Keegan also stresses that other Free Flight initiatives are being tried and implemented, such as Display System Replacement (DSR): the first DSR was incorporated in the Seattle ATC centre at the end of 1998<sup>806</sup>; the \$1 billion project was completed in 2000<sup>807</sup>. The short-term ATM improvements that are mentioned in **Section 3.6.1** have also been implemented to date, in addition to some activities relating to WAAS, as assessed in **Section 4.3.3**. In addition, future technologies for the oceanic centres are presently being evaluated<sup>808</sup>: the routes from the US mainland to Hawaii have been a focus of Flight 2000<sup>809</sup>, a mainly Alaska-based plan that the FAA decided to compile in 1998 to evaluate many operational aspects of Free Flight<sup>810</sup>. Flight 2000 was shelved after it failed to get Congressional approval and now exists as a scaled-down version, the Capstone project, which is due to continue in Alaska until 2003<sup>811</sup>. Capstone is also validating other Free Flight operational enhancements and technologies. Flight 2000 and Capstone are both pre-cursors to Free Flight<sup>812</sup>.

The FAA also says that lack of new runway construction at the US's busiest airports will be the most serious capacity problem affecting their air transport system in the coming years<sup>813</sup>. Therefore, it has initiated improvements in ATC procedures that

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<sup>801</sup> 'Self-Managed Arrival Resequencing Tool (SMART): an experiment in Collaborative Air Traffic Management' – *Journal of ATC*, April-June 1997.

<sup>802</sup> 'Surfing the CDMnet' – *air traffic management*, March-April 1999.

<sup>803</sup> 'Conflict probe for airspace users and controllers' – *Air Traffic Technology International* '98.

<sup>804</sup> 'FAA departure sequencing system goes operational' – *Air Transport Intelligence*, 2 June 2000.

<sup>805</sup> 'Passive acceptance' – *air traffic management*, May-June 1999.

<sup>806</sup> 'Sweetness in Seattle' – *air traffic management*, January-February 1999.

<sup>807</sup> 'DSR system now fully operational at all FAA ATC centres' – *Air Transport Intelligence*, 18 July 2000.

<sup>808</sup> 'ARINC team set to show oceanic ATC system to FAA' – *Air Transport Intelligence*, 3 March 2000.

<sup>809</sup> 'Free Flight – who pays?' – *Flight International*, 22 October 1997.

<sup>810</sup> 'Modernising US airspace' – *Flight International*, 18 February 1998.

<sup>811</sup> 'Alaska High' – *air traffic management*, September/October 2000.

<sup>812</sup> 'Flight 2000: path to Free Flight' – *Journal of ATC*, October-December 1997.

<sup>813</sup> 'Lack of runways will plague US air transport system: FAA' – *Air Transport Intelligence*, 17 January 2001.



increase utilisation of multiple runways, thereby providing additional capacity. In order for airports with closely spaced parallel runways to take advantage of the maximum capacity gains possible from the use of simultaneous approach procedures, they need to use airport surveillance radars with high-azimuth accuracy and rate of return. Precision Runway Monitors (PRM) have been developed to facilitate this<sup>814</sup>. PRMs employ electronically scanned, circular phased array antenna and colour Cathode Ray Tube (CRT) monitors, which enable simultaneous parallel approaches to be conducted with a radar controller monitoring traffic on each approach path. Accordingly, it should be noted that runway incursions are considered to be a big problem in the US<sup>815</sup> and are a high-priority issue<sup>816</sup>. Indeed, the FAA announced in 2000 that it is implementing ten near-term measures at congested airports, mainly based on training procedures<sup>817</sup>.

However, there are still many concerns with the certification, requirements, procedural concepts and deployment rate limitations for Phase 1. It would appear, from a study conducted by US airlines and the FAA, that ATM in the US is plagued with major flaws from poor equipment standardisation to lack of communications with the FAA<sup>818</sup>. Correspondingly, a government watchdog report recently blamed a lack of urgency in the FAA for strong increases in the number of operational errors by controllers<sup>819</sup>. These and other sagas have prompted calls for improved ATC<sup>820</sup>.

Nonetheless, airlines have become more content with progress of the US approach to CNS/ATM over the last few years, stressing that collaboration is essential to tackle the large amount still to be done prior to ultimate benefits being obtained: to the passenger in terms of reduced delays and increased schedule predictability; to airline economics from increased abilities to plan routes and altitudes. Ultimately, the airlines believe that a future NAS solution is possible<sup>821</sup>.

Correspondingly, the (US) National Air Traffic Controllers Association (NATCA) has accepted Free Flight as the way forward, albeit after much initial scepticism. NATCA believes that collaboration among the various players of the air transport industry is essential for the implementation of CNS/ATM<sup>822</sup>. The Association also observes that, even though a set of operational guidelines have been developed, no set of metrics has been agreed, upon which the safety level of the ATC system may be assessed. NATCA is a member of the Free Flight Select Committee, which is finally adopting recommendation based on consensus of its members. Phase 1 is an example. Ultimately,

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<sup>814</sup> 'Airports with parallel runways can increase capacity, improve safety by using PRM system' – ICAO Journal, March 1998.

<sup>815</sup> 'No trespassing' – Air Transport World, March 2000.

<sup>816</sup> 'FAA declares war on runway incursions' – air traffic management, September/October 2000.

<sup>817</sup> 'FAA carries out runway plan' – Flight International, 8 August 2000.

<sup>818</sup> 'Report highlights FAA air traffic deficiencies' – Flight International, 15 September 1999.

<sup>819</sup> 'DOT IG blames FAA laxity for ATC operational error surge' – Air Transport Intelligence, 20 December 2000.

<sup>820</sup> 'FAA directed to shake-up ATC' – Flight International, 12 December 2000.

<sup>821</sup> 'Free Flight: Preserving Airline Opportunity' – R Chew, American Airlines. Air Navigation Conference, Amsterdam, 1997.

<sup>822</sup> 'Free Flight Collaboration: The Politics and Pain of Change from the Perspective of the National Air Traffic Controllers' Association' – K Grundman, NATCA. Air Traffic Management: Prospects for Free Flight Conference, London, 1999.



according to NATCA<sup>823</sup>, “Free Flight is a platform for discussions about improving an inadequate air traffic control system”. Correspondingly, NATCA thinks<sup>824</sup> that “Free Flight is just a banner ... to enhance capacity”.

It is said that one of the major issues affecting the progression of Free Flight has been the adoption of enabling technologies<sup>825</sup>. Another is the question of funding, with US budgetary approvals always the subject of debate<sup>826</sup> and contention<sup>827</sup>, although a \$40 billion FAA funding budget was granted earlier in 2000<sup>828</sup>, which will “allow the agency to complete several modernisation projects”. It is argued that industry is putting practically no finance towards the \$700 million bill for Phase 1<sup>829</sup>. However, as an example, the US cargo industry has been heavily involved in developing an aspect of Free Flight through its ADS-B activities (see **Section 4.4.2**)<sup>830</sup>. Therefore, a new joint FAA/industry concept of operations is evolving, based on the following architecture<sup>831</sup>:

- Government-industry concept of operation, developed jointly by the FAA and the RTCA;
- A Concept of Operations for the National Airspace System in 2005, developed by the FAA’s Air Traffic Service Organisation;
- A set of capabilities recommended by the RTCA Task Force 3 Report on Free Flight.

Thus, the overall effectiveness of Free Flight remains to be proven and there are many sceptics who question its feasibility. Ex-United Airlines’ Bill Cotton claims<sup>832</sup> that “the barriers are almost entirely political, cultural and institutional, not technical”. Northwest Airlines’ VP of flight operations says<sup>833</sup> that “it is essential that there is a clear business case ... if it is to become reality”.

Finally, the methods of achieving the ambitious aims of truly flexible Free Flight may be available some day through investigations of operational methods that could support implementation of airborne separation assurance in Free Flight airspace<sup>834</sup>. These methods include the concept of strategic cooperative conflict avoidance, a CDM technique. Such advances will enable the US to implement its next generation gate-to-gate ATM, which aims to create a third tier of air transport using personal aircraft linking thousands of small airports<sup>835</sup>.

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<sup>823</sup> ‘Free Flight’ – *The National Air Traffic Controllers Association*. Vol 1, No. 2.

<sup>824</sup> ‘Diverging courses’ – *Air Transport World*, March 1997.

<sup>825</sup> ‘Unknown territory’ – *Air Transport World*, June 1997.

<sup>826</sup> ‘FAA seeks further FANS funding’ – *Flight International*, 4 March 1998.

<sup>827</sup> ‘WAAS funding freeze’ – *Flight International*, 19 August 1998.

<sup>828</sup> ‘US controllers give general approval to FAA bill’ – *Air Transport Intelligence*, 16 March 2000.

<sup>829</sup> ‘Working the details’ – *Air Transport World*, September 1999.

<sup>830</sup> ‘US freight carriers drive towards Free Flight’ – *Air Transport Intelligence*, 11 May 1998.

<sup>831</sup> According to the Civil Air Navigation Services Organisation (CANSO).

<sup>832</sup> ‘Diverging courses’ – *Air Transport World*, March 1997.

<sup>833</sup> ‘Northwest ops chief has big doubts on free flight’ – *Air Transport Intelligence*, 4 February 1999.

<sup>834</sup> ‘Researchers study methods for ensuring co-operative airborne separation in “free flight” airspace’ – *ICAO Journal*, November 1999.

<sup>835</sup> ‘Interstate skyways’ – *Flight International*, 8 February 2000.



#### 4.5.5 IATA's implementation plans

The International Air Transport Association (IATA) has produced a set of user-driven CNS/ATM implementation plans, which outline the organisation's views on a global scale over four evolutionary phases, thus<sup>836</sup>:

- **Better use of existing systems** – some early improvements in system capacity and flexibility can be achieved by taking better advantage of the existing systems in place today. Capacity improvements can be obtained through implementation of 1,000ft vertical separation above 29,000ft, installation of ATS units of airspace display systems for non-radar areas, adoption of procedures already in use in some parts of the world and increased use of airborne collision avoidance systems. Increased use of flight management systems for arrival and departure will allow greater use of user preferred routing. Initial SATCOM and datalink applications have expedited clearance request and delivery;
- **Initial CNS/ATM functionality** – the initial use of GPS, SATCOM, CPDLC and advanced FMS capabilities will enable aircraft separation minima to be reduced, thus allowing more dynamic route and altitude access and improved flight planning. All of these tend to reduce flight time and fuel burn with the potential to reduce contingency fuel and increase payload;
- **Free Flight** – the functionality of GNSS, ATN, ADS, ADS-B available in this Phase will enable initial free flight operations and worldwide standards, systems and procedures to be put in place to provide global uniformity. Benefits include routing based on minimum time and cost, making better use of speed, wind and altitude; reduced weather impact on flights; and reduced training costs. Airlines will be able to increase the revenue opportunity of their resources. Airline management and air traffic flow management will co-ordinate their activities to increase system capacity and flexibility;
- **Follow-on** – follow-on activities will increase airport capacity with full surface automation, on-board taxi guidance, low visibility operations and standardised procedures and systems. ATS providers will continue to replace outdated systems and equipment.

IATA claims<sup>837</sup> that CNS tools may be divided into three parts: those already in place and not fully exploited (e.g. ACARS, RNAV and RVSM); those being progressively installed (such as GPS and FANS-1/A); and tools that will be required over the coming decades (ATN, ADS-B and others). In addition, it should be noted that **Section 4.7** contains IATA's summary of CNS/ATM priorities based on worldwide regions.

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<sup>836</sup> 'A guide to CNS/ATM: equipment, programmes & markets' – Jane's Information Group. February 1999.

<sup>837</sup> 'The road map' – IATA FANS FACTS, 1998/2.



## 4.6 Equipment availability

This section analyses and describes the present availability of CNS/ATM infrastructure. It should be noted, however, that many types of equipment have been covered as inherent elements of trials and products described in other sections. Therefore, this section aims to complete the picture, with discussions on:

- Boeing's FANS-1 and Airbus Industrie's FANS A/B packages;
- The market for CNS/ATM equipment;
- Suppliers of CNS/ATM products;
- Ground-based CNS/ATM equipment;
- Airborne CNS/ATM equipment.

### 4.6.1 FANS-1 and FANS A/B packages

This section discusses Boeing's FANS-1, Airbus Industrie's FANS-A/B packages and CNS/ATM for Boeing Classic aircraft that are ineligible for FANS-1. It should be noted, however, that regional aircraft are also obtaining CNS/ATM cockpits<sup>838</sup>.

FANS-1/A packages are designed to enable aircraft to achieve early benefits from the CNS/ATM environment<sup>839</sup>. CNS/ATM-based avionics enable users to benefit from near-term FANS solutions<sup>840</sup>: FANS-1/A is an initial implementation of CNS/ATM in oceanic and remote airspace regions. FANS packages aim to facilitate reduced separation between aircraft through improved CNS functions, with consequent increased possibility of flying more flexible tracks and a greater ability to request changes with ATC. FANS-1/A aircraft provide a subset of the ICAO-defined ADS and CPDLC functions over existing VHF and satellite ACARS datalinks, through application of the ARINC 622 protocol. Correspondingly, many CNS/ATM systems and functions are direct results of the FANS-1/A avionics: in the absence of ICAO SARPs, standards documents by ARINC, the RTCA, Airbus and Boeing have been used to implement FANS-1/A in the CNS/ATM environment.

#### Boeing's FANS-1

In 1994, in response to requests from operators of Boeing 747-400 aircraft in the South Pacific, Boeing developed the FANS-1 package for this aircraft type. FANS-1 was certified in 1995<sup>841</sup>. It was subsequently made available for Boeing 757, 767 and 777 aircraft. Using ARINC Specification 622 protocol, which describes means to transmit ADS and CPDLC via satellite, ARINC and SITA terrestrial networks, FANS-1 adds the following functionalities to the Flight Management System (FMS):

- **Communications** – Airline Operational Control (AOC) and ATC datalink using CPDLC and SATCOM. FANS-1 uses the ACARS system to take advantage of the

<sup>838</sup> 'Fokker seeks new air navigation system' – *Flight International*, 10 October 2000.

<sup>839</sup> 'Equipping aircraft to benefit' – *Integrating Global Air Traffic Management*, ISC & ICAO, 1998.

<sup>840</sup> 'Meeting the FANS' – *Flight International*, 18 June 1997.

<sup>841</sup> 'B747-400 FANS-1 upgrade approved' – *Aeronautical Satellite News*, August/September 1995.



established avionics and ground network infrastructure. The FMS is upgraded, with the existing ACARS datalink unit used to send position reports and to exchange datalink messages via the aircraft's SATCOM terminal;

- **Navigation** – GPS, Required Navigation Performance (RNP) and Required Time of Arrival (RTA). Honeywell produced the pioneering FMS with integrated GPS;
- **Surveillance** – ADS.

Operational use of FANS-1 started on a Qantas B747-400 in June 1995<sup>842</sup> in the South Pacific, where the first real airline benefits have been gained, and has now spread to Asia. Cathay Pacific and others soon followed suit<sup>843</sup>. Dynamic Airborne Route Planning System (DARPS) and user defined routes operations have commenced<sup>844</sup>. Today, there are 500 FANS-1 equipped Boeing 747-400s, over 200 777s and 100 757/767s. The B747-400 and B777 now come off the production line with the FANS-1 package. Thus, FANS-1 aircraft in the Pacific region have enjoyed operational advantages for over half a decade.

FANS-1 was supposed to be a small stepping-stone towards the ATN, but it has grown in popularity<sup>845</sup> because it has enabled FANS benefits to be realised early. Indeed, the FANS routes over the Pacific acted as a catalyst for airlines purchasing CNS/ATM equipment, noting that “the business case a carrier builds [to support FANS acquisition] is highly specific not only to aircraft type, but to the routes they are flying on<sup>846</sup>.” Airlines are inherently reluctant to invest in the technology until there is a clear, quantifiable payback. This fact is incorporated in the framework developed in **Part 2**.

### **Airbus Industrie's FANS A/B**

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Airbus' FANS A and B packages, termed Airbus Interoperable Modular – Future Air Navigation System (AIM-FANS), are the aircraft manufacturer's solutions to CNS/ATM. AIM-FANS aims to adapt the aircraft to the various CNS/ATM environments using Human Machine Interfaces (HMI) architecture. Datalink Control & Display Units (DCDU), in a manner that minimises the burden to airlines moving to CNS/ATM<sup>847</sup>. Therefore, AIM-FANS acknowledges the potential problem of having CNS/ATM elements introduced at different times. Additionally, it should be noted that the DCDU is not used for safety-critical communications. The AIM-FANS avionics package employs FMS software, developed by two competing FMS supplier consortia: Honeywell and Sextant (now part of Thales)/Smiths Industrie<sup>848 849</sup>. Airbus Industrie has also involved Pegasus FMSs<sup>850</sup>.

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<sup>842</sup> 'The future is now' – *Air Transport World*, January 1996.

<sup>843</sup> 'Cathay will launch FANS 747 flights by year's end' – *Flight International*, 29 January 1997.

<sup>844</sup> 'The Global Area Network' – D Featherstone, *Inmarsat. Inmarsat Aero Conference*, May 2000.

<sup>845</sup> 'Needs and realisation' – *Aircraft Technology Engineering & Maintenance*, June/July 1998.

<sup>846</sup> 'Equipping for FANS' – *Air Transport World*, September 1996.

<sup>847</sup> 'An ATM/CNS update from Airbus Industrie' – P Potocki, *Airbus Industrie*. 5<sup>th</sup> Air Navigation Conference, Amsterdam. September 1999.

<sup>848</sup> 'AIMS-FANS: an update' – P Potocki, *Airbus Industrie*. 3<sup>rd</sup> Air Navigation Conference, Amsterdam. September 1997.

<sup>849</sup> 'Thales/Smiths delivers Airbus FMS software' – *Air Transport Intelligence*, 12 January 2001.

<sup>850</sup> 'Pegasus FMS heads for A340 flight tests with CNS/ATM' – *Flight International*, 23 June 1999.



FANS-A is similar to FANS-1. According to Airbus Industrie<sup>851</sup>, FANS-A's **Communications** element is ARINC 622 analogue radio and preliminary CPDLC through a dedicated communications unit, the Air Traffic Services Unit (ATSU), which selects the optimum medium (satellite, HF or VHF<sup>852</sup>). Its **Navigation** element comprises GPS sole means and initial RNP, in addition to RNAV and RVSM capability. Its **Surveillance** element consists of TCAS and preliminary ADS. A Multi Mode Receiver (MMR) has been developed to cope with different landing systems that should be available in the future, namely DGPS, GLS, ILS and MLS approaches. The MMR output is similar to the ILS concept.

The Airbus Industrie approach<sup>853</sup> is to install FANS A on a short-term basis for routings that are open or will be shortly. The manufacturer<sup>854</sup> is looking at how to "mass produce the technology". In the medium term, until 2008, they believe that ATN development will allow FANS-B to spread around the world after its introduction in 2003<sup>855</sup>, enabling a full-performance datalink. Regions of low traffic density may then leapfrog the FANS-1/A step and go directly to FANS-B, noting that FANS-B is particularly designed for potential economic benefits in high-density airspace. On a long-term basis, Airbus expects a generalisation of FANS-B. Irrespectively, it is likely that FANS 1/A, FANS B and non-FANS environments will co-exist for many years. Thus, an aircraft's ability to travel seamlessly from one environment to another is a fundamental expectation. Correspondingly, the issue regarding accommodation of FANS-1/A aircraft in an ATN environment arises again.

Pre-FANS (ACARS) for the Airbus A330/A340 aircraft was available at the end of 1998. A320 family pre-FANS (ACARS) arrived in the middle of 1999. It was initially thought that AIM-FANS 'A' would be ready for the A330/340 in 1998/1999, but final flight tests weren't completed until early 2000<sup>856</sup>. FANS-A for the A330/340 was certified in August 2000, with work on the A320 family version being developed<sup>857</sup>. FANS B, due in 2003, will have ATN-network Communication, in addition to GNSS-based Navigation and Surveillance functions for ATC or AOC. Singapore Airlines was the first customer for FANS-A<sup>858</sup>, having placed an order in 1997. In contrast, Cathay Pacific reversed a decision to equip its long-haul Airbus fleet in 1998, due to slow progression by the ATS providers<sup>859</sup>.

It should be noted that Airbus is involved in the Aircraft in the Future ATM System (AFAS) programme that aims to devise operational ATM concepts for European airspace and develop a validated Airbus-based avionics platform to support them so that

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<sup>851</sup> 'AIM-FANS business process' – Airbus Industrie, January 2000.

<sup>852</sup> 'The Airbus solution' – Global Airspace, November/December 1998.

<sup>853</sup> 'The Airbus Industrie Approach to CNS/ATM' – JF Bousquié, Airbus Industrie 4<sup>th</sup> Air Navigation Conference, Amsterdam, 1998.

<sup>854</sup> 'Freeing up the skies' – Airline Business, November 1999.

<sup>855</sup> 'FANS in high places' – air traffic management, March-April 2000.

<sup>856</sup> 'Airbus performs FANS-A global tests as certification nears' – Air Transport Intelligence, 24 February 2000.

<sup>857</sup> 'Airbus certifies FANS-A on A330/340' – Air Transport Intelligence, 23 August 2000.

<sup>858</sup> 'SIA is first to order FANS-A upgrade for Airbus A340s' – Flight International, 16 April 1997.

<sup>859</sup> 'Cathay dumps Airbus FANS' – Flight International, 18 February 1998.



an integrated avionics package will be ready in 2005<sup>860</sup>. Based on similar technologies to FANS-A, the programme will select the most promising options and apply them to the Airbus A320 family, of which there are over 600 flying in European airspace.

### **CNS/ATM for Boeing Classics**

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ARINC's B747-200 programme began in 1995<sup>861</sup>. Using a software certification facility and a cockpit integration laboratory, the system upgrades provide the following interfaces: EFIS (situation awareness display minimum), colour weather radar, EGPWS, enhanced TCAS, SATCOM, scanning DME, a performance management system and INS<sup>862</sup>. The system supports ACARS and HFDL. Noting that map displays will undoubtedly be required to support terminal area operations in the future, colour Liquid Crystal Display (LCD) instruments have been developed that can be installed as direct replacements for existing electromechanical instruments in older aircraft<sup>863</sup>.

ARINC claims that the initial installation takes 18 months from contract signing, with customers obtaining a return on investment within 30 months for a typical route structure. A cost-benefit model is conducted for each project, due to the variances in customers' economics. The Brunei royal family ordered the first FANS-1 upgrade for a Classic B747<sup>864</sup>. Others have followed since, including, recently, Air France<sup>865</sup>.

BAE Systems Canada has an upgrade programme to bring the lives of Classic Boeing 747s beyond 2010, using triple FMSs and 12-channel GPS sensor avionics<sup>866</sup>. Flight tests were completed in 1999<sup>867</sup>. Boeing's upgrade package for Classic 747s gives dual type ratings with the 747-400<sup>868</sup>. In addition, Boeing recently announced plans to launch major cockpit upgrade programmes for the 737 Classic, MD-80 and MD-90 aircraft as part of a US RTCA initiative<sup>869</sup>. This will help airlines equip older aircraft with technologies such as ADS-B and CDTI.

#### **4.6.2 Market for CNS/ATM equipment**

Allied Business Intelligence estimates that the potential CNS/ATM market this decade will be worth \$80 billion. Jane's Information Group has estimated that the worldwide

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<sup>860</sup> 'Big European avionics programme starts shortly' – *Air Transport Intelligence*, 30 March 2000.

<sup>861</sup> 'CNS/ATM for Classics: ARINC's B747-300 programme' – D Melton, ARINC. *Air Navigation Conference*, Amsterdam, 1997.

<sup>862</sup> 'FANS for Classics: the ARINC B747-200' – D Melton, ARINC. *Airline Navigation '96 Conference*, Amsterdam, October 1996.

<sup>863</sup> 'What technologies are available?' – C Jones, Rockwell Collins Avionics. *Airline Navigation '96 Conference*, Amsterdam, October 1996.

<sup>864</sup> 'Brunei FANS-1 upgrade is first on 'Classic' 747' – *Flight International*, 26 June 1996.

<sup>865</sup> 'Air France hints at upgrading Classic 747 cockpits' – *Air Transport Intelligence*, 20 October 2000.

<sup>866</sup> 'Upgrade will extend lives of 747 Classics' – *Flight International*, 30 June 1999

<sup>867</sup> 'KLM 747 cockpit upgrade tested' – *Air Transport Intelligence*, 26 February 1999

<sup>868</sup> 'Classic' cockpit to be upgraded' – *Flight International*, 2 May 2000.

<sup>869</sup> 'Boeing set to launch cockpit upgrades for classic airliners' – *Flight International*, 27 October 1999.



spending on ATC equipment will evolve over the period 1998-2005, as depicted in **Figure 4.1**, thus:

System type	1998 (\$)	2005 (\$)	% change
Radars	1,000 m	900 m	-10
Control centres (incl. workstations)	2,400 m	3,900 m	+62.5
Nav aids/landing aids	1,300 m	1,700 m	+30.8
Communications	4,900 m	9,900 m	+102.0
MET systems	100 m	150 m	+50.0
Lighting systems	150 m	180 m	+20.0
Voice switching	72 m	85 m	+18.1
<b>Total</b>	<b>9.9 billion</b>	<b>16.8 billion</b>	<b>+69.7</b>

**Figure 4.1** - Worldwide spending on ATC equipment (1998-2005)

Source – derived from data contained in 'Jane's Air Traffic Control' (6<sup>th</sup> Ed. 1999-2000)

It is interesting to note that the market for radar equipment is still strong and that a large number of ILS systems are still being ordered. A substantial increase in projected spending by 2005 is evident, noting in particular the doubling of expenditure on communications equipment. As the evolution towards future CNS/ATM systems progresses, greater spending will undoubtedly be incurred by the airlines, which may account for this large increase. Nonetheless, the cumulative total change for ground infrastructure is significant, although this may be due to the start-up costs of many CNS/ATM programmes.

The annual publication from which the data in **Figure 4.1** was obtained also contains a review of national spending by Civil Aviation Authorities. However, content of the listing is beyond the scope of this section's survey of the worldwide market for CNS/ATM equipment, because the listing is inconsistent in terms of ATC infrastructure project costs. Correspondingly, given that the Jane's publication already conducts such a survey on a worldwide basis, it is unnecessary to duplicate this task.

Funding of projects is beginning to be conducted on a regional basis. The European Commission's Treaty Two study found that the split for ATC equipment around the world is 33% in North America, 32% in the European Union, 15% in Asia & Pacific States and the remaining 20% among other nations. With reference to the survey of CNS/ATM equipment suppliers conducted in **Section 4.6.3**, it should be noted that the US supplied over 90% of the market in 1996<sup>870</sup>. The consultants Booz-Allen & Hamilton, who were Treaty 2 Study members, believe that the EU is lagging behind North America.

In addition to that for CNS/ATM equipment, the following market segmentation exists:

- *Services* – ATS, COM (incl. AIS), Engineering/Consulting;
- *Systems integration* – ATC, CNS, Airborne.

<sup>870</sup> 'The World Market for ATC Equipment' – Jane's Information Group, September 1996.



### 4.6.3 Suppliers of CNS/ATM products

**Appendix 4.4** lists around 300 companies and organisations that currently manufacture CNS/ATM products around the world. Data sources for this survey include hundreds of brochures, a comprehensive search of the Internet and trade publications, in addition to information contained in 'Jane's Air Traffic Control' (6<sup>th</sup> Ed. 1999-2000) and a booklet produced by the Civil Air Navigation Services Organisation (CANSO) in 1999.

From the results of the survey, which are split by activity in the Communications, Navigation, Surveillance and ATM markets, it is apparent that many companies are involved in one, or maybe two, of the markets and that the larger manufacturers provide products in all four markets. This latter fact is undoubtedly due to the consolidation among the providers during the last five years:

- ❑ Honeywell now includes AlliedSignal. In January 2001, Honeywell said that its shareholders voted in favour of a merger with General Electric (GE) and that it was on course to formally close the proposed deal in the first quarter of the year<sup>871</sup>;
- ❑ Thales is the new company formed by the merger of Thomson-CSF, Racal and Sextant<sup>872</sup> (which incorporated Aérospatiale and Dassault Électronique). In addition, it should be noted that, although Thales and Raytheon recently entered into an agreement to form an equally owned military venture, their ATM businesses will continue to compete in the ATM marketplace<sup>873</sup>;
- ❑ Raytheon recently teamed with Northrop Grumman;
- ❑ Rockwell Collins, which was recently spun off by its parent company<sup>874</sup>, bought Flight Dynamics. Additionally, Rockwell Collins and BFGoodrich Aerospace have entered into a strategic alliance agreement<sup>875</sup>;
- ❑ Canadian Marconi became BAE Systems Canada after BAE Systems bought GEC Marconi. However, it is presently being sold<sup>876</sup>;
- ❑ Boeing has bought Hughes Electronics' space and communications business<sup>877</sup>.

Given the sheer amount of providers, their products and components in the CNS/ATM industry, it is practically impossible and certainly beyond the scope of this dissertation to discuss the equipment, other than to point to advances mentioned in this thesis.

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<sup>871</sup> 'Honeywell shareholders approve GE merger' – *Air Transport Intelligence*, 11 January 2001.

<sup>872</sup> 'Sextant and Racal names go as Thompson becomes Thales' – *Air Transport Intelligence*, 7 December 2000.

<sup>873</sup> 'Thales includes joint venture with Raytheon in expansion strategy' – *Flight International*, 16 January 2001.

<sup>874</sup> 'Rockwell Collins to become stand-alone company' – *Air Transport Intelligence*, 8 December 2000.

<sup>875</sup> 'Collins and BFGoodrich Aerospace form products and services alliance' – *Air Navigation International*, 20 March 2000.

<sup>876</sup> 'BAE Systems Canada to be bought by Onex unit' – *Air Transport Intelligence*, 2 February 2001.

<sup>877</sup> 'Boeing eyes CNS/ATM in Hughes buy' – *Air Navigation International*, 24 January 2000.



#### 4.6.4 Ground-based CNS/ATM equipment

It is obvious that the ground-based element of CNS/ATM is essential for successful implementation of FANS. To date, there has been a significant amount of Automatic Dependent Surveillance (ADS) and/or Controller Pilot DataLink Communication (CPDLC) air traffic management systems introduced in various parts of the world, as portrayed in **Figure 4.2**.

ADS and/or CPDLC used to support airspace organisations	ADS and/or CPDLC used in demonstrations and experiments	ADS and/or CPDLC with planned implementation by 2000
Anchorage, Alaska Auckland, NZ Bangkok, Thailand Brisbane, Australia Fiji Jakarta, Indonesia Johannesburg, South Africa Kuala Lumpur, Malaysia Madras, India Magadan, Russia Myanmar Oakland, California Singapore Stockholm, Sweden Tahiti Tokyo, Japan Ulan Bator, Mongolia	Beijing, China Hong Kong North Sea, Norway Ottawa, Canada Riga, Latvia Tague, South Korea Tehran, Iran North Sea, United Kingdom	Canada Calcutta, India Chengdu, China Chennai, India Delhi, India Kuming, China Lanzhou, China Mauritius Melbourne, Australia Mumbai, India North Atlantic region Urumqui, China Vietnam

**Figure 4.2 - Sites with operational CNS/ATM functions**  
 Source - Civil Air Navigation Services Organisation (CANSO), 1999

CNS/ATM has functions other than ADS and CPDLC, as cited throughout this text. However, the implementation of ADS and CPDLC systems is indicative of a distinct migration towards a CNS/ATM environment and is the first FANS step. It is therefore encouraging to observe the geographical spread of the ADS and/or CPDLC stations around the world. Nonetheless, it should be remembered that ADS and CPDLC require the combination of both aircraft and ground systems, working jointly, to be effective.

A survey of the six ICAO regional Air Navigation Plans' 'ATS Routes and Associated Navigation Means' sections shows that the provision of Air Traffic Services is still very much based on traditional aids. Although the plans give some indication of a region's main equipment, they are relatively slow to incorporate new ground CNS/ATM infrastructure developments. It is for this reason that this dissertation has drawn its information from a multitude of sources.



#### 4.6.5 Airborne CNS/ATM equipment

The contents of this dissertation's Part 1 have, by definition, constantly referred to airborne CNS/ATM equipment through the systems and technologies that have been discussed. This section complements the previous descriptions by discussing aspects of the physical cockpit infrastructure, thus:

- **Display systems** – Honeywell has developed the 'Primus Epic' next generation integrated avionics system cockpit<sup>878</sup>, with flat panel LCDs that employ modular avionics architecture, replacing Cathode Ray Tube (CRT)<sup>879</sup>. Another manufacturer is Interface Displays & Controls. Boeing 777s have an earlier generation of LCD by Honeywell. Boeing 737NG aircraft contain a Common Display System (CDS), which has the ability to portray Electronic Flight Instrument System (EFIS) and map display in previous 737 models or the Primary Flight Display (PFD) and Navigational Display (ND), which are used in 747-400 and 777 models. Flat panel TFT active matrix LCDs are set to become standard across the Airbus family<sup>880</sup> and the new A340-500/600 aircraft features LCDs by Sextant (now Thales). The next generation of Honeywell systems will include 3D<sup>881</sup> and 4D displays<sup>882</sup>, which have already been tested. The general aviation market is also able to avail of flat-panel display technology<sup>883</sup>. Boeing is in the final stages of developing a new display, the Vertical Situation Display (VSD), which aims to reduce Controlled Flight Into Terrain (CFIT). The VSD is designed to give the flight crew the same sort of view as the PFD, but from the side<sup>884</sup>. It will appear the same in all flight phases, whether using VOR/DME, ILS/MLS or LAAS/WAAS<sup>885</sup>. Airbus Industrie plans to integrate a peaks display into the Navigation Display (ND) as an interim measure, citing that a VSD will have to wait until bigger displays arrive with the A380<sup>886</sup>. In addition, it should be noted that Thin-Film ElectroLuminescent (TEFL) displays, which use optical interference to counteract reflection and obtain sun-light readable contrast, have been developed<sup>887</sup>;
- **Flight Management Systems (FMS)** – now seen as the heart of the modern commercial aircraft's cockpit, the FMS is essential for operating in a CNS/ATM

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<sup>878</sup> There are two outboard electronic personal assistants, with Flight Situational Displays (FSD) before each pilot. The FSDs contain all the information necessary for the pilot to determine the status of major aircraft parameters: the top half portrays the primary flight display of altitude, airspeed, attitude and navigation, information with communications systems' status; the bottom section contains the Engine Monitoring and Control System (EMCS), which replaces EICAS. Inboard primary flight displays are multi-functional, with the ability to present video (of external aircraft cameras), chart, utility (electrical, hydraulic and air systems), weather and (flight) plan modes. Back-up electromechanical instruments form the traditional T-shape in the centre panel.

<sup>879</sup> 'An Epic in the Making' – *Commuter World*, December 1996 – January 1997.

<sup>880</sup> 'FANS drives flight deck avionics changes' – *Interavia*, January 1998.

<sup>881</sup> 'Honeywell displays advances' – *Flight International*, 21 October 1998.

<sup>882</sup> 'Highways in the sky – the promise of four-dimensional displays' – *Flight Deck International '98*.

<sup>883</sup> 'Advanced avionics for all' – *Flight International*, 28 October 1998.

<sup>884</sup> 'Boeing aims to improve safety with new display' – *Flight International*, 20 June 2000.

<sup>885</sup> 'FI2000: Boeing timetables new flightdeck nav display technologies' – *Air Transport Intelligence*, 27 July 2000.

<sup>886</sup> 'Airbus plans peaks display as step toward VSD' – *Air Navigation International*, 1 May 2000.

<sup>887</sup> 'Bright future for high-contrast TFEL cockpit displays' – *Flight Deck International*, September 1999.



environment<sup>888</sup>. It is for this reason that airlines are retrofitting aircraft. Airbus has two suppliers: Honeywell's Pegasus advanced FMS and a joint development by ex-Sextant and Smiths Industries, which will start deliveries in 2002<sup>889</sup>. The latter company is the sole FMS supplier of New Generation Boeing 737. However, Rockwell Collins has been selected by Boeing to be the sole supplier of the Flight Control System (FCS) for its 737NG from mid-2002<sup>890</sup>. Smiths Industries also manufactures FMCs<sup>891</sup>. Honeywell has developed a system, which integrates the autopilot controls and the FMS in a manner that reduces the cognitive workload of the pilot<sup>892</sup>. Presently, the corporate market's standard of FMS is more advanced than commercial airlines'. FMSs incorporate Built-In Test Equipment (BITE) for maintenance<sup>893</sup>: Honeywell and Rockwell Collins are competing fiercely for their respective avionics operating systems to become the standard for preventative maintenance<sup>894</sup>. However, commercial airline reality dictates that there will be at least two, incompatible operating systems;

- **Paperless cockpits** – Airbus A340 and Boeing 777 aircraft have been involved in tests towards implementing the paperless cockpit, whereby variations of the paper charts are displayed on the screens<sup>895</sup>. Such systems have the ability to enhance an integrated CNS/ATM environment. Current charts contain procedural information issued by Aeronautical Information Services (AIS) offices for approaches. They also display topographical details and contain briefing data for airfields. It is possible, however, that the FMS can be merged with the charts' electronic contents, in order to enhance the autopilot's ability to fly the aircraft. The chart display system, JeppView, has been available since 1996 with images the same as paper charts. Indeed, Boeing's purchase of Jeppesen Sanderson means that the latter's information resources will be converted into electronic products<sup>896</sup>. An Integrated Crew Information System (ICIS)<sup>897</sup> provides information support through a digital unit mounted on an aircraft panel. ICIS becomes the single source for all of the aforementioned supplementary information. When connected via datalink to a carrier's operations department, information such as updated weather or data on performance can be transferred to the cockpit.

It should be noted that the US National Transportation Safety Board (NTSB), Radio Technical Commission for Aeronautics (RTCA), the European Organisation for Civil Aviation Equipment (EuroCAE) and ICAO are examples of the bodies that recommend standards and certify CNS/ATM products. **Part 2** of this thesis considers their rôle.

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<sup>888</sup> 'Management actions' – *Flight International*, 20 January 1999.

<sup>889</sup> 'Sextant/Smiths faces big delay on Airbus FMS' – 14 February 2000.

<sup>890</sup> 'Rockwell Collins to be sole-source supplier of 737NG digital FCS' – *Air Transport Intelligence*, 4 October 1999.

<sup>891</sup> 'Lufthansa contracts Smiths for 737 FMC upgrades' – *Air Transport Intelligence*, 23 February 2000.

<sup>892</sup> 'Honeywell develops intuitive aircraft flightdeck system' – *Flight International*, 19 November 1997.

<sup>893</sup> 'A330/A340 Central Maintenance System: philosophy, implementation and in-service use' – J Grossin & P Schuster, *Aérospatiale. RAeS Advanced Avionics Conference*, November 1993.

<sup>894</sup> 'Avionics on the front line' – *Airline Business*, March 1999.

<sup>895</sup> 'Electronic Mapping: Moving Towards a Paperless Cockpit' – E Schuster, Jeppesen. *Air Navigation Conference, Amsterdam*. 1997.

<sup>896</sup> 'Boeing plans major e-market push for Jeppesen data' – *Air Transport Intelligence*, 15 August 2000.

<sup>897</sup> 'Paperless cockpit' – *Flight Deck International*, April 2000.



## 4.7 National and regional CNS/ATM activities

It is possible to conclude from **Section 4.2** to **Section 4.6** inclusive that elements of the CNS/ATM concept are already in place. In conjunction with the individual analyses contained in these previous sections on the four components of CNS/ATM, this section analyses the activities of nations and regions. It assesses the situation regarding implementation of CNS/ATM technologies and procedures around the world, noting that it is sometimes necessary to refer to programmes and technologies in this section that are also mentioned in the component analyses.

A dual format is adopted in order to complete the assessment of worldwide CNS/ATM current status in this chapter:

- **Appendix 4.5** contains a summary of CNS/ATM implementation activity in nearly 100 countries. Together with the numerous references cited throughout this text and in other appendices, they form the results of this research's comprehensive and representative survey of national CNS/ATM endeavours. Data sources for this assessment are many different publications, including Jane's annual 'Air Traffic Control,' which sends questionnaires to countries and their civil aviation authorities in order to ascertain CNS/ATM activities. Some of the results from Jane's surveys over the last three years are included. It is for this reason that a questionnaire methodology was not adopted specifically for this evaluation;
- **Appendix 4.6** details the situation in worldwide regions. For the purposes of this exercise, the world is split into the five regions mentioned in **Chapter 1**, in addition to the North Atlantic region, thus: Africa, Americas & Caribbean, Asia & Pacific, Europe, Middle East and North Atlantic Ocean. Although **Section 4.5.2** discusses the present progress with ICAO's Global Plan, it is important to cite the activities of the ICAO Regional Groups because ICAO is attempting to implement CNS/ATM through these groups. However, it is not feasible to assess the degree of implementation by analysing the regional Air Navigation Plans because they are not up to date. Indeed, as portrayed in **Appendix 4.1**, ICAO is still at the planning stage in many regions. Thus, ICAO's 'Global Air Navigation Plan for CNS/ATM Systems' (1<sup>st</sup> Ed., 2000) and many other sources are employed to provide an appraisal of the current status, which includes the regional strategies. Finally, it should be noted that **Appendix 1.3** contains descriptions of the regional en-route agencies that exist: ASECNA, COCESNA, Eurocontrol, PIARCO FIR and Roberts FIR.



In conjunction with **Appendix 4.6** and the discussion on its CNS/ATM implementation plans in **Section 4.5.5**, the International Air Transport Association (IATA)<sup>898</sup> has cited the following CNS/ATM priorities for the various worldwide regions, thus:

- ❑ *Europe* – airspace capacity must be increased without any additional cost to the user and European Air Traffic Management System (ETMS) planning must move into its operational deployment without further delay;
- ❑ *North America* – extend RVSM to North America’s domestic airspace and agree CNS/ATM implementation planning with user representatives;
- ❑ *Latin America and the Caribbean* – continue the development of GPS routes, GPS-based instrument approaches in the entire region, demonstrate the value of ADS and CPDLC, in addition to implementing RVSM;
- ❑ *Asia/Pacific* – pursue the evolution of FANS-1/A applications throughout the region and eliminate bottleneck traffic congestion through the creation of FANS-only routes;
- ❑ *Africa* – develop an implementation programme for RVSM on selected North-South routes, aggressively pursue overall ATM improvements in identified deficient areas through the implementation of CNS/ATM systems where warranted and improve the region’s communications capability;
- ❑ *Middle East* – eliminate circuitous routes due to airspace restrictions by various States, establish RNP routes to reduce lateral spacing between routes and examine the feasibility of introducing the ATN in the region.

It should be remembered that the need to implement CNS/ATM varies throughout the world, based on safety and/or efficiency requirements of a particular country or region. The pressure points on the system result from particular situations in different geographical scenarios. For example, high-density traffic areas such as the core of Europe would find certain CNS/ATM applications, such as Mode S surveillance, more useful than low-density airspace regions would. The latter regions would find applications such as ADS more applicable. Therefore, different solutions apply to the various regions.

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<sup>898</sup> According to the Civil Air Navigation Services Organisation (CANSO).



## 4.8 Summary

This chapter integrates the findings of **Chapter 2** on CNS systems and **Chapter 3** on ATM concepts with an assessment of the current status of CNS/ATM implementation, in order to complete the first objective of this dissertation, namely to evaluate CNS/ATM and its current worldwide status. Specifically, this chapter analyses the present and planned integration situation of those technologies and concepts that are thought to form the future CNS/ATM air navigation system. It also completes this thesis' first aim with an appraisal of CNS/ATM equipment, which includes a comprehensive survey of suppliers, in addition to discussions on the numerous national and regional CNS/ATM programmes that are being conducted around the world.

It is possible to conclude that the implementation of CNS/ATM has not progressed as fast or as far as had been envisaged. The plethora of delays and poor safety in various airspace regions are testament to this. All stakeholders and users of the ATM system are frustrated in virtually all the world's areas. ICAO acknowledges<sup>899</sup> that "implementation has been taking place at something less than a blistering pace." Although the development of technical standards (SARPs) for the CNS systems has proceeded relatively well, the lack of an operational concept providing a detailed vision of the ATM system means that there is little detail on how the new technologies should lead to a more effective ATM system. It is for this reason that the EU and US have worked on their respective operational concepts.

Nonetheless, the evaluation of CNS/ATM integration status in this chapter highlights the fact that many technologies, systems and procedures are nearly ready for mainstream implementation. Advances have been made with datalink applications and satellite-based communications facilities. GPS-enhanced navigation procedures in all flight phases are becoming more mature, while the concept of Required Navigation Performance (RNP) is aiding airspace planning and facilitating adherence to standards in many regions. Correspondingly, the success of surveillance systems, such as Automatic Dependent Surveillance (ADS) and its Broadcast derivative (ADS-B), is encouraging.

Given the increasing availability and reliability of these CNS/ATM systems, in addition to the sense of urgency for improvement that exists around the world, it is possible to observe that implementation programmes are starting to gather greater momentum. Therefore, it would appear that the CNS/ATM arena is at a crossroads and that a higher level of systems introduction may be expected during this decade. However, noting that CNS/ATM requires a global approach, there is a need to ensure that the process is conducted and guided correctly. Such facts justify the rationale for this dissertation's evaluation of CNS/ATM's worldwide implementation and its framework for improved introduction of CNS/ATM in **Part 2**. Indeed, it should be noted that the development of the framework in **Chapter 5** draws on results from this original appraisal of CNS/ATM.

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<sup>899</sup> 'Evolutionary approach to transition now focused on detailed vision of how to exploit technologies' – ICAO Journal, September 2000.



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# **PART 2**

## **DEVELOPMENT AND VALIDATION OF A FRAMEWORK TO IMPROVE WORLDWIDE IMPLEMENTATION OF CNS/ATM**

**“THE FUTURE SYSTEM WOULD BE EXPECTED TO EVOLVE AND  
BECOME MORE RESPONSIVE TO THE NEEDS OF THOSE OPERATING  
IN THE SYSTEM, AND WHOSE ECONOMIC HEALTH IS DIRECTLY  
RELATED TO THE EFFICIENCY OF THAT SYSTEM”**

**ICAO FANS COMMITTEE**



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## CHAPTER 5

# CNS/ATM IMPLEMENTATION FRAMEWORK

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## 5.1 Introduction

It is evident in **Part 1** of this dissertation that the integration of CNS/ATM technologies and procedures is far from complete. Countries and regions have advanced at different rates, if at all, even though their ultimate ambition is to obtain harmonised and safe airspace regions. While this objective may always remain aspirational and theoretical, there is still much scope for improvement. Therefore, this chapter develops a framework strategy for successful implementation of CNS/ATM at national, regional and global levels. The framework is structured so that the perspectives of all stakeholders<sup>900</sup> are included, with the expectation that each player should benefit from this strategy. Indeed, it should act as a catalyst and handbook to further and guide integration as the potential for CNS/ATM becomes more apparent.

The methodology adopted for generation of this framework has been conducted by determining obstacles to smooth worldwide integration of CNS/ATM systems using the evaluation sources in **Part 1**. Based on the identification of stumbling blocks, this chapter uses these hindrances as the framework's solution components, which are split in the following distinct sections:

- Integration management;
- Project appraisal techniques;
- Institutional issues;
- Mandatory matters;
- Financial factors;
- Performance parameters.

Within each section, the components are developed and discussed, with suggestions on how to solve the specific problem(s) and guide implementation. Remembering that this framework's objective is to expedite the introduction of CNS/ATM, further analysis of particular aspects is warranted: **Chapter 6** and **Chapter 7** examine financial and performance components respectively in greater detail. Validation of the framework is conducted using assessments of best practice examples or benchmarked indicators that are established and computed for the purposes of this endeavour.

It should also be noted that this framework formula refers to the technical components in **Part 1**. Correspondingly, it may be observed that technologies and procedures are enablers, not a full answer, with the need for this associated implementation framework. Indeed, based on **Chapter 4**, it is evident that technological and procedural solutions are maturing, with some entering operation: hence the need for this framework.

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<sup>900</sup> As mentioned in Chapter 1, stakeholders are deemed to include airports, Air Navigation Service (ANS) providers, civil aviation authorities, financial institutions, general communities, ICAO, (aircraft and CNS/ATM equipment) manufacturers, military authorities, nations, network service or satellite communications providers, regions (and their associations), regulators, in addition to (cargo/passenger airline, general aviation, leasing company and military) users and their staff. It should be noted that many of the aforementioned groups have representative associations or bodies.



## 5.2 Integration management

This section discusses methodologies for managing the implementation of CNS/ATM at four levels: global, regional, national and project. Lack of co-ordinated management for introduction of CNS/ATM is a big obstacle to comprehensive integration. This aspect of the framework's suggested formula develops implementation strategy components that apply to and have an impact on all aviation stakeholders. Thus, each stakeholder's perspective is included, noting that national and/or regional co-operation possibilities are discussed in **Section 5.4's** institutional issues and that standardisation solutions are incorporated as part of **Section 5.5's** mandatory matters.

### 5.2.1 Global management

With reference to **Section 3.4** and **Section 4.5.2**, the International Civil Aviation Organisation (ICAO) conducts the global planning of CNS/ATM. Aviation's governing body is attempting to manage implementation of the future seamless, global air traffic management system through application of its policies (see **Appendix 5.1**), Standards And Recommended Practices<sup>901</sup> (SARPs) and Procedures for Air Navigation Services (PANS). ICAO intends to assemble the global model through functional integration, as discussed in **Chapter 3**, with a renewed emphasis on fostering the development and implementation of SARPs. This framework strategy recommends that ICAO swiftly expedite the completion of SARPs for those technologies that were planned, but also for non-ICAO compliant systems, as cited in **Part 1** of this thesis.

In addition, as also mentioned in **Part 1**, ICAO has developed a Global Air Navigation Plan (ANP), which aims to provide guidance information for introduction of CNS/ATM systems that could be used in conjunction with SARPs and PANS. However, it is argued that the Global ANP offers little practical advice and that it lacks a co-ordinated, integrated implementation plan. Indeed, this is one of the reasons that this research develops a framework strategy in conjunction with **Part 1's** evaluation of CNS/ATM systems. Correspondingly, ICAO's plan lacks an operational concept, which will be the basis for developing standards, having obtained consensus on many issues, as discussed in **Section 3.4.1** and elsewhere in this thesis<sup>902</sup>. In a similar manner, the performance concepts, RCP, RSP and RTSP<sup>903</sup>, have not been comprehensively developed: RNP is being introduced around the world.

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<sup>901</sup> Noting that **Section 5.5** deals with technical SARPS standardisation, ICAO SARPs are used by stakeholders as guidelines for development and implementation of systems.

<sup>902</sup> Nonetheless, some progress is being made: an ATM operational Concept Panel (ATMCP) was set up by ICAO in 1998 to develop the necessary SARPs, procedures and guidance material for the Global Plan. The ATMCP is part of ICAO's Air Navigation Commission (ANC).

<sup>903</sup> RCP – Required Communication Performance; RNP – Required Navigation Performance; RSP – Required Surveillance Performance; and, RTSP – Required Total System Performance.



Therefore, it is not yet possible to harmonise or standardise Air Traffic Management (ATM) systems at a global level so that all future systems are compatible. However, will a definitive operational concept ever be realised, noting that the EU and US have developed other concepts as their strategic goals? Implications still exist from the introduction of emerging ATM concepts in terms of issues such as conflict resolution, freedom and metering or sequencing of flights. There is a need for convergence on a solution for an operational concept that can define the necessary tools and procedures before global CNS/ATM is comprehensively possible.

It should be noted that the regional planning process, which is discussed hereunder in **Section 5.2.2**, is the principal engine of ICAO's planning and implementation work. In addition, it should be added that the aforementioned creation of operational concepts has occurred in some cases at regional levels. Thus, if ICAO can co-ordinate the various regional plans for implementation of facilities and services associated with CNS/ATM systems, it should be able to manage integration at the worldwide level. Additionally, ICAO should abide by the precepts cited in its 'Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation', which is summarised in **Appendix 5.1**. This particularly applies to the technical co-operation aspect, in addition to the responsibility and rôle of ICAO, which includes the development of SARPs. In addition, it should be noted that ICAO has succeeded in bringing the world's nations together for discussion and awareness of CNS/ATM: its Rio Conference in 1998 is seen as a milestone in this regard. However, the major aspirations at national levels have not yet been fulfilled. Hence, this research builds on ICAO's endeavours.

Thus, this framework recommends that the best global management strategy is for ICAO to act as the co-ordinating body, ensuring that safe regional plans are harmonised, standardised and implemented in an expeditious manner. Accordingly, given that global management requires harmonised implementation of CNS/ATM systems, it should be noted that this framework develops other components in this chapter under the auspices of project appraisal techniques, institutional issues, mandatory matters, financial factors and performance parameters.

## **5.2.2 Regional management**

ICAO Planning and Implementation Regional Groups (PIRG) perform planning at a regional level, sometimes in conjunction with regional bodies. For instance, Eurocontrol manages the implementation plans of the Western European region, noting that the ICAO European PIRG overviews strategies developed by Eurocontrol. The world is split into seven regional planning groups, thus:

- APANPIRG for the Asian & Pacific region;
- APIRG for the African region;
- EANPG for the European region;
- GREPECAS for the Caribbean & South American region;
- MIDANPIRG for the Middle Eastern region;
- NATSPG for the North Atlantic region;
- NAMPG for the North American region.



The ICAO PIRGs report to ICAO's Council, Air Navigation Commission (ANC) and ALLPIRG, which ensures that the regional plans are harmonised. **Section 4.5.2** states that the ICAO ALLPIRG is an interregional co-ordination mechanism and advisory group, which represents the PIRGs and aviation stakeholders. Hence, stakeholders now have direct input to the ICAO regional process. Additionally, the PIRGs participate with developing or updating SARPs and providing technical assistance to countries.

PIRGs specify requirements for infrastructure facilities and services to supply adequate Air Navigation Services (ANS), which are based on computed traffic forecasts. In its most basic form, the output from the regional process is a listing of air navigation facilities and services together in the relevant regional ANPs. These plans also cite each region's basic operational requirements and planning criteria. Accordingly, it should be noted that the Global ANP has created the basis for development of a Facilities and Services Implementation Document (FASID), which aims to contain future regional-specific details. ICAO wishes the FASID to become a living document that reflects changes.

As discussed in **Chapter 4**, the majority of PIRGs are still assessing the situation in their respective regions: most regional ANPs that incorporate CNS/ATM have not been produced yet. The North Atlantic planning group, NATSPG, was the first to produce a CNS/ATM plan: as a case study example of the regional planning process, **Appendix 5.2** outlines the NATSPG's planned concepts and implementation strategies. It should be noted that the North Atlantic plan also demonstrates aspects of the airworthiness approval process for new CNS/ATM systems. **Part 1** of this research also demonstrates that different problems exist within the various regions, which require unique solutions.

When complete, all PIRG plans should include indications of timelines for the various transitional stages, which incorporate:

- Completion of technical SARPs;
- Adoption of CNS avionics standards;
- Completion of relevant Research & Development (R&D);
- Availability of avionics and other CNS capabilities, including ground infrastructure;
- Completion of pre-operational trials and validation process;
- Availability of suitable procedures;
- Effective date for mandatory carriage, where appropriate;
- Withdrawal of obsolete systems.

In addition, PIRGs must ensure that adequate provision of meteorological information, based on the future meteorological systems discussed in **Section 2.7.7** and **Section 4.4.7**, occurs in an equally co-ordinated manner. This is already evident through ventures such as the world and regional area forecast centres for provision of weather forecasts<sup>904</sup>. In a similar manner, the provision of flight information services must also be adapted for the CNS/ATM environment, as mentioned in **Section 3.4.4**.

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<sup>904</sup> 'Manual of Aeronautical Meteorological Practice' – ICAO Doc. 8896-AN/893/3, 1985.



In order that they manage the integration of CNS/ATM into a harmonised and standardised environment with similar functional requirements, PIRGs should ensure that national CNS/ATM implementation plans conform to a regional norm. Countries draft their own Aeronautical Information Publications (AIP), as discussed in **Section 5.2.3**. Continuous contacts between nations and PIRGs will ensure more comprehensive introductions of future air navigation systems. Accordingly, constant interaction between PIRGs and the ALLPIRG will also aid progress.

This framework recommends that ICAO PIRGs co-ordinate integration of CNS/ATM in the seven regions, but with an emphasis on complete co-ordination with all stakeholders through the ALLPIRG and other endeavours. Therefore, regional agencies such as ASECNA or Eurocontrol should influence decisions. Indeed, such agencies should be given decision-making powers by their member countries. This should ensure that regional implementation occurs as quickly as possible through general consensus. Noting that each stakeholder has its own agenda and preferences, there is a need for an independent governing body with leadership status, whose objective is to expedite the process. In fact, regional management should be enhanced through the following specific stakeholder actions:

□ **Non-ICAO regional aviation authorities:**

- Ensure that CNS/ATM requirements have been established within the whole region, noting that a method for identifying CNS/ATM requirements is given hereunder after the stakeholder action plans;
- Liaise with the relevant ICAO PIRG to formulate optimum implementation plans based on credible operational concepts<sup>905</sup> that are incorporated in the relevant ANP, noting the importance of accommodating the transitional period when the aircraft population and ground stations, where applicable, use a mixture of old and new technologies and procedures;
- Confirm that a sufficient number of alternate airfields is provided with adequate physical characteristics for landing/take-off requirements of diverted aircraft and sufficient nav-aids. Given the propensity for Extended Twin-engine OPERations (ETOPS), incorporate this increasingly important issue;
- Participate in the development of standards such as ICAO SARPs, in addition to facilitating R&D;
- Employ suitable project appraisal techniques when developing solutions, such as the suggestions in **Section 5.3** of this framework;
- Create or maintain beneficial institutional structures and international co-operative ventures using organisations similar to those described in **Section 5.4**;
- Ensure that all training requirements are determined and planned as soon as possible, given the potentially long lead times (see **Section 5.4**);
- Adhere to the implementation plans through legislative methods, as per **Section 5.5**, with an emphasis on early introductions of CNS/ATM technologies and procedures such as those cited in **Part 1** of this thesis (**Appendix 5.3** contains a summary of the

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<sup>905</sup> Operational concepts should be developed through identification and improvement of capacity or efficiency constraints, in addition to establishing aircraft and infrastructure requirements that produce a positive business case (see **Section 5.3**). New operational concepts should be predominantly based on the existing EU, ICAO and US models (see **Chapter 3**).



- CNS/ATM systems). Accordingly, this may facilitate decommissioning of obsolete equipment;
- With reference to **Section 5.6** and **Chapter 6**, advise nations within the region on innovative financing methods;
  - Set up a performance-related standards framework based on the contents of **Section 5.7** and **Chapter 7**;
  - Remain in contact with all other stakeholders.
- **Air Navigation Service (ANS) providers:**
- Commission and install the necessary infrastructure;
  - Employ suitable project appraisal techniques when developing solutions, such as the suggestions in **Section 5.3** of this framework;
  - Create or maintain beneficial institutional structures and international co-operative ventures using organisations similar to those described in **Section 5.4**;
  - Ensure that all training requirements are determined and planned as soon as possible, given the potentially long lead times (see **Section 5.4**). Utilise the increased availability of CNS/ATM training facilities;
  - Adhere to the timelines in regional implementation plans;
  - Participate in the development of standards, such as ICAO SARPs, in addition to R&D;
  - Use innovative financing methods, such as funding based on projected revenues, as discussed in **Section 5.6** and **Chapter 6**;
  - Set up a performance-related standards framework based on the contents of **Section 5.7** and **Chapter 7**;
  - Remain in contact with all other stakeholders.
- **Users:**
- Install the necessary avionics in a timely manner: early introductions of CNS/ATM technologies and procedures, such as those cited in **Part 1** of this thesis (**Appendix 5.3** contains a summary), can provide operators with significant benefits;
  - Participate in the development of standards such as ICAO SARPs, in addition to facilitating R&D through aircraft trials;
  - Employ suitable project appraisal techniques when assessing solutions, such as the suggestions in **Section 5.3** of this framework. Specific factors that affect the decision to adopt new technology include reductions in overall costs (which include aircraft equipment, training and operating expenses) and increases in benefits, in addition to a national or regional mandate to equip;
  - Utilise the availability of CNS/ATM training facilities, as per **Section 5.4**. In addition, ensure that all training requirements are determined and planned as soon as possible, given the potentially long lead times;
  - With reference to **Section 5.6** and **Chapter 6**, use innovative financing methods;
  - Encourage performance-related standards for ANS providers based on the contents of **Section 5.7** and **Chapter 7**;
  - Airlines with hub and spoke networks should, where possible, spread the load of flight arrivals and departures throughout the day so that congestion and missed connections are minimised;
  - Remain in contact with all other stakeholders, noting that industry pressure from users is essential.



□ **Airframe and CNS/ATM equipment manufacturers:**

- Develop suitable technologies, based on the world's specific regional CNS/ATM requirements, with emphasis on early introduction of technologies and procedures. Remember that **Part 1** of this thesis contains an evaluation of CNS/ATM systems, which are summarised in **Appendix 5.3**;
- Employ suitable project appraisal techniques, such as the suggestions in **Section 5.3** of this framework, when developing solutions that involve all stakeholders' views;
- Adhere to the timelines in the worldwide regional implementation plans;
- Participate in the development of standards, such as ICAO SARPs, in addition to R&D. Indeed, co-operate with the creation of performance-related standards that use the contents of **Section 5.7** and **Chapter 7**;
- Use innovative financing methods, as discussed in **Section 5.6** and **Chapter 6**, for implementation of products;
- Ensure adequate provision of support and training for CNS/ATM products;
- Remain in contact with all other stakeholders, noting that industry pressure from manufacturers is essential.

Some of the aforementioned stakeholder action plans cite that it is necessary to identify CNS/ATM requirements for each region. It is possible to conduct such an exercise on the basis of identified homogeneous ATM areas and/or major international traffic flows. Indeed, it should be noted that global harmonisation of ATM will require that such regional areas interface. Findings from identification of ATM areas may subsequently be amalgamated with the requisite CNS elements, as discussed in **Part 1** of this thesis, to meet the ATM requirements. An overview of the exercise, which is adapted from the recommended ICAO methodology<sup>906</sup> with additions to suit this framework, follows:

- **Determine homogeneous ATM areas** – consider the varying degrees of complexity and diversity of the region's air navigation infrastructure. Organise the airspace based on ATM areas of common requirements, such as traffic density and sophistication, noting that **Appendix 3.2** lists the different types of airspace with their related ATM procedures and benefits;
- **Identify major international traffic flows** – similar to homogeneous ATM areas, traffic flows can be identified in terms of areas that include groupings of routes or as RNAV regions;
- **List and categorise the areas** – List the Flight Information Region(s) (FIR) within the homogeneous areas and/or international traffic flow regions. Then, categorise the regions by origin and destination geographic areas or as continental/oceanic en-route regions. ICAO has identified some international traffic flow regions, as discussed in the analysis of regional CNS/ATM activities in **Section 4.7** and its associated **Appendix 4.6**. However, the PIRGs still have a lot to identify in detail;
- **Determine the number of aircraft movements** – whether determining the ATM requirements for a homogeneous ATM area or major international traffic flows, it is essential to forecast its level of traffic per annum and to determine the peak demand

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<sup>906</sup> 'Global Air Navigation Plan for CNS/ATM systems' – ICAO. 1<sup>st</sup> Ed. 2000.



for the area. The International Air Transport Association (IATA) and ICAO are presently evaluating and manipulating aircraft movement figures;

- **Evaluate the current infrastructure** – analyse separation standards, availability of CNS technologies and ATM limitations of the identified homogeneous areas and/or international traffic flow regions. Develop a list of operational problems or system constraints for the different operating phases, namely airspace and flight planning; airport surface; departure and final approach; departure and arrival transition; and en-route. Many aspects of the phases' CNS/ATM and environmental factors affect the capacity, efficiency and safety of the respective airspace regions, with resultant ability to reduce the number of delays. Indeed, ground or airborne delays arise from:
  - Direct factors – such as separation standards, flight procedures, weather, traffic demand/variability and difference in the region's aircraft performance;
  - Indirect factors – politics and regulation;
- **Apply ATM design elements** – noting that **Section 3.3.4** discusses future ATM system design methods, draft suitable solutions based on the new CNS tools that are (becoming) available for the identified homogeneous areas and/or international traffic flow regions, remembering that the areas must interface in as harmonised a manner as possible. This should achieve increased capacity and efficiency. It should be noted that it is possible to create FANS-1/A based routes, which have the added benefit of freeing up some capacity on the traditional routes. Some FANS routes have been created, as stated in **Chapter 4's** analysis. Correspondingly, it should be noted that changes to airspace design, usually with reduced separation standards such as RHSM/RVSM<sup>907</sup>, and provision of more runways also increase system capacity. The efficiency of systems may be improved through automation, Collaborative Decision Making (CDM) and/or redesign<sup>908</sup> of airspace. The latter could be manifested through the creation of new routes<sup>909</sup> or reduction in the number of area control centres<sup>910</sup>. As ever, there is a need to maintain or improve safety;
- **Specify CNS technologies** – with reference to the identified ATM requirements, use **Part 1** of this thesis to apply suitable CNS technologies within the airspace regions.

Given that this framework wishes to expedite the implementation of CNS/ATM, the following constraints on capacity, efficiency and safety of the system around the world should be remembered when determining CNS/ATM requirements for each region:

- **US/Western Europe** – noting that many high-density operations occur in these regions, there is a need to address airport gates, runway slots, wake vortex management of arriving aircraft, noise, emissions, human performance, Air Traffic

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<sup>907</sup> RHSM/RVSM – Reduced Horizontal Separation Minima / Reduced Vertical Separation Minima.

<sup>908</sup> For instance, the US FAA announced in 1998 that it would redesign all its airspace regions. The FAA recently unveiled redesign concepts for New York airspace, upon which the final solution will be decided in the latter half of 2001.

<sup>909</sup> A recent example of new routes is the deal brokered by ICAO in the South China Sea's Chinese and Vietnamese airspace that will benefit traffic between Jakarta/Kuala Lumpur/Singapore and Hong Kong/Manila/Taipei from the end of 2001.

<sup>910</sup> Germany will consolidate the number of area centres from five to three from 2003. Accordingly, in numerous areas around the US, the FAA is housing several local Terminal Radar Approach CONTROL (TRACON) facilities under a single roof.



Control (ATC) sector capacities, traffic flow management and politics regarding integration of systems;

- **Other regions** – constraints in these regions include controller and pilot proficiency, CNS infrastructure and financial issues.

Many other constraints exist, but authorities should concentrate on the aforementioned restrictions when drafting requirements of the future CNS/ATM system. Accordingly, ICAO believes that the approach leading to implementation of airspace enhancements and reduced separation initiatives is based on the following three steps<sup>911</sup>:

- **Assessment of requirements** – requirements should be based on the capability or performance of the current system and aircraft in the region. Then the benefits, costs and impact of the enhanced requirements can be considered;
- **Planning and preparation** – this should be initiated using the results of the first stage and should incorporate amendments to regional procedures that contain criteria to implement operational enhancements and/or reduced separation minima. An approval process should then be completed for aircraft and operators;
- **Operational implementation** – should ensure that appropriate organisations and countries initiate on-going safety and performance monitoring programmes.

The three steps should be conducted on a project basis (see **Section 5.2.4**), in order to enable efficient planning of the following operational planning phase functions, which are described and discussed in more detail in **Section 3.4**:

- **Strategic ATFM** – to recognise constraints in order to detect possible congestion and implement remedial actions when and where necessary;
- **Tactical ATFM** – to detect more immediate congestion problems and solve them by actions on individual flights before take-off;
- **Planning ATC** – to detect separation or airspace conflicts and identify those flights that are not involved in potential conflicts;
- **Tactical ATC** – responsible for the implementation of solutions to problems left to the controller by the planning ATC function.

Ultimately, if the aforementioned actions by ICAO and other stakeholders are carried out in a timely manner, the proposed regional management strategy of this framework should secure the successful introduction of safe, gate-to-gate CNS/ATM systems in the world's regions and, correspondingly, at a global level. Indeed, noting the extent of delays in Europe and the US, it is often beneficial to plan on a regional basis. However, the success of regional management processes is heavily dependent on planning that is conducted at the national level, as discussed in **Section 5.2.3**.

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<sup>911</sup> 'Global Air Navigation Plan for CNS/ATM systems' – Volume I, ICAO. 1<sup>st</sup> Ed. 2000.



### 5.2.3 National management

All countries are responsible for the provision of air navigation facilities and air traffic management in their airspace<sup>912</sup>. Therefore, each nation should establish a CNS/ATM planning group, with the regulatory powers (see **Section 5.5**), whose members represent all the country's stakeholders. The aim of the planning group should be to develop a national plan for CNS/ATM systems and subsequently manage its related integration projects. The group's mission statement should incorporate the objectives for implementation of future ATM systems, as discussed in **Section 3.3.2**. thus:

- Meet evolving air traffic demand;
- Support a safe and orderly growth of international civil aviation;
- Enhance safety, regularity and efficiency;
- Minimise delays;
- Provide greater flexibility by accommodating user-preferred flight profiles;
- Improve the provision of information to users;
- Organise airspace in accordance with ATM provisions and procedures;
- Optimise benefits through global integration;
- Enhance economy of commercial air transport.

The planning group should initially study the future air navigation technologies and procedures, as conducted in **Part 1** of this thesis (**Appendix 5.3** contains a summary of the CNS/ATM systems, noting the applicability of certain technologies to different airspace types that have inherent problems). It should then review the country's related regional Air Navigation Plan (ANP) if it has been adapted for CNS/ATM because national plans should be similar to regional plans and based on regional requirements. Indeed, national plans can use regional ANPs for guidance. The planning group should also initiate contact with the ICAO Planning and Implementation Regional Groups (PIRG) and other regional groups, if applicable. In a similar manner, the planning group should liaise and co-ordinate activities with adjacent nations to maximise interoperability and harmonisation of systems. Correspondingly, it should be noted that regional co-operation possibilities are included in **Section 5.4**'s institutional issues.

Having assessed available CNS/ATM systems and the regional ANP, if applicable, this framework recommends that the planning group should create the national plan using a method similar to that for CNS/ATM requirements, which is suggested at regional level in **Section 5.2.2**, but with greater attention to detail, thus:

- **Conduct detailed analyses of existing or already-planned CNS infrastructure and ATM services** – a status report should be prepared as part of a systems inventory that evaluates the country's airports (including type and amount of

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<sup>912</sup> National aviation authorities are also responsible for aircraft registration; airports; international affairs; (economic and safety) regulation; research, engineering and development. In addition, it should be noted that nations must publish Aeronautical Information Publications (AIP), which detail their air navigation infrastructure, services and rules.



traffic), airspace (in terms of air traffic route structures, with any military areas highlighted, traffic density of the routes, the separation minima applied and area of the airspace regions), in addition to CNS systems (outlining the type of system, its location, date of installation and time until the existing system will be retired);

- **Identify the shortcomings of the current CNS/ATM systems** – noting that **Part 1** of this thesis highlights the hindrances of present infrastructure, the operational and system limitations should be analysed, with a view to determining shortcomings that require immediate action, with consequent short-term improvements, and those involving longer-term attention. This has the benefit of facilitating improvements in the near future. It is essential that problems are classified and prioritised:
- **Determine the number of aircraft movements** – using forecasting methods, predict the number of freight and passenger aircraft movements at major airports and on major air routes. This capacity assessment should incorporate overflying aircraft, in addition to the summation of the number of departures and landings at the country's airports so that domestic and international traffic is included;
- **Assess airspace users' needs** – the requirements or expectations of the country's commercial, general and military aviation industries must be included. For instance, many commercial operators have equipped their aircraft with FANS-1/A technology, which can avail of the new breed of routes. Therefore, implementation of such routes should be encouraged. Accommodating users' perspectives may be easily conducted if the planning group has members that represent all stakeholders. It should be noted that general aviation is not too enthused about CNS/ATM<sup>913</sup>, but that airlines have realised the need to work together<sup>914</sup>;
- **List the CNS/ATM solutions** – based on CNS tools that are available, existing or planned ATM infrastructure and services, prioritised shortcomings of the present system, projected traffic levels and the needs of the country's operators, the planning group should draft the short-term and long-term solutions for the nation's plans in terms of CNS/ATM improvements. The selection process should use project evaluation techniques, as discussed in **Section 5.3**, making sure that technological maturity does not outstrip the business case maturity. In other words, technical developments matched to desired operational concepts, if available, must ensure a positive benefit-cost ratio. In order to enhance regional and global harmonisation, the chosen CNS/ATM systems should be interoperable with neighbours' solutions, which can be achieved through integration of Commercial Off-The-Shelf (COTS) technologies based on modular designs, as discussed in **Chapter 3**. In addition, the country's CNS infrastructure should support as much flexible ATM as possible. Indeed, it may be necessary to redesign airspace.

Once the CNS/ATM requirements have been determined, the planning group should cite realistic implementation timelines that guarantee a smooth transition to the country's future system. Experience to date<sup>915,916</sup>, as emphasised in **Part 1** of this research, has

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<sup>913</sup> 'General aviation community voices concern over future access to airspace system' – *ICAO Journal*, November/December 1999.

<sup>914</sup> 'World's airlines demand modern ATC, no undue taxes' – *Air Transport Intelligence*, 17 February 2000.

<sup>915</sup> 'Study reveals that evolutionary introduction of CNS/ATM systems will bring major benefits' – *ICAO Journal*, November/December 1999.



demonstrated that an evolutionary approach with progressive implementation of technologies and procedures is more successful than a 'big-bang' style. Indeed, this philosophy brings immediate benefits of CNS/ATM systems. Therefore, a project management schedule (see **Section 5.2.4**) should be created, which indicates the various milestones. Given that the schedule will extend for at least ten years, it should allow some element of flexibility for development of superior systems that may be substituted. Correspondingly, each step should have its own adequately positive business case (see **Section 5.3**). **Appendix 5.4** describes the planning process adopted by the Republic of Cape Verde as a case study example of national concepts and implementation strategies.

The transition strategy should accommodate the fact that introduction of CNS/ATM may take place at varying rates in the different geographical regions of the country, with dissimilar interface at FIR or geographical boundaries and phasing-out of current systems at alternate times. In addition, different systems will be in use in the various flight phases. Correspondingly, there will be varying aircraft capabilities within the same airspace. Indeed, traffic should be segregated according to ability, with the preferred routes given to those that equip, thereby providing users with incentives for equipage. Ultimately, the national CNS/ATM planning group should use all the other components that this framework formula considers by:

- Creating or maintaining beneficial institutional structures and international co-operative ventures using organisations similar to those described in **Section 5.4**;
- Enforcing the implementation plans through legislative methods, as per **Section 5.5**;
- Participating in the development of standards such as ICAO SARPs, in addition to facilitating R&D, as described in **Section 5.5**;
- With reference to **Section 5.6** and **Chapter 6**, advising the country's operators on innovative financing methods;
- Setting up performance-related standards systems for the country's ANS provider(s) based on the contents of **Section 5.7** and **Chapter 7**;
- Remaining in contact with all other stakeholders.

Once all decisions have been made and agreed with the country's stakeholders<sup>917</sup>, they should be incorporated and harmonised with the regional ANP. **Chapter 4** demonstrates how nations have already started to implement CNS/ATM systems and that some have drafted their national plans. However, the evaluation also portrays that many projects, such as Australia's TAAATS and the UK's NERC, are late and overbudget. Indeed, the success of CNS/ATM implementation is based on the introduction of enhancements in a co-ordinated manner, both in the air and on the ground. Upgrades in the air will not come into effect unless the ground systems are capable of providing advanced services. In addition, there is a need for partnerships between stakeholders, such as government-industry co-operation, which is becoming increasingly apparent in the US.

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<sup>916</sup> 'Enter the pacemaker' – *Air Traffic Management*, September/October 1998.

<sup>917</sup> It should be noted that the regional management analysis in **Section 5.2.2** contains suggested methods for all stakeholders.

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Correspondingly, global interoperability using a gate-to-gate systems approach based on modular solutions for flexible ATM will only be achieved if all countries develop their national plans. Nations must make decisions that balance the need for projects to have a positive business case, but that also conform with systems chosen by neighbouring and regional countries. Indeed, it is imperative that countries adopt the recommendations of this framework because they will remain responsible for provision of ANS in their airspace, whether it is outsourced or conducted by indigenous providers (see **Section 5.4**). In a similar manner, it is in the interest of all stakeholders to facilitate swift completion of national plans so that the safety of future operations is enhanced, with increased fuel savings and delay reductions.

#### **5.2.4 Project management**

In addition to the discussions at the three previous levels, there is a need to mention more measures about the management of CNS/ATM implementation projects, so that this framework strategy is as complete as possible. Noting that **Section 5.3** covers project appraisal techniques and that current decision-making processes are sometimes ten or more years in duration, this framework recommends that the following stages be conducted, where applicable, by stakeholders when managing CNS/ATM projects:

- **Input process:** Planning should begin with input from potential suppliers of the technology or procedure and all other stakeholders that are involved. It is often the case that bidders have already conducted substantial work on the CNS/ATM system's particular application(s). This is enhanced through market competition and can lead to large reductions in lead times to further stages;
- **Selection process:** As part of the decision-making process, perform a preliminary analysis of the CNS/ATM system based on the input process' information. This is crucial, yet somewhat subjective, due to selection usually being based on predictions of future requirements. Sort the candidate CNS/ATM systems by their current, short- and long-term requirements, which should minimise any uncertainties that may be present;
- **Analysis process:** There is a general emphasis that projected costs are usually easy to determine, but that predicting benefits can be more dubious. In addition to determining its costs and benefits, as deemed necessary by **Section 5.3's** recommended project appraisal techniques, the analysis process must also check that each CNS/ATM system would work in its intended environment. Ultimately, this stage of the decision-making process validates the potential technologies or procedures, prior to rating the CNS/ATM systems in desirable order;
- **Approval process:** This final stage of the decision-making process consists of the economic or financial approval and the technical approval of the recommended CNS/ATM system. Refer to **Section 5.3** for the former and **Section 5.5** for an analysis of certification, standardisation and other regulatory processes. There is a need to involve all other relevant stakeholders in a Collaborative Decision Making (CDM) process. Once this approval process is completed, the stakeholder should have made its decision of what option to choose;



- **Implementation process:** At this stage, project management brings the CNS/ATM system into operation, having obtained operational approval as part of the regulatory process discussed in the previous stage. The project management schedule, which indicates various milestones, should be defined and prioritised. Given that the schedule could extend for up to or more than ten years, it should allow some element of flexibility for development of superior systems that may be substituted for CNS/ATM systems that are presently planned. When the project is being integrated, it is extremely beneficial to check its progression constantly in terms of cost, quality and time by iteratively analysing specific project elements. The project performance may be appraised using a categorising mechanism, such as:
  - **Good:** the project does not face any significant problems, noting that its budget and timetable are within 5% of their desired levels;
  - **Satisfactory:** the project is experiencing some implementation problems, such as delays, bad management or procurement issues. Its budget and timetable are running under 10% over the planned levels;
  - **Poor:** extreme delays are being experienced and/or the project is not advancing at all.
- **Autopsy process:** the whole project and its management should be subject to an audit, so that future CNS/ATM projects benefit from experiences gained as part of the current project.

Noting that most CNS/ATM system introduction processes are conducted on a project basis, there is a need to evaluate projects, as mentioned previously in the **Analysis process** and **Approval process** parts of this section. Therefore, **Section 5.3** develops project appraisal techniques.



### 5.3 Project appraisal techniques

The evaluation of CNS/ATM in this thesis' **Part 1** makes it abundantly clear that the worldwide implementation of future air navigation systems is predominantly project based. **Section 5.2** reiterates this fact. It is consequently essential that the framework include methods for conducting appraisals of CNS/ATM projects. In a similar manner, this research stresses the importance of financial factors regarding successful implementation of CNS/ATM, whereby most stakeholders have to generate a business case for their projects. Indeed, the project's decision makers are usually not those who develop the technical solutions, but those who appraise the project from an economic or financial perspective. Correspondingly, with respect to ATM service-related projects, it should be noted that the performance of Air Navigation Service (ANS) organisations is developed as part of this chapter's framework in **Section 5.7**. The results of such evaluations may be included in project appraisals.

Therefore, this section summarises two techniques that may be applied to assess the viability of CNS/ATM projects in terms of profitability: financial evaluations and the economics-based Cost-Benefit Analyses (CBA)<sup>918</sup>. By definition, CBAs consider more economic issues than financial evaluations, but both incorporate elements of project management and it should be noted that CBA contains financial analyses. Economics is an important driver in this framework. Thus, this section concentrates on developing the economic component of the framework after a brief overview of financial evaluations. When assessing a potential project, any stakeholder may use the approach to economic assessments that is developed in this section and in **Section 5.2.4**. However, prior to assessing the two types of project profitability appraisal methods, consider the following suggested content for a CNS/ATM systems evaluation report:

- Purpose and location of project;
- Context of required implementation, including value of the outcome;
- Market and demand;
- Description of project's main elements;
- Particular technical details;
- Environment effects;
- Procurement of equipment;
- Investment requirements, split by type of equipment or service;
- Implementation management and timetable of the project;
- Operational management and costs/revenues;
- Profitability based on financial and economic assessments.

A conclusion of the risks (which can be financial, political or technical in nature) and recommendations should be included when the project appraisal is complete after the assessment of the financial and/or economic profitability. It should be noted, however, that the recommendations from economic and financial appraisals might conflict, which means that the project could have a form of subjective analysis applied.

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<sup>918</sup> Cost effectiveness analysis, economic impact analysis, least-cost analysis, pay-off period, snapshot approach and utility value analysis are other economic appraisal methods.



### 5.3.1 Financial evaluations

Financial evaluations deal with the direct costs, revenues and funding sources associated with specific investments for projects. The evaluations aim to demonstrate the financial viability of a project and its investment by identifying the total costs and comparing them with the scope for recovering costs through revenue over the project's life. The expected return must exceed the amount of investment, therefore providing a positive rate of return or return on investment. Consider costs and revenues, thus:

- **Total costs** include the initial capital investment, in addition to operation and maintenance costs that are incurred throughout the project's useful life:
  - Capital costs include the procurement expenses and the interest costs of borrowing the funds, which are often restated as depreciation and interest to be recovered over the life of the project;
  - Operation and maintenance costs may be a negative amount if the capital investment results in reduced staff or other maintenance costs over the life of the asset.

Both cost sectors should be split by type of equipment or infrastructure;

- **Revenue** sources must be identified and the risks associated with the sources assessed. Given the many types of CNS/ATM projects that warrant financial evaluation, sources can vary considerably. Nonetheless, revenue from the various sources must be forecast per annum for each revenue stream. Taking the implementation of CNS/ATM infrastructure on behalf of an ANS service provider as an example, the revenues usually come from charges. As discussed in **Chapter 6**, the fees would normally be related to cost recovery. In order to assess the risks, increases in user charges can be related to their impact on users: the increase in user fees would have a direct impact on the demand for services provided. The extent to which the demand is affected can then be taken into account when determining the risks associated with this revenue stream and, ultimately, the financial viability of the project itself. Correspondingly, the business case must also incorporate the effect of downward changes in revenues.

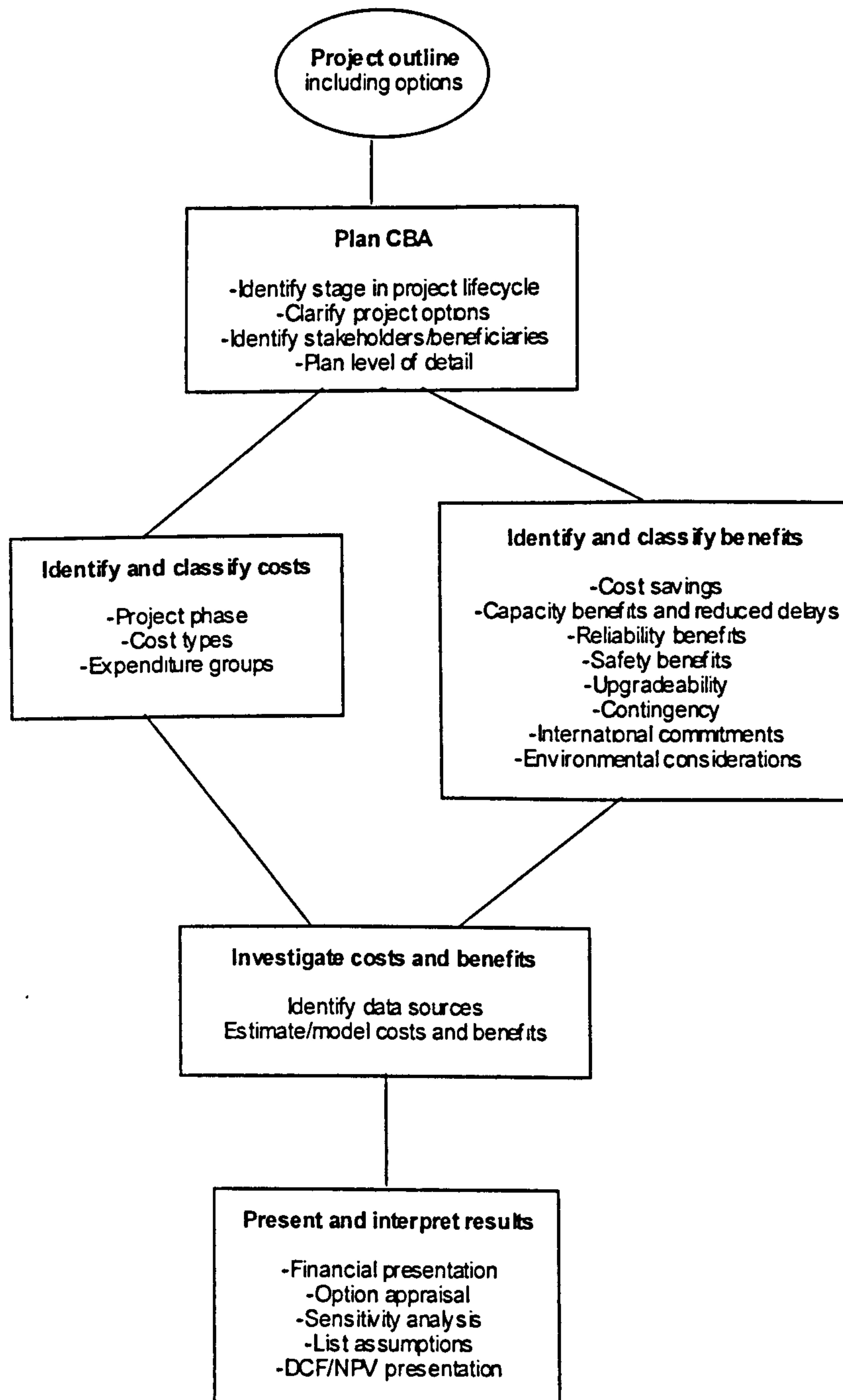
Financial evaluations can also provide complete assessments of cash flows associated with each investment option, which can assist with choosing between alternative solutions. In addition, the financial integrity of the debtor should be determined through an analysis of its credit record and its accounts, which should include assets that may be used as collateral security.

With respect to this framework for implementation of CNS/ATM, it is suggested that financial evaluations are useful for providing indications of projects' financial viability. However, it is essential that economic drivers are also associated with the business side of CNS/ATM. Therefore, this part of the framework on project appraisal techniques concentrates in more detail on an economic method, cost-benefit analysis, which is discussed in **Section 5.3.2**.



### 5.3.2 Cost-benefit analysis

With reference to the theoretical summary flow chart of Cost-Benefit Analysis (CBA) in **Figure 5.1**, this section discusses each of the flow chart's boxes as separate tasks, together constituting this framework's approach to conducting CBA.



**Figure 5.1** – Summary flow chart of this framework's approach to CBA



Therefore, this framework for improved implementation of CNS/ATM suggests that all stakeholders should take the following steps (split into five main parts) when evaluating the viability of a project through CBA, which determines the net benefits for projects:

### **1. CBA planning**, which should:

- Identify the relevant stage in the project's development or lifecycle, thus:
  - CBA can be applied at virtually any stage in a product's life cycle, so assess the project's planned duration and the timescales of sub-projects, if applicable. In particular, CBA is useful in the life of a CNS/ATM project to prove its economic viability, in addition to choosing between different implementation options on institutional, operational and technical grounds;
- Clarify the project's options and/or scenarios, noting that the 'do nothing' option is the reference, which is termed 'base case', is contrasted with the 'project case'. Both the base and project cases are always considered: measures of CNS/ATM viability should be based on a comparison between the two cases. The following should be included in each option's description:
  - A planning & development schedule and a certification schedule;
  - Expected operational date of the option plus an operational schedule;
  - Type of equipment: with reference to the evaluation of CNS technologies and ATM procedures in this thesis' **Part 1** for the different types of airspace scenarios that exist, this stage of the CBA planning should state the various technological specifications for CNS/ATM systems configuration;
  - Whether there are different levels of service to be considered;
  - Economic life of the option;
  - Transition schedule;
  - Functional and operational capability of the option, having determined that each option is logical, reliable and stable;
- Identify project stakeholders, as previously listed, which could include:
  - Aircraft and CNS/ATM equipment manufacturers;
  - Airports;
  - Financiers, who may be public or private;
  - General community;
  - Military authorities;
  - Nations or regions;
  - Providers, such as ANS organisations and satellite consortia;
  - Regulators, from ICAO on a global scale to national aviation authorities;
  - Users, whether airlines and other aircraft operators;
- Identify project beneficiaries from the aforementioned list of stakeholders, noting that, by the definition of CNS/ATM, stakeholders share risk parameters. In addition, different stakeholders are now involved in the decision-making process;
- Plan the level of detail for the CBA, which will depend on the project phase and the size of project. It could be an assessment of the need or opportunity for the project, a scoping CBA or a full CBA, but will also be based on:
  - Whether a decision has already been made;



- If the decision is to be based purely on external factors;
- When the decision will be made;
- Determine the extent to which local or regional institutional and regulatory policies affect the costs and benefits of the project. They affect the economic viability of CNS/ATM decisions and the impact of the new systems on its stakeholders and the CBA. For instance, the institutional cost allocation principles that the project must follow will influence the CBA (see **Section 5.6** and its associated **Chapter 6**). Accordingly, the proportion of a region or nation's aircraft fleet that has been equipped with the necessary equipment for a CNS/ATM project has profound implications for many of the CBA's components. It should be noted that CBA is also very much concerned with current and expected performance of systems, which is dealt with in **Section 5.7** and **Chapter 7**;
- Compute or forecast any base data and assumptions that may be required;
- Conduct a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of the project to ensure that all angles have been covered;
- Minimise the pitfalls of CBAs, which include:
  - Double counting;
  - Projects being technology-led;
  - Consistency across projects, such as using the same cost and benefit data.

The aforementioned issues serve to highlight the need for clearly stated assumptions at the beginning of every cost-benefit analysis. In addition, some essential calculations are usually necessary at the planning stage of CBAs, such as forecasting various parameters.

**2. Identifying and classifying costs** for both base and project cases, if applicable, which should include all anticipated expenditure associated directly and indirectly with the project. Costs can be classified according to:

- The project phase in which the cost is incurred:
  - During Research & Development (R&D);
  - During implementation;
  - During operation;
- Project cost types, which should be categorised as:
  - Investment costs – associated with R&D, acquisition of equipment, start-up costs, installation costs, training expenses and other one-off expenditure for the project. Note the similarities in categories, for example, in airline and aircraft-related projects. The capital cost of CNS systems should be contrasted with the fact that improved ATM creates financial gain through better procedures and lower distances. Evaluation of the required equipment or infrastructure should be completed as part of the project management process described in **Section 5.2**, which necessitates development of detailed system specifications and equipment configurations by operational and technical experts;
  - Operating costs – comprising administrative, staff, operations (including maintenance) and overheads, which may be direct or indirect. It should be noted



- that these costs could go down and would therefore be net benefits: for instance, automation facilitates reduced staff costs;
- Transition costs – where it is necessary to maintain parts of the current system or equipment during the transition period to the new system or equipment. Indeed, termination costs will undoubtedly be incurred when closing down or removing the old equipment, if applicable. Transition costs incorporate conversion costs, which cover the expenditure required to retrain staff;
  - Opportunity costs – what the financier could otherwise be doing with the funds required for the project;
- Expenditure groups, such as:
    - Ground;
    - Airborne;
    - Space;
  - Stakeholder groups, with economic factors that include:
    - Airlines: higher operating costs and loss of business from delays;
    - ANS providers: reduced revenues and efficiencies;
    - Airports: lower revenues through delays;
    - Passengers: loss of productivity from delays;
    - National tourist and business industries: loss of revenues;
    - Manufacturers: potentially lower aircraft production due to the inability of the ATM system to meet demand;
  - Qualitative costs, which include disadvantages that are difficult to quantify, such as:
    - Socio-economic costs due to negative social effects such as increased traffic and noise experienced by individuals living or working in the vicinity of the airport;
    - The impact on the environment, which is often difficult to quantify and may have no direct market value, is an important effect of many large transport projects. Emissions and noise are examples of environmental costs. There is the unfortunate irony that as capacity increases, the rate of traffic flow can also rise, with negative environmental consequences.
  - Cost drivers, using an ANS provider as an example, would include:
    - Airspace structure: number, complexity, capacity of sectors;
    - Provision of equipment and facilities: amount of CNS/ATM infrastructure, level of automation, amount of investment required, in addition to age, condition and maintenance standard of infrastructure;
    - Services: level of demand, number of services to be provided, whether any services are non-chargeable, service level required;
    - Staff: salaries and employee productivity levels, in addition to provider's propensity to outsource activities;
    - External factors: including exchange rates and geographic or regulatory aspects.



**3. Identifying and classifying benefits** for both base and project cases, if applicable, which are not just merits of new technology, but can include any of the following quantitative and qualitative benefits:

□ Type of benefit, such as:

- Efficiency improvements, which could be:

- Flight time – flight time saved per flight, number of flights per annum, cost saved per flight time saved or % of flight time saved that is predictable;
- Fuel savings – gallons of fuel per flight, fuel efficiency in %, number of flights per annum or cost per fuel gallon;
- Revenue enhancement – % of fuel saved that is predictable, % of flights that are payload limited, number of flights per annum or additional revenue in terms of value per equivalent seat added, number of equivalent seats per flight and equivalent seats per gallon of fuel saved;

- Increased capacity or throughputs:

- Delay savings – % of capacity increase converted into delay reduction, number of flights per annum, delay minutes saved per flight or cost per delay minute in terms of cost per Direct Operating Cost (DOC) minute or cost per flight cancellation minute;
- Revenue enhancement – % of capacity increase converted into revenue enhancement, number of flights per year or value per flight created;

**Quantitative benefits** – including:

□ Cost savings or cost avoidance drivers, which would be attributable to the main beneficiaries. For instance:

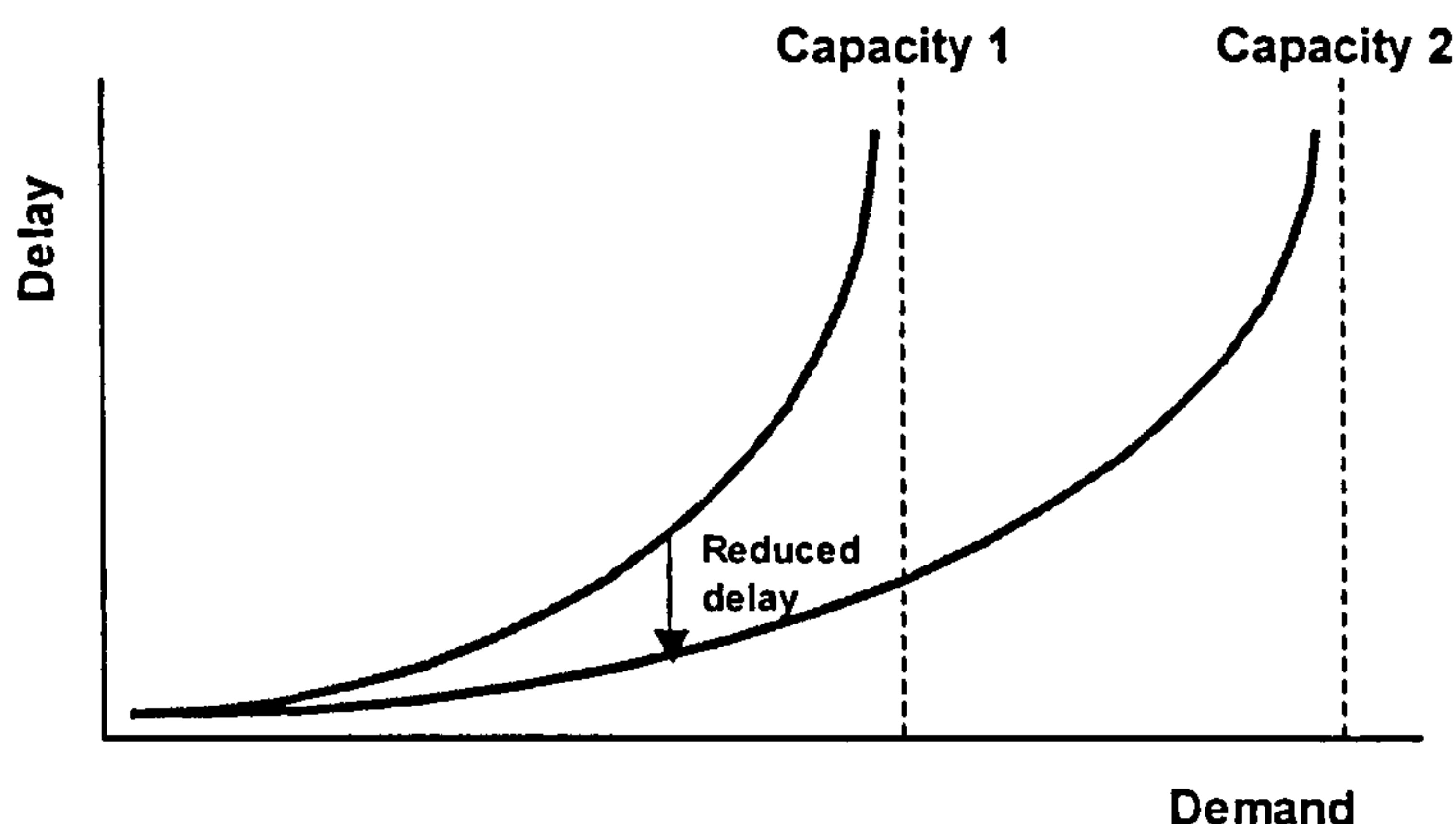
- Service providers: comprising staff, operations, overheads and withdrawal of ground-based equipment;
- Users: due to fuel savings per flight from greater opportunity to fly direct routings nearer optimum profile over shorter time and distance, which has the added benefit of usually incurring lower air navigation charges (see Chapter 6). Lower fares can be indirect benefits for passengers in this case;

In addition to unit operational cost savings, there are benefits in terms of incremental costs, which, if the CNS/ATM systems were not implemented, would be incurred for continued operation of the existing system. These costs would be avoided if CNS/ATM were implemented and are therefore beneficial;

□ Capacity-related benefits through improved CNS/ATM, such as airport, airspace, controller or equipment capacity, which all have economic benefits that should be considered in terms of:

- Limits to capacity;
- Demand for facilities;
- Relationship between capacity and forecast demand: **Figure 5.2** portrays the relationship between capacity, demand and delay overleaf.





**Figure 5.2 – Relationship between capacity, demand and delay**  
**Source – www.boeing.com**

If demand exceeds capacity, congestion<sup>919</sup>, delays<sup>920</sup> or saturation<sup>921</sup> occur, with resultant increased costs and lost economic benefits. In contrast, a system where capacity exceeds demand realises economic benefits.

- Reduction in congestion and delays, which are closely linked with capacity benefits, results in the following benefits:
  - Reduced operating costs to users – in terms of fuel savings and lower navigation fees;
  - Increased aircraft utilisation for users – with resultant traffic growth and consequent increased revenues (for both ANS providers and users);
  - Greater efficiency-related benefits through enhanced service reliability and predictability, which facilitate direct routings and optimum trajectories;
  - Reduced costs to passengers – in terms of time, which is increasingly having a value attached to it, and potential lower fares, as previously mentioned. It should be noted that a concept, which incorporates passengers' willingness to pay, could be used as an indicator here;
  - Secondary benefits – lack of delays result in further knock-on effects;
- Productivity gains for service providers, which may reduce the number of air traffic controllers required, thereby reducing operating costs;
- Reliability benefits of equipment, which are usually considered in replacement projects. Reduced maintenance costs (from purchasing more reliable equipment) and the cost of delays caused by equipment failure form the basis of the benefits case for investment projects that seek to replace or upgrade old and/or obsolete kit. Given the reduced failure time of new equipment, the total reduced delay costs can be calculated as the (change in frequency of failure) x (change in downtime per failure) x (number flights per hour) x (cost of delay per hour);

<sup>919</sup> Congestion – situation where demand approaches capacity.

<sup>920</sup> Chapter 7 considers delay in greater detail.

<sup>921</sup> Saturation – situation where demand exceeds capacity.



**Qualitative benefits** – including any advantages that are difficult to quantify, such as:

- Safety benefits, noting that it is vital for current levels of safety to be maintained or surpassed. Different theories exist regarding the value of accidents or incidents in terms of cost – an analysis of the safety risks can attribute specific monetary values to the risks, thus:
  - Where losses involve tangible goods such as property, risks can be valued on the basis of replacement or repair costs;
  - Where losses have intangible consequences such as personal injury or loss of life, the proper valuation of accident or incident risk becomes more uncertain and judgmental;

Thus, given the difficulties involved with measuring safety benefits, they are often omitted in analyses unless safety benefits would differ among the options considered or prove decisive in establishing a positive net benefit for a single investment. Where a project cannot be justified by consideration of the non-safety benefits, it may be necessary to consider whether the project would lead to safety-related improvements;

- Technical issues such as upgradeability, whereby new systems can be implemented as a means of facilitating future upgrades to incorporate new functionality or contingency for other systems, which could also be considered as a safety benefit. It should be noted that technical issues are very specific to the type of equipment or system being appraised;
- Operational enhancements such as increased capacity, efficiency or flexibility in the system. It is more useful to assess these enhancements by looking at those that may be available in successive implementation steps. Indeed, benefits will be maximised if each phase builds on the previous one. An example is introduction of successive reductions in separation minima through progressive integration of CNS tools;
- Environmental issues, which include noise and emissions, whereby the latter aspect has local, regional and global implications;
- International commitments.

**4. Investigating costs and benefits**, which may be seen as a key element of the appraisal, should be conducted by:

- Identifying relevant data sources such as expert opinions, raw data, models, research, prototyping and databases so that costs and benefits can be forecast over the project's life;
- Estimating costs and benefits, which depend on the parameter being investigated and the level of detail required. For instance, a very basic Automatic Dependent Surveillance (ADS) system could cost less than \$1 million, but a large system could cost \$100 million<sup>922</sup>. Accordingly, **Appendix 5.5** lists some standard cost values that have been developed through Eurocontrol's CBA Group, which may be applied when using this framework's approach to CBA. Additionally, in order to gain an

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<sup>922</sup> 'Demystifying CNS/ATM' – CANSO, June 1999.



understanding of effects on an airline, note that an estimate rendered the cost impact on United Airlines of operational problems during Summer 2000 at \$200 million<sup>923</sup>. Accordingly, **Section 7.3.2** cites other cost data relating to delays. In addition, **Appendix 5.6** quotes values (in US¢ per gallon) for fuel costs at airports around the world during July 2000. Using the sample fuel costs, in addition to other data available from airlines or aircraft manufacturers, it is usually quite straightforward to estimate direct and indirect operating costs or benefits. In this case, the latter are often savings in equipment or fuel expenses. However, estimation of other costs or benefits is sometimes a subjective exercise, noting that attributing values to benefits is often more difficult than for costs;

- Modelling costs and benefits for different options and/or scenarios, noting that manipulation of costs or benefits may aid attainment of the goal, which is to assess whether the project is viable. The modelling should assess the risk impact of the various costs and benefits. It should include all factors that would affect the risk, such as the CNS/ATM operational enhancements or, indeed, lack of an operational concept;
- Importing any uncertainties into the equation, such as institutional and governmental policy issues;
- Noting that benefits in some cases may indeed be costs in others: for instance, the improved ATM capabilities of future CNS technologies may result in lower distances travelled by aircraft on regional routes, thereby being a benefit at regional level, but the traffic may not fly over certain nations thereafter, thus depriving them of revenue and correspondingly lowering their profit margins.

##### **5. Presenting and interpreting results** in a clear manner to the decision maker, thus:

- The financial presentation, which should be decided before the CBA starts because it can affect the manner in which benefits and costs are calculated, can be shown as:
  - Total benefits and costs of each project option, independent of the other options;
  - Incremental costs and benefits, whereby the benefits and costs of the base case option are presented in full, with the incremental benefits and costs of the other options presented individually, relative to the base case;
- Use the results for appraisal of different options or scenarios, given that the costs and benefits of the project's various options or scenarios, if applicable, are now known and quantified in financial terms, together with the years in which they will accrue. The following methods may, among others, be employed:
  - Net Present Value (NPV) – focusing on annual flows of costs and benefits, this is the most popular and often most appropriate approach, where a series of costs and benefits over time are reduced to a single value, the NPV (which is the current year capitalised value). The NPV is obtained through a process termed 'discounting', which facilitates the calculation of present values streams of costs and benefits, termed Discounted Cash Flows (DCF), over a project's lifetime

<sup>923</sup> 'Delays, cancellations may cost United \$200m: report' – Air Transport Intelligence, 10 August 2000.



using the formula: the present value of  $M = M / (1+r)^n$ , where  $M$  is the financial amount of benefits and/or costs and  $n$  is the number of years. The NPV is the sum of discounted benefits minus discounted costs. The interest,  $r$ , should be the minimum rate of return required from the project's investment. The preferred option is the one with the highest NPV. This approach notes that the costs and benefits, in cash flow terms, may not be evenly distributed over time: typically, there will be large capital expenditures<sup>924</sup> in the early years of a new project, followed by many years of benefits, in addition to operating and maintenance costs;

- Annual Equivalent Values (AEVs) – these criteria work well if all project options do not have the same analysis period, whereby the net cash flows of projects can be expressed as equivalent values. Cash flow items can be translated into constant annual values for comparative purposes;

Examples of summary statistics that may be derived include:

- Benefit-cost ratio;
  - Internal Rate of Return (IRR);
  - Return On Investment (ROI)
  - Payback (break-even) point;
- Conduct a sensitivity analysis, which examines the sensitivity of the project's economic performance, its costs and benefits, in contrast with the variation of individual parameters in order to identify the most critical issues and the degree of their impact. Factors which are important for such an analysis include:
- Projected traffic growth;
  - Capacity increases achieved by the project;
  - Efficiency improvements;
  - ATM system costs;
  - User direct operating costs;
  - Financial parameters such as discount or interest rates;
- A discounted cash flow (DCF) should be given for each option;
- Qualitative costs and benefits should be described, noting that their inclusion could alter the outcome of the evaluation: the process of project appraisal can demonstrate that the project is necessary due to the inaccuracies of assigned monetary values;
- Assumptions must be listed.

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<sup>924</sup> CBAs and financial evaluations treat capital costs differently: while a financial investment would normally restate the capital costs into annual depreciation and interest expenses, a CBA measures capital costs by the cash expenditures required in future years. The cash stream of expenditures is compared to the stream of benefits and the annual net amounts are usually discounted to compute the NPV for the investment option.



## **Example of cost-benefit analysis for CNS/ATM implementation**

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Consider the discussion on integration management of CNS/ATM at national or regional levels in **Section 5.2**. There follows a suggested template that should be performed for each year of the project's life:

### **Base data**

- Forecast the traffic demand, in terms of total flight-hours and aircraft numbers by type of aircraft operator, split for domestic and international carriers. Note that, if total flight-hours are unavailable, it is possible to compute their value through: (aircraft movements x average distance flown) / (average speed). For General Aviation, categorise by IFR and VFR.

### **Costs**

- Forecast the required investment in the CNS/ATM system by type of equipment and/or infrastructure, whichever is applicable, split by aircraft-based and ground-based if both are relevant. Thus, there is a need to know the details and number of facilities that are part of the potential CNS/ATM project;
- Forecast the investment in present technology during transition to the CNS/ATM system, categorised by type of airborne and/or ground equipment. In addition, compute the termination costs of the current system;
- Forecast the operating costs with a CNS/ATM system installed, such as staff costs or communication bills to service providers, which may be obtained by multiplying the quantity of messages per year ('000 Kbits) and the transmission price (per Kbit);
- Consider any other relevant quantitative and/or qualitative economic costs, such as training, as described in the framework above.

### **Benefits**

- Forecast the investment in equipment required for keeping the current system operational over the project's life, if applicable, split by aircraft-based and ground-based;
- Predict the operating costs for keeping the current system operational, such as the aforementioned communication bills to service providers example;
- Forecast the aircraft efficiency benefits of CNS/ATM for particular aircraft categories by calculating the reduction in number of flight-hours that are attributable to the CNS/ATM system. Operational benefits in terms of lower time and fuel consumption should be achieved through increased capacity, improved flight efficiency and direct routing possibilities. It is thought that a 3% reduction value is realistic once CNS/ATM is fully installed;
- Determine the cost savings to all relevant stakeholder;
- Forecast the value of passenger time saving from CNS/ATM in terms of passenger-hours saved by determining the value per hour of passenger time saved and multiplying accordingly;
- Consider any other relevant quantitative and/or qualitative economic benefits as described in the framework above. They may relate to capacity, delay, environment, productivity, reliability, safety or technical aspects of the CNS/ATM system.

Compute the Net Present Value (NPV) results for each type of operator using one of the manners described in the framework, such as the benefit:cost ratio or the difference in



monetary terms between the cost and benefits. It should be possible to relate the individual operator type values to determine a system-wide result. Thus, the economic viability of the project has been realised.

### **Summary of Cost Benefit Analysis (CBA)**

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Therefore, CBA is an evaluation technique that tries to consider and incorporate all aspects relating to a CNS/ATM implementation project, based on forecast values or issues. In addition to quantifying and stating the financial implications of various alternatives or a project's different steps, CBA takes account of economic consequences. Indeed, it is the assigning of economic values to costs and benefits that requires the greatest attention. In practice, CBA is not so straightforward: while costs and most types of benefits can generally be quantified, an economic breakdown of all the projected costs or benefits is usually more elusive. Thus, attributing values to economic costs and benefits is very important, albeit subjective.

Correspondingly, it should be remembered that projects are inherently interdependent, which means that the value of a single project's costs and benefits are related to other projects being implemented or not. Indeed, if any of the individual groups deems an aspect of the project to be too costly, CBA facilitates the variation of certain parameters in the model, which consequently means that a component may be altered in an attempt to rectify the perceived poor benefits of the new system. For example, en-route fees could be adjusted to cover the cost of providing the service: this philosophy is suggested as a method of financing as part of this framework in **Section 5.6**. Should this not be possible or not agreeable to all parties, the project may not go ahead as tested in the cost-benefit model. Thus, the most appropriate situation may be determined for the specific circumstances, such as optimum scheduling of investments.

With respect to **Section 5.2.4**, a cost-benefit analysis can be used to assist decision-making processes at all stages during a project's life cycle through the identification of options that conform to the goal of maximising net benefits. CBA is applicable to small and large projects alike. Indeed, CBA can be the basis of every development decision because groups can conclude whether they should proceed with implementation as planned, having assessed the economic viability of the CNS/ATM project. CBA can provide guidance on the appropriate timing for introduction of the project's elements. It can justify implementation costs to stakeholders. CBA also has the ability to determine the rôle of the stakeholders involved with the implementation process, in addition to including the financial, institutional, management, political, regulatory and technical implications. It is for these reasons that CBA is part of the framework for successful implementation of CNS/ATM that is developed in this chapter. Ultimately, CBA can be used to answer many key questions, such as:

- What are the project's costs?
- What financial and/or economic cost savings exist by implementing it?
- What operational benefits exist to users of the system, whatever part of CNS/ATM?
- What risk exists regarding the economic viability of the project?
- What alternative approaches are there to the project?



## 5.4 Institutional issues

Governmental and public awareness of air traffic delays is at an all-time high in many nations has highlighted the fact that institutional aspects of CNS/ATM must be improved. This section discusses the framework strategy's institutional components, which are grouped under the following headings:

- Organisational structures of national ANS providers
- International co-operation
- Human factors

Each aspect of the institutional issues suggests optimum solutions, remembering that the methodology of this framework is to provide parameters for all stakeholders that help overcome obstacles to worldwide introduction of future air navigation systems.

### 5.4.1 Organisational structures of national ANS providers

The ICAO Chicago Convention states that each country is ultimately responsible for the provision and operation of its air navigation facilities and services, in addition to setting and maintaining service standards. Therefore, the decision on what organisational structure its Air Navigation Service (ANS) provider(s) should adopt is a matter for the government: it has the choice between some form of national company and outsourcing the activity to an international firm or other country (for this second option, see **Section 5.4.2**). Hence, even if the country delegates service provision on an international basis, the national authorities must govern the provision of ANS in their airspace.

The principal objective for all ANS providers is to plan and operate safe, effective and efficient services that are focused on the needs of the user. Indeed, such a focus will expedite the worldwide implementation of future air navigation systems. In order to achieve this, optimum provider organisational structures are crucial: this section details and analyses the structuring possibilities that exist, in addition to suggesting an approach as part of this research's framework. The contents of this section are also used as the basis of the ANS provider organisational performance analysis, which is conducted in **Section 7.2.3**.

**Section 6.2.2** discusses the major categories of air navigation facilities and services that ANS organisations provide, namely:

- **Air Traffic Management (ATM)**, which is further divided into Air Traffic Services (ATS) and its two sub-components, Air Traffic Flow Management (ATFM) and AirSpace Management (ASM);
- **Communications, Navigation and Surveillance (CNS)**, which is classified according to the three individual CNS components;
- **METEorological (MET)** services for air navigation;
- **Search And Rescue (SAR)**;



- **Aeronautical Information Services (AIS).**

The provision of services within each category varies by country, as do the basic organisational characteristics of their air navigation services. Historically, ATM was provided by nations' civil aviation administrations, but is increasingly being performed by autonomous<sup>925</sup> authorities that are corporatised<sup>926</sup> or by privatised providers. In many cases, the same operating agency is also responsible for providing facilities and services from the other four main ANS categories. It should also be added that governments often retain activities, such as civil-military co-ordination or airspace classification.

Based on an evaluation of the structures that exist around the world, this framework considers three core forms of organisation, at national level, for providing ANS, thus:

- 1. Government department;**
- 2. Autonomous or corporatised public sector agency;**
- 3. Privatised entity.**

It should be noted that the three forms of organisation are not mutually exclusive and that countries can draw on features from one or more of the options by adopting partial execution solutions. Each form is described separately hereunder, followed by a discussion on one of the framework suggestions, commercialisation of ANS providers.

**1. Government department – Key factors and features of the government department approach are that:**

- The organisation provides all types of air navigation services, including related ones such as Search And Rescue (SAR);
- Its brief includes responsibility for the safety regulation of the industry;
- The organisation does not usually have a formal agreement regarding the provision of services to military aircraft;
- Capital expenditure is subject to competition from other claims for government funds;
- The organisation head reports directly to the government;
- It is funded by the government and sometimes from general taxation;
- User charges levied can be retained by the provider or by the government for general purposes;
- The organisation may not be subject to taxes similar to those paid by a private corporation.

**2. Autonomous or corporatised public sector agency – Virtually all transitions that have occurred from a government department have been to an autonomous or corporatised organisation. Noting that the leasing of facilities falls under this category, this type of commercialised provider normally has the following key aspects:**

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<sup>925</sup> **Autonomy refers to the ability of provider organisations to use revenues and make decisions without any reference to the government. However, major capital investments usually require governmental approval.**

<sup>926</sup> **Corporatisation means creating a legal entity outside the government to manage the provision of ANS. Ownership of corporatised ANS providers remains with the government.**



- The government, as owner of the organisation, is responsible for setting the provider's objectives and monitoring its performance;
- Activities are overseen by a government-appointed board of directors and major capital investments would usually be subject to governmental approval;
- However, the organisation is usually free to manage its capital investment and is typically able to borrow on open markets;
- The organisation is self-financing through user fees and is allowed to achieve a financial return on capital employed, as per ICAO's guidelines on charging policies, which are covered in **Section 6.2.1** of this dissertation;
- Revenue from service charges may be used to fund operating expenses and to finance capital expenditure or may be returned to the exchequer as dividends;
- Some operations, such as military and those to remote regions, may be exempt from fees and the cost can be transferred to the government;
- The provider uses a commercial form of accounting and is subject to normal taxes;
- Noting that there is a greater tendency to monitor performance, the management team is led by continued increases in efficiencies, whether financial or performance;
- Legal status of corporatised bodies can take one of several forms, according to its government's desires, but legislation is required;
- Given that such organisations are usually monopolistic, the government retains a sufficient level of expertise to both regulate and oversee the performance of air navigation service providers in terms of their safety regulation, economy and user satisfaction;
- Staff usually have private sector pay and conditions;
- The government can still provide direct loans and other forms of financing.

**3. Privatised entity** – In contrast with the aspects and factors of the aforementioned two other types of organisational forms, the following list details key features of this third structure type, private sector providers, thus:

- The organisation is self-financing through charges for its services, but may have inherent purchase cost debts and capital investment plans, which may be offset by a nominal profit;
- Funds can be obtained from capital markets;
- The firm applies commercial accounting practices and normal business taxes apply;
- In order to maximise efficiency, the board of management focuses on performance monitoring, with greater incentive to adopt an entrepreneurial mentality;
- Aviation safety regulation standards set by a government body must be adhered to;
- In the case that no competition with the provision of air navigation services exists, user fees must be subject to independent economic regulation;
- Some military and remote regions' services may be exempt from charges, which should be borne by the government;
- Arrangements for the co-ordination of civil-military traffic and the use of common facilities must be formalised.

It should be noted that this category contains the possibility of creating Public-Private Partnerships (PPP), which are becoming increasingly popular throughout all industries.



### Commercialisation of ANS providers

With reference to the three main types of structure that have been identified for the purposes of this framework strategy, the degree of commercialisation varies from 0% in type 1 to 100% in type 3. The facts in **Figure 5.3** summarise the migration from a government owned and run entity to a fully-privatised company:

Degree of commercialisation:	0%	→	→	100%
Ownership:	100% government			100% public shares
Accounting methodology:	Cash accounts			Commercial practices
Capital financing options:	National budget			All options
Cash flow financing	Budget and/or fees			Charges
Employee status:	Civil servants			Corporate
Legal status:	Government			Private
Entrepreneurial impetus:	Little			Considerable
Management reports to:	Politicians			Board of directors
Management focus:	Government policies			Financial/performance
Taxation:	Low			As for private companies

**Figure 5.3** – Differences between government and private entities

Over the last 25 years, moves have been made in numerous countries to separate the provision of air navigation services from direct government management to one that adopts commercial costing and pricing. Indeed, commercialisation has become more common in recent years.

ICAO conducted a study of ownership and operation of ANS in 1999/2000<sup>927</sup>. Data was received from 81 nations around the world. In order to assess the split between the three different levels of organisational structure, the results may be adapted to conclude that, of the 81 sample set, 37 nations have adopted the autonomous or corporatised public sector agency organisational structure, one has privatised its provider, while 43 countries still use the government department approach. In addition, this research observes that Austria, Latvia, Moldova, the Slovak Republic and Ukraine have corporatised their providers, but they were not included in the ICAO study. The amalgamated findings are thought to be representative of the situation. Thus, with reference to the list in **Appendix 1.1** of 205 countries that this dissertation analyses, there remains plenty of scope for further commercialisation processes. Interestingly, the ICAO study showed that the majority of countries' en-route ATS providers also supplied AIS, COM and SAR, but that only a minority of providers supplied their national MET services. Accordingly, the research demonstrated that, with the exception of Europe and the US, approach and aerodrome control services are provided in a virtually even split among countries of each region by the airport administration or the en-route ATS organisation.

<sup>927</sup> 'Organizational aspects of the provision of airports and air navigation services' – ICAO Air Navigation Services Conference 2000, Working Paper 18.



**Appendix 5.7** contains a case study analysis of commercialised ANS providers, which emphasises that the increased freedom of being corporatised or (part) privatised brings gains in efficiency and reduced cost structures, in addition to facilitating greater levels of capital investment. Organisations consequently become more competitive and do not possess hindrances associated with government departments. Management is perceived as being more alert, with a public service ethos. In addition, corporatised or privatised providers have greater potential to become involved in international projects, which secures their position for the future: it may be predicted that consolidation will occur in the ANS provision industry during this decade, with those commercialised providers already establishing reputations for sound economic operations.

Corporatised or privatised bodies have the sole task of providing efficient and safe air navigation services, which should enable them to understand the specific needs of their customers to a greater extent. This, in turn, should lead to focus on maximising service standards and the realisation that air navigation charges represent large proportions of users' costs, which may subsequently force providers to concentrate on the institutional efficiency of their operations. Accordingly, commercialised bodies can incentivise the implementation of CNS/ATM through reduced charges for equipping with certain technologies, which consequently acts as a substantial driver for improved implementation of future air navigation systems. Therefore, the perception that higher charges are synonymous with commercialisation is not always true.

However, even though numerous nations' providers have been corporatised or privatised, this thesis' **Chapter 1** and **Part 1** demonstrate countless examples of problems that still exist with the provision of ANS in many parts of the world. The latter experiences are due to many factors, which reinforce the need for the other components of this framework strategy. Nonetheless, ever-increasing ANS provider efficiencies will improve the situation. Indeed, the lead times for CNS/ATM projects are frequently very long, often taking years before distinct benefits are evident. Therefore, this framework recommends that nations commercialise most types of their ANS providers.

Noting that each country's circumstances are different, a decision on what new structure the ANS organisation(s) should adopt<sup>928</sup> is influenced by:

- Organisation of the country's airspace;
- Whether any provision has been historically delegated to other nations and/or international operators;
- The government's liberalisation policies, if any, noting the different cultural and political situations that exist.

With reference to the previous descriptions of the three national organisational structure types<sup>929</sup> and the discussion in **Section 5.4.2** on international possibilities, this strategy

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<sup>928</sup> Whether corporatised, privatised or outsourced internationally.

<sup>929</sup> Namely government department; autonomous or corporatised public sector agency; and, (part) privatised entity.



suggests that national authorities should perform the following to alter the institutional structure of its ANS provider:

- List the various structural options for providers: corporatised, (part) privatised or an international venture (**Section 5.4.2**), noting that forms of organisation are not mutually exclusive and that countries can draw on features from one or more of the options by adopting partial execution solutions;
- Use **Appendix 5.7** to determine whether any neighbouring or regional nations have corporatised their ANS provider. Learning from their experiences should alert the country to potential pitfalls, thereby ensuring that commercialisation occurs swiftly;
- Assess the financial situation of the nation's ANS provider and its requirement for investments. Incorporate the implications of commercialised providers being able to borrow larger amounts of funds. In addition, remember that the integration of CNS/ATM systems offers greater levels of performance, thereby providing a country with an opportunity to generate substantial sums through user charges that may be used to offset its costs. **Chapter 6** conducts a benchmarking exercise of fees for 205 countries, which demonstrates the scope for increased fees in many cases;
- Study the managerial situation in terms of its propensity for efficiency: **Chapter 7** develops and applies performance parameters for this purpose;
- Decide whether to implement organisational structure and/or ownership changes in addition to the possibility of delegating to an international venture (**Section 5.4.2**);
- If (part) privatising, determine a market value for the ANS provider: as an indicator, note that Nav Canada acquired the assets necessary for operation of the Canadian ATS for \$1 billion<sup>930</sup>. Use revenues raised to improve any aspects of national ANS provision that remain owned by the government;
- Conduct a selection process for potential bidders and/or operators, if applicable, and decide accordingly. Note that certain structural models to date, such as Nav Canada and Swisscontrol, have included the ownership and participation of numerous stakeholders;
- Ensure that the regulatory authority is independent of service provision by remaining as a central government function (see **Section 5.5**). This applies to:
  - Economic regulation – although dependent on the degree of corporatisation, care must be taken with issues such as over-charging, non-discrimination between categories of users and conformity with international agreements or obligations;
  - Safety regulation – with emphasis placed on ensuring that the new service complies with international and regional standardisation, including ICAO Standards And Recommended Practices (SARPs);
- Change the legal framework (see **Section 5.5**): issues that must be considered when developing a new charter include:
  - Establishing formal relationships between the government and the organisation;
  - Creating agreements between the organisation and the aviation safety and economic regulators;
  - Identifying, valuing and transferring assets;
- Create an ANS Corporation with financial autonomy, which is owned by the nation, through the requisite legislation. If the government decides that the provider should become corporatised, then the company will remain in this format; if the provider is

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<sup>930</sup> 'A towering success' – *Air Transport World*, October 2000.



destined for (part) private ownership, then assets should be transferred to the Corporation at market value;

- Address all human resource effects, issues and structures (see hereunder in **Section 5.4.3**), noting that employees usually obtain increased salaries when moving to a corporatised or privatised sector;
- Ensure that the newly corporatised, privatised or international ANS provider becomes a member of the Civil Air Navigation Services Organisation (CANSO), noting that **Section 1.5** contains a description of CANSO and its members. This framework recommends that bodies such as CANSO, whose members include representatives of many stakeholders, further the integration of CNS/ATM;
- Plan whether competition (by national or international providers) could be injected into the market in the future, noting that multiple providers in a liberalised environment would certainly stimulate the commercial aspects of the market, but would require absolute guarantees of safety. Other industries have experienced this level of competition, whereby utilities such as electricity have been provided by at least two independent companies. Based on the present situation with the provision of ANS, this is some way in the future. Indeed, competition would probably be more suitable at a regional level.

It should be noted that the International Air Transport Association (IATA) supports the trend towards commercialisation of ANS services and the fact that it enables management to operate in an efficient manner, although the association stresses concern regarding potential for increased navigation fees due to rises in cost base and abuse of monopoly situations<sup>931</sup>. In a similar manner, controllers' unions do not object to corporatisation, but do not approve of privatisation<sup>932</sup>. Correspondingly, the International Council of Aircraft Owner and Pilot Associations is very concerned with the propensity for nations to commercialise its provision of ANS<sup>933</sup>, stressing that privatisation can lead to trimming of non-profitable facilities or services, such as flight plan filing services for General Aviation aircraft.

Irrespective of the differing opinions, commercialisation of ANS offers those countries with poor or unsafe CNS/ATM a possibility of rectifying the situation. It need not be conducted on a stereotypical basis, but rather in a manner to suit the particular cultural and political situation, using the contents of this section as guidance. If a nation or its stakeholders are unwilling to follow this path, then the authorities could consider international co-operation, which is covered hereunder in **Section 5.4.2**.

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<sup>931</sup> 'Airport and air navigation services commercialization' – ICAO Air Navigation Services Conference 2000, Working Paper 26.

<sup>932</sup> 'Giving over control' – *Flight International*, 4 August 1999.

<sup>933</sup> 'General aviation and aerial work concerns for privatisation of airport and air navigation services' – ICAO Air Navigation Services Conference 2000, Working Paper 64.



## 5.4.2 International co-operation

Planning and implementation of CNS/ATM systems requires co-operation among all partners that have a stake in each venture, as portrayed in **Section 5.2**. International co-operation by stakeholders of CNS/ATM institutional issues can exist through:

- Provision of air navigation facilities or services;
- Operational and technical advice;
- Training at an international level.

The former two types of co-operation are covered in this section, while training is assessed in **Section 5.4.3** hereunder. In addition, it should be noted that international co-operation in CNS/ATM is conducted through:

- Planning or integration at regional or global levels (as discussed in **Section 5.2**);
- International financial activities (joint charges collection agencies and financing arrangements are covered in **Section 5.6** and its associated **Chapter 6**).

### International provision of Air Navigation Services (ANS)

Due to reasons that may be financial, operational or technical in nature, a nation's provision of air navigation services may occur at an international level by:

- Multinational sharing of facilities and services with neighbouring countries; or,
- Delegating service provision to an international operating agency.

It should be noted that both options form the fourth possibility for the organisational structure of national ANS providers, as discussed in **Section 5.4.1**, whether the countries contract with international certified service providers, commission an existing international operating agency to act on their behalf or form a new international organisation.

With reference to the **first option**, nations have frequently shared air navigation facilities and services on a multinational basis with neighbouring countries in the past. This is still conducted on a bilateral basis, whereby no charge is levied between the two relevant countries if they each provided similar levels of service. Where there is an imbalance, the cost of providing the services is levied on the users who traverse the airspace for which the providing State is responsible. Equity in sharing of costs is essential. Cyprus has established a mutual co-operation agreement with its neighbouring Middle East countries that deals with ATFM, exchange of radar data and route structuring<sup>934</sup>. Additionally, in a move that demonstrates the ability for nations of different geographic regions to enter into an agreement, Australia, New Zealand and

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<sup>934</sup> 'Eurocontrol lauds Cyprus' ATM co-operation plans' – *Air Transport Intelligence*, 25 April 2000.



Singapore are working on a tri-partite open skies policy<sup>935</sup>. However, it should be noted that some nations have gone as far as outsourcing the provision of ATS in their country to other nations. For example, ATM over Luxembourg is conducted by Belgium. It should be added that the large size of some countries does not lend itself to sharing facilities and services because economies of scale already exist within their borders.

However, this framework suggests that multinational sharing could be brought to a new level of co-operation, with nations and/or their ANS provider(s) forming pseudo-alliances, thereby maximising economies of scale and scope. This could apply to en-route and/or terminal ANS. Where the latter is provided by the airport authority, the agreement could exist in the form of airport alliances. Similar to airline alliances, ANS provision agreements could be created among two or more nations and/or providers. Such agreements could differ in terms of commitment: they could consist of joint purchasing strategies that avail of bulk buying powers. This would have the added bonus of enhancing the probability of increased system standardisation, which is an essential prerequisite for comprehensive, worldwide CNS/ATM. Co-ordination of systems would also facilitate the creation of backup centres, given that each would use similar technology, thereby avoiding the system failures that have been experienced in recent years. Correspondingly, airlines should be encouraged to extend their common purchasing strategies, in particular within alliances, which can range from aircraft orders to Information Technology (IT) implementation plans, to cover avionics.

For instance, this style of international co-operation could reduce the level of congestion that presently exists in the European region. Europe needs short- and long-term improvements, as discussed in **Chapter 4**. Greater harmonisation of ANS provision in the long term would undoubtedly be achieved if a small number of providers existed in the region because the aforementioned alliance and joint purchasing ideas were implemented. Correspondingly, upper airspace co-ordination activities such as an extended Maastricht ATFM centre and the Central European Air Traffic Services (CEATS) centre will be further enhanced in the long term. In the short term, however, it is possible to adopt the level of international co-operation that was employed in the Kosovo conflict crisis. This may seem like too obvious an answer, but why has it not been conducted since?

The **second possibility** for international co-operation with provision of air navigation services is for nations to establish an **autonomous international operating agency**<sup>936</sup>, whether for route or terminal facilities and services. In this case, the operation of designated air traffic management facilities and services within a defined area on behalf of two or more countries is assigned to the authority, which is a separate entity. A treaty or agreement is created so that the agency can contract the countries' provision of ANS (see **Section 5.5.4**). The services provided are usually in the categories cited at the beginning of **Section 5.4.1**, namely ATS, CNS, MET, SAR and AIS. Examples<sup>937</sup>

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<sup>935</sup> 'Asia-Pacific common area seen as elusive goal' – *Air Transport Intelligence*, 12 May 2000.

<sup>936</sup> A separate entity assigned with the task of providing ANS within a defined area on behalf of two or more countries. The entity can be a joint venture of a few States or an international body.

<sup>937</sup> The rôle of these autonomous international operating agencies varies from provision of all forms of air navigation facilities and services for every flight phase to provision of ATS in upper airspace regions.



include ASECNA, COCESNA, Eurocontrol<sup>938</sup>, PIARCO FIR and Roberts FIR. They are referred to throughout this thesis and are described in **Appendix 1.3**. These agencies have proven that increased efficiency may be obtained in the provision of facilities and services at potentially lower cost to both providers and users. In addition, such agencies are also often responsible for collecting user charges relating to the services provided and they are often more successful in collecting overflight charges (see **Section 6.2.3**).

The size, composition and consequently geographic scope of such an agency depends on demographic, economic, geographic and political factors, in addition to the extent to which new and improved facilities may be required. Correspondingly, these factors influence the structure of the agency. Therefore, the organisational arrangement can adhere to numerous patterns. However, certain basic common features include:

- The policies governing the agency's functions, operations, financial affairs and decisions on fundamental matters such as capital investments and appointments of key staff are usually the responsibility of a management board composed of representatives from the member countries;
- Similarly, the chief executive is invariably responsible to the board for the general administration of the agency;
- Sound and well-defined economic and financial policies and practices need to be established, relating to cost recovery and financial control, including accounting and budgetary procedures;
- Recruitment of agency personnel must reflect the international status of the organisation.

It should be noted that **Appendix 5.8** contains a list of contents from the 'Aeronautical Accord' of the African Roberts FIR, which could be considered as a template for future, similar international co-operation ventures between nations. The agreement between the Robert FIR's three member nations, Guinea, Liberia and Sierra Leone, applies to the control of safety (which includes joint provision of search and rescue services) and provision of air navigation facilities and services: it is consequently a pertinent example for the purposes of this framework.

With reference to the previous discussion on pseudo-alliances of national ANS providers, commercialised international operating agencies could also form alliances, certainly at management and ownership levels. They would benefit from increased synergy, but need to constantly assess whether they were reaching critical mass.

In addition to the aforementioned examples, this framework considers the following as demonstrative methods to highlight the possibilities for countries and/or providers regarding this second form of international co-operation for the provision of ANS, thus:

- The **South Pacific Forum** comprises Australia, New Zealand and 14 Pacific Island nations. At present, ATC for the 16 member States is split in to five Flight

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<sup>938</sup> As mentioned throughout this research, the extent of Eurocontrol's mandate is presently being discussed: although its actual provision of ATM services is increasing with upper airspace agreements and ATFM multinational centres, its regulatory rôle is being redefined by the European Commission.



Information Regions (FIRs) handled separately by the US, Fiji, New Zealand, Nauru and the Solomon Islands. The Forum is working on establishing a single FIR. The countries' transport ministers agree that the region's upper airspace should be managed co-operatively, in order to enhance cost efficiencies, but the smaller nations maintain that they must play an operational rôle too. IATA is helping identify and justify the most appropriate arrangement for the management of a unified airspace in the Forum Pacific region. Even though the analysis of regional CNS/ATM in **Section 4.7** and its associated **Appendix 4.6** states that South Pacific Forum activities have stalled, this method is indicative of the potential for a regional emphasis on the provision of ANS, as mentioned as part of the integration management component of this framework in **Section 5.2**;

- The **African countries** considered in this research (see **Appendix 1.1**) realise the potential of international co-operation with provision of ANS and increasingly place emphasis on it, noting that the following ventures now exist:
  - Arab Maghreb Union – this organisation, which consists of 5 African countries, is considering joint co-operation for airspace management;
  - ASECNA<sup>939</sup> – see **Appendix 1.3**, but note that ASECNA is actively involved with preparations for CNS/ATM technologies and procedures<sup>940</sup> through introduction of digital satellite telecommunication network, GNSS trials and the ADS tests that are mentioned in **Part 1** of this research. In addition, ASECNA is looking at automated and other computerised ATM processes;
  - COMESA – its 21 member countries entered into partnership with the Safe African Skies Group (SASG)<sup>941</sup>, as discussed in **Section 4.7**, to cater for the long-term ATM needs in the upper airspace of the nations under its jurisdiction, using self-financing principles and managed in a private sector manner. This liberalisation of air transport also extends to other freedoms, such as bilateral agreements<sup>942</sup>. The nations, the SASG and private African investors will own a new ATM company. Live operations are expected in 2003. Thus, COMESA is an example of CNS/ATM provision in which nationality does not impinge on ATM. Eurocontrol should be expanded using a similar model, noting that the solution for European CNS/ATM means a solution for the organisational structure of Eurocontrol;
  - Roberts FIR – see **Appendix 1.3** and **Appendix 5.8**;
  - Southern African states Development Community (SADC) – comprising 14 African nations, they have implemented some aspects of CNS/ATM systems on co-operative bases, such as the Very Small Aperture Terminal (VSAT) network, which is covered in **Part 1** of this research. Improvement with communications between ground stations is seen as the region's primary objective<sup>943</sup>. Regional air transport liberalisation is being implemented among the countries<sup>944</sup>;

<sup>939</sup> ASECNA - Agence pour la Sécurité de la Aérienne en Afrique et à Madagascar.

<sup>940</sup> 'Cooperation in Africa' – *Integrating Global Air Traffic Management*, ICAO. 1998.

<sup>941</sup> 'CNS/ATM and the African continent' – *Air Traffic Technology International* 2001.

<sup>942</sup> 'COMESA states agree open skies' – *Flight International*, 25 August 1999.

<sup>943</sup> 'Southern comfort' – *Air Traffic Management*, November/December 1997.

<sup>944</sup> 'Under open skies' – *Flight International*, 29 August 2000.



- The AEFMP Plan – which aims to harmonise the different air navigation systems in Algeria, France, Morocco, Portugal and Spain, with a view to improving air traffic management;
  - The East African Co-operation Member States – comprising three nations, it wants a unified upper airspace area control centre;
- In contrast with the aforementioned terrestrial-based service provision, satellite systems that provide communication and navigation facilities are other examples of international co-operation with ANS. This type of co-operation has the added benefit to a nation of reduced need for ground-based, conventional aids within the country's borders. Existing examples include the space segments of private global economic organisations, ARINC and SITA, in addition to the Arab Satellite Organisation, ARABSAT and the Inmarsat constellation, which are discussed in **Part 1** of this research. It should be noted that they all have their own legal responsibility (see **Section 5.5.4**). Additionally, there is the possibility to avail of unilateral provision on an international basis, through the use of GPS and GLONASS. Future satellite augmentation services, such as EGNOS, MTSAT and WAAS, are examples of unilateral provision that have international implications. Correspondingly, potential satellite constellations such as the European Galileo system will require international co-operation: institutional issues include multi-national agreements, but also management of the system. This latter aspect is one of the reasons for European ministers' delay in authorising Galileo's development<sup>945</sup>.

The provision of air navigation facilities or services on an international basis is an established method of international co-operation. However, there still remains much scope for greater levels of activity and subsequent operational synergy. Indeed, this framework recommends that international co-operation is a critical element that will ensure successful integration of future air navigation systems. The advantages very much outweigh disadvantages, whether considered from cost or efficiency perspectives (see **Chapter 6** and **Chapter 7** respectively). In addition, similar to commercialisation, international co-operation offers those nations that have poor or unsafe ANS an opportunity to rectify the situation: such actions will expedite the introduction of harmonious CNS/ATM through creation of centralised execution and management of ANS provision. Accordingly, this strategy suggests that each nation develop a mechanism to disburse surplus funds generated from usage of ANS facilities and services for the development of further infrastructure, so that the provision of ANS is guaranteed to meet demand for many years to come.

### **International operational and technical advice**

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In addition to the other components of this framework, stakeholders frequently require advice on operational and technical matters when introducing new systems and methods of providing ANS. It is often the case that the advice extends beyond the contractual agreement of system suppliers. Indeed, the advice may be necessary prior to deciding what equipment to purchase.

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<sup>945</sup> 'Ministers fail to approve go-ahead of Galileo navigation system' – *Flight International*, 2 January 2001.

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With reference to **Part 1** of this thesis, it is evident that some CNS/ATM projects have been completed: therefore, stakeholders involved in these programmes should be able to offer technical advice or collaborate with new implementations. This advice or assistance could be provided on an individualised consultancy basis or through mass informing methods, such as trade publications or the plethora of forums that exist within the CNS/ATM arena. Other possibilities of providing assistance are to train staff or to manage projects by procuring, installing and/or commissioning equipment.

ICAO has offered technical assistance since 1952<sup>946</sup>: its Technical Co-operation Bureau (TCB) carries out projects funded by the nations involved. The criterion for its Technical Co-operation Programme (TCP), noting that ICAO supports technical co-operation among developing countries, is that “ICAO will co-operate with Governments in providing assistance to civil aviation development in any sector, international or domestic, when such development will promote the economic and/or social growth of the country concerned, or will enhance the safety and efficiency of civil aviation and implementation of the Regional Air Navigation Plan.” As part of ICAO’s new Strategic Plan that was published in 1997, the TCP is placing increased emphasis on developing technical Standards And Recommended Practices (SARPs). The ‘ICAO Objectives Implementation Mechanism’ now funds ICAO’s endeavours in this area.

With reference to the provision of operational and technical advice for worldwide implementation of CNS/ATM systems, this framework suggests that ICAO be used to house a database of operational and technical assistance given to CNS/ATM projects, which can subsequently be dispersed to other stakeholders. Using evaluations similar to that conducted in **Part 1** of this research, but in greater detail where required, the database could be made readily available to stakeholders. Given the Internet’s unique ability to offer global access, a system could be set up to harbour the information. The fee for access to this service could be adapted from the existing methods. Given that such a database would have to include the various alternative CNS/ATM systems that exist or are being developed, and noting that there is sometimes no single best option, this method would have additional benefits, such as acceptance by ICAO of technologies and procedures that may have been developed using standardising processes other than the time-consuming development of SARPs. Accordingly, a greater level of standardisation could be achieved in time, in particular if a lot of projects drew from information sources within this database.

Ultimately, the fact that global availability of operational and technical assistance with the implementation of CNS/ATM systems will improve their rate of integration should be a sufficient catalyst to develop such a database or, at the very least, a catalogue of advisory sources.

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<sup>946</sup> ‘Global Air Navigation Plan for CNS/ATM systems’ – Volume I, ICAO. 1<sup>st</sup> Ed. 2000.



### 5.4.3 Human Factors

Human Factors (HF) issues are essential for efficient and safe provision of ATM. In addition to aiding performance, HF drastically affects costs. It is imperative to adopt a rigorous safety-conscious culture, noting that adverse HF conditions can be due to a wide range of possibilities, from poor technological designs to changes in economic regulations that have profound effects on employees. Yet, human factors are inherently difficult to quantify. Thus, in order to maximise the safety of CNS/ATM systems, there is a need to adopt a proactive management of people-related matters at all stages in the implementation process, from design through installation to the operation of systems.

Noting that a comprehensive analysis of HF issues in CNS/ATM is beyond the scope of this endeavour<sup>947</sup>, this section briefly considers two aspects of human factors that affect virtually all stakeholders:

- The Human-Machine Interface (HMI);
- Training.

Although HF techniques can be applied at any stage in the life cycle of a CNS/ATM system, the most effective stage to address HF aspects is during the technology design, so that optimum **human-machine interfaces** can be developed. The design should consider HMI issues because the most important HF issues related to the CNS/ATM human-machine interface are the human ability to maintain situational awareness and understanding of any automated systems. Correspondingly, the debate on whether human control of systems should be remain available affects the rate of progression to fully automated technologies and procedures: the manual control process of Air Traffic Control (ATC) limits the potential of systems because it relies on controllers' cognitive abilities<sup>948</sup>. Similarly, pilots are concerned with the ethos of Free Flight<sup>949</sup> per se, noting that, according to the US FAA, flightdeck automation can confuse pilots<sup>950</sup>. It is consequently essential to adopt adequate Crew Resource Management (CRM) methods and a set of guidelines<sup>951</sup> for the operation of automated systems, which can improve awareness of the aircraft's status so that the pilot remains in the loop<sup>952</sup>.

Nonetheless, as discussed in **Part 1** of this research, automated processes are now commonplace. Indeed, it is better to perform certain tasks using automated procedures, such as satellite-based CNS/ATM aeronautical information services<sup>953</sup>. It could be some

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<sup>947</sup> Human Factors is overviewed here for completeness – for further requirements, noting that many other studies have been conducted in this area, consult ICAO's Human Factors Digest No. 8, 'Human Factors in Air Traffic Control' (ICAO Circular 241-AN/145).

<sup>948</sup> 'Enhancing the Manual ATC control process' – A Smoker, PhD Thesis. Cranfield University, 1996.

<sup>949</sup> 'The Future of Air Traffic Control – Human Operators & Automation' – C Wickens, University of Illinois, Air Traffic Management – Prospects for Free Flight Conference, January 1999.

<sup>950</sup> 'Unwanted demands' – Flight International, 9 October 1996.

<sup>951</sup> Standard operating procedures should be developed so that human constraints and needs are accommodated.

<sup>952</sup> 'Understanding design philosophy can help pilots benefit from modern automated flight systems' – ICAO Journal, November/December 1999.

<sup>953</sup> 'Air traffic growth creates need for flexible and more cost-efficient information services' – ICAO Journal, September 1996.



time, however, before fully automated systems are universally necessary and, indeed, accepted. Many think that pilots and controllers must remain involved in the ATC process. Thus, noting that CNS/ATM systems are technology-intensive, there is still a need to balance the technological intensity of systems with human abilities and requirements. Indeed, it should be noted that much experience has been obtained over the last few decades, since the advent of glass cockpits<sup>954</sup>, that is relevant for the integration of CNS/ATM systems, which are often based on similar platforms and theories. Additionally, ICAO has a Flight Safety and Human Factors programme that is now analysing the HF effect of CNS/ATM-related ground and airborne CNS/ATM elements. The ICAO programme interacts with Eurocontrol, Flight Safety Foundation (FSF), International Air Transport Association (IATA), International Federation of AirLine Pilots Associations (IFALPA) and International Federation of Air Traffic Controllers Associations (IFATCA)<sup>955</sup>.

The second aspect of human factors that this framework considers is **training**, which applies to all CNS/ATM stakeholders. ICAO conducted a study<sup>956</sup> to evaluate the degree to which job disciplines in the aviation industry will change due to CNS/ATM. The research concluded that (re)training will be required for 75% of jobs, that several types of job will no longer be needed due to increased automation and that new disciplines will evolve. Thus, training is a very important aspect of human factors that is required at three levels:

1. **Foundation training** for all personnel involved with CNS/ATM technologies and procedures from planning to operation. **Part 1** of this research provides a suitable overview of CNS/ATM;
2. **Training for implementation planners and decision makers**, with emphasis on the need for global or regional standardised methods. Indeed, given the aspirations of CNS/ATM systems for increased standardisation, it is particularly important to ensure that staff receive consistent training. Both parts of this dissertation contain information that could be employed in this level of training;
3. **Job-specific training** for the multitude of aspects pertaining to maintenance, management and operation of CNS/ATM systems. This framework recommends that each stakeholder adopt a long-term strategy for job-specific training, which may be out-sourced: for instance, the company, FANS Information Services, has been contracted by Eurocontrol to develop an online CNS/ATM training course for pilots, air traffic controllers and airline operational staff<sup>957</sup>, noting that Eurocontrol's CNS/ATM training centre, the Institute of Air Navigation Services, also conducts in-house training<sup>958</sup>. This demonstrates that, similar to the international co-operation in the provision of air navigation facilities and services, training may be conducted

<sup>954</sup> 'The interfaces between flightcrews and modern flight deck systems' – Flight Safety Foundation, *Flight Safety Digest*, September-October 1996.

<sup>955</sup> 'ICAO human factors programme expands scope beyond the flight deck and ATC facility' – ICAO *Journal*, January/February 2000.

<sup>956</sup> 'Global Air Navigation Plan for CNS/ATM systems' – Volume I, ICAO. 1<sup>st</sup> Ed. 2000.

<sup>957</sup> 'Eurocontrol training goes to FANS' – *Flight International*, 1 September 1999.

<sup>958</sup> 'Meeting the CNS/ATM training needs in the European environment' – ICAO Rio de Janeiro Conference Proceedings, 1998.



in conjunction with one or more other stakeholders. Correspondingly, there is a need to train those controllers in regions that will accommodate FANS routes, where little traffic has been previously handled<sup>959</sup>. Such ventures are beneficial because changing technologies and increasing air traffic are placing greater demands on training programmes for air traffic controllers<sup>960</sup>. Indeed, controllers will have to think differently in the CNS/ATM environment<sup>961</sup>: in the future, controllers will become system monitors rather than being involved in control decisions<sup>962</sup>. It should be noted that ICAO established its TRAINAIR programme in 1990, which has a standardised course development methodology that is starting to prepare CNS/ATM system training<sup>963</sup>. Similar to standardisation of technologies, harmonisation of training systems across regions or globally will expedite the implementation of future air navigation systems: for instance, air traffic controller licences should be rated by region, similar to initiatives with pilot licensing in European Joint Aviation Authorities (JAA) countries. Controllers are already starting to take up posts in other countries<sup>964</sup>.

The need for training is especially high during the transition period to future air navigation systems, when systems will operate in parallel: the US FAA estimates that it will be 2,500 controllers short of its requirements over the period 2003 to 2007<sup>965</sup>; Europe is already suffering from a 10% shortfall in controllers<sup>966</sup>.

Therefore, as mentioned in **Section 5.2**, this framework strategy suggests that stakeholders plan their training requirements immediately, noting the long lead times of at least 5 years that tend to be associated with human resource training. Planning strategies should include reviewing the implications of any new organisational structures on manpower and ensuring that selection criteria are still relevant. Given the increased emphasis of CNS/ATM systems on international operations, there is a need to incorporate any regional co-operation or guidance that may have been drafted. Accordingly, strategy planning should allow for the aforementioned fact that some jobs will not be needed in a CNS/ATM arena, while others will need to be created.

Correspondingly, there is a need to address regulatory issues, which is conducted in **Section 5.5** with other mandatory matters.

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<sup>959</sup> 'ATC training requirements and technologies for the 21<sup>st</sup> century' – *Civil Aviation Training*, Vol. 8 No. 4.

<sup>960</sup> 'New-generation ATC simulators designed to provide quicker, more cost-effective training' – *ICAO Journal*, April 1999.

<sup>961</sup> 'Training issues in Air Traffic Flow Management' – *Developing the Future Aviation System*, R Baldwin, 1998.

<sup>962</sup> 'Training controllers for the new environment' – *Integrating Global Air Traffic Management*, ICAO, 1998.

<sup>963</sup> 'The TRAINAIR Programme' – *ICAO Rio de Janeiro Conference*, 1998.

<sup>964</sup> 'Controllers on the move' – *air traffic management*, July/August 2000.

<sup>965</sup> 'ATC Training – the key to air transport' – *Civil Aviation Training Magazine*, September 1999.

<sup>966</sup> 'European shortfall in air traffic controllers' – *Air Transport Intelligence*, 27 November 2000.



## 5.5 Mandatory matters

This framework strategy for improved and successful implementation of future air navigation systems includes components that relate to mandatory matters, noting that the following issues affect all stakeholders in some way:

- Standardisation and certification;
- Regulation;
- Political;
- Legal.

### 5.5.1 Standardisation and certification

Due to the requirement for extremely high levels of safety, the air transport industry is heavily regulated. All aspects of CNS/ATM must adhere to rules: communication, navigation and surveillance equipment is standardised and certificated; correspondingly, ATM is subject to regulated procedures. This section discusses the standardisation and certification processes that exist, in addition to mentioning their implications on stakeholders and methods that would improve the introduction of CNS/ATM. Noting that some sufficient methods are already in place, they are described as examples of best practice for the purposes of this thesis' framework, while emphasising the need for increased harmonisation of standardisation and certification mechanisms.

#### Standardisation

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It is cited throughout this dissertation that the integration of CNS/ATM around the world will only be achieved if equipment and procedures are standardised to similar specifications. Equipment will be more intercompatible and interchangeable. Procedures will have greater levels of similarity. In order to provide the technical information necessary for equipment or procedure development, a set of specifications is required, which usually includes the minimum performance required from the equipment or procedure to ensure flight safety, in addition to the tests necessary to demonstrate that this performance will be achieved in all foreseeable flight conditions.

Therefore, the wide range of CNS/ATM systems' technological advances can only be effectively implemented if stakeholders co-ordinate standardisation. Standards should not result in one technology or procedure being mandated: they should define it more clearly. Accordingly, this framework strategy recommends that the following bodies or organisations continue to conduct their standardising mechanisms, but with greater co-operation and impetus to develop joint standard specifications:

- **AEEC:** The US Airlines Electronic Engineering Committee (AEEC) is heavily involved in the US standardisation process;



- **ARINC:** Its standards are widely adhered to by manufacturers, in particular regarding modern avionics systems, but not by aviation authorities;
- **EUROCAE:** In Europe, the EUROpean Organisation for Civil Aviation Equipment (EUROCAE) organises teams to conduct tests and publishes the specifications that they develop<sup>967</sup>. EUROCAE's members include airframe, engine and equipment manufacturers, in addition to civil aviation authorities;
- **Eurocontrol:** The organisation develops standards, although its methods for the production of standards and technical specifications are said to be slow;
- **ETSI:** The European Telecommunications Standards Institute (ETSI) is a body that develops standards in conjunction with EUROCAE and Eurocontrol;
- **FAA:** Similar to many countries' national aviation authorities, the US Federal Aviation Administration (FAA) produces acceptable means of compliance in the form of FAA Airworthiness Requirements (FAR) and National Technical Standard Orders (NTSO). The NTSOs are based on ICAO's Standards and Recommended Practices (SARPs) process (see hereunder), which can be general in content, thereby leaving room for national interpretations. It should also be added that, although each country is responsible for its standardisation process, it is increasingly delegated to a regional level. Correspondingly, it should be noted that the FAA is becoming involved in partnerships with the US aviation industry, which should speed up development of its standards;
- **ICAO:** The ICAO SARPs quasi-legislative process is analysed in greater detail as **Appendix 5.9**. It should be noted that this framework recommends that the SARPs process should be amended or enhanced and given greater prominence;
- **JAA:** The European Joint Aviation Authorities (JAA) body is increasingly acting on behalf of its member nations, issuing Joint Technical Standard Orders (JTSO) and acceptable means of compliance in the form of Joint Airworthiness Requirements (JAR). These demonstrate how the JAA and US FAA are aligning their standardisation activities. Correspondingly, Eurocontrol and the JAA have issued an Agreement of Co-operation to provide a basis for working together on CNS/ATM standardisation issues. In a similar manner, EUROCAE and the JAA have signed a Memorandum of Understanding on the production of equipment standards. Indeed, a CNS/ATM steering group has been established, with representation from aviation authorities and bodies, in addition to EUROCAE, Eurocontrol and the JAA<sup>968</sup>;
- **RTCA:** The Radio Technical Commission for Aeronautics (RTCA) is the US equivalent of EUROCAE, therefore covering all aspects of equipment technical performance. Committees from the two bodies develop common standards. Indeed, a joint EUROCAE/RTCA working group has started drafting a set of guidance documents to support the introduction of CNS/ATM, in addition to establishing Minimum Operational Performance Standards (MOPS);
- **SAE:** the US Society of Automotive Engineers (SAE) has a strong aeronautical division, which is involved in the US standardisation system and, consequently, in the European process.

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<sup>967</sup> 'Standards and specifications – the role of EUROCAE' – *Air Traffic Technology International* '99.

<sup>968</sup> 'CNS/ATM considerations in aircraft systems and equipment certification' – D Hawkes, *Air Navigation Conference* '97.



In addition, as mentioned elsewhere in this chapter, this framework strategy suggests that stakeholders maximise the use of Commercial Off-The-Shelf (COTS) technology. This should, by definition, enhance the harmonisation of standards. Accordingly, there is a greater chance of similar CNS/ATM system specifications being realised if airlines enter into alliances and Air Navigation Service (ANS) providers join a body such as the Civil Air Navigation Services Organisation (CANSO) or co-operate internationally (see **Section 5.4.2**). Such actions increase the probability of systems being interoperable, with corresponding potential for greater levels of automation.

## **Certification**

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With reference to the aforementioned requirement for high safety standards in the air transport industry and the description of standardisation processes, equipment and procedures are also subject to certification processes based on the standards<sup>969</sup> that are developed.

Aviation has been subject to certification processes for many years: airlines and other airspace users must obtain their Air Operator's Certificate (AOC); airports are subject to many certification processes; controllers and pilots must be trained and licensed to specific stipulations; and aircraft must be operated in compliance with the terms of their Certificate of Airworthiness (CoA) so that each operation adheres to the Minimum Equipment List (MEL), which cites the least numbers of equipment, including CNS/ATM systems, that an aircraft must have on board so that operations can occur. However, certification of CNS/ATM systems has only recently been comprehensively addressed and its importance is now increasingly acknowledged. Indeed, certification of systems is becoming extremely pertinent because of the ever-greater need for harmonised interactions between automation-oriented technologies and procedures. Ultimately, development and application of certification procedures is necessary to guarantee the implementation of compatible systems.

Certification may be defined as the legal recognition that a technology or procedure complies with applicable requirements. Therefore, it aims to ensure that a system is designed and installed in a manner appropriate to its intended functions, in addition to functioning properly. Certification consequently involves assessing the design, whilst ensuring that it complies with the set standards. The requirements for certification depend on the particular system's application, but the certification process is based on safety objectives, minimum equipment standards and implementation quality control. The operational approval officially declares that a system can be used as specified. A certificate is issued to declare that the CNS/ATM system has achieved satisfactory levels of conformity.

Certification of CNS/ATM technologies and procedures requires unprecedented co-operation at an international level, in particular for maximum safety and operational

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<sup>969</sup> Such standards are regulatory instruments that include the aforementioned airworthiness requirements, equipment Technical Standard Orders (TSO), Minimum Operational Performance Standards (MOPS) and SARPs.



benefits to be realised. However, there are no internationally agreed procedures to certify CNS/ATM systems, although ICAO guidelines exist for minimum safety, performance and functional requirements. Therefore, this strategy recommends the adoption of a streamlined certification process for CNS/ATM systems and suggests that stakeholders start the certification process as early as possible, using a methodology similar to the following structure, which has been adapted for the purposes of this framework from a certification process developed by EUROCAE and the RTCA<sup>970</sup>:

- **Approval planning:** In addition to describing the CNS/ATM system, this stage should incorporate national or regional regulatory requirements to establish the approval basis and means of compliance scheduling. Certification should follow a formalised regulatory process that relies on internationally promulgated criteria;
- **Co-ordinated determination of requirements:** This stage identifies benefits, interoperability issues, the operational environment, performance and safety<sup>971</sup> requirements for the development, qualification, operation and approval of the CNS/ATM technology or procedure. Other issues, such as human factors or maintenance, are also incorporated. CNS/ATM has many unique permutations and possibilities of certification requirements, with a corresponding need for evolving change. For instance, no single body in the European Union has the authority, remit or mandate to certify the potential future European satellite system, Galileo, for all its applications. Indeed, there is no competency to certify its space and ground segments in its civil aviation applications<sup>972</sup>;
- **Development and approval:** Each stakeholder involved in the process must ensure that their element of the CNS/ATM system achieves its integrity objectives and requirements. Processes should accommodate end-to-end certification<sup>973</sup>, which can become complicated due to the sheer number of companies, individuals and systems that are invariably involved. Evidence of the development process could be a technology or procedural specification, in addition to design data. Risk mitigation is achieved through the design of procedures, with the requirements derived from hazard analysis. Approval qualification, which is proof of the operational concept, may be manifested through configuration management, validation and verification of the system. Different operational scenarios must be tested so that all specific operational environments are considered: alternate separation minima, traffic density or complexity configurations could be accommodated. System certification should be separated from the approval of its operational use because some technologies or procedures may be appropriate for certain applications, but not adequate in all circumstances;
- **Entry into service:** Co-ordination of the results from development and approval activities performed by each organisation should lead to subsequent publication of operational specification and procedures. Evidence of entry into service could be a

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<sup>970</sup> 'End-to-end certification' – *Air Traffic Technology International* 2001.

<sup>971</sup> For example, safety assurances are required to different degrees for parameters such as accuracy, availability/continuity, coverage, integrity, redundancy and security.

<sup>972</sup> 'Global Navigation Satellite System – GNSS: Options for a Community strategy on a satellite system' – *European Parliament STOA study*, 2000.

<sup>973</sup> End-to-end relates to the entire path from the origin of raw data to the presentation of information to the operator, whether ATC controller or pilot.



development qualification meeting requirements and a corresponding notification notice. The process must complement the phased deployment of CNS/ATM operations so that financial, operational and technical risks are minimised;

- **Operations using the system:** Once evidence of the development and entry into service are obtained, with constant assurance that the aforementioned objectives and requirements are met, the system can start operations.

As previously mentioned, it should be noted that countries are responsible for certification of all aviation infrastructure and systems under their jurisdiction. However, similar to the provision of air navigation services, this may be delegated to a regional body. For instance, the European JAA co-ordinates and harmonises airworthiness and operational certification requirements for its member nations. Thus, this strategy suggests that countries outsource this activity to their regional authorities (using, where possible, the bodies or organisations listed in the discussion on standardisation). All regional authorities should co-operate with one another, which should ensure greater harmonisation, to generate guidance material and minimum acceptable criteria for each CNS/ATM technology or procedure. For instance, co-operation on both sides of the Atlantic is increasing the potential for a worldwide certification process<sup>974</sup>. Co-operation should also be maximised among the requisite bodies or organisations within each country and region. High levels of co-operation are achieved in the US between the AEEC, FAA and the RTCA. Nonetheless, the FAA recently said that it intends to study the possibilities of speeding up its certification process<sup>975</sup>.

### 5.5.2 Regulation

The previous section emphasises that the air transport industry needs to be heavily regulated in order to maintain high safety levels. Standardisation and certification processes are part of the industry's technical regulatory environment. Given its acute relevance to the worldwide implementation of future air navigation systems, technical regulation warrants discussion in a separate section. However, other regulation-related mandatory matters exist, which exercise control over CNS/ATM operations. This section suggests that stakeholders consider these additional regulatory mechanisms as components of the framework strategy, split in the following distinct areas, which are discussed individually hereunder:

- Airspace regulation;
- Economic regulation;
- Safety regulation.

Correspondingly, the nature of rule-making processes is related to the regulatory function. Therefore, it is also considered as part of this framework hereunder. In addition, it should be noted that this framework recommends that nations' regulatory

<sup>974</sup> 'The international regulatory climate' – Airbus FAST, Number 22.

<sup>975</sup> 'FAA to reorganise internally to speed up certification: Garvey' – Air Transport Intelligence, 31 October 2000.



authorities are independent organisations, with the ability to ensure that all stakeholders meet minimum standards in an unbiased manner. Independent regulation protects users' interests in terms of safety, in addition to the availability, cost and quality of CNS/ATM systems and services. In particular, this applies to countries that have commercialised their Air Navigation Service (ANS) providers (see **Section 5.4**): thus, provision and regulatory rôles should be separated when commercialisation commences, if not prior to the process. An independent regulatory régime must be backed by the necessary legislation.

At a national level, this responsibility should be discharged through an administration that specifies regulations and guarantees compliance with national or international rules and obligations. However, given the need for increased international co-operation, certain powers should be delegated, where possible, at a regional level, which could prove beneficial to the implementation of future air navigation systems. At a global level, ICAO is the principal regulatory body. ICAO's regulatory powers are minimal, but countries use its Standards And Recommended Practices (SARPs) as the basis of their national rules, albeit at each country's discretion. The SARPs process is discussed in **Appendix 5.9**.

### **Airspace regulation**

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Airspace regulation should be conducted in a manner that is complementary to, but separate from, safety regulation (see hereunder). Noting that airspace design is the responsibility of ANS providers, core responsibilities of the airspace regulator are to<sup>976</sup>:

- Be the overall authority for the use of airspace;
- Lay down the appropriate regulations and minimum standards for access to and use of airspace in compliance with any other relevant national or international regulations;
- Ensure compliance with such regulations and standards so that all users' needs are met. Airspace must be divided between civil, general and military aviation traffic.

A similar requirement is the regulation of Global Navigation Satellite System (GNSS) signals' availability and continuity, in addition to the authorisation for use of GNSS services. Regulatory mechanisms for new satellite constellations, such as the potential European Galileo system, will require unprecedented levels of international co-operation and management. In this case, no single body in the European Union has the authority, remit or mandate to regulate Galileo.

### **Economic regulation**

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Air transport is circumscribed by a multitude of historic national, bilateral and multilateral agreements that act as forms of economic regulation<sup>977</sup>. However, there has been an economic deregulation, termed liberalisation, of markets in recent decades that has had profound effects on the CNS/ATM business through increases in numbers of

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<sup>976</sup> 'Relationship between service provision and regulation' – CANSO position paper, 2000.

<sup>977</sup> 'The regulation of international air transport' – R Doganis, Chapter 2, *Flying Off Course*, 1991.



operators and rises in traffic volumes. In addition, airlines and ANS providers have become more commercially aware. Therefore, there have been changes in the economic regulatory mechanisms in recent times, which render the previous methods insufficient.

Correspondingly, a close relationship between a provider or user and regulator undermines confidence. In addition, other micro-economic sectors, such as electricity or gas, benefited positively by separating their provision and regulatory rôles. It is for such reasons that this framework recommends the creation of independent economic regulators in all countries, with some services conducted at regional level if possible. The regulator could be used for multiple micro-economic sectors<sup>978</sup>. A pan-regional approach may take many years to implement, but it is possible to increase co-operation in the short term. This co-operation could lead to the development of guidelines by a regional body or organisation. The guidelines could be integrated in an iterative manner.

Economic regulators are particularly relevant in the CNS/ATM industry because of the inherent tendency for ANS providers to have monopolistic control of the market. Indeed, the primary objective of economic regulation is to curb abuse of a natural monopoly and ensure equitable access to services. Therefore, economic regulation is discussed here in relation to the provision of ANS and not the sale of CNS/ATM equipment because the latter market has substantial levels of competition, which is subsequently self-regulated. However, **Chapter 4** emphasised an increased tendency for consolidation of supplier firms in the CNS/ATM equipment industry during the last decade. Accordingly, due to safety concerns, ANS provision will most likely remain a monopoly service for many years to come. Hence, regarding ANS, the economic regulator should be expected to perform the following<sup>979</sup>:

- Ensure that air traffic service demands are met, encouraging investment in new CNS/ATM systems if necessary;
- Regulate in a manner that would not make it unduly difficult for the service provider to finance its activities;
- Protect users' rights to reasonable cost and quality of ANS, which means protection from potential abuse by guaranteeing reasonable fees and performance standards;
- Implement bilateral or international obligations, which include the ICAO Chicago Convention stipulation to ensure that services are safe;
- Promote efficiency and economy in service provision;
- Minimise the cost of regulation;
- Accommodate environmental issues, which could be conducted economically by altering the international agreement that there is no tax on aviation fuel;
- Take into account the nation's obligations to international bodies or organisations.

One of the principal aims of the regulator should be to agree charges that stimulate a competitive environment, whilst protecting the interests of the users. This is essential whether or not the provision of ANS has been commercialised because, if the provider is government-run or corporatised (see **Section 5.4**), it is usually not allowed to make a

<sup>978</sup> *Economic regulation: application of general competition law to airports and air navigation services* – ANSConf-WP/109, ICAO Conference on the economics of airports and air navigation services, 2000.

<sup>979</sup> *'Pennies from heaven' – Air Traffic Management, November/December 1998.*



profit or, indeed, a loss, as its charges are determined on a cost recovery basis (see **Section 6.2**). Thus, costs could escalate, with corresponding increases in charges. There is consequently a need to adopt a pricing control mechanism, which could be instigated by issuing a licence to the provider that is based on certain compliance stipulations. The licences should incorporate the fact that certain service obligations are necessary.

It should be noted that a licensing form of regulatory control will be applied to the successful consortium bid by the Airline Group, which is subject to European Union approval, for Public-Private Partnership (PPP) in the UK's National Air Traffic Services<sup>980</sup> (NATS), as discussed in **Appendix 5.7**. Additionally, it should be added that NATS will use the Retail Price Index (RPI-X) formula price cap regulation method for its fees, whereby the charges are capped on an annual basis according to an efficiency factor, X%, less general inflation. X is adjusted every five years based on projected costs and demand, with the first five years capped at 2.2% below inflation in NATS's case<sup>981</sup>. The determination of X can be a subjective exercise because it incorporates issues such as service quality, values of the regulatory asset base and the cost of capital<sup>982</sup>. There is an incentive with the RPI-X price cap method for the provider to maximise its efficiency, which is greater if the price cap is not varied once set<sup>983</sup>.

In contrast with the RPI-X price cap regulation method, a rate of return regulatory mechanism exists, whereby an upper limit is prescribed on the amount that a monopolist can earn on its assets. This, by definition, involves detailed analysis of the provider's cost base, which may not always be desired by the provider. The International Air Transport Association (IATA) has called for profit caps to be similar to the average rate of return of the airline industry<sup>984</sup>. However, it is thought that the price cap model is the more suitable for ANS because of its strong incentives on the provider to reduce costs and invest appropriately.

Noting that **Section 5.7** and **Chapter 7** develop performance measures, it is possible to implement quality-related charges using the contents of this framework strategy. This could provide incentives to encourage efficiency that apply to both providers and users. The latter could be subject to incentive and penalty systems relating to equipage of CNS technologies, which could encourage carriers to obtain the relevant systems, thereby improving the integration of future air navigation systems. Therefore, in contrast with safety regulation's safety standards, economic regulation could encourage performance improvements by incentivising efficiency.

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<sup>980</sup> As a monopoly provider, the part-privatised NATS will be subject to statutory economic regulation: the UK CAA will become the economic regulator.

<sup>981</sup> 'Busy year for NATS' – *Aerospace International*, March 2001.

<sup>982</sup> 'National Air Traffic Services Public-Private Partnership: setting the charges for the first five years' – *Economic Regulation Group, Civil Aviation Authority*, December 1999.

<sup>983</sup> 'The principles of the economic regulation of air navigation service provision' – *ANSCConf-WP/88, ICAO ANS Conference*, 2000.

<sup>984</sup> 'Air Navigation Service (ANS) economic regulation' – *ANSCConf-WP/28, ICAO ANS Conference*, 2000.



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## Safety regulation

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Minimum acceptable performance and safety standards have been set for many years through standardisation and certification processes, as discussed in **Section 5.5.1**. By definition, the processes are forms of safety regulation. However, with the increasing tendency for the provision of ANS to migrate from being government-run to a commercialised status, there is a new requirement for independent<sup>985</sup> safety regulators at national levels, with regional co-operation where possible<sup>986</sup>. Indeed, safety standards should be developed in partnership with other regulators, service providers and users at both domestic and international levels to improve the implementation of CNS/ATM so that similar Air Navigation Orders (ANO) are issued in numerous countries. Correspondingly, there is frequently a need for consensus at international level on whether equipage of certain CNS/ATM systems should be mandatory or voluntary.

The use of safety standards derived by ICAO and other bodies or organisations, as mentioned in **Section 5.5.1**, implies that the process is already internationally based. It should be added that ICAO is developing its Global Aviation Safety Plan (GASP), through which it wishes to improve its capability to compile, assess and disseminate safety-related information<sup>987</sup>. Accordingly, with reference to the performance analyses in **Chapter 7**, ICAO is introducing quality assurance through its Safety Oversight Programme (SOP), in addition to encouraging the global harmonisation of safety standards.

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## Rule-making process

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The rule-making process is deemed relevant for inclusion in this framework strategy, in particular for those stakeholders that have not already adopted a rule-making methodology. Given the diverse range of new technologies and procedures that form CNS/ATM, there is a distinct need for a flexible rule-making process. Therefore, with reference to **Appendix 3.6**, consider the new European rule-making process as an example: Eurocontrol has proposed a new regulatory procedure, based on the US FAA Notice of Proposed Rule Making (NPRM), which is very relevant to the implementation of future air navigation systems. It initially covers air traffic management issues, but will also encompass safety and economic regulatory matters in the future.

The main objectives of the Eurocontrol NPRM (ENPRM) are to secure the commitment of all stakeholders and ensure fulfilment of their obligations, in addition to facilitating effective and timely implementation of agreed programmes. ENPRM aims to be compatible with the European Joint Aviation Authorities (JAA) rule-making process so

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<sup>985</sup> The safety regulator, whose role is to set and maintain acceptable safety levels, should be independent of the provision and decision or rule-making structure.

<sup>986</sup> Europe, which already uses Eurocontrol Safety Regulation Requirements (ESARR) as a legal method, plan to create the European Aviation Safety Authority (EASA). EASA's establishment will involve a transformation of the joint Aviation Authorities (JAA) into an agency of the European Commission. As a result of new European legislation, EASA will be empowered to set technical and other standards, which will be legally binding in all 15 member EU states.

<sup>987</sup> 'ICAO Global Aviation Safety Plan (GASP)' – A32-WP/58, ICAO 32<sup>nd</sup> Assembly, 1998.



that the level of uniformity achieved in European CNS/ATM is determined by the application of common rules<sup>988</sup> consistently by all member countries<sup>989</sup>. Accordingly, given its aspiration to allow easy integration into European or national legislation, ENPRM ensures compatibility with other international processes, such as Eurocontrol's standardisation processes and ICAO's SARPs.

The following steps are envisaged for the ENPRM:

1. Initiate proposal, validate and refine;
2. Draft ENPRM for approval to consult;
3. Consult;
4. Review comments;
5. Formal adoption;
6. Promulgation;
7. Implement, monitor, enforce and review.

Noting that the revised 1997 Eurocontrol Convention didn't approve it<sup>990</sup>, the successful development of ENPRM is dependent on more legal<sup>991</sup> and regulatory powers being given to Eurocontrol through a revised Convention framework.

### 5.5.3 Political

The aviation industry is rife with politics and their effects have major ramifications on the worldwide implementation of future air navigation systems. Many aforementioned components of this framework have referred to political parameters or, indeed, are part of the political process. However, political agendas that may appear to be extraneous to CNS/ATM actually have significant impact on the ability of stakeholders to swiftly expedite the introduction of CNS/ATM. This section considers some other types of 'aeropolitics' that exist, thus:

- **Ownership or control rules:** Such political aspects affect many stakeholders and their freedom to conduct business, which have corresponding implications on the integration of CNS/ATM. Ownership or control rules may apply to, among others, equipment manufacturers, providers or users. For example, the presence of low-cost airlines in a market increases the market's volume, with subsequent additions to airport and airspace congestion. The latter is the subject of much discussion in this dissertation, but the former also has profound effects on aeropolitics, through the need for larger terminals and limited landing slot availability. The lack of landing slots consequently pushes airlines to purchase bigger aircraft and airport authorities to maximise the utilisation of their runway(s), which can be conducted through improved CNS/ATM techniques. Indeed, the need for new runways generates even greater political levels of activity;

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<sup>988</sup> 'eurocontrol notice of proposed rulemaking (enprm)' – era regional report, December 1999.

<sup>989</sup> 'working with eurocontrol to expand capacity' – era yearbook 2001.

<sup>990</sup> 'Eurocontrol delays steps to taking regulatory powers' – Flight International, 21 July 1999.

<sup>991</sup> 'Eurocontrol legal power looms' – Flight International, 16 June 1999.



- **Route-related:** These political issues could be in the form of international route rights, bilateral treaties, granting of rights, capacity or frequency restrictions and route licensing. The propensity for nations to adopt open skies agreements is a result of these political forms. Traffic levels in regions or on international city-pairs are directly related to these political entities, which are invariably the basis of a particular area's CNS/ATM problems, or lack thereof;
- **National security or sovereignty:** Each country's claim to control of the airspace above its borders is the source of many political problems related to the implementation of harmonised CNS/ATM. Most nations' basis for exercising sovereignty<sup>992</sup>, which amounts to control of its airspace territory and the aircraft that transit it, is because there is a national identity associated with ownership of its airspace, in addition to national security-related matters and the fact that its skies are also used for military purposes. In order to enhance international or regional co-operation, countries need to become less obsessed with strict sovereignty matters. Indeed, it should be noted that co-operative ventures cited elsewhere in this dissertation are indicative of the fact that nations do not lose the essence of sovereignty by entering into international agreements that improve air traffic flow management. For instance, many of Europe's air traffic management problems would be alleviated through adoption of such mentalities: indeed, **Chapter 3** refers to Eurocontrol's 'ATM Strategy for 2000+' quote that "every country shall continue to have complete and exclusive sovereignty over the airspace above its territory" if the European airspace region is unified.

#### 5.5.4 Legal

This section analyses the legal aspects of this framework strategy, which serve to show stakeholders what law practices presently exist and how they will be affected by the implementation of future air navigation systems.

The current legal framework for the provision of Air Navigation Services (ANS) is based on the ICAO Chicago Convention and its Annexes, which governs the conduct of stakeholders at national and international levels for countries that are members of ICAO. The Chicago Convention is one of the world's most widely accepted international legal instruments. However, each nation has other inherently individual national laws: each country defines its own legal standards and notifies ICAO accordingly. In addition, noting that **Section 5.5.3** discusses route-related and sovereignty political issues, the freedom for a country's aircraft to fly through other nations' airspace regions has been achieved by a plethora of treaties and agreements, none of which neglect or remove the principle of sovereignty. This constitutes the legal basis of international flights and freedom of the air exists within its constraints.

Correspondingly, as mentioned in **Section 5.4**, each nation is responsible for the provision of ANS. However, it should be noted that this does not necessarily mean that the State is liable for damage incurred by the ANS provider: indeed, this legality is not

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<sup>992</sup> Both the Paris Convention in 1919 and Chicago Convention in 1944 firmly stipulate the right of any nation to exercise exclusive sovereignty over its airspace.



stipulated in ICAO's Chicago Convention. Thus, the general rules of national and international law apply, which vary for the different legal systems involved. It is for this reason that one of the problems in connection with legal aspects of international co-operation is the question of liability for any damage caused by ANS providers. Indeed, the legal issues arising from national liability are more complicated if damage is caused by ANS involving more than one country. Certain bilateral or multilateral<sup>993</sup> agreements have allowed for such possibilities, principally through provision of insurance cover.

Therefore, the current legal framework consists of the ICAO Convention, its Annexes and bilateral or multilateral agreements<sup>994</sup>, in addition to national and international laws. Together, they form a complicated law structure that controls air navigation. In contrast, noting the global nature of CNS/ATM systems, it would appear that a unified set of legal rules based on a new Convention or Treaty that limits the provider's liability and sets service obligations would be necessary to ensure that future air navigation systems are implemented in a comprehensive manner. It should therefore be noted that efforts have been made to reach a unification of liability rules by means of an international multilateral agreement similar to the airlines' Warsaw Convention, which limits the liability of carriers<sup>995</sup>. Given that CNS/ATM systems are characterised by constant technological developments, a new multilateral Convention or Treaty would be rendered technically obsolete before it could even be implemented unless copyright laws are included that allow for technical advances.

Correspondingly, ICAO has determined that there is no legal obstacle to the worldwide implementation of CNS/ATM systems and that the CNS/ATM concept is compatible with the provisions of the Chicago Convention. Nonetheless, ICAO's 'Strategy for guiding international civil aviation into the 21<sup>st</sup> century', which was adopted by its Council in 1997 as the first re-evaluation of ICAO's mission since it was formed in 1944, has listed objectives that include its wish to "strengthen the legal framework governing international civil aviation by the development of new international air law instruments as required and by encouraging the ratification by States of existing instruments". ICAO aims to fulfil this strategic objective through key activities, which include determination of all legal aspects to govern operation of CNS/ATM and development of a legal framework on GNSS. The former key activity will take many years to complete, whilst a draft Charter has been prepared as part of the latter key activity. The draft Charter states that GNSS is fully consistent with the Chicago Convention, which consequently includes sovereignty concerns, and that there are no fundamental legal or liability obstacles to the implementation of GNSS.

Therefore, given that a serviceable legal framework already exists in the Chicago Convention, which is complemented by ICAO's policy on CNS/ATM systems (see **Appendix 5.1**), it would appear logical to base legal stipulations on existing tools. Thus, any legal changes are likely to be incremental rather than fundamental, with implementation continuing through existing mechanisms for the foreseeable future.

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<sup>993</sup> For example, ASECNA, COCESNA and Eurocontrol.

<sup>994</sup> Which often exist as letters of legal agreements or memorandums of understanding.

<sup>995</sup> 'Liability with regard to Air Traffic Management' – Chapter VIII, *Aspects of international co-operation in Air Traffic Management*, R & W Schwenk. 1998.



## 5.6 Financial factors

This framework strategy for improved implementation of CNS/ATM systems includes financially-related components. The inclusion of financial factors is essential because all CNS/ATM projects have funding requirements, whether government run or orchestrated solely in the private sector. Indeed, the importance of finance is evident in the evaluation of CNS/ATM in **Part 1** and emphasised in the other sections of this chapter. Accordingly, the International Civil Aviation Organisation (ICAO) believes that finance issues are big hurdles to the complete introduction of future air navigation systems.

**Chapter 6** analyses the financial factors of this framework by initially examining the worldwide charging for air navigation facilities and services from theoretical and benchmarking perspectives. Noting that charging systems and levels for Air Navigation Services (ANS) affect virtually all stakeholders that are related to CNS/ATM systems, the framework provides:

- A theoretical analysis with an overview of guidelines by ICAO on ANS charging policies, principles for allocation of costs, charging methods and the billing process for air navigation facilities and services. Eurocontrol's approach to air navigation facility charges is also detailed as an example of best practice;
- A benchmarking exercise of worldwide charging levels for air navigation facilities and services in 205 countries.

In addition, this part of the framework strategy suggests and discusses alternative methods for funding CNS/ATM projects, irrespective of their size, having considered the cost levels that apply to such projects. It evaluates finance sources by conducting an analysis of methods that may now be applied to CNS/ATM. Ultimately, **Chapter 6** contains much information and benchmarked charging data for analytical, referencing and strategic purposes by all stakeholders. Accordingly, the chapter forms the basis of some analyses in **Chapter 7**.



## 5.7 Performance parameters

As part of the framework strategy for improving implementation of CNS/ATM that this thesis develops, **Chapter 7** accommodates the essential need to assess the quality and performance of air navigation services provision from different perspectives around the world, given that the situation in Europe is very different from that in Africa, but each has its inherent problems: the former is saturated and urgently requires more capacity; the latter has a perception of poor safety levels.

Therefore, **Chapter 7** develops and computes criteria that assess the performance of Air Navigation Services (ANS) provision, in addition to determining levels of worldwide ANS provided and conducting a route performance analysis. All stakeholders may use the various sections for a variety of analytical or strategic purposes, noting that they endeavour to expedite the implementation of CNS/ATM systems by facilitating the identification and rectification of lower quality airspace regions or ANS providers. The chapter drafts indicators in terms of:

- The performance of ANS organisations;
- The quality of CNS/ATM that they provide.

It then applies the indicators to nations, in order to provide an overall analysis of their ANS providers' organisational efficiencies and standards of the countries' CNS/ATM systems. Accordingly, **Chapter 7** assesses airline route performance with a case study analysis. This all further develops the framework strategy by validating the criteria developed, providing results from a survey of nations or providers and supplying information that may be added to the other framework guidelines given in this chapter.

Additionally, it should be noted that **Chapter 7** contains much information and benchmarked data that may be used for referencing purposes by stakeholders. All stakeholders should be able to draw from this material as part of the framework strategy to swiftly develop their individual strategies to assessing performance of CNS/ATM, in addition to stating their minimum acceptable or expected efficiencies and standards. Accordingly, ANS providers, financiers, national or regional authorities and users should be able to apply the experiences cited in **Section 7.4** to other route developing areas.



## 5.8 Summary

This chapter builds on the findings of **Part 1**, which evaluates CNS/ATM technologies and procedures, to develop aspects of the framework strategy that improves worldwide integration of CNS/ATM systems. Having highlighted obstacles to implementation of future air navigation systems, the framework's components are categorised into distinct sections, thus:

- Integration management;
- Project appraisal techniques;
- Institutional issues;
- Mandatory matters;
- Financial factors;
- Performance parameters.

Each section discusses various components and strategies from the perspectives of all stakeholders, where applicable, so that players can benefit from this strategy. When amalgamated, the sections provide stakeholders with the ability to guide and expedite the introduction of CNS/ATM projects using suggested management and appraisal techniques, in addition to having an increased awareness of many issues relating to organisational structures, co-operation opportunities, human factors, regulatory aspects, legal considerations, financial facts and performance standards.

In addition to fulfilling this thesis' second objective, the framework strategy aims to act as a catalyst to improve the integration of CNS/ATM, which should maximise the potential of CNS/ATM systems and justify their implementation. Thus, in order to develop the framework strategy, this chapter drafts recommended guidelines and conducts analyses in each of the aforementioned component areas, with the exception of financial and performance components, which are examined in **Chapter 6** and **Chapter 7**. Validation of the framework is conducted using assessments of best practice examples or benchmarked indicators that are established and computed for the purposes of this endeavour. In addition, stakeholders are provided with much information that should prove useful when appraising and implementing their system(s).

With reference to the components that are covered in this chapter, it is possible to conclude that improved management of the CNS/ATM systems' integration will be very beneficial from all stakeholders' perspectives. Accordingly, execution of proper project appraisal techniques will introduce an impetus to change for stakeholders. The plethora of aspects relating to institutional issues and mandatory matters that are also developed in this chapter should ensure that the provision of air navigation facilities and services in the future is conducted in an efficient and safe manner, with ample capacity available to meet demand.



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## **CHAPTER 6**

### **FINANCIAL FACTORS**

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## 6.1 Introduction

With reference to **Section 5.6**, the framework strategy that this research develops for improved implementation of future air navigation systems includes financially-related components. The inclusion of financial factors is essential because all CNS/ATM projects have funding requirements, whether government run or orchestrated solely in the private sector. Indeed, the importance of finance is evident in the evaluation of CNS/ATM in **Part 1** and emphasised in the other sections of this framework, as cited in **Chapter 5**. Accordingly, ICAO believes that finance issues are big hurdles<sup>996</sup> to the complete introduction of CNS/ATM.

This chapter analyses the financial factors of this framework by initially examining the worldwide charging for air navigation facilities and services from theoretical and benchmarking perspectives. Noting that charging systems and levels for Air Navigation Services (ANS) affect virtually all stakeholders that are related to CNS/ATM systems, the framework provides:

- A theoretical analysis with an overview of guidelines by the International Civil Aviation Organisation (ICAO) on ANS charging policies, principles for allocation of costs, charging methods and the billing process for air navigation facilities and services. Eurocontrol's approach to air navigation facility charges is also detailed as an example of best practice;
- A benchmarking exercise of worldwide charging levels for air navigation facilities and services in 205 countries.

In addition, the framework strategy suggests and discusses alternative methods for funding CNS/ATM projects, irrespective of their size, having considered the cost levels that apply to such projects. **Section 6.4** evaluates finance sources by conducting an analysis of methods that may now be applied to CNS/ATM.

Ultimately, this chapter contains much information and benchmarked charging data for referencing purposes by CNS/ATM stakeholders. Correspondingly, stakeholders will be able to draw from this material to swiftly develop their individual strategies. In addition, the information in this chapter forms the basis of some analyses in **Chapter 7**.

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<sup>996</sup> 'Step by step' – *Flight International*, 22 September 1999.



## 6.2 Charging systems

The basic aeronautical charging structure for the use of air navigation facilities and services may be split between the:

- **En-route fee**, which is levied for use of facilities and services available or provided to aircraft in flight, outside the terminal area<sup>997</sup>, which include air traffic navigation services, communications, surveillance and meteorological assistance;
- **Terminal navigation charge**, for use of the meteorological, Air Traffic Control (ATC) communications, landing navigation systems and surveillance facilities during approach, landing, take-off and departure phases of flight.

This section analyses the worldwide charging systems for both types of ANS fee with:

- A discussion on ICAO's regulatory charging policies and cost recovery, which is the basis of many components in this framework;
- An overview of cost allocation for air navigation charges, so that nations, service providers and prospective financiers are aware of how to structure rates. In addition, users are therefore aware of how the charges are developed;
- Comparisons of charging methods and formulae for en-route and terminal navigation used by the 205 countries surveyed in this thesis, in order to have a clear view of the charging structures employed;
- Information on how the billing process and collection of payments are expedited, noting that joint charging agencies and international co-operative ventures exist (as per **Section 5.4**);
- A synopsis of Eurocontrol's approach to charging for en-route and terminal navigation because it is an example of best international standard practice.

These individual sections provide a detailed evaluation of how charging mechanisms for air navigation services are implemented by financiers, nations or providers. In addition, they outline the various possibilities that exist in terms of structuring the fees and being part of international agencies. This is essential because the ability to generate revenue through the provision of ANS, in conjunction with the co-operation possibilities that are cited here and in **Chapter 5**, offers significant freedom to fund new CNS/ATM systems. Thus, this framework strategy recommends that nations and their providers use this section to determine their optimum solution.

In contrast, improved implementation of CNS/ATM systems requires increased transparency in ANS fees, their determination and collection for all stakeholders, which includes the users. Therefore, aircraft lessors, airlines and other operators may employ this section to improve their awareness of how the ANS fees that they pay are developed. Accordingly, noting that the contents of this section form the background to the benchmarking exercise of the 205 nations in **Section 6.3**, users may refer to the theoretical information that is given here when analysing the benchmarking findings.

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<sup>997</sup> The terminal area is that approach and aerodrome airspace within the vicinity of an airport, which is under the jurisdiction of the airport's arrival or departing procedures.



### 6.2.1 ICAO's guidelines on charging policies

Given that 185 out of the 205 nations from around the world surveyed in this thesis are ICAO Contracting States, it is pertinent to review ICAO's policy on charging for air navigation, because these countries must apply the principles contained in the Articles of the Chicago Convention on International Civil Aviation. Article 15 of the Convention sets out the following basic principles on the charges for air navigation facilities for countries to comply with, thus:

- “Uniform conditions shall apply to the use of air navigation facilities in a Contracting State by aircraft of all other Contracting States”;
- “The charges imposed by a Contracting State for the use of such air navigation facilities shall not be higher for aircraft of other Contracting States than those paid by its national aircraft engaged in similar international operations”;
- “No charge shall be imposed by any Contracting State solely for the right of transit over or entry into or exit from its territory of any aircraft of a Contracting State or person or property thereon” – the main intention of this point is that a nation should not charge solely for granting an authorisation for a flight into, out of or over its territory;
- “States should publish all their air navigation service charges”, which are collected and published by the International Air Transport Association (IATA) in its ‘Airport and En Route Aviation Charges Manual’, which is produced at varying intervals, and every other year by ICAO in its ‘Manual of Airport and Air Navigation Facility Tariffs’<sup>998</sup>. These sources are used for the analysis of charging levels in **Section 6.3**.

More specific policy guidance on charges for air navigation services is provided by the ICAO Council in their publication, ‘Statements by the Council to Contracting States on Charges for Airports and Air Navigation Services’<sup>999</sup>. This is revised periodically and differs in status from the aforementioned Chicago Convention Articles in that an ICAO Contracting State is not bound to adhere to the Statement's recommendations. Since these recommendations have been developed in conjunction with airlines, government authorities and service providers at international conferences, there is a strong incentive on the behalf of countries to ensure that their air navigation services cost recovery practices conform to policies and philosophy set out in the Statement. However, this is not always the case: for instance, the Russian Federation policies do not conform to these Statements. Therefore, noting that ICAO has not developed any specific charging principles for CNS/ATM systems, this framework recommends a continuation of current principles contained in the Council Statement, which cover:

- **The balance of interests of air navigation service providers and users**, denoting that States should exercise caution in their general policy on charges for air

<sup>998</sup> ICAO Doc. 7100 (1998).

<sup>999</sup> ICAO Doc. 9082/4.



- navigation services and take into consideration the effect on users, in particular the carriers who must adjust their tariffs to deal with new charges;
- **Consultation with users regarding charges and air navigation services planning**, so that users are given advance notice of significant changes to existing charges and have the opportunity to agree on proposed fees through discussions. This greater level of co-operation between the users, providers and regulators applies to situations when major new air navigation services are being planned and are subsequently in operation. Consultation among stakeholders is a fundamental aspect of this thesis' framework strategy;
  - **Proliferation of charges on air traffic**, whereby national authorities are encouraged to refrain from imposing charges that discriminate against international civil aviation in relation to other modes of transport. Additionally, the charges should be non-discriminatory between local and international users. Correspondingly, users such as general aviation operators must be accommodated<sup>1000</sup>. In contrast, IATA is willing to only pay for the systems that they require<sup>1001</sup>;
  - **The cost basis for air navigation services charges, charging systems and collection of charges**, which is dealt with in more detail hereunder. Ultimately, the Council recommends that revenues, which should be directly related to the cost of service provision, may exceed the operating costs. Therefore, countries and providers may offset expenses that are attributable to the provision of ANS, which include the cost of CNS/ATM systems, against ANS revenues. However, caution is required to ensure that the other recommendations are adhered to: thus, for example, it would not be equitable to drastically increase charges so that the cost of a CNS/ATM technology is offset within a year. Correspondingly, charges should not be levied for any facilities or services before they become operational<sup>1002</sup>. Additionally, the Council recommends that approach and aerodrome control charges can be a single rate per flight or based on the aircraft weight, whilst en-route fees should be based on distance flown and aircraft weight, whereby the weight is taken less than proportionately. According to ICAO<sup>1003</sup>, "as to their relative significance in financial terms, indications are that ATS, COM<sup>1004</sup> and MET may on average account for over 90% of a State's total air navigation service costs". Indeed, IATA believes that aeronautical users are being burdened with an unduly high share of meteorological services costs and proposes that competition in the provision of MET services be encouraged<sup>1005</sup>. The World Meteorological Organisation (WMO) opposes this proposal<sup>1006</sup>. Thus, it is important that nations ensure the recovery of costs from each

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<sup>1000</sup> 'User charges need to be equitable and aim to accommodate all types of operators' – ICAO Journal, April 2000.

<sup>1001</sup> 'Economic issues relating to the transition to CNS/ATM' – International Air Transport Association (IATA), ICAO Rio de Janeiro Conference, 1998.

<sup>1002</sup> 'Statements by the Council to Contracting States on charges for airports and air navigation services – status, structure and form' – Working Paper 4, ICAO Air Navigation Services Conference 2000.

<sup>1003</sup> 'Manual on Air Navigation Services Economics' – ICAO Doc. 9161-AT/724, 1997.

<sup>1004</sup> COM – previous communications category, now part of CNS.

<sup>1005</sup> 'Cost recovery of aeronautical meteorological services' – Working Paper 78, ICAO Air Navigation Services Conference 2000.

<sup>1006</sup> 'Cost recovery of aeronautical meteorological services' – Working Paper 97, ICAO Air Navigation Services Conference 2000.



category. In contrast, it is argued that the provision of search and rescue services should be derived by countries from a general revenue source<sup>1007</sup>;

- **Currency aspects**, noting that the ICAO Council recommends that the user charges should be expressed and payable in the country's local currency, but that where there is a lack of economic stability, airlines can pay a rate which is based on the exchange rate for the local ticket sales. It is also recognised, however, that when air navigation charges are billed on a regional basis, such as on behalf of several nations, it can be advantageous to users and providers to denominate and pay in a single convertible currency;
- **Cost recovery of search and rescue services**, where costs which are attributable to the provision of such services by the provider can be included in the cost basis for the air navigation services charges.

The principles contained in the ICAO Council air navigation charges statements on the cost basis for the charges and their billing suggest that:

- The full cost of providing the air navigation services, including interest on capital investment and depreciation, be shared;
- States maintain accounts for the air navigation services they provide in a manner which ensures that the charges are properly cost-based;
- Air navigation services may produce sufficient revenues to exceed all direct and indirect operating costs and therefore provide for a return on assets to contribute towards necessary capital improvements;
- The allocation of air navigation services' costs among aeronautical users and the proportions of cost attributable to all users of the facilities or services, including domestic civil aviation, should be determined in such a way as to ensure that no users are burdened with unnecessary costs;
- Any charging systems should be suitable for general application on a regional basis and that the administrative cost of collecting charges should not exceed a reasonable proportion of the charges collected;
- The charges should not be imposed in such a manner as to discourage the use of facilities and services necessary for safety or the introduction of new aids and techniques;
- Any charging system should take into account the cost of providing air navigation services and the effectiveness of the services rendered;
- The charging system should be introduced in such a fashion as to take account of the economic and financial situation of the users and the State;
- The charges should be assessed having regard to the costs of the facilities needed and used;

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<sup>1007</sup> 'Funding search and rescue services' – Working Paper 63, ICAO Air Navigation Services Conference 2000.



- The approach and aerodrome control charges, whether a part of the landing charges or levied separately, should as far as possible be a single element of the landing fee or a single charge per flight and could take aircraft weight into account, but less than in direct proportion;
- En-route air navigation services charges should essentially be based on distance flown and aircraft weight, but that the weight be taken into account less than proportionately;
- All users be required to pay their share of the costs of providing air navigation services, regardless of whether or not the utilisation takes place over the territory of the provider nation.

The aforementioned guidelines act as a framework on which countries should base their charges for air navigation services. It should be noted, however, that some developing nations do not adhere to all of the stipulations. Accordingly, air navigation service providers face different circumstances in the various worldwide regions. In addition to the aforementioned Chicago Convention Article 15 obligations, it should be noted that ICAO demands that States should publish their charging policies and how the fees are implemented: such a listing may be found in their 'Manual of Airport and Air Navigation Facility Tariffs'<sup>1008</sup>.

**Section 6.2.2** considers how countries may use these principles to allocate costs for air navigation services.

### **6.2.2. Allocation of air navigation costs by ANS providers**

This section considers an approach for allocating the costs associated with air traffic services, so that financiers, nations or providers may apply suitable fees. In addition, it is important that regulators and users are aware of this ICAO-derived method<sup>1009</sup>, which is based on the following stages:

1. Categories of facilities and services;
2. Determination of costs;
3. Allocation of costs.

#### **Stage 1 – Categories of facilities and services**

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The first step in determining the costs of air navigation services is to draw up an inventory of all facilities and services that directly provide en-route and/or terminal navigation. The latter encompasses navigational aid in the approach and aerodrome phases of flight. Some facilities may have functions in en-route and terminal navigation.

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<sup>1008</sup> ICAO Doc. 7100 (1998).

<sup>1009</sup> Based on information in their 'Manual on Air Navigation Services Economics' (ICAO Doc 9161-AT/724).



Given ICAO's recommendation that the cost basis for air navigation service charges should be established based on the cost of operating the facilities and services, it is beneficial to develop a methodology whereby the necessary equipment is classified according to service provided. This should be performed separately for en-route and terminal facilities. Noting that **administrative** costs should be included, consider the five following categories of facilities and services:

- **Air Traffic Management (ATM)**, which can be divided into a main component, air traffic services (ATS) and its two sub-components, air traffic flow management (ATFM) and airspace management (ASM), as follows:
  - ✓ For costing purposes, **ATS** facilities are the most important and consist of different entities such as building infrastructure, personnel and equipment for en-route and terminal operations, thus:
    - En-route facilities comprise those required area control centres, which include oceanic area control centres, and flight information centres;
    - Terminal facilities for approach and aerodrome control consist primarily of those necessary for aerodrome control towers and approach control offices;
  - ✓ **ATFM** is typically based on a centralised flow management unit (CFMU), which serves an extensive geographical area, covering a considerable number of flight information regions (FIRs). CFMUs are established in area control centres and, similar to ATS, require dedicated personnel and equipment;
  - ✓ In contrast, **ASM** necessitates negligible resources and is performed by personnel engaged in other ATM tasks;
- **Communications, Navigation and Surveillance (CNS)**, whereby air and ground-based equipment are required in conjunction with personnel to facilitate:
  - ✓ Communications, which may be broadly classified as Aeronautical Fixed Services (AFS), providing communication services between two or more fixed points on the ground for the transmission of messages; and Aeronautical Mobile Services (AMS), enabling communication services between aircraft and ground stations or between aircraft;
  - ✓ Navigation services, which currently comprise ground-based equipment such as VOR/DME/NDB<sup>1010</sup> and precision approach and landing aids such as ILS. Satellite-based facilities and their associated (local and wide area) augmentation systems are being increasingly included in costing. It should be noted that Eurocontrol established a Task Force on the allocation of Global Navigation Satellite System (GNSS) costs in 1998<sup>1011</sup>; it concluded<sup>1012</sup> that the requirements-driven method<sup>1013</sup> is the preferred cost allocation method;

<sup>1010</sup> VOR/DME/NDB – VHF Omnidirectional Radio Range / Distance Measuring Equipment / Non-Directional Beacon (see Chapter 2).

<sup>1011</sup> 'Study on the allocation of Global Navigation Satellite Systems (GNSS) costs' – Working Paper 20, ICAO Air Navigation Services Conference 2000.

<sup>1012</sup> 'The allocation of GNSS (Global Navigation Satellite Systems) costs' – Working Paper 65, ICAO Air Navigation Services Conference 2000.

<sup>1013</sup> It is based upon the requirements of aviation and non-aviation users by application or operation phase, which are analysed and harmonised into a common set of service levels by



- ✓ **Surveillance services** using primary and secondary radar, in addition to surface movement radar. Automatic Dependent Surveillance (ADS) and its supporting network and maintenance requirements is becoming ever-relevant for costing.
- **METEorological services for air navigation (MET)**, which cover services such as meteorological observations, reports and forecasts; upper area and world area forecasts; briefing and flight documentation. The facilities required include equipment, forecast centres and watch offices for the various types of aforementioned services. Savings can be made on MET costs when non-aeronautical climatological and meteorological services are also offered;
- **Search And Rescue (SAR)** for aviation, which necessitate adequate personnel, the establishment of rescue co-ordinating centres and the purchase of aircraft and boats varying in range capability;
- **Aeronautical Information Services (AIS)**, which require staff to collect, collate, edit, publish and distribute aeronautical information. This includes the preparation and dissemination of Aeronautical Information Publications (AIP), NOTices to AirMen (NOTAM), Aeronautical Information Circulars (AIC) and the provision of pre-flight information bulletins.

## **Stage 2 – Determination of costs**

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In order to establish the full costs of air navigation services, it is essential to include the cost of relevant facilities and services provided by all parties, which includes those performed by third party agencies. Accordingly, it is important to apportion the costs between those associated with en-route and those responsible for terminal navigation control. Correspondingly, the cost base for military air navigation services should not be included with civil aviation's. In the case that sharing of facilities exists, the costs should be correctly apportioned: if different en-route air navigation service charges apply to various flight information regions, then the share of the en-route costs attributable to each should be established. Similarly, the terminal navigation fee should be allocated to each airport served. This is particularly relevant where the approach and aerodrome control services are being provided under contract at the airport(s) concerned.

This costing approach may be summarised by segregating the costs for the facilities and services cited in the first step above in the following categories, thus:

- Costs incurred by the entity providing services;
- Transfers to/from third party agencies, whether other civil aviation authority departments or commercial organisations;
- Costs attributable to non-aeronautical utilisation;
- Costs attributable to military traffic and official government business.

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determining the incremental costs of providing the level of service. It is then necessary to ascertain the number of users and allocate the core GNSS costs accordingly.

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Thus, it is possible to obtain the adjusted air navigation service costs attributable to civil aviation, which should be subsequently broken down into:

- Costs attributable to **en-route** navigation facilities and services;
- Costs attributable to **terminal** navigation facilities and services.

Again, it should be noted that one organisation may be involved in providing more than one of the given facilities and services. In such cases, it is necessary to ensure that cost data is made available for each usage. In practice, however, it is sometimes difficult to directly link many costs with usage because the original systems were not designed to identify costs independently. Additionally, it is not advisable to rely solely on the accounts of the organisation(s) providing the services when estimating the cost basis for navigation service charges. Factors that should be considered regarding the difference between these costs and those recorded for providing air navigation services include:

- Operation, maintenance and administrative overhead costs;
- Depreciation and/or amortisation rates, which may not reflect the true operating life of the building infrastructure or equipment concerned or may not be implemented at all. It is essential to ensure that the depreciation element accurately accounts for the reduction in the value of assets during the period concerned;
- Cost of capital imputed on the net capital value of the assets, which would not normally be in the accounts of a provider, but should be included in the cost basis for charges. This falls into two basic categories:
  - Interest paid to the providers of debt capital;
  - The appropriate cost of capital applied to equity, which should be calculated annually on all capital invested in fixed assets and on working capital.

The organisational structure of air navigation service providers has a direct bearing on their financial management and the approach taken in arriving at the total costs to be included in the cost basis for the charges. This particularly applies to the situation where part of the service is conducted by other departments within the organisation: the cost of such functions must be attributed to the air navigation services department. Conversely, the air navigation services department may be performing services for other sections: such costs should be apportioned and removed from the accounts to the cost basis of air navigation services. It is frequently difficult to perform such operations for government-run entities (see **Section 5.4**) due to the accounting methods in place, which are often based on a general budget, with little distinction between facilities and services.

### **Stage 3 – Allocation of costs**

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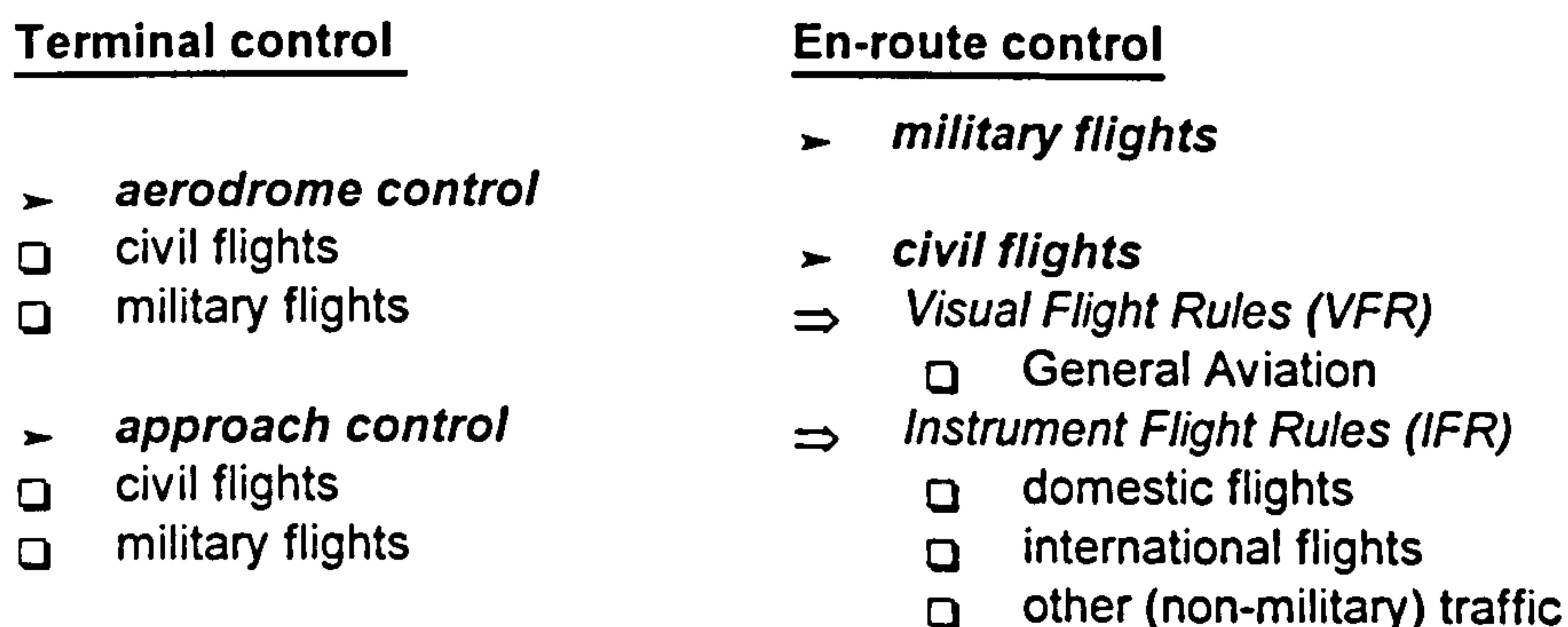
Allocation of expenses requires the cost accounting system to permit an assessment of total costs attributable to individual categories of services and facilities. This enables the distinction between categories to be determined, so that:

- **Non-aeronautical utilisation costs** may be identified. Although this does not apply to all categories, some have non-aeronautical functions. For instance, it is frequently difficult to apportion the costs of military personnel and equipment for search and rescue purposes;



- ❑ **Costs for facilities and services serving both en-route and terminal traffic** may be appropriately allocated. Reflection of this dual utilisation may be conducted with a split in time given to both activities, noting that this depends on the country's geographical location, which influences the number of aircraft transiting its airspace and its amount of airport movements. Correspondingly, the apportioning of hours is based on the average time it takes to handle the en-route and terminal traffic;
- ❑ **The total costs** may be allocated to the various accounting service locations;
- ❑ **En-route costs** may be determined for **Flight Information Regions (FIR)** other than the one where the equipment physically is, because the user charges received may be levied on an FIR basis;
- ❑ Costs can be determined to ensure that **no users are burdened with costs** that are not relevant to them;
- ❑ It is possible to check that **no double counting** has occurred and that the allocations add up to the total costs.

The first stage in allocating costs among categories of users is to define the categories of users as a function of the services provided and/or the traffic concerned. Users may be categorised differently according to the type of airspace and air traffic service involved. Such categorisation may be structured as portrayed in **Figure 6.1**.



**Figure 6.1 – User categorisation**

The second stage is to apply appropriate parameters to those costs that are found to be attributable to two or more categories of users: if facilities and services have been provided to serve only one category of user, then the costs should be allocated to that user category. Such parameters include:

- *Number of flights*, which is very suitable for allocation of costs purposes;
- *Distance flown*, which is also useful for sharing the costs;
- *Time in the system*, which is less accurate due to varying aircraft speeds. However, slower aircraft do spend more time in the system and affect its capacity;
- *Aircraft weight*, which is not beneficial to cost allocation because it does not provide an indication of the extent of equipment use.



It is then possible to segregate the terminal control costs from the en-route equivalents and allocate them on a pro rata basis among the various user categories by identifying traffic that is exempt from charges, such as government flights, and then deciding on the parameter or combination of parameters to be applied in allocating the costs. It should be noted that, of the aforementioned four parameters, distance flown, time in the system and aircraft weight are not as relevant for the terminal phase of flight as the number of flights.

Finally, once the total costs attributable to the civil traffic have been established and divided into their domestic and international components, the cost basis for both en-route and terminal air navigation services charges may be translated into:

- The **en-route air navigation services charge**, which includes all relevant costs by entities providing ATS, COM, MET, SAR and AIS facilities and services;
- The **approach and aerodrome terminal control charge**, which covers all costs attributable to the provision of terminal navigation services, noting that many countries still levy these as part of the landing charge. Hence the separate analysis of such charging levels in **Section 6.3.2**. However, as the number of autonomous authorities increases, there is an ever-increasing need to separate such charges.

In order to apportion the costs, the flights that can be charged must first be identified, which is often performed by the ANS provider. Correspondingly, there is a need to ensure that revenue from charges is shared among the different agencies providing air navigation services. Such sharing should be conducted in proportion to the costs incurred by each entity in providing air navigation services.

It should be noted that the allocation of costs and their use of the four parameters is for accounting purposes and is different from the recommendations of the ICAO principles, which are that the “approach and aerodrome control charges can be a single rate per flight or based on the aircraft weight and that the en-route fees should be based on distance flown and aircraft weight, whereby weight is taken less than proportionately”.

Given these stipulations, **Section 6.2.3** analyses the various mechanisms employed around the world for setting air navigation services charges.



### 6.2.3 Charging methods and formulae

With reference to the policy regulations and principles cited in **Section 6.2.1**, this section analyses the basic charging methods and formulae for navigation, which may be split between the:

- En-route fee;
- Terminal navigation charge.

Such charges aim to recover the costs for the provision of air navigation services, as explained in **Section 6.2.2**. It is considered best practice to set the charges on forecasts of costs for the next financial year using data for existing and past years. However, full cost recovery is not always realised, although the tendency to commercialise Air Navigation Service (ANS) providers has increased the number of such agencies operating with a positive return. It should be added that the ICAO principles stipulate users' requirements to only pay for their share of the related costs. Therefore, it is essential to allocate costs as per the previous section based on an accurately predicted traffic volume, split by the relevant categories. However, this may be more difficult or subjective to conduct in the future when, for instance, user charges will undoubtedly apply to some satellite services that are globally or, at least, regionally available. At present the US GPS and Russian GLONASS are available free of charge, but augmentation systems will soon be available. It should be added that the International Air Transport Association (IATA) believes that satellite costs should be borne by nations<sup>1014</sup>.

#### En-route fee

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As mentioned in **Section 6.2.1**, en-route navigation charges are set to cover the cost of providing the following services:

- ❑ **Air traffic services** – provided to aircraft en route, including area control, flight information and alerting services, as distinct from the services provided by approach and aerodrome control;
- ❑ **Communications and navigation aids** – communication facilities, visual and radio aids to navigation, whereby communications used for approach or aerodrome control are excluded;
- ❑ **Meteorological services** – meteorological services that are allocated to civil aviation for simplicity of costing should be considered an en-route service, subject to the proviso that, where a nation considers such services to be greatly utilised for airport operations, it should consider allocating the costs of these services between airport and en-route utilisation;
- ❑ **Other auxiliary aviation services** – which includes all services that are allocable to civil aviation of equipment and personnel maintained for providing search and rescue, accident investigation, aeronautical charts and/or information services.

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<sup>1014</sup> 'User charges aspects of CNS/ATM' – Working Paper 25, ICAO Air Navigation Services Conference 2000.



The charges for en-route air navigation facilities and services should, according to ICAO<sup>1015</sup> and as per **Section 6.2.1**, be a single charge per flight, essentially based on:

- *Distance flown within a defined area* – which should be applied by means of a distance scale using great circle (orthodometric) distances or other commonly agreed distances;
- *Aircraft weight* – which should be standardised as far as possible and taken into account less than proportionally than the distance flown.

With reference to the worldwide analysis of en-route charges in 205 countries, which is conducted in **Section 6.3.1** for the purposes of this framework strategy, it is apparent that the general categories of formulae and their structures for en-route fees that exist include:

- **Distance and weight-based charges:**
  - Unit rate x some distance-weight coefficient;
  - MTOW category rate per distance;
- **Distance-based charges:**
  - Distance category fixed rate per flight;
  - Fixed charge + rate per distance;
  - Fixed rate per distance;
- **Weight-based charges:**
  - Aircraft type rate per flight;
  - MTOW category fixed rate per flight;
  - Fixed charge + rate per MTOW;
  - Unit rate x weight coefficient;
- **Landing-based charges:**
  - Flat rate + percentage of landing charge;
  - Percentage of landing charge.

Additionally, the characteristics of certain airspace structures are integral in determining the optimum charging method: in some cases, a uniform rate is applied to all aircraft migrating through the airspace. Although this is suitable when the distance flown and/or aircraft types, and consequently weights, are homogenous, such an approach may not fully recover the costs or, indeed, be equitable to all users.

**Appendix 6.1** lists the results from a survey, conducted as part of generating this framework using 1999 data, of the bases and structures of en-route formulae, where applicable, for the 205 nations considered in this research. It is interesting to note that, for all regions, most charges are based on both distance and Maximum Take-Off Weight (MTOW). It is also possible to observe, particularly in the Americas & Caribbean region, those countries that do not enforce any charging policy for the provision of en-

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<sup>1015</sup> 'Statement by the Council to Contracting States on Charges for airports and air navigation services' – ICAO Doc 9082/4.



route navigational facilities and services. Correspondingly, with the exception of Europe, it is evident that all regions have a virtually equal spread of formulae that are structured in stepped and continuously progressive manners. The former has an incremental effect on the charges, whereby increases in the levels of fees are category-based; the latter's impact is that the fee rises in proportion with greater distances and/or aircraft weights.

Such formulae, which are based on both aircraft weight and distance travelled, often include a unit rate, so that the resultant charge is frequently an amalgamation of:

*unit rate x distance x aircraft weight*, where ...

- The **unit rate** to be applied for each user category is determined by dividing the total estimated route facility costs to be recovered from each user category by the estimated total of all traffic units produced by that user category. The unit rate can be expressed in either local or more internationally accepted currencies;
- The **distance flown** is usually expressed in hundreds of kilometres or occasionally in nautical miles. A standard deduction is often made for each take-off and landing at an airport within the country concerned, to reflect the extra cost associated with using the approach and aerodrome terminal control facilities and services. The distance flown is identified from the Air Traffic Control (ATC) flight records;
- The **aircraft weight** is normally designated in metric tonnes and usually has its square root applied in the formula. It is important to incorporate the weight in such a manner so that heavier aircraft are not penalised drastically. Indeed, use of larger aircraft should not be discouraged because they increase the capacity of ATC systems in terms of passenger throughput without need for more capital investment. However, operators of heavy aircraft usually benefit from economies of scale from having large numbers of passengers. In contrast, aircraft with lower weights usually fly at slower speeds, with lower passenger numbers, thereby severely limiting the capacity of airspace regions.

**Appendix 6.2** also shows results from the worldwide survey of formulae structures by demonstrating the effect of formulae differential on en-route charges for countries, thus:

- It portrays how most nations reduce the fees if an aircraft is landing in the country;
- It highlights that the point of origin or destination of a flight can also lower the rate.

Rates are rarely higher if landing occurs or if the flight is categorised as domestic. In addition, the tables indicate how many nations do not specify any landing or domestic policies, noting that those countries with no entries:

1. Do not apply charges;
2. May state that the rate is the same when landing or if a domestic flight; or,
3. May have just one airport;
4. Have not replied to the request for information.

Correspondingly, it should be noted that international organisations exist, which have defined formulae because they charge on behalf of their member countries. The billing process is discussed in **Section 6.2.4**. Organisations include ASECNA, COCESNA,



Eurocontrol, PIARCO FIR and Roberts FIR. Contracting and member nations of these organisations are listed in **Appendix 1.2** and descriptions given in **Appendix 1.3**.

The organisations employ the following formulae for computation of en-route fees:

- **ASECNA:** charge = unit rate x coefficient for aircraft over 14 tonnes, where the 1999 unit rate varies whether the flight is domestic, regional or international; and the coefficient is determined from:

MTOW (tonnes)	Distance in kilometres			
	0 - 750	750 - 2,000	2,000 - 3,500	Over 3,500
14 - 20	1	5	12	20
20 - 50	1.2	6	14.4	24
50 - 90	1.4	7	16.8	28
90 - 140	1.6	8	19.2	32
140 - 200	1.8	9	21.6	36
200 - 270	2	10	24	40
270 - 350	2.15	10.75	25.8	43
350 - 440	2.3	11.5	27.6	46
440 - 540	2.45	12.25	29.4	49
540 - 650	2.6	13	31.2	52

- **COCESNA:** charge = unit rate x nautical miles flown, where the 1999 unit rate is weight-dependent and has the following current values:

Up to 50,000 lbs.	USD 0.10
50,001 - 80,000 lbs.	USD 0.12
80,001 - 110,000 lbs.	USD 0.25
110,001 - 170,000 lbs.	USD 0.33
Over 170,000 lbs.	USD 0.52

- **Eurocontrol:** charge = unit rate x GCD x  $\sqrt[3]{\frac{\text{MTOW}}{50}}$ , where the unit rate differs for each country (published annually) and GCD is the Great Circle Distance flown, expressed in hundreds of kilometres that are taken to two decimal places<sup>1016</sup>;
- **Roberts FIR:** charge = unit rate x kilometres flown, where the unit rate in 1999 was \$0.81 per kilometre;
- **PIARCO FIR:** flat charge + rate per nautical mile, where the rate is different for flights east and west of the 57° West Longitude, noting that Trinidad & Tobago levies the charges for the member countries.

<sup>1016</sup> Eurocontrol is presently debating whether to adopt a different charging structure: see Section 6.2.5.



**Section 6.3.1** contains details and results of the findings from this research's worldwide benchmarking exercise of en-route air navigation fees in over 200 countries, which includes the application of these regional agencies' formulae.

### **Terminal navigation charge**

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At many airports around the world, the landing fee has an element that covers use of the ANS and meteorological facilities used during approach, landing and take-off phases of flight. However, at other airports, a terminal navigation charge is levied independently of the landing fee. The latter case can arise due to:

- The cost of approach and aerodrome ANS not being covered by the landing fee or being funded separately;
- The proliferation of commercialised air navigation service providers. In this situation, the competitive provision of airport terminal area air navigation facilities and services is similar to the en-route situation described in **Section 5.4**. Terminal providers ensure that, in collaboration with the airport, their costs are recovered;
- The demand for transparency of charges by the users.

Most Australian, some European, and Latin American airports have a surcharge to the landing fee, which is independently categorised as a terminal navigation charge. However, some Asian, Canadian, US and some Middle Eastern countries tend not to, although the US is presently reviewing its situation. Other Asian, African, some European and other Middle Eastern States tend not to specify any. Indeed, a 1998 study on aircraft turnaround costs at European airports<sup>1017</sup> that was conducted by Cranfield University for the Association of European Airlines (AEA) reinforces these statements. The study found that 17 from a sample set of 29 European airports did levy a separate terminal navigation charge. In addition, it confirms that US airports did not stipulate any such fees, while two SE Asian airports did not charge independently either.

As per ICAO's principle recommendations, whether levied as part of the landing fee or separately, the terminal navigation fee should be a single charge per flight and can take the aircraft weight into account, but less than in direct proportion. If its basis is the Maximum Take-Off Weight (MTOW) of the aircraft, the charge is usually:

- A fixed unit rate  $\times \sqrt[3]{\frac{\text{MTOW}}{50}}$ ;
- A fixed rate per tonne, irrespective of aircraft weight;
- A rate per tonne with weight break-points, such that the rate increases in steps as the total weight rises;
- As per the former method, but the charge is cumulative;
- A fixed fee plus a rate per tonne.

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<sup>1017</sup> 'User costs at airports in Europe, SE Asia and the USA' – Air Transport Group, Cranfield College of Aeronautics, 1998.



As for en-route air navigation services, it may be more appropriate to implement a single, fixed terminal navigation fee. Indeed, weight-based landing charges are increasingly being replaced with such single, fixed runway use charges, which are per aircraft, regardless of size. The rationale for this charging method is that aircraft each take up one runway landing slot and require the same amount of CNS aid. However, a pedantic assessment would observe that a greater separation is required after heavier aircraft and that aircraft approach speeds vary, with correspondingly different times requiring ANS.

It should be added that there is a growing tendency, especially in complex, highly congested areas, for an airport's approach control services to be centralised with other airports. This has also occurred due to airports being commercialised, which turns the provision of approach and aerodrome navigation services into one or more cost centres. Thus, consolidation of localised providers can occur<sup>1018</sup>. Cost accounting methods must reflect this co-ordination of approach control in the individual airport's terminal navigation fee. Indeed, with the continuing growth in financially autonomous bodies operating airport navigation services, it should be assumed that the application of a separate terminal navigation charge will become more widespread.

Airports often have diverse systems of surcharges and rebates on the basic landing charge, which may be related to the distance of the flight, its nature, aircraft noise levels, other environmental effects<sup>1019</sup> and whether the flight is domestic or international. Nighttime and airport peak periods have also created separate surcharge categories. In most cases, however, terminal navigation fees do not have as many categories of surcharges applied to them: they have peak charging structures, or minimum fees, which could help to encourage, from an ANS provider's revenue perspective, the efficient use of capacity where General Aviation movements account for a relatively high share of the total movements. A domestic/international differential could be applied.

Noting that the landing fee normally covers use of the aforementioned landing/take-off facilities and services, in addition to the provision of fire services and runway lighting, the terminal navigation fee is consequently a large component of the landing charge. Given that the terminal navigation charge is still levied as part of the landing fee at many airports and that it is usually not possible to obtain the navigation element of the landing charge, this thesis considers the overall landing fee when numerically analysing terminal navigation charges. This ensures that comparisons between countries' fee levels are based on similar constituents in **Section 6.3.2**. Terminal navigation fees are included where appropriate, so that consistent comparisons may be conducted.

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<sup>1018</sup> 'Recovery of costs of approach and aerodrome control services' – Working Paper 21, ICAO Air Navigation Services Conference 2000.

<sup>1019</sup> The ICAO Council Committee on Aviation Environmental Protection (CAEP) is presently studying a range of options for charging or taxing aircraft emissions.



#### **6.2.4. Billing and collection of payments**

**Section 6.2.3** discusses the two main types of air navigation charges that exist, namely en-route and terminal navigation fees. This section considers aspects of implementing policies and practices concerning charging systems for these fees.

Data for billing can be obtained from a variety of sources, thus:

- For terminal airspace coverage, the source may be the same as that for the landing charge computation, such as Air Traffic Control (ATC) or apron control logs;
- Regarding en-route flights in controlled and oceanic regions, data may be retrieved from daily flight summaries, the Flight Data Processing System (FDPS) or ATC flight progress strips;
- Outside controlled airspace, information may be determined from Flight Information Services (FIS) or flight plans.

Identification of the correct operator is fundamental for smooth operation of the billing system. Unknown users, as is often the case with leased aircraft, can be a source of problems, but normal, scheduled operations use the ATC flight strip and are therefore easily identifiable. It is important to make (automated) use of operational ATC systems where possible, particularly where there are high volumes of traffic.

The legal basis for the charge assumes that the liability to pay the fee falls on the user who, at the time of the flight, was the operator of the aircraft concerned. According to ICAO, a flight may be defined as “an aircraft movement through any airspace and defined by aircraft identity and/or airline flight identity, aircraft type, flight category, respective entry and exit points, departure and destination airports, date and time of departure”.

A formal agreement between the air navigation service provider and the operator is not usually required. As mentioned throughout this chapter, the charges are usually levied according to formulae that are publicly available for en-route and terminal air navigation. In some cases, where air navigation services are provided under contract to another service provider, such as an entity providing Air Navigation Services (ANS) for an airport, then it may recover its costs by means of a periodic charge directly to the airport organisation.

Programmes that extract chargeable data from the FDPS do the verification of data. But, given the wide range of data sources that exists, there is a need for a data validation process. A timetable should be established for validating and transmitting the data to the billing department. Where there are high volumes of traffic, it is advisable to break the traffic down by categories.

Following collection of data on chargeable flights, the bills must be prepared, noting that the entity providing navigation services may outsource the preparation of bills. It is more practical to bill periodically, such as once per calendar month, rather than for each flight. However, billing should be carried out soon after the flight to ensure that the provider receives revenue promptly and that the operator can easily verify the bills. In addition, the bill or invoice should provide the aircraft operator with the information



necessary for verification and payment purposes. It should therefore include the type of charge, amount due, flight(s) involved and the date by which the payment is required. Terms of payment and destination of funds should also be indicated. The invoice should also show the standard weights and airspace distances on which the system is based. Eurocontrol use a route per country overflown basis.

The country's civil aviation authority or the ANS provider organisation normally collects en-route charges. However, joint collection international organisations exist, as mentioned in **Section 6.2.3**. Such agencies, described in **Appendix 1.3**, are responsible for the collection of payments for groups of nations, as listed in **Appendix 1.2**. A list of countries, from this thesis' sample set of 205, who levy their own fees was determined by an analysis of the International Air Transport Association (IATA)'s 'Airport & en-route aviation charges manual'. The results of this evaluation may be found in **Appendix 6.3**. The joint collection agencies, which principally apply to en-route air navigation services, but do collect terminal fees as well, can provide economies of scale for the participating nations, particularly where a substantial volume of traffic overflies the country. Such agencies also enable international co-operation in the provision of air navigation services, as discussed in **Section 5.4**. However, countries may wish to provide their own ANS functions, but still participate in the operation of a charges collection agency.

The agencies bill, collect and transfer the revenue from services charges on behalf of the countries. The costs involved to the participating nations are minimal and start-up funds are only needed for the acquisition of premises and data processing. Additionally, regional collection agencies appeal to the operators, who only receive one bill, regardless of the number of States overflown. In the specific case of airports collecting navigation-related charges, revenues are passed on to the relevant services provider. In certain circumstances, the charging authority may prefer to collect the charge immediately after landing or prior to take-off. This is particularly applicable to occasional users or those who have a poor payment record. In dealing with such problems, the extent and costs of any collection efforts should be commensurate with the amount involved. Difficulties encountered in collecting outstanding amounts will vary depending on whether or not the parties concerned are located in the country that is imposing the fee. It should be noted that the Information Co-ordination Council for Debts in Air Navigation Service (IKSANO) has been set up in recent years, with a view to sharing information so that fees may be recovered<sup>1020</sup>.

In the case where regional, joint charges collection agencies exist, the problems with non-payments are reduced. Recoverage rates are good for Eurocontrol States, but some of the other organisations, such as ASECNA, have lower recovery levels or experience late payments. Countries that collect charges themselves can also experience difficulty in obtaining payments, especially where the majority of aircraft in that country's airspace are only overflying. The ANS provider is in a difficult situation because it cannot refuse entry to an aircraft solely on the basis of a poor payment record. If all attempts to recover the charges fail, it may be necessary to make the granting of any overflight permit or pre-flight clearance subject to the operator concerned naming an

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<sup>1020</sup> 'Collecting air navigation fees' – *Journal of ATC*, April – June 2000.



agent in the country, which should make its acceptance of such an agent contingent upon their having proper authorisation from the operator and being capable of making the payments concerned.

IATA also provides a collecting facility for en-route charges through its clearing house, which normally pays its member airlines their share of interlining tickets. Indeed, this only other function of the clearinghouse collects en-route charges on behalf on 23 countries, as listed in **Appendix 6.4**. These countries pay amounts that vary from 1% to 3% for the privilege, but at least their recoverage rate is better, often because IATA just debits its relevant member airline's account and credits the country's ANS organisation with the required amount.

En-route air navigation service charges are an essential source of revenue, and it is consequently important that the countries concerned remain fully in control of the charges collection function so that a high recovery rate is experienced. However, it should be noted that corrections and claims in the form of disputed bills are practically unavoidable. Large operators receive details of invoices electronically, which eases verification since they can compare the bill details with their own flight data. In all other cases, the authority should ensure that a suitable process is available to crosscheck charges.

When charges collection is outsourced to a non-government controlled or operated contractor, the nation should insist that it receives the full fees and that payment to the contractor is from a supplement added to the operator's bill: this is essential for financial planning and is standard practice. Confidentiality with operators is also essential. The ICAO Council recognises that "when route air navigation service charges are billed on a regional basis, it may be advantageous to both users and providers to denominate and pay for charges in a single convertible currency." Although countries and the joint collection agencies often levy their bills in international currencies, many other nations use their own currency. This is evident in **Appendix 6.5's** listing of billing currencies, noting that the full name of each currency code is listed in **Appendix 6.6's** \$ exchange rates.

This section shows that a variety of methods exist for recouping the costs of providing air navigation services. It would appear that the regional approach offers the most viable opportunity to ensure repayment, particularly for en-route flights, at a minimum cost. A similar procedure applies to international territories, with an example being the separate, single oceanic charge levied by Eurocontrol States as part of a transatlantic journey. It is for this reason that the framework strategy, which is outlined in **Chapter 5**, suggests that nations enter into international or regional co-operation ventures, where possible. An example is given in **Section 6.2.5** hereunder, which analyses Eurocontrol's approach.



### 6.2.5. Eurocontrol approach

This section analyses Eurocontrol's approach to air navigation charges, which is an example of best international standard practice, with reference to the topics of the four previous sections, namely:

- ICAO's guidelines on charging policies;
- A method for allocation of air navigation costs by nations;
- Charging methods and formulae;
- Billing and collection of charges.

It is not relevant to analyse the US Federal Aviation Administration (FAA) approach because it does not levy en-route or terminal navigation charges to a great extent: it started charging the operators of those aircraft not landing or taking-off in the US for crossing its airspace in August 2000<sup>1021</sup>. Such facilities were covered heretofore by the domestic federal tax fund, whose income is derived from passenger taxes.

This section's discussion on the Eurocontrol approach to administering air navigation charges is split by en-route and terminal fees, as follows:

#### En-route fees

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With reference to the description of Eurocontrol in **Appendix 1.3**, its Central Route Charges Office (CRCO) offers its member countries (see **Appendix 1.2**<sup>1022</sup>) a calculation, billing and collection service for both en-route fees through its 'Route Charges System' (RCS). Eurocontrol nations adopted the basic principles for this harmonised regional en-route charges system in 1969 and it came into effect in 1971. In addition, the CRCO provides this service for non-member nations on a bilateral basis<sup>1023</sup>. The CRCO also has an advisory service, which can provide assistance on any aspect of charging for air navigation services.

In line with the ICAO guidelines that are stated in **Section 6.2.1**, operation of the common route charges system contributes to the funding of the European air traffic management system. It also facilitates consultations with users. Countries participating in the scheme determine the level of these charges. Accordingly, the member countries have agreed to implement a common policy for the establishment and calculation of charges levied on aircraft operators for en-route air navigation facilities and services. The system is organised on a co-operative basis, but is governed by a Commission

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<sup>1021</sup> 'FAA to charge for overflights from 1 August' – *Air Transport Intelligence*, 6 June 2000.

<sup>1022</sup> It should be noted that the Republic of Moldova is presently being integrated into the Eurocontrol system as a full member, having previously used some services on a bilateral basis (see hereunder).

<sup>1023</sup> Belarus, Bosnia and Herzegovina, Latvia, Lithuania, Moldova, the Ukraine and Uzbekistan take advantage of this facility for en-route charges; in addition, Lithuania, Moldova and the Ukraine avail of the billing service for terminal navigation charges.



composed of the national Ministers with responsibility for transport and a Committee consisting of representatives from States. It complies with ICAO's stipulations that the system should be regional by nature and that the administrative cost of collecting charges should not exceed a reasonable proportion of the income from fees.

En-route charges are established according to a common formula, which is discussed in **Section 6.2.3** and takes account of the costs incurred by nations in providing the Air Navigation Service (ANS) facilities. A fee is levied for each flight performed under Instrument Flight Rules (IFR) in the Flight Information Regions (FIR) of the countries. The total charge per flight, which is collected by Eurocontrol as a single fee, is the sum of the charges generated in the FIRs of individual nations. These charges may also be imposed for aircraft flying under Visual Flight Rules (VFR), but do not apply to:

- Circular flights, those terminating at the aerodrome from which the aircraft has taken off and during which no intermediate landing has been made;
- Flights performed by aircraft with a Maximum Take-Off Weight (MTOW) of less than 2 tonnes;
- State flights;
- Search and rescue missions.

Eurocontrol has drafted common rules<sup>1024</sup> for calculating charges, which detail:

- The **conditions of application** in the form of ten Articles and one Annex, encompassing regulations that include the categories of flights applicable for charges, the cumulative nature of the single fee, the structure and basis of the formula and exempted categories;
- The **conditions of payment** in the form of an Annex, noting that the standard currency is the Euro (€).

Examples of best practices, additional explanations and practical advice exist as addenda to these common rules, published by Eurocontrol in their booklet titled 'Guidance on the rules and procedures of the route charges system'<sup>1025</sup>.

**Section 6.2.1** states the ICAO recommendation that charges should be directly related to the cost of service provision. Eurocontrol adheres to this cost recovery method. The cost basis of the en-route charges considers the expenses incurred by the countries for these services and the costs incurred by Eurocontrol. Common principles<sup>1026</sup> for the calculation of costs, which are similar to the method that is described in **Section 6.2.2**, cover:

- *Accounting principles* for the costs by:
  - **Types** – investment, operating and staff costs;
  - **Category** – Air Traffic Management (ATM), Communications, Navigation & Surveillance (CNS), training, research, administration, Aeronautical Information

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<sup>1024</sup> 'Conditions of Application of the Route Charges System and Conditions of Payment' – Eurocontrol Doc. No 00.60.02, January 2000.

<sup>1025</sup> Electronic copy of all CRCO studies were obtained from <http://www.eurocontrol.be/>.

<sup>1026</sup> 'Principles for establishing the cost-base for route facility charges and the calculation of the unit rates' – Eurocontrol Doc. No 99.60.01/1, August 1999.



Service (AIS), METeorological (MET), Search And Rescue (SAR) and Eurocontrol;

- *Calculation of the unit rate;*
- *Calculation of the regional administrative unit rate.*

Essentially, according to Eurocontrol<sup>1027</sup>, each country establishes its forecast cost-base by applying the common principles for the year in which the charges are to be collected. This cost-base comprises operating costs plus depreciation costs and the cost of capital, in addition to the nation's share of the Eurocontrol costs (which do not include CRCO fees). A unit rate, expressed in €, is determined for each State and consists of two parts:

- The national unit rate, obtained by dividing the en-route facility cost-base of the country concerned for the reference year by the number of service units generated in the nation's airspace during the same year;
- The administrative unit rate, the purpose of which is to recover the expenses of collecting en-route charges (CRCO costs). It is obtained by dividing these costs by the number of service units generated in the Eurocontrol charging area as a whole.

Country representatives provisionally discuss the figures for the following year with the user organisations at the Committee sessions every June and then as definitive figures in November. The unit rates are applicable from the 1<sup>st</sup> of January each year, but nations can modify their unit rate at a mid-year point, provided that all other countries agree. An analysis of the change in unit rates from 2000 to 2001 for 25 of the 28 Eurocontrol member nations concludes that 3 countries did not alter their rate over the period, 12 reduced their unit rate and 10 increased their charge<sup>1028</sup>. This indicates that virtually 50% of countries actually lowered their fees for en-route air navigation in 2001, when compared with rates for the previous year. It is interesting to note the variation in magnitude of fluctuation: Italy lowered its rate by 23%, while Malta increased its unit rate by 30%, which compare with increases by these two countries in the period from 1999 to 2000 of 13% and 3% respectively.

However, it should be noted that Eurocontrol decided in 1999 to allow an alternative methodology to the cost recovery method for setting charges: with reference to **Section 5.5.2's** discussion on the planned economic regulation of the UK's National Air Traffic Services (NATS) once its Public-Private Partnership (PPP) process is complete later in 2001, each Eurocontrol nation may adopt the Retail Price Index (RPI-X) principle for setting fees. The RPI-X method has an inherent price cap regulation method for its fees, whereby the charges are capped on an annual basis according to an efficiency factor, X%, less general inflation. X is adjusted every five years based on projected costs and demand. The determination of X can be a subjective exercise because it incorporates issues such as service quality, values of the regulatory asset base and the cost of capital. In order to control the level of charges, the UK's Civil Aviation Authority (CAA), which will be the economic regulator of NATS when the PPP is complete, has

<sup>1027</sup> <http://www.eurocontrol.be/>

<sup>1028</sup> Data obtained from Eurocontrol.



proposed<sup>1029</sup> that the permitted maximum average charge per service unit in a particular year 't',  $MC_t$ , be limited by the formula:

$$MC_t = \left[ \frac{1 + RPI_t - X_t}{100} \right] SC_{t-1} + Y_t + S_{t-1} - K_t$$

The formula's variables have the following definitions or computations:

- $RPI_t$  is the percentage change in the Retail Price Index between the index determined in year 't-1' and that determined in year 't-2';
- $X_t$  is the aforementioned efficiency factor for year 't', noting that it would most likely remain constant for the first five years, as discussed above;
- $SC_{t-1}$  is an average charge per service unit in year t-1, which is calculated in accordance with the formula  $SC_{t-1} = SC_{t-2} \left[ 1 + \frac{RPI_{t-1} - X_{t-1}}{100} \right]$ ;
- $Y_t$  means the allowed cost per service unit in the particular year 't';
- $S_{t-1}$  is the service quality factor per service unit in the year 't-1', which may be subjective to determine;
- $K_t$  is the correction factor per service unit, which (other than in the first two years) is calculated in accordance with the formula  $K_t = \frac{TR_{t-2} - (Q_{t-2}MC_{t-2})}{Q_{t-2}} \left[ 1 + \frac{I_t}{100} \right]$ , noting that  $TR_{t-2}$  is the total Eurocontrol revenue in the year 't-2',  $Q_{t-2}$  is the quantity of service units supplied in the year 't-2' and  $I_t$  is an interest rate that is normal for past under-recovery and punitive for over-recovery.

It should be noted that the Eurocontrol Enlarged Committee for Route Charges has a Possible Pricing Mechanism (PPM) task force that is presently evaluating the possibility of changing the structure of en-route tariffs<sup>1030</sup>. The task force recommends that a two-part fee, with fixed and variable components, replace the existing formula (see **Section 6.2.3**). Two options have been proposed for the fee's variable component: use 50% of the existing national unit rates; -or, apply a distance-based rate<sup>1031</sup>. The task force believes that this structure would reflect the real cost of providing Air Navigation Services (ANS). Indeed, there is a certain irony that aircraft of lower weight may, in fact, require ANS for a longer period than heavier airplanes because the former usually fly at slower speeds. Accordingly, regional and smaller aircraft operators are particularly concerned about the PPM charging structure: the european regions airline association (era) believes that a new formula would cause the fees for its member

<sup>1029</sup> 'National Air Traffic Services public-private partnership: setting the charges for the first five years' – Economic Regulation Group, (UK) Civil Aviation Authority, December 1999.

<sup>1030</sup> 'eurocontrol enlarged committee for route charges' – era regional report, may 2000.

<sup>1031</sup> 'possible higher eurocontrol charges' – era regional report, august/september 2000.



airlines to rise considerably<sup>1032</sup>, claiming that they could pay an 83% increase in charges<sup>1033</sup>. The era says that the proposals are “a poor substitute for providing more capacity”<sup>1034</sup>. In addition, the PPM task force is analysing an environmentally beneficial pricing mechanism. A final report is due in June 2001 from the PPM task force<sup>1035</sup>. Other stakeholders from different worldwide regions should make note of these developments in Europe, remembering that it would be possible to link charges with the performance of CNS/ATM systems by using the contents of this framework strategy.

Eurocontrol’s Route Charges System billing procedure, which is non-discriminatory<sup>1036</sup>, is similar to the description in **Section 6.2.4** and consists of:

- *Data collection* – which is supplied by the States in the form of one message per flight, irrespective of the number of countries overflown, with the relevant nation of departure or arrival in Eurocontrol airspace being responsible for collecting and sending the information. The CRCO receives specific data about the flight within ten days of it having taken place;
- *Data verification* – messages are processed by the CRCO’s computer to check for errors in their format and discrepancies with CRCO computer files. Rejected messages are corrected within the CRCO or, if necessary, sent back to the national office for clarification;
- *Data validation* – the Eurocontrol Central Flow Management Unit (CFMU) provides the CRCO with the route description filed by the aircraft operator, based on the last filed flight plan, to compute the distances flown;
- *Billing* – every month, the following documents are issued to the operator:
  - The **bill**, with its date of payment being 30 days thereafter;
  - The **pro-forma statement**, containing a chronological account of the flight(s);
  - The **statement of account**, showing all movements of the operator’s account;
- *Collection of charges* – given their policy for rapid recovery of charges, Eurocontrol systematically recovers over 99% of en-route fees, at a typical cost to the user of less than 0.5% of total billed amount. The CRCO levies interest on late payments and it is able to take legal action against defaulting users. In fact, Eurocontrol has the power to impound aircraft<sup>1037</sup>;
- *Disbursement of charges income* – occurs every week to countries, including interest earned from short-term investment of funds and from late payments. The CRCO has the facility to pay third-parties on behalf of States;
- *Claims* – with under 2% of flights affected, each claim is investigated by the CRCO and, if accepted, involves a credit note being issued.

<sup>1032</sup> 'Eurocontrol still working on alternative charging scheme' – Air Transport Intelligence, 27 November 2000.

<sup>1033</sup> 'European regionals bemoan navigation fee proposal' – Air Transport World, November 2000.

<sup>1034</sup> 'Abandon changes to route charging formula, says era' – Air Navigation International, 29 June 2000.

<sup>1035</sup> 'ppm task force continues with simulations' – era regional report, march 2001.

<sup>1036</sup> 'Route charges are based on harmonized regional system applying common-costing principles' – ICAO Journal, April 2000.

<sup>1037</sup> 'Turkey pleads airlines' case as Eurocontrol loses patience' – Air Transport Intelligence, 27 November 2000.



### **Terminal navigation fees**

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In contrast with the 'Route Charges System' (RCS), which is applicable to the en-route fees, the CRCO also performs a terminal navigation service on a bilateral basis with nations. This service collects the charges imposed by airports for terminal navigation aid, as per the discussion in **Section 6.2.3**. Levied for each departing flight, terminal charges are based on flight messages used for the aforementioned RCS and computed according to the nation's individual formula structure and unique set of rules. The production of bills is fully integrated with the automated process of en-route fees described above, but accounts and recovery of charges are handled by a separate system. Bills are, however, dispatched at the same time as the en-route bills. Denmark, France (for billing only), Ireland and Italy are the only countries that presently use this system.



## 6.3 Worldwide benchmarking of ANS fee levels

This section contains a benchmarking and contrasting analysis of air navigation fees for 205 countries, split into the five worldwide regions mentioned in **Chapter 1**. Charges for Air Navigation Services (ANS) are computed separately for en-route services and terminal navigation facilities. Therefore, this evaluation enables airports, nations and/or their ANS provider(s) to apply suitable charging levels so that additional funding may be generated for upgrading infrastructure with CNS/ATM systems. Correspondingly, users benefit from this examination of charging levels because they may observe the relative ranking of countries' rates and can consequently choose to fly through different airspace regions if the potential savings are sufficient. Additionally, both examinations aim to highlight relevant aspects of the charging mechanisms, which are referred to in **Section 6.2.3**.

Results from this analysis show that a large variance exists in styles and magnitudes of formulae that are implemented around the world to recover air navigation service costs. Specifically, it may be seen that:

- Different distances travelled and aircraft weights can have significant effects on the progression of formulae;
- En-route navigation fees vary sizeably both between regions and among countries within regions;
- Terminal navigation charges also fluctuate considerably among countries and regions alike;
- Charging structures are dependent on a country's policy and whether the nation is a member of a collection agency;
- Correspondingly, rates are influenced by geographic location of a country and whether it lies in the path of the world's major traffic flows and city-pairs.

It should be noted that all financial results from this study of navigation charges use the US Dollar as the standard currency. Comparisons are consequently clearer.

### 6.3.1 En-route fees

With reference to the discussion on air navigation fees in **Section 6.2.3**, this section is split into three parts, containing:

1. An analysis of the effect of variables in formulae on charging levels;
2. A comparison of charging data for over 200 countries to provide the benchmarking comparison between the magnitude and types of rates applied throughout the world, which is an important source of data for users of this framework strategy;
3. Comparison of trends and values between regions.



## 1. Effect of the variables in formulae on charging levels

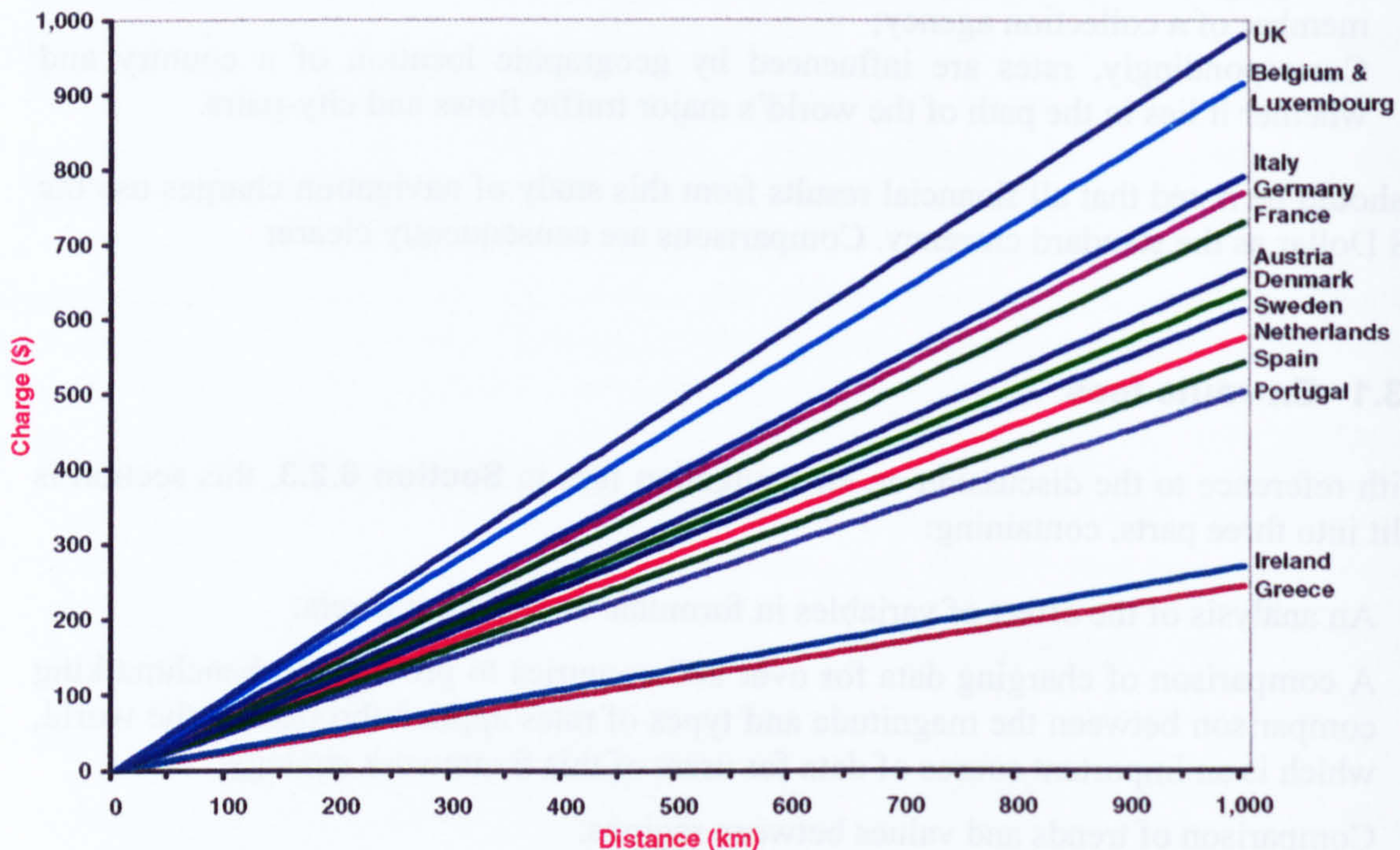
As mentioned in **Section 6.2.3**, four categories of en-route charges have been identified and different organisations employ specific formulae. The latter cover two of the main categories, namely:

- Distance and weight-based charges;
- Distance-based charges.

As is evident in **Appendix 6.1**, most fees use a formula structure of a *unit rate x some distance-weight coefficient*, with the consequence that many permutations of varying distance and weight factors exist. Aside from the cases where minimum and maximum values apply to the charging mechanism, aircraft operators can pay a range of amounts, depending on what aircraft type they are flying and the chosen specific routing, which determines the distance. Therefore, it is pertinent to demonstrate the effect of varying distances and weights on:

- The **Eurocontrol style of charge computation** because it incorporates the distance and weight, with the latter having its square root applied;
- The **ASECNA style of formula structure** because the distance-weight coefficient is derived from a table with values varying incrementally with changing distance and weight categories;
- The **Roberts FIR charge** because it is only dependent on the distance travelled by the aircraft in the respective Flight Information Regions (FIR).

### Eurocontrol formula



**Figure 6.2** – Effect of distance on the Eurocontrol formula for the Airbus A320-200



Noting that nations other than the Eurocontrol Member States apply the Eurocontrol formula and that the Eurocontrol formula is described with those for other en-route agencies in **Section 6.2.3**, **Figure 6.2** portrays the effect of varying the distance with a comparison from 0 to 1,000km travelled by an Airbus A320-200 for the various 1999 annual unit rates of European Union (EU) Member States. The ranking of countries is as follows, with the most expensive first: UK, Belgium and Luxembourg together, Italy, Germany, France, Austria, Denmark, Sweden, Netherlands, Spain, Portugal, Ireland and Greece. It should be noted that Portugal and Spain's unit rates were taken as their Continental FIR values to ensure that the data are comparable. This graph has the dual purpose of:

- Showing the rate of increase in the charges with greater distances travelled: the continuous progression of the formula structure is apparent, although it is not directly proportional to the distance variable;
- Comparing and contrasting the level of charges for Eurocontrol nations, noting that each country has specific reasons for applying different unit rates.

The unit rates applied by countries differ because of the:

- Inherent costs of operating their systems, in addition to other locally derived expenses such as social costs. As per **Section 6.2.1**, ICAO allows nations to set their own charges, stipulating that they reflect the costs incurred;
- Geographical location of a country, which has a direct bearing on its charging level because a dimensionally small nation will still need to cover the indirect costs associated with operating en-route navigational equipment and will therefore require a higher unit rate to compensate for the short distance aircraft fly through its airspace.

This should explain why Belgium and Luxembourg have the joint second highest unit rate, noting that Belgium provides en-route air navigational services on behalf of Luxembourg. Both are consequently classified together with the same unit rate. In contrast, Ireland is located at the bottom of the list because most of its en-route traffic is transiting the sizeable Shanwick Oceanic Flight Information Region (FIR) to traverse the North Atlantic region. Hence the unit rate is low because average distances travelled are higher than for other EU nations. If Ireland had more continental en-route traffic, then it may be pertinent to adopt a two-tier rate structure like that of Portugal and Spain.

**Figure 6.3** overleaf shows the effect of varying aircraft weight over a constant 100km distance, with an EU-wide comparison for all aircraft types from the ATR 42-200 at 15.8 tonnes to the Boeing 747-400 at 395 tonnes. The ranking of countries is as before, again noting that Portugal and Spain's unit rate were taken as the Continental FIR values. It is possible to observe that the Eurocontrol formula conforms with ICAO's recommendation that heavier aircraft are not penalised financially for en-route navigation in a direct proportion to their weight.



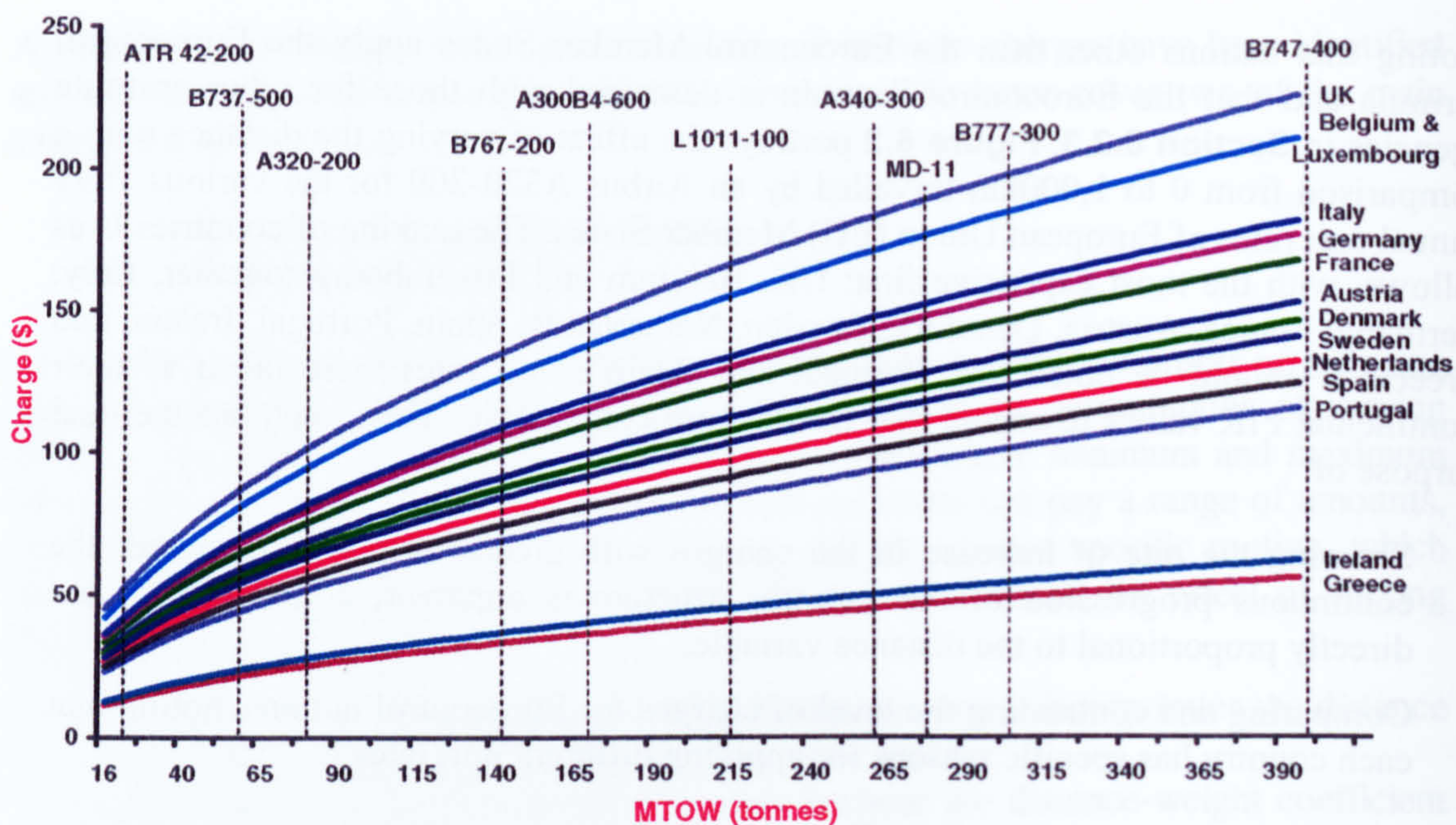


Figure 6.3 – Effect of aircraft weight on the Eurocontrol formula for 100km

### ASECNA formula

The ASECNA formula is described with those for other en-route agencies in **Section 6.2.3**. It is evident that, for aircraft with an MTOW of 4 to 14 tonnes, the ASECNA rate is uniform per flight, with a domestic and international differential; for aircraft with an MTOW greater than 14 tonnes, the style of formula (**charge = unit rate x coefficient**) portrays the effect of:

- A unit rate, which varies for domestic, international and regional flights. Note that the unit rates are the same for all nations subscribing to the ASECNA en-route agency;
- A tabular distance-weight coefficient where both factors are incrementally structured by two, independent categories.

**Figure 6.4** overleaf demonstrates the step-increase implications of such a two-tiered structure for 100km distance flown by aircraft on international bases. It is interesting to note that aircraft weighing 4 tonnes pay exactly the same to fly through 100km of airspace as aircraft of 270 tonnes. Correspondingly, **Figure 6.5** shows the implications of the structure for 1,000, 3,000 and 5,000 kilometre distances, again flown by aircraft on international bases. Given that the Boeing 747-400 is one of the heaviest civil aircraft flying at the moment, the last two weight categories are not usually required in commercial aviation calculations.



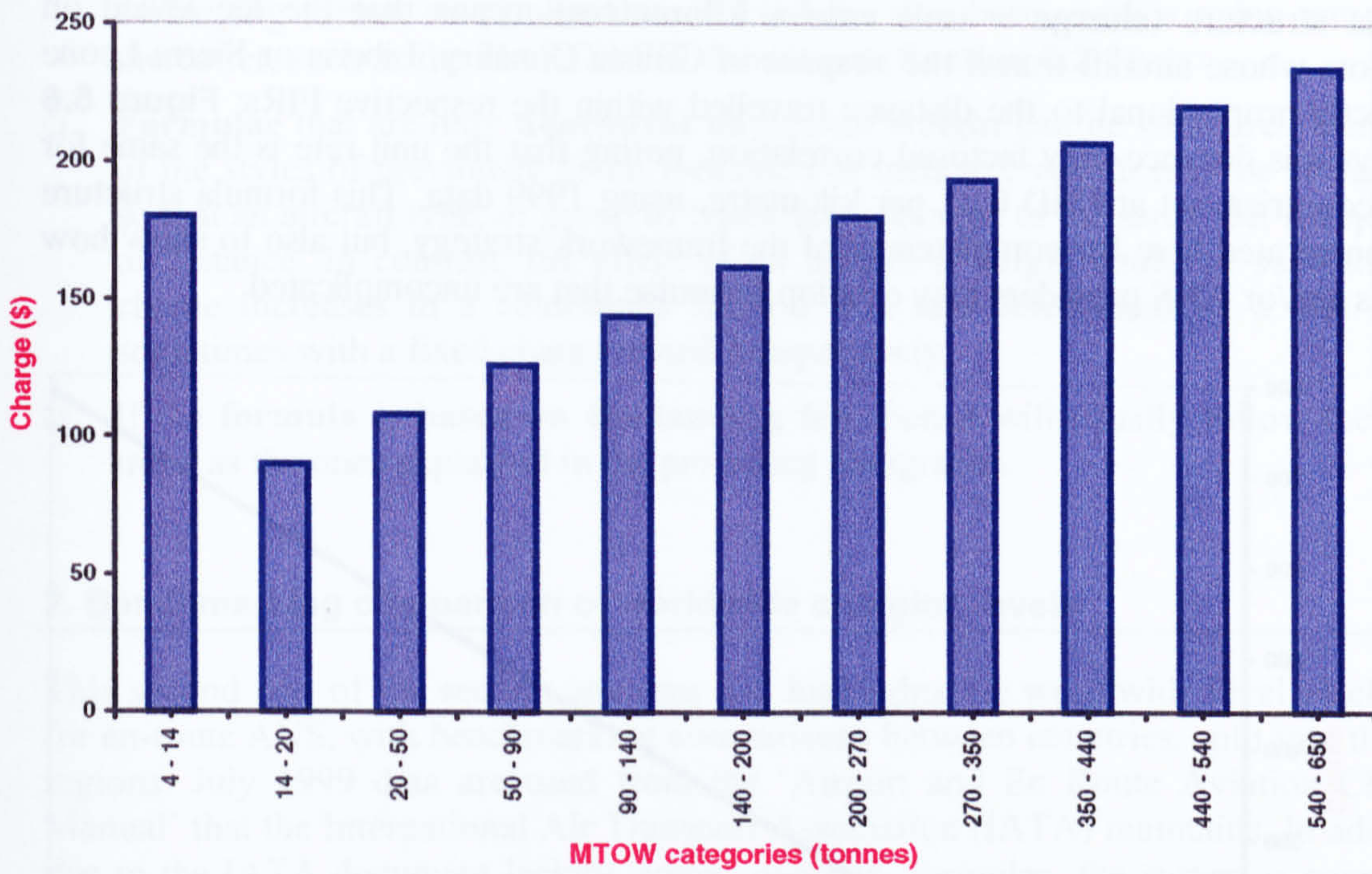


Figure 6.4 – Effect of aircraft weight on the ASECNA formula for 100km

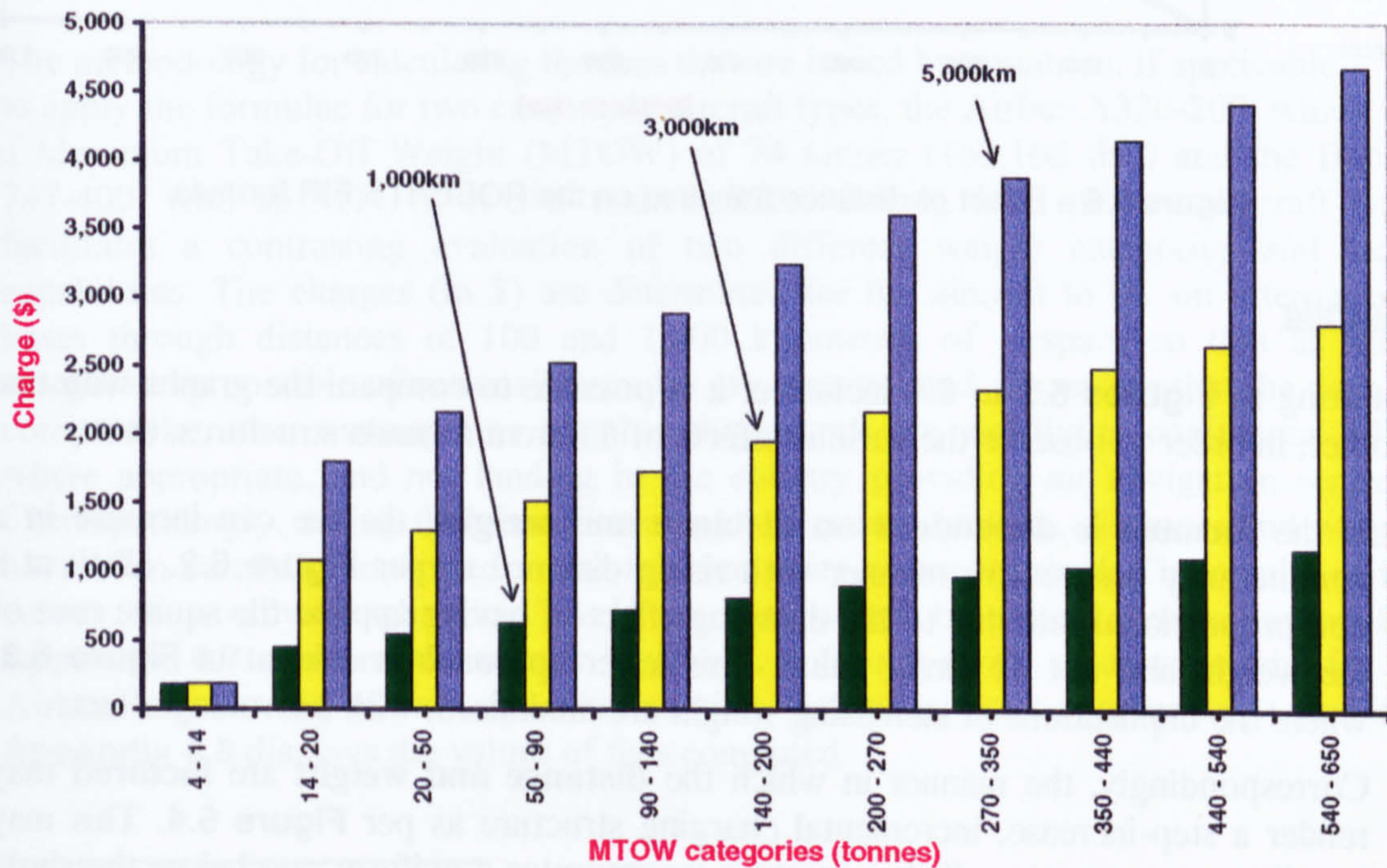
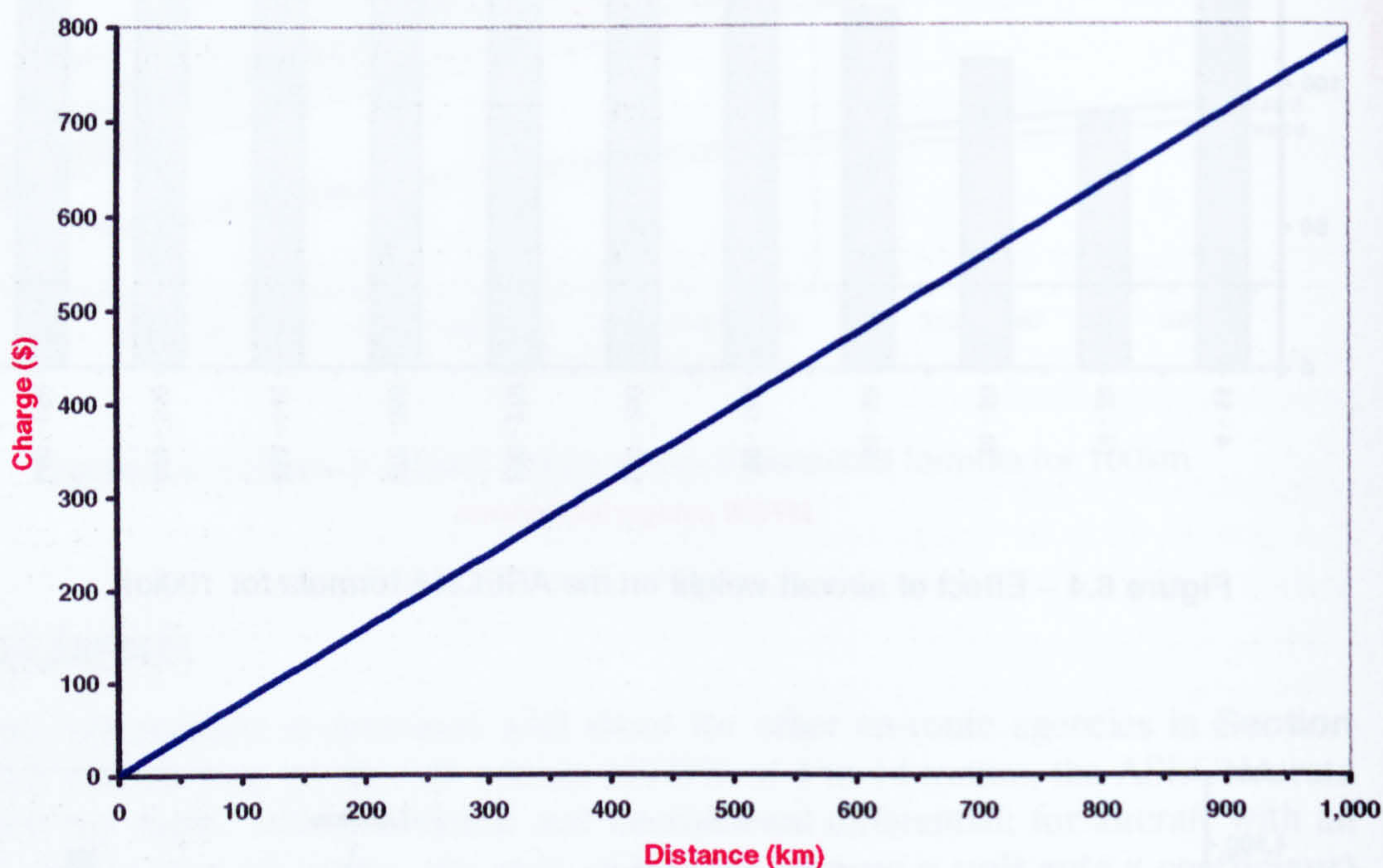


Figure 6.5 – Effect of aircraft weight on the ASECNA formula for 1,000, 3,000 and 5,000km



### Roberts FIR formula

**Section 6.2.3** also discusses the formula for the Roberts FIR. For aircraft weighing over 5 tonnes, and flying under either instrument or visual flight rules, the simple charging formula structure (**charge = unit rate x kilometres**) means that the fee levied on operators whose aircraft transit the airspace of Guinea Conakry, Liberia or Sierra Leone is directly proportional to the distance travelled within the respective FIRs: **Figure 6.6** portrays this distance-only factored correlation, noting that the unit rate is the same for the 3 countries, set at USD 0.81 per kilometre, using 1999 data. This formula structure is demonstrated here for completeness of the framework strategy, but also to show how nations and/or ANS providers may develop formulae that are uncomplicated.



**Figure 6.6** – Effect of distance travelled on the ROBERTS FIR formula

### Addenda

Referring to **Figures 6.2** to **6.6** inclusive, it is possible to compare the graphs with one another, in order to observe the various effects of different formula structures, thus:

- If the **formula is dependent on distance and weight**, the fee can increase in a continuously progressive manner with rising distance as per **Figure 6.2**, albeit at a non-proportional rate due to the damping effect of having applied the square root of the weight and not its direct value. This latter approach is evident in **Figure 6.3**, where the implications of increasing weight are minimised, with a levelling effect;
- Correspondingly, the manner in which the **distance and weight** are **factored** may render a step-increase, incremental charging structure as per **Figure 6.4**. This may penalise some operators if the structure incorporates a uniform rate below threshold weight. But, a multitude of distances must be considered, to demonstrate the full range of the formula's effect, as is given in **Figure 6.5**;



- If the **formula only has the distance travelled as a factor**, as in **Figure 6.6**, then the weight of the aircraft is superfluous and has no implication on the charging structure. In this case, the charge rises at the rate of a given value. Thus, it is this value that determines the relative increase per distance. It should be noted that such a charging format could also have a fixed fee as a basis, with a rising rate added thereafter, such as the PIARCO FIR format (see **Section 6.2.3**);
- **Formulae** that are only **dependent on aircraft weight** can be structured using any of the styles of previously given formats. For instance, weight may be categorised so that an aircraft type, or group of types, are subjected to the same fee, irrespective of distance. In contrast, the effect of an aircraft's weight could be such that the charge increases in a continuous fashion at a rate determined by a unit value, sometimes with a fixed charge levied irrespectively;
- If the **formula is based on the landing fee**, then it will usually follow the same trend as the ones explained in the preceding paragraphs.

## 2. Benchmarking comparison of worldwide charging levels

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This second part of the section analyses and highlights the worldwide level of charges for en-route ANS, with benchmarking comparisons between countries, split into the five regions. July 1999 data are used from the 'Airport and En Route Aviation Charges Manual' that the International Air Transport Association (IATA) maintains. In addition, due to the IATA document lacking some countries' formulae, the survey is completed and verified using the 1998 edition of ICAO's 'Manual of Airport and Air Navigation Facility Tariffs'<sup>1038</sup>. The raw data consists of charging formulae, rules and structures for countries, with unit rates given separately. Exchange rates for the 30<sup>th</sup> of June 1999 have been obtained and are listed in **Appendix 6.6**.

The methodology for calculating the fees that are levied by countries, if applicable<sup>1039</sup>, is to apply the formulae for two case study aircraft types, the Airbus A320-200, which has a Maximum Take-Off Weight (MTOW) of 74 tonnes (163,160 lbs.) and the Boeing 747-400, with an MTOW of 395 tonnes (870,000 lbs.). Use of these aircraft types facilitates a contrasting evaluation of two different weight categories and range capabilities. The charges (in \$) are determined for the aircraft to fly on international bases through distances of 100 and 1,000 kilometres of airspace so that as many categories as possible of nations' formulae are incorporated. To ensure that the data are comparable, other assumptions are that the aircraft are overflying continental FIRs, where appropriate, and not landing in the country providing air navigation services. Correspondingly, noting that formulae employ a variety of units, distances and weights have been carefully converted to the relevant units where required. The results of this survey of worldwide charging levels are categorised by region below, noting that **Appendix 6.7** contains the results in graphical format (with separate graphs for the Airbus and Boeing aircraft in a layout that facilitates cross-comparisons) and that **Appendix 6.8** displays the values of fees computed.

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<sup>1038</sup> ICAO Doc. 7100 (1998).

<sup>1039</sup> As discussed in Section 6.2.3, Appendix 6.1 incorporates those nations that have no ANS fees.



## **Africa**

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Appendix 6.7 shows the range of charges to fly an Airbus A320-200 and a Boeing 747-400 over distances of 100 and 1,000km in the African region. It is evident that Sudan's fees are considerably higher than the rest of their African counterparts: their structure is category-based and is dependent on weight and not on distance travelled. However, by comparing the two Sudan graphs, it may be observed that the rise in charge for the Boeing 747-400 over the Airbus A320-200 is not that significant. Thus, the structure is similar to a uniform rate.

The effects of implementing both distance and weight as bases of the formulae may be seen in the graphs, whereby most nations have lower charges for the A320 than the B747 in the individual distance categories. This applies to the ASECNA formula, with the following implications on the charging structure:

- It costs considerably less to fly 100km than 1,000km for both aircraft types;
- The magnitude of charges in both distance categories is higher for the B747, thereby portraying the effect of greater aircraft weight;
- The fee levels for this formula are only surpassed for the 1,000km category by Nigeria and Sudan for both aircraft types.

Some nations base their fees on weight and not on distance travelled: Burundi, Eritrea, Somalia, Tanzania and others are the same for both the 100 and 1,000km categories, with higher charging levels for the B747.

Correspondingly, the effect of the Roberts FIR formula in the graphs, which applies to Guinea Conakry, Liberia and Sierra Leone, should be noted: for the A320, the 1,000km category is more expensive than the ASECNA formula, but less expensive to travel 100km; and, for a B747, ASECNA has higher fees in both categories.

In addition, it may be added that five countries of the sample set do not levy charges and that a large variance in the magnitude of fees exists: for instance, Djibouti impose charges for the A320 that are 60 times less than Sudan's. Finally, it should be remembered that many African nations lower the level of charges if the aircraft lands in their country. Correspondingly, domestic flights also often receive rebates.

## **Americas & Caribbean**

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Appendix 6.7 also shows the level of charges to fly an Airbus A320-200 and a Boeing 747-400 over distances of 100 and 1,000km in the Americas & Caribbean region. It is evident that quite a large proportion of the region's nations do not levy fees for the provision of en-route air traffic services. This includes the US: however, it should be noted that the US FAA has charged operators of those aircraft not landing or taking-off in the US for crossing its airspace since August 2000<sup>1040</sup>. The rate is \$19.69 per 100km, irrespective of aircraft type, with a separate structure in the oceanic regions of \$10.90. It should be noted that most aircraft transiting US airspace either take-off or land in the

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<sup>1040</sup> 'FAA to charge for crossing US airspace' – *Flight International*, 13 June 2000.



country. Correspondingly, it should be added that Canada and Russia will levy fees for using the polar routes when they are permanently opened (see **Section 4.7**).

Those nations enforcing charging policies do so predominantly using both distance travelled by the aircraft and its weight as the bases of the formulae, which are mostly structured in a manner that progresses continuously: the effect is that charges for the B747 are nearly double for most countries.

It should be noted that 12 countries in the region, as listed in **Appendix 1.2**, are part of the PIARCO FIR, which bills and collects fees for the whole FIR and not for the individual nation. Hence, the graphs show these Eastern Caribbean States as one entry, the PIARCO FIR. This applies to their en-route traffic only and not their terminal air navigation services. Correspondingly, the six nations subscribing to the COCESNA en-route agency have the same charges, noting that their formula structure clearly differentiates between both distance and weight, with fees disproportionately higher for the B747.

Cuba, the Dominican Republic, Haiti, Surinam and Uruguay all base the rates on weight, irrespective of distance travelled. With the exception of Uruguay, the rate differs for the two aircraft types in this analysis: Uruguay has a category-based structure, which does not vary for aircraft over 70 tonnes in weight.

Given its geographical location and its rôle in transatlantic traffic, Greenland imposes a uniform charge, which equates to \$47.93 per flight. The authorities maintain that the same amount of work is necessary for all IFR flights, irrespective of aircraft size. There is a large variance in the magnitude of Greenland's fees and the higher ones such as Brazil's: this Latin American country's charges increase directly with distance travelled and indirectly with weight. A B747 pays \$1,264.81 per 1,000km, which is much more than the Greenland rate.

It is interesting to note the regional effect on charges: South American countries tend to have higher charges than their Central American counterparts, who in turn are higher than those Caribbean nations imposing fees. Finally, it should be added that many nations in this category lower their charges if the aircraft lands in their country and/or if the flight is domestic. Mexico is the most obvious exception to the rule.

### ***Asia & Pacific***

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Accordingly, **Appendix 6.7** portrays the fees for flying Airbus A320-200 and Boeing 747-400 aircraft distances of 100 and 1,000km in the Asia & Pacific region. With the most notable exception of the People's Republic of China, other nations base their charges on both the distance travelled and the weight of the aircraft. China differentiates between the distances travelled, but not aircraft weight. The fact that many aircraft transit Chinese airspace travelling between Asia and Europe may be the reason that China relates the charge directly proportional to distance: a B747 pays the equivalent of \$100 to fly through 100km of airspace, and \$1,000 for 1,000km.



In contrast, a relatively high number of countries in the Asia & Pacific region do not differentiate between distances: however, their rates are higher for the B747 than for the A320. Some of these nations that do not take the distance travelled into account actually have a uniform charge. The effect is similar, though, to those countries adopting category and continuously structured formulae.

It is evident that only a few nations in this region do not levy fees for the provision of en-route air traffic services. It should be noted, however, that Japan introduced a fee at the beginning of 2000. It should also be added that Australia's new automated air traffic system (see **Chapter 4**) and a restructuring of its business have enabled the provider, Airservices Australia, to reduce en-route charges in 2001 by 6%<sup>1041</sup>.

Many countries in the region lower their en-route charges if an aircraft lands in the nation. However, fees are increased in the Philippines, the Republic of Korea and Vietnam if landing occurs. Additionally, few nations differentiate between domestic and international flights. Correspondingly, although no en-route agency operates in the region, numerous nations have similar charges, in particular for the Boeing 747-400.

## **Europe**

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**Appendix 6.7** shows the level of charges to fly an Airbus A320-200 and a Boeing 747-400 over distances of 100 and 1,000km in Europe. It is immediately evident that:

- All nations in this sample set levy fees for the provision of en-route air traffic services;
- With the exception of Albania and Iceland, European countries' charging structures are all based on distance travelled in the respective FIRs and aircraft weight;
- Most countries implement a progressively continuous formula, which is usually the Eurocontrol standard method (see **Section 6.2.3**), with the consequent effect that charges are proportional to distance travelled and indirectly variable with weight.

It should be noted that Belgium and Luxembourg have the same unit rate: indeed, they act as the same en-route authority, with Belgium performing en-route navigation services for its neighbour. It should also be added that, due to its geographical location and its rôle in controlling transatlantic traffic, Iceland imposes a uniform charge, which equates to \$47.93 per flight, the same rate as Greenland in the Americas & Caribbean region. Again, the authorities maintain that the same amount of work is necessary for all IFR flights, irrespective of aircraft size.

There is a large range in the magnitude of fees, with the UK levying the highest rate at \$2,338.05 for a B747 to fly 1,000km. At the other end of the variable formula scale, a B747 pays \$540.00 per 1,000km to fly over Armenia, which is considerably more than the Iceland rate. Of course, it is not possible to fly 1,000km over Armenia and some other nations, but these figures are employed for demonstrative purposes and to incorporate the effect of different charge structures. Accordingly, it should be noted that

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<sup>1041</sup> 'Airservices Australia cuts en route ATC charges' – *Air Transport Intelligence*, 5 December 2000.



most nations in this region lower their charges if the aircraft lands in their country, but do not specify their policy if the flight is domestic.

### **Middle East**

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**Appendix 6.7** finally shows the charging levels for flying Airbus A320-200 and Boeing 747-400 distances of 100 and 1,000km in the Middle Eastern region. Other than Kuwait and Lebanon, who impose no fees, nations vary their charges for the two aircraft types, indicating that the formulae are weight based. It is also possible to observe that the formulae adopted by Iran, Saudi Arabia and Turkey incorporate a distance element.

No uniform charges are implemented in this region, with the formulae being both stepped and continuously structured. Correspondingly, half of the countries lower their en-route charges if the aircraft is landing in the country, whilst only one nation lowers the fee for domestic flights. In addition, it should be noted that no en-route agency operates in the region and that no two countries have the same fees. Iran and Turkey change positions as the region's most expensive countries to fly over, with Turkey charging \$552.71 for an A320 to fly 1,000km through its airspace and Iran levying \$1,603.70 for a B747 also to fly 1,000km. At the other end of the scale, the Republic of Yemen charges \$11.55 and \$92.08 for the respective scenarios.

### **3. Comparison of trends and values between regions**

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This analysis of worldwide en-route air navigation fees calculates and details the level of charges imposed for the provision of en-route air traffic services based on the style, method and structure of formulae described in **Section 6.2.3**.

The first part of this section examines the effect of variables in established formulae on charging levels and discovers that the structure's trend is heavily dependent on the variables employed and the style of formula, whether category-based, continuously or uniform. With reference to **Figures 6.2 to 6.6** inclusive, it may be observed that values between countries vary substantially (**Figures 6.2 and 6.3**), but that the financial implications of different formulae can be similar: **Figures 6.2 and 6.5** show that the cost of flying an Airbus A320-200 through 1,000 kms of airspace is practically the same for the average EU State and the ASCENA countries. This also applies to **Figures 6.2 and 6.6**.

Accordingly, these findings must be remembered when analysing results of the section's second part, the benchmarking comparison of worldwide charging levels. Many permutations and combinations of formula styling or structure are employed throughout the world, which can have significant implications when comparing the fees. With reference to the graphs in **Appendix 6.7, Figure 6.7** overleaf details the various regional averages, which do not include the effects of nations that impose no fees.



Region	Airbus A320-200 (\$)		Boeing 747-400 (\$)	
	100km	1,000km	100km	1,000km
Africa	139.45	435.89	225.36	724.39
Americas & Caribbean	52.84	202.51	87.77	415.66
Asia & Pacific	123.81	287.66	198.48	468.43
Europe	61.47	583.72	133.47	1,303.69
Middle East	68.83	162.99	276.80	584.48

**Figure 6.7 – Regional average en-route fees (currency: \$)**

There is a large range in each category, with only Europe being the most expensive in more than one category, thus:

- For the A320-200, Africa has the highest average rate per 100km, while Europe has the largest per 1,000km;
- For the B747-400, the Middle East has the highest average fee per 100km and Europe per 1,000km by a large margin.

These results indicate that Europe is the most expensive region for aircraft to transit, with the highest actual charge of \$2,338.05 per 1,000km for the B747 over the United Kingdom. However, this may be due to the inherent reality in Europe that the average distance flown by aircraft over nations is well below 1,000km: the Eurocontrol formula reflects this and imposes an average charge of \$133.47 per 100km in comparison with, for example, the Middle Eastern equivalent of \$276.80.

With reference to the contents of **Appendix 6.9**, it is interesting to note that, based on an additional analysis of the survey data (which relates to 1998/1999), many nations had not changed the rates or structures of their charges since the early 1990s, while some had made no alterations since the 1980s. There is an even spread of dates among the regions, with the exception of Europe because the Eurocontrol formula is reapplied annually. This information should be useful to a nation and/or provider when assessing whether their formulae should be updated, if applicable. Additionally, financiers and equipment manufacturers could use these facts to target a nation and/or provider that has not changed its formulae for quite some time, based on the logic that increased rates should bring more revenue, which could be used to offset costs associated with implementing new CNS/ATM systems, thereby expediting the introduction of future air navigation systems (see **Section 6.4.1**).

The following points, some of which are general in nature, should be noted regarding this analysis of en-route charges:

- It was not possible to get the charging structure for Bermuda, Israel, Marshall Islands or Nauru;
- Qatar's policy states that charges may be levied by an approved agency of the government, but does not stipulate any;
- Some countries are part of other nations' Flights Information Regions (FIR) and are therefore not listed separately: Réunion is part of Madagascar FIR; New Caledonia



and Tonga are part of the Fiji FIR. This ties in with **Section 5.4.2**'s discussion on international co-operation;

- It is often the case that countries do not actually measure 1,000km at their widest point, so the 1,000km category may not truly reflect their charging structure. This is one of the reasons for including the 100km category;
- Correspondingly, rates are influenced by a nation's geographic location and whether it lies in the path of the world's major traffic flows and city-pairs;
- Although the benchmarking results are based on flights over continental FIRs, some countries such as Brazil, Canada, New Zealand, Portugal, Spain and the UK have different oceanic fees. In addition, it should be noted that the UK has introduced a 'North Atlantic RVSM fee', which is collected on behalf of ICAO, to recover the cost of the Reduced Vertical Separation Minima (RVSM) programme;
- Some nations implement a separate communication charging structure, which can be a unit rate or vary with the aircraft weight and/or whether it is a domestic flight;
- A few countries impose a separate meteorological charge.

Ultimately, this survey of en-route air navigation fee levels around the world and the analysis of charges in **Section 6.2.3** are important aspects of this thesis' framework strategy. When considered in conjunction with the evaluation of terminal navaid charges in the next section, the results provide many stakeholders with useful information that should improve the implementation of future air navigation systems.

### 6.3.2 Terminal navigation charges

As cited in **Section 6.2.3**, other than for en-route air traffic services, navigation charges consist of terminal navigation fees to cover the provision of Air Navigation Services (ANS) and use of facilities in airspace surrounding an airport and on approach to the aerodrome. Similar to and in tandem with the analysis of en-route air navigation fees in **Section 6.3.1**, this section provides and discusses the results from a benchmarking evaluation of terminal navigation charges that is conducted as part of generating this dissertation's framework strategy for improved implementation of CNS/ATM systems. Different stakeholders should benefit from the information that is given in this section, whether airport authorities, financiers, nations regulators or users.

The terminal charge may be incorporated in the landing fee, levied separately as an independent fee or sometimes part of the en-route charge's landing differential. Noting that the landing fee normally covers use of the landing/take-off facilities and services, in addition to the provision of fire services, meteorological advice and runway lighting, the terminal navigation fee is consequently a large component of the landing charge. Additionally, given that the terminal navigation fee is still levied as part of the landing fee at many airports and that, anyhow, it is usually not possible to obtain the navigation element of landing charges in such cases, this thesis considers that landing fees are indicative of terminal navigation charges. Indeed, this approach ensures that comparisons of fees are based on similar constituents, noting that terminal navigation charges should be added to landing fees where the two are separate.



Therefore, this section benchmarks landing charges to provide an indication of how terminal navigation fees vary among the worldwide regions. The methodology adopted is similar to that in **Section 6.3.1**, based on an examination of the following case study aircraft types: the McDonnell Douglas MD-80, which is similar in size to the Airbus A320-200, with a Maximum Take-Off Weight (MTOW) of 64 tonnes (140,000 lbs.); and the Boeing 747-400 aircraft, with an MTOW as in the previous section of 395 tonnes (870,000 lbs.). It is assumed that both are engaged in daytime, scheduled, international operations. Although mainly based on an assessment by ICAO in their 'Manual of Airport and Air Navigation Facility Tariffs'<sup>1042</sup>, this analysis is completed using IATA information for 1998 from their 'Airport and En Route Aviation Charges Manual'. In their comparison, ICAO based countries' billing currency to \$ exchange rates on May 1998 values that were obtained from the July 1998 issue of 'International Financial Statistics', which is published by the International Monetary Fund.

The task of covering every airport for all 205 countries in this research's worldwide analysis is beyond the scope of this study and would, indeed, not provide much additional value to the framework strategy. Accordingly, it should be noted that nations usually adopt the same strategy for structuring their terminal navigation charges for all airports. Therefore, this exercise considers one airport per nation, which is either the main international gateway or one that is specifically referred to. Indeed, this approach is considered to give a fair indication of nations' policies.

Correspondingly, **Appendix 6.10** portrays the significant degree to which landing fees vary throughout the world, split into the five regions, with copies of results in graphical format. **Appendix 6.11** contains the values for these graphs and also details relevant notes, which ensure that this comparison is consistent. In order to assess the trends and average values between the regions, it should be noted that there is a large range in the values for each region, particularly for the Boeing 747, thus:

- Aside from a nominal rate for Angola, **Africa** ranges from \$449 in Lesotho to \$5,411 in Guinea Conakry;
- Surinam only charges \$17 in the **Americas & Caribbean** region, whereas Martinique levies \$5,319;
- In the **Asia & Pacific** region, Malaysia has a \$1,085 fee, in contrast with Japan's \$6,811 at Tokyo's Narita;
- **Europe** ranges from a \$664 charge in Greece to a \$10,514 at Frankfurt in Germany;
- Kuwait has a \$501 fee in the **Middle East**, which compares with Iran's \$4,341.

The graphs indicate that the rates and magnitude of their variance for the B747 are much greater than for the A320. However, it should be remembered that many of the airports surveyed might not actually frequently handle the B747. Indeed, some are not capable of receiving this aircraft at all. Hence, their charging structures may reflect this and may consequently distort the results. Additionally, there are significant variations

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<sup>1042</sup> ICAO Doc. 7100 (1998).



among regions: this may be observed from the figures reproduced above and from **Figure 6.8**, thus:

Region	MD-80 (\$)	B747-400 (\$)
Africa	318.69	2,404.28
Americas & Caribbean	259.58	1,486.12
Asia & Pacific	491.50	2,920.91
Europe	746.82	4,160.80
Middle East	302.14	1,806.07

**Figure 6.8** – Regional average landing fees (currency: \$)

Therefore, landing fees vary considerably around the world. By the aforementioned rationale that the magnitude of terminal navigation charges is proportional to the size of landing fees, it is possible to conclude that terminal navigation charges differ drastically. Thus, this supports the logic that there is scope to increase rates in some nations, which should bring more revenue that could be used to offset costs associated with implementing new CNS/ATM systems, thereby expediting the introduction of future air navigation systems (see **Section 6.4.1**). Therefore, this framework strategy suggests that different types of stakeholder employ the information provided in this section and in **Section 6.3.1** to assess the situation in their particular nation or region. The solution to their particular problem may only be slightly alleviated by increasing fees, so there is a need to evaluate other funding mechanisms that exist, which is conducted in **Section 6.4**.



## 6.4 Funding methods

Virtually all CNS/ATM projects require financing, whether government run or part of the private sector. Adequate financing can be a stumbling block for many CNS/ATM projects. However, noting that the actions cited in **Section 5.2's** framework guidelines on integration management suggest that stakeholders evaluate various funding sources, this section suggests and discusses the following alternative methods<sup>1043</sup> for funding CNS/ATM projects:

- User charges;
- Debt financing;
- Government contributions;
- Equity financing;
- Joint financing arrangements;
- Leasing.

The choice of optimum financing source is dependent on many factors relating to an individual project's circumstances, which may vary from its budget to the specific type of CNS/ATM system being introduced or the country where it is being implemented. Therefore, there is no definitive funding method that this framework can recommend to cover all situations. However, it is possible to make suggestions that stakeholders should adopt, which relate to all types of funding. The recommendations complement the guidelines on integration management and project appraisal techniques given in **Chapter 5**. Thus, prior to evaluating different types of funding mechanisms that may be applied to CNS/ATM projects, which are covered in separate sections hereunder, all relevant stakeholders should consider the following points:

- The increasing trend towards commercialisation of Air Navigation Service (ANS) providers means that the policies of private investors are involved. Financing of service provider infrastructure is consequently subject to new requirements. Thus, there is a need for providers to adopt effective cost and revenue accounting systems, which could be based on International Accounting Standards (IAS<sup>1044</sup>) and/or US General Accepted Accounting Principles (US GAAP). This should enhance the opportunity for providers to exploit international capital markets due to facilitating better comparability of their accounts with companies from other industries. Indeed, at the ICAO ANS Conference 2000, there was broad support for countries to apply internationally accepted accounting standards<sup>1045</sup>;

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<sup>1043</sup> It should be noted that it is possible to apply more than one financing mechanism simultaneously for funding a CNS/ATM system.

<sup>1044</sup> The IAS method has evolved since the mid-1990s to become a comprehensive code of practice that is being encouraged in national State accounting standards of many countries. IASs are gradually approximating the US GAAP requirements.

<sup>1045</sup> 'Report on introduction and agenda items 1-6' – Working Paper 115, ICAO Air Navigation Services Conference 2000.



- In relation to the requirement for improved accounting methods, stakeholders should identify and allocate costs for their product, which, for instance, may be CNS/ATM equipment that they manufacture or ANS service(s) that they provide (see **Section 6.2.2**). Regarding cost allocation, the fact that satellite systems usually have non-aviation users (see **Section 6.2.2**) should be incorporated. Additionally, there is a need to ensure that the value placed on assets reflects market values and that depreciation rates are set accordingly. The availability of accurate and transparent cost data is important when drafting financial plans because prospective financiers will want to see that systems or services are cost-effective (see **Chapter 7**). With respect to financial plans, it should be noted that **Section 5.3** demonstrates how to generate a business case using financial evaluations and economic cost-benefit analysis. In summary, financial plans should include details and estimates of projected costs, revenues and funds required, based on past cost information and traffic predictions;
- Thus, in order that costs may be identified and allocated, there is a need to compute expenses, as described in **Section 5.3**. Given the sheer number of permutations and combinations of costs that exist regarding manufacturing of CNS/ATM systems or provision of ANS services, it is very much beyond the scope of this thesis to cite such expenses. It is for this reason that guidelines are given on how stakeholders should identify and allocate their costs. Nonetheless, with respect to requests for funding, it should be noted that CNS/ATM systems and the provision of ANS often require very large investments, which are usually long-term. For instance, the ICAO FANS Committee predicted that the total cost of FANS would be \$1 billion annually after an initial investment of \$2.6 billion, with a return of \$5 billion per annum once CNS/ATM systems are implemented globally. These figures compare with the projected development costs this decade for the Airbus A380 of \$8 billion and the Boeing 747X of \$5 billion. Another comparison is the projected investment requirement of the UK's National Air Traffic Services (NATS) for this decade, which has been estimated at \$1.8 billion<sup>1046</sup>, with the cost of 12 Boeing 747-400s at \$150 million each. Therefore, the true levels of funding in CNS/ATM systems can be appreciated;
- Correspondingly, management of CNS/ATM manufacturers and ANS providers should strive to maintain low cost bases, which prove beneficial when requesting funding, in addition to preparing the CNS/ATM market for the adverse impact of an economic recession. Thus, they should be aware of the wide range of issues that affect present and future costs, as discussed in **Section 5.3**. Ultimately, management should realise that many factors have implications on their cost base: for instance, airline economics in terms of carriers' propensity to fly jet aircraft rather than turbo-prop, which is affected by price of purchasing or leasing aircraft and fuel costs (see **Appendix 5.6**), has a direct impact on CNS/ATM equipment manufacturing and ANS provision markets; also, the number of movements affects their revenues, which may be enhanced by the presence of low cost carriers and other airlines that wish to maximise aircraft utilisation; accordingly, airport costs determines the

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<sup>1046</sup> 'National Air Traffic Services Public Private Partnership: setting the charge control for en-route services in UK airspace for the first five years'– Economic Regulation Group, (UK) Civil Aviation Authority, April 2000.



tendency for operators to use certain aerodromes, which consequently has an effect on air navigation providers;

- Thus, in addition to reducing costs, revenues should be maximised, which may be addressed through manipulation of user charges (see **Section 6.4.1** hereunder) and employment of beneficial currency techniques. The latter includes policy decisions regarding what currency to levy charges, which are based on conditions that are specific to each nation, such as foreign exchange rates and their propensity to change over time. **Appendix 6.5** lists countries' billing currencies and it is evident that many do not use their domestic currency. Accordingly, those seeking finance should decide on the desired denomination of a loan, if applicable, remembering that many costs associated with the CNS/ATM project would undoubtedly be in both domestic and international currencies.

Given that these suggestions instil good practice in organisations and that they would be required for most forms of funding, it is advisable that nations, providers or financiers apply the aforementioned recommendations as soon as possible. Indeed, they should be conducted in conjunction with the actions cited in **Section 5.2's** framework guidelines on integration management, which include continuous consultation among stakeholders.

#### **6.4.1 User charges**

The analysis of air navigation charging systems in **Section 6.2** and the benchmarking exercise of fees around the world in **Section 6.3** provide a comprehensive background to many aspects of air navigation charges. All stakeholders can use the evaluations in these sections for many purposes relating to the introduction of CNS/ATM systems. In the sections, references are made to the ability and potential of user charges to cover costs associated with CNS/ATM systems. This section draws on the references and other information to promote air navigation charges as this framework strategy's primary source of funding for CNS/ATM technologies and procedures.

With respect to **Section 6.2**, ICAO recommendations on the cost basis of air navigation charges are that "revenues may exceed all direct and indirect operating costs so as to provide for a reasonable return on assets to contribute towards necessary capital improvements". Capital improvements may be manifested as investments in expanded or new facilities and services. Thus, navigation charges should, in theory, be able to cover expenses associated with implementation of CNS/ATM systems. Accordingly, **Section 6.3** discovers that a large variation exists in unit en-route and terminal fees for the provision of Air Navigation Services (ANS) around the world. Thus, assuming that their facilities and services are of sufficient standard (see **Chapter 7**), many nations should have scope to increase their rates. However, if their services do not conform to international expectations, it should be remembered that the main objective of CNS/ATM systems is to improve performance aspects of ANS. By that rationale, integration of CNS/ATM should bring nations' systems to acceptable quality levels, which consequently warrant greater fees in line with the regional average.



Funding through user charges is a form of internal self-financing using retained earnings. Noting that ICAO guidelines discourage excessive saving of user charges to accumulate a development fund for future projects, it is possible to supplement income through provision of ancillary services, such as advisory or consultancy practices. In a similar manner, airlines may obtain satisfactory returns on their investments in CNS/ATM technology by enabling their system to support, for instance, air-ground passenger communications (noting that, by definition, the other funding mechanisms in subsequent sections are more applicable to users). Ultimately, it should be possible for providers and other non-user stakeholders to implement CNS/ATM projects that are financially viable through user and ancillary revenues. This statement may be justified by the following results from an evaluation of net REVEX ratios<sup>1047</sup> for commercialised ANS providers that have been calculated for the purposes of this framework using data in their financial accounts' Profit and Loss Statements, which were obtained from the Civil Air Navigation Services Organisation (CANSO):

Country	ANS Provider	Financial Year End	REVEX (%)
South Africa	ATNS	31-Mar-98	114.8
Latvia	LGS	31-Dec-97	114.3
Ireland	IAA	31-Dec-98	105.5
Switzerland	Swisscontrol	31-Dec-97	103.5
UK	NATS	31-Mar-98	102.8
Thailand	Aerothai	30-Sep-97	101.4
Germany	DFS	31-Dec-98	100.9
Canada	Nav Canada	31-Aug-98	100.7
New Zealand	Airways Corporation	30-Jun-98	98.7
Austria	Austrocontrol	31-Dec-97	97.3
Spain	AENA	31-Dec-98	97.2
Australia	Airservices Australia	30-Jun-98	94.9

It is evident that, with the exception of Australia, Austria, New Zealand and Spain, each nation's provider made an overall profit for their respective financial year, the latest year for which data were available. It is important to note that the four providers, which did not produce an overall profit, did record operating profits. Burdens due to extraordinary debts reduced their overall net REVEX ratios.

Therefore, remembering that many countries' navigation charges are well below their regional averages (as per the survey of 205 countries in Section 6.3), it would appear that these nations already have access to funding for CNS/ATM projects if their provider is commercialised. However, caution is required to ensure that the other ICAO recommendations are adhered to. For example, it is not equitable to drastically increase fees so that the cost of a CNS/ATM technology is offset within a year. Accordingly, it should be noted that those nations with high average charges would find a lot of aversion to any increases in their fees. Indeed, their national economic regulator would

<sup>1047</sup> The net REVEX ratio is the proportion of total net revenue to total net expenditure in % terms. Thus, if a provider has a ratio greater than 100, it achieved a profit. Use of the ratio removes the need to convert currencies and consequently enhances accuracy.



probably disallow such moves and operators might choose to fly through other airspace regions. Correspondingly, another ICAO recommendation stipulates that charges should not be levied for any facilities or services before they become operational, which means that nations and/or providers should raise funds through other methods to cover the implementation stages of a CNS/ATM project (see the methods in subsequent sections). Naturally, these funds could then become part of the system's cost base once it is operational, resulting in eventual coverage by user charges.

The International Air Transport Association (IATA) is obviously of the opinion that major capital investments, such as Air Traffic Control (ATC) centres, should not be funded from current income charges<sup>1048</sup>. Their rationale for this view is that: airlines may no longer exist or fly in the area where the project is based when it becomes operational; large projects may ultimately be cancelled or delayed; and passengers would refuse to accept increases in their ticket charges for investments that do not presently realise benefits. However, IATA believes that both fixed and variable costs may be added to the cost-base of a provider once benefits are being reaped<sup>1049</sup>. It would appear, therefore, that the airlines are willing to fund those CNS/ATM systems that will bring benefits to operators in the near future through payment of user charges and implementation of required avionics. With respect to their adoption of airborne technology, it should be added that airlines usually demand a return on investment within 2 years. Having had poor experiences in the past, carriers are inherently reluctant to invest in technology until there is a clear, quantifiable payback. Thus, there is a need for all other stakeholders to ensure that their CNS/ATM project has transitional periods that are as short as possible and that are driven by benefits. This may be achieved through iterative implementations, with incremental improvements, which are suggested in the integration management guidelines in **Section 5.2**.

Hence, the philosophy that user charges may cover CNS/ATM system-related expenses is acceptable to providers, regulators and users alike, albeit subject to some juggling of finances. Thus, noting that all CNS/ATM projects ultimately play some rôle in the provision of ANS, this framework strategy recommends that all stakeholders requiring finance for their project liaise in partnership with other stakeholders, where possible, to ensure that a revenue stream is established from the end user through the provider to the manufacturer, thereby acting as an innovative method of financing the implementation of future air navigation systems. Financial management must be adopted, so that loans and other forms of funding (as described in the different sections hereunder) bridge the cash flow requirements of the project in its early stages and maybe over longer periods. This also satisfies regulatory concerns. Additionally, assessments must be conducted to ensure that projected operating revenues will comprehensively cover forecasted operating costs because forms of subsidised funding may be required if the charging methodology does not generate sufficient financing to cover the CNS/ATM project's requirements. If this situation were to arise, which may be due, for instance, to the geographic location of the provider only accommodating low traffic levels, the nation, provider and/or financier would have to ensure that all other co-operation options and

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<sup>1048</sup> 'Forward financing' – Working Paper 31, ICAO Air Navigation Services Conference 2000.

<sup>1049</sup> 'User charges aspects of CNS/ATM' – Working Paper 25, ICAO Air Navigation Services Conference 2000.



ancillary revenue opportunities had been exhausted, in addition to ascertaining that the CNS/ATM implementation is essential from an economic perspective (in line with the economic appraisal techniques in **Section 5.3**, which include safety considerations).

Therefore, it is imperative that nations and/or providers identify all expenses<sup>1050</sup> so that the chance of cost recovery, which is the fundamental basis of this funding method, is maximised. Costs should also be allocated correctly, accommodating all facts, such as satellite systems usually having non-aviation users (see **Section 6.2.2**). Additionally, there is a need to ensure that the value placed on assets reflects market values and that depreciation rates are set accordingly. It is for such reasons that accounting systems should be based on international standards. Users' expectations that ANS should be more cost-effective in the long run through the introduction of CNS/ATM, with consequent reductions in fees, must also be accommodated. In short, it is an acquired art to align user concerns with national and/or provider interests. Accordingly, costs should be minimised, where possible, using actions such as international co-operation, which is discussed in **Section 5.4.2**. International agencies have the added benefit of increasing chances of fee retrieval, which is another prerequisite for this cost recovery method working properly. However, nations should be careful because some approaches to outsourcing services may reduce revenues.

Nonetheless, this framework suggests that nations and/or commercialised air navigation service providers with proper cost recovery mechanisms and suitable international co-operation ventures (see **Section 5.4** and **Section 6.4.5**) should have minimal problems financing CNS/ATM implementation through user charges, noting that an additional financing method is usually required for cash flow purposes in the early stages of the project, which should expedite the introduction of future air navigation systems.

### 6.4.2 Debt financing

With reference to **Section 6.4.1**'s discussion on financing CNS/ATM systems by all non-user stakeholders through air navigation charges, other forms of funding are usually required for cash flow purposes, due to an ICAO recommendation that discourages excessive saving of air navigation fees to accumulate a development fund for future projects. Indeed, many costs associated with implementation of CNS/ATM systems are frequently incurred in the development and integration stages. Thus, substantial sums may be required. Accordingly, noting that users are not subject to the same, stringent financing rules that apply to nations and their providers, airlines and general aviation users often require additional sources of finance. Therefore, this section considers commercial loans, termed debt financing, as a form of funding CNS/ATM projects that may be used by all stakeholders, from equipment manufacturers to users.

Many institutions are involved in commercial debt financing and a multitude of possibilities exist in this arena for funding CNS/ATM projects. Indeed, noting the

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<sup>1050</sup> This is of acute relevance to many nations whose ANS entities are either still government run or have recently been corporatised.



different circumstances that surround such projects, each is unique in terms of the loan amount, its term and the rate of interest. These variables are dependent on the risk of the project. Indeed, the amount that an institution would wish to lend in terms of its percentage of the overall project worth is also dependent on the lender's desired exposure level. In addition, currency issues arise, which are invariably linked with the stability of all denominations in terms of their propensity to fluctuate. Loans are often secured against assets. Larger loans can be done through a syndicate of banks, whereby one bank acts as the lead institution.

Prior to agreeing to finance a commercial loan, an institution would conduct a detailed credit analysis of the CNS/ATM project and the stakeholder requesting the loan. Many matters would be assessed, as discussed at the start of **Section 6.4**, including the stakeholder's cost base and ability to repay the loan over its term. It should be remembered that expenses associated with the loan itself are an important cost element. Commercialised and international agencies are more attractive to lenders than government-run departments. Loans to State-owned companies are limited by governmental borrowing capacities. As mentioned in **Section 6.4.1**, most CNS/ATM projects aim to be self-sustainable by covering their costs through user charges. Thus, a repayment schedule would be agreed between the institution and the stakeholder that is dependent on forecast revenues and costs. In the event that full cost recovery is not possible, the financier and stakeholder would undoubtedly seek contributions from governmental or other funding sources (see **Section 6.4.3**). If full cost recovery were dubious, this would be reflected in the amount of the loan, its term and interest rate.

Ultimately, noting that a plethora of loan types and situations exist, it is beyond the intention of this chapter to analyse them in great detail. Nonetheless, it should be added that the provision of air navigation facilities and services are essential to national or regional economies. Therefore, CNS/ATM projects may warrant some form of 'soft' loan with preferential terms. Indeed, given the restricted ICAO guidelines that exist, the practice of providing such debt financing is of acute relevance to CNS/ATM systems and should further their introduction. 'Soft' loans can be a form of aid provided by foreign governments, thus: France provided Indonesia with a soft loan to help fund a CNS/ATM project in 2000<sup>1051</sup>; Germany's Development Bank, the Kreditanstalt für Wiederaufbau (KIW), also funded an Air Navigation Service (ANS) system upgrade in 2000<sup>1052</sup>.

Accordingly, projects not qualifying for 'soft' loan aid from foreign governments are often able to avail of assistance through export credit agencies, which promote trade and culture between nations. Examples of export credit agencies include the Export-Import bank (Eximbank) of the US, the Export Credit Guarantee Department (ECGD) of the UK and HERMES of Germany. It is often the case that the agencies complement bank loans by providing guarantees, in particular where banks are reluctant to assume the whole risk, noting that developing countries are deemed high risk, but that proper management of their CNS/ATM projects, as suggested throughout this framework, should make all CNS/ATM system development or implementation projects virtually

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<sup>1051</sup> 'France firms \$54m loan for Indonesian ATS project' – *Air Transport Intelligence*, 15 February 2000.

<sup>1052</sup> 'PNG to upgrade air traffic systems' – *Orient Aviation*, November 1999.



viable. However, the Eximbank and ECGD have also lent money directly in the past, with the actual finance being provided by banks as syndicated loans, thereby spreading the risk. Export credit agencies tend to help projects that use equipment manufactured by one of the agency's national companies.

Correspondingly, banks and funds have been established to assist with the financing and execution of projects seeking national economic development around the world. Thus, CNS/ATM projects are often eligible for their 'soft' loans. Examples include the Asian Development Bank, European Bank for Reconstruction and Development (EBRD), the European Investment Bank (EIB) and the World Bank. It should be noted that the latter bank's main lending institution is the International Bank for Reconstruction and Development. As examples of development banks, brief descriptions of the EBRD and EIB follow<sup>1053</sup>:

- The governments of Europe and North America established the **EBRD** after the break-up of the Soviet Union to help with economic restructuring CIS and Eastern European countries. The EBRD fosters transition towards market-oriented economies and promotes private entrepreneurial initiatives<sup>1054</sup>. It has been involved in Russian efforts to implement CNS/ATM<sup>1055</sup>;
- The **EIB**'s mission is to contribute to the European Union's balanced development. It is an autonomous public institution that grants long-term loans or guarantees to public and private sectors for investments that help the economic development of regions that are structurally weak. The loans or guarantees are either made directly or through other financial institutions. Noting that EIB lending is on a project and not asset basis, loans normally cover up to 50% of the gross investment costs of a project, thereby supplementing other funds.

In summary, banks are willing to finance CNS/ATM projects and have been in contact with ICAO to reiterate this point<sup>1056</sup>. It is worth noting that larger, regionally based projects would usually obtain better financial deals, in addition to the economies of scale and scope that exist (see **Section 5.4** and **Section 6.4.5**). Thus, this framework strategy suggests that stakeholders avail themselves of this willingness, remembering that 'soft' loans are also available, in addition to other forms of funding, which are described in subsequent sections.

### 6.4.3 Government contributions

The subject of Air Navigation Service (ANS) providers being under government control is covered extensively in this chapter. However, in the past, many other stakeholders were also government departments. For instance, airlines and airports were operated and

<sup>1053</sup> 'Sources of airline finance' – Chapter 8, *Airline Finance*, P Morrell, 1997.

<sup>1054</sup> 'EBRD's experience in financing ATM systems' – B Millot, EBRD. *The 4<sup>th</sup> Air Navigation Conference*, Amsterdam. September 1998.

<sup>1055</sup> 'Searching for finance' – *Flight International*, 5 August 1998.

<sup>1056</sup> 'Cost recovery and financing' – Working Paper 8, ICAO Rio de Janeiro Conference, 1998.



owned by their State. This even applied to some aerospace equipment manufacturers. It was therefore understandable that these entities would receive funding in the form of direct government contributions because any surpluses that had been generated by the stakeholder would invariably be placed in the general national exchequer and not into the particular aviation business. Reliance on government subsidies is still significant in many countries<sup>1057</sup> due to political or strategic reasons. Nevertheless, commercialisation of stakeholders has changed the practice of direct contributions by governments. Thus, given that this framework encourages that ANS providers be commercialised, this section discusses indirect government contributions based on the assumption that all stakeholders are not government owned or run.

In contrast with the foreign government preferential loans that are mentioned in **Section 6.4.2**, governments may assist with the procurement and installation of CNS/ATM systems where full cost recovery would not be forthcoming (see **Section 6.4.1**) and the authorities view that the system would be beneficial for their country and/or region. Accordingly, a CNS/ATM system component, such as a satellite constellation or augmentation system, may have an application that is extraneous to aviation. Therefore, the government could contribute to its development or operation. Correspondingly, a government could relax taxation laws, which would act as a contributing incentive for whatever purpose taxes have been reduced. For example, aviation fuel is not subject to international taxes. It is also possible for governments to underwrite a stakeholder's CNS/ATM project with a State guarantee for security on loans, whether the financing is received from private banks or other governments.

Similar to the development banks that are cited in **Section 6.4.2**, governments are also involved in development funds on an international basis to finance CNS/ATM and other projects in developing nations that promote national economic development. For instance, the European Development Fund and Saudi Fund for Development exist. In addition to its principal function as an advisory entity, the United Nations Development Programme (UNDP) also offers funding for minor ANS projects in developing nations. Finally, noting that African countries maintain that financing remains a major concern<sup>1058</sup> regarding the implementation of CNS/ATM<sup>1059</sup>, it should be added that 53 African States proposed the creation of an International Development Fund (IDF) at the 1998 Rio Conference<sup>1060</sup>. ICAO planned to investigate this option<sup>1061</sup>, but little has occurred since. However, would this form of funding through grants not disrupt the initiative for self-financing that this framework strategy believes is possible, even in developing nations, when all financing methods are evaluated in line with the other suggestions? A counter argument would be that air transport is an economic necessity for nations. Some countries were, however, concerned that an IDF would conflict with

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<sup>1057</sup> 'Funding issues' – Working Paper 8, ICAO Air Navigation Services Conference 2000.

<sup>1058</sup> Many African nations typify the references to countries that have insufficient traffic levels for complete cost recovery, yet Africa is a region that would benefit immensely from safety enhancements. Thus, the authorities in the region should continue to enter into partnerships with international agencies and manufacturers, as discussed in Section 5.4.2's coverage of the COMESA and other initiatives.

<sup>1059</sup> 'The needs of airlines in African airspace in the implementation of CNS/ATM principles' – Capt M Mitchell, Air Mauritius. The Airline Navigation Conference '95, Amsterdam. September 1995.

<sup>1060</sup> 'Report' – Doc. 9719, ICAO Rio de Janeiro Conference, 1998.

<sup>1061</sup> 'Fool's gold' – Air Traffic Management, May/June 1998.



established ICAO principles<sup>1062</sup>. Thus, should some form of aviation development bank be created?

Ultimately, the tendency for a country or region to continue the practice of government contributions is inherent within the economic prosperity and rules of that country or region. Indeed, contributions from foreign governments could even come in the form of international co-operation (see **Section 6.4.5**), whereby a country that cannot afford CNS/ATM outsources as many ANS activities as possible through a co-operation venture. Its financial reward may not be too high, but it will fulfil its international and national obligations to provide safe ANS. Thus, stakeholders, who include national and regional authorities, should remember this framework's guidelines on regional co-operation and the fact that other financing methods exist, which are particularly receptive to regional ventures' requests.

#### 6.4.4 Equity financing

Equity financing involves raising funds through the sale of shares in a company. In the CNS/ATM arena, equity financing could become a more common phenomenon due to increasing tendencies towards commercialisation and inter-stakeholder company partnerships. This section analyses the following forms of equity financing that apply to CNS/ATM stakeholders:

- **Share capital** – Funds are raised by placing a certain proportion of the firm for sale through the issue of shares. Noting that many different possibilities exist, countless CNS/ATM stakeholders, such as airlines and equipment manufacturers, are 'publicly-listed' on a stock exchange or have sold shares in their firm through a private sale. As discussed in **Section 5.4.1** and its associated **Appendix 5.7**, the present Public-Private Partnership (PPP) process of the UK's National Air Traffic Services (NATS) is an example of raising capital funds by selling shares, as follows: the UK government is selling 46% of its interest in NATS to a strategic partner, the Airline Group, and a further 5% to NATS's employees, therefore retaining a 49% share. In addition, it should be noted that the UK government will be able to raise further capital in the future from the shareholders through a rights issue, whereby the owner of each share has the right to subscribe to a given number of new shares in proportion to their existing holdings<sup>1063</sup>. Accordingly, it is thought that the potential European satellite constellation, Galileo, will adopt a PPP approach to raising finance<sup>1064</sup>, in addition to revenue through categorised user charges<sup>1065</sup> and a European Union (EU) budget, to cover the estimated costs of over \$2 billion<sup>1066</sup>. It should be noted, however, that PPP conditions are said to be the major stumbling block to

<sup>1062</sup> 'Rio Conference explores innovative approaches to financing and managing CNS/ATM systems' – ICAO Journal, June 1998.

<sup>1063</sup> 'Sources of airline finance' – Chapter 8, *Airline Finance*, P Morrell, 1997.

<sup>1064</sup> 'Chairman's Report' – Galileo Task Force on Public Private Partnership, 4 June 1999.

<sup>1065</sup> 'EC thinking confirms airline satnav fears' – *Air Transport Intelligence*, 30 September 1999.

<sup>1066</sup> 'Finding the way' – *Flight International*, 2 January 2001.



Galileo's launch<sup>1067</sup>. Nonetheless, consortia are preparing to bid for the Galileo PPP<sup>1068</sup>. Funding from the EU budget is likely because Galileo will also have applications outside aviation. This may prove essential because many satellite operators have gone bankrupt heretofore (see **Chapter 4**), even though over \$11.4 billion was raised around the world through public share offerings over the period from 1993 to 1998<sup>1069</sup>,

- **Bonds** – A bond is a documentary promise by a company listed on the stock exchange to repay long-term borrowed funds with interest at a definite date, having used potential equity in assets as security. Convertible bonds allow finance to be raised, often at a time when the share price is weak, on a fixed interest basis, but with rights attached to convert to ordinary shares at a future date<sup>1070</sup>. Bonds are usually employed in the US, but should become more prevalent in CNS/ATM activities due to commercialisation of ANS providers<sup>1071</sup>;
- **Venture capital firms** – Their belief that a large potential gain is commensurate with high risk could be applied to the development and implementation of a CNS/ATM system. Thus, venture capital firms could take an equity stake in return for funds.

Consolidation is occurring in the CNS/ATM industry through mergers and acquisitions, as portrayed in **Chapter 4**. Thus, these bigger corporations should be able to generate significant funding levels through equity financing, in particular by issuing shares. Accordingly, the issue of bonds applies to listed companies. In contrast, smaller CNS/ATM projects with little credence may be able raise finance by offering an equity stake to a venture capital firm.

#### 6.4.5 Joint financing arrangements

This framework strategy emphasises that all stakeholders should co-operate on national and/or regional bases, as discussed in **Chapter 5**. Given the multi-national applicability of CNS/ATM, it is particularly suited to joint ventures. Therefore, this framework strategy recommends that the present ICAO Joint Financing Agreement (JFA) method for air navigation facilities and services should be applied as a joint financing concept for all elements of CNS/ATM systems, which is available to all stakeholders. Therefore, this section outlines the current ICAO joint financing agreement method.

The present ICAO JFA, which finances and provides air navigation facilities and services, has existed for more than fifty years: the North Atlantic region was the first application of JFAs in 1948<sup>1072</sup>, with an agreement between Denmark and Iceland as the

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<sup>1067</sup> 'Galileo stuck on the launch pad' – *Navigation News*, January/February 2001.

<sup>1068</sup> 'Astrium group to bid for Galileo management' – *Flight International*, 12 December 2000.

<sup>1069</sup> 'Financing satellites: easier said than done' – *Air & Space Europe*, Vol. 1, No. 1, 1999.

<sup>1070</sup> 'Sources of airline finance' – Chapter 8, *Airline Finance*, P Morrell, 1997.

<sup>1071</sup> 'Funding issues' – Working Paper 8, ICAO Air Navigation Services Conference 2000.

<sup>1072</sup> 'The ICAO joint financing arrangements' – Working Paper 7, ICAO Air Navigation Services Conference 2000.



provider nations, whereby financial responsibilities are assumed by Denmark, Iceland and 21 other countries. ICAO administers and supervises the agreement, which includes constant assessment of funding requirements, in addition to control of costs and revenues. The method used by the 23 participating governments to finance the services is set forth in the joint financing agreement. Denmark and Iceland, in their capacity as provider countries, contribute 5% of the total service costs, because they receive aeronautical and indirect benefits arising from the JFA. A special user charge is paid by aircraft that fly across the North Atlantic region north of 45°N latitude, whether or not their government is a member of the JFA. The fee covers the cost of air traffic control, communications and meteorological services, in addition to expenses to cover ICAO's input. The remainder of the costs are shared by the 23 nations using a cost recovery method that ensures correct payment.

This framework cites numerous examples of international ventures around the world. It also mentions the fact that nations have difficulty with providing air navigation facilities and services. It would appear, therefore, that such countries should co-operate with other stakeholders. Thus, where there is no international agency available, such as ASECNA, COCESNA or Eurocontrol, joint-financing arrangements should be suitable towards solving that country's provision problems. JFAs are particularly applicable to satellite integrity monitoring and wide area augmentation systems, whereby it is possible for one provider to operate the CNS/ATM system on behalf of another or a group of countries could jointly operate the system (see **Section 5.4**). Other possible candidates for JFA could be the new breed of Polar routes (see **Section 7.4**). In addition, it should be noted that JFAs are being employed in Africa situation (as per **Section 5.4**).

In practice, given that each situation is individual, this suggestion should be moulded with the other guidelines that this strategy develops so that an equitable solution is applied. Accordingly, stakeholders should provide the following when generating a joint financing concept:

- Clear description of the project and its objectives, which should be to establish an air navigation facility or service;
- Clear identification of the facility or service(s) to be jointly financed;
- Definition of the responsibilities of the different partners;
- Simplicity and flexibility of the arrangements;
- Equitable recovery of all costs through user charges.

#### **6.4.6 Leasing**

Similar to the very active aircraft leasing market, this framework recommends that all stakeholders consider the application of such philosophies to CNS/ATM systems. This section analyses the concept of leasing and its relevance as a funding method.

With reference to the discussion in **Section 5.4** on international co-operation ventures and **Section 6.4.5** on joint financing arrangements, leasing of CNS/ATM facilities and services could be applied as a means of avoiding the need to raise funds. For instance,



the provision of satellite integrity monitoring and augmentation systems would save each nation or provider the financial outlay associated with implementation, in addition to speeding up its integration. Correspondingly, the US FAA is planning to lease CNS/ATM equipment from industry over 5-8 year periods to modernise its centres<sup>1073</sup>. The FAA has realised that the chance of technologies and procedures being successfully implemented is much greater if industry is behind the ventures<sup>1074</sup>. However, stakeholders need to remember that they would not be the owners of leased facilities and that the resultant lack of assets could affect their ability to borrow funds in the future. This would not be a problem in all cases: for example, if a user were to lease their avionics suite. Nonetheless, leasing tends to be more expensive in the long run based on total costs, although tax laws in some countries encourage leasing.

An example of leasing in the Air Navigation Services (ANS) provision market is the Private Finance Initiative (PFI), whereby the control centres and their CNS/ATM equipment are designed, built, financed, owned and managed by a private sector contracting company, which may be a CNS/ATM equipment manufacturer, but operated by the ANS provider<sup>1075</sup>. A long-term concession agreement is formed between the parties, which usually has a minimum term of 10 years, but is closer to 20 years in most cases<sup>1076</sup>. The contractor does not guarantee the financing: lenders take the risk that the project will be able to generate the necessary cash flow to repay the debt. The provider pays nothing until the service starts and then reimburses the contractor, noting that the level of payment is related to performance levels achieved by the contractor (see the performance parameters that are developed in **Chapter 7**). Thus, the provider does not have to generate any initial financing, yet is still able to operate its ANS facility and services. The provider must only decide what form the service should take. On the other hand, the contractor must incorporate many financial aspects in its plans, which could range from the cost of its financing programme to ensuring that reliable revenue streams will exist once the project is operational. The New En-Route Centre (NERC) of the UK National Air Traffic Services (NATS) is an example of a PFI. However, it should be noted that subsequent NATS projects that were destined to be part of the PFI scheme have since been removed from PFI. Indeed, it is thought that PFI ventures are not ultra long-term, viable propositions due to diverse ownership and management, which could potentially lead to a defragmented organisation.

Ultimately, this section demonstrates that stakeholders can avail of leasing methods that range in commitment and cost as innovative financing mechanisms. This framework strategy recommends that dedicated CNS/ATM leasing companies be established, which have outright ownership of the infrastructure and apply reliable project financing. Given the inherent problems with integrating CNS/ATM systems that are quoted throughout this dissertation, leasing vehicles will undoubtedly offer other stakeholders attractive, alternative methods so that the implementation of future air navigation systems is swiftly expedited.

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<sup>1073</sup> 'FAA settles on leasing plan for ATC update' – *Flight International*, 3 March 1999.

<sup>1074</sup> 'FAA, NTSB to jointly study new flight data technology' – *Air Transport Intelligence*, 6 May 1999.

<sup>1075</sup> 'FANS in Europe: an alternative procurement for the Future Oceanic Air Traffic Management System' – C Gibson, EDS. *Air Traffic Management in Europe: the business case for CNS/ATM Conference*, June 1997.

<sup>1076</sup> 'Project financing for air traffic control' – *Journal of ATC*, July-September 2000.

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## 6.5 Summary

This chapter analyses the financial components for the framework strategy that this research develops. Financial factors affect every stakeholder because all CNS/ATM projects have funding requirements, whether they are government run or orchestrated solely in the private sector. This chapter provides the framework for improved implementation of future air navigation systems with:

- A theoretical analysis of air navigation charging mechanisms based on an overview of guidelines by the International Civil Aviation Organisation (ICAO) on ANS charging policies, principles for allocation of costs, charging methods and the billing process for air navigation facilities and services. Eurocontrol's approach to air navigation facility charges is also detailed as an example of best practice;
- A benchmarking exercise of worldwide charging levels for air navigation facilities and services in 205 countries, which concludes that a wide range of fees exists. All stakeholders may employ this survey, in order to ascertain their average regional fee, among other criteria. Accordingly, nations and/or ANS providers should be able to apply en-route formulae that they consider to be more pertinent for their operation and users may realise that alternative routes may demand lower navigation charges;
- Alternative methods for funding CNS/ATM projects, irrespective of their size, having considered the cost levels that apply to such projects. **Section 6.4** evaluates finance sources by conducting an analysis of methods that may now be applied to CNS/ATM. Non-user stakeholders are urged to maximise their revenue through cost recovery principles, while users should be aware of the other financing methods that exist. Indeed, cost control is essential and should be easier with continued implementation of CNS/ATM. Correspondingly, the analysis of funding methods offers other suggestions regarding accountancy and other business practices. In line with the guidelines given in **Chapter 5**, the framework calls for continuous consultation among all stakeholders.

Ultimately, this chapter contains much information and benchmarked charging data for referencing purposes by CNS/ATM stakeholders. Correspondingly, stakeholders will be able to draw from this material to swiftly develop their individual strategies. In addition, the information in this chapter forms the basis of some analyses in **Chapter 7**.



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## **CHAPTER 7**

### **PERFORMANCE PARAMETERS**

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## 7.1 Introduction

As part of the framework for improving implementation of CNS/ATM that this thesis develops, **Section 5.7** states how it is essential to assess the quality and performance of Air Navigation Services (ANS) from different stakeholders' perspectives. Indeed, it should be possible to apply such analyses around the world, noting that, for instance, the ANS situation in Europe is very different from that in Africa, but each has its inherent problems: the former is saturated and urgently requires more capacity; the latter has a perception of poor safety levels.

Thus, this chapter develops and computes criteria that assess the performance of ANS provision, in addition to determining levels of ANS provided around the world and conducting a route performance analysis. All stakeholders may use the various sections for a variety of analytical or strategic purposes, noting that they endeavour to expedite the implementation of future air navigation systems by facilitating the identification and rectification of lower quality airspace regions or ANS providers. **Section 7.2** drafts indicators in terms of:

- The performance of ANS organisations;
- The quality of CNS/ATM that they provide.

The subsequent section, **Section 7.3**, applies the indicators and criteria drafted in **Section 7.2** to nations, split by the regional categories defined in **Chapter 1**, to provide an overall analysis of their ANS providers' organisational efficiencies and standards of the countries' CNS/ATM systems. This further develops the framework strategy by validating the criteria developed, providing results from a survey of nations or providers and supplying information that may be added to the other framework guidelines given in this dissertation so that all stakeholders can apply its suggestions. **Section 7.4** complements **Section 7.3** with a case study analysis of airline route performance.

Ultimately, this chapter contains much information and benchmarked data that may be used for referencing purposes by CNS/ATM stakeholders. All stakeholders should be able to draw from this material as part of the framework strategy to swiftly develop their individual strategies to assessing performance of CNS/ATM, in addition to stating their minimum acceptable or expected efficiencies and standards. Accordingly, ANS providers, financiers, national or regional authorities and users should be able to apply the experiences cited in **Section 7.4** to other route developing areas.



## 7.2 Indicators and criteria

This section analyses the performance and quality of Air Navigation Services (ANS) with:

1. An assessment of the approaches used by the US Federal Aviation Administration (FAA) and the International Federation of Air Line Pilots' Associations (IFALPA) to categorise ANS in countries;
2. Information on the ANS performance measurement system employed by Eurocontrol's independent Performance Review Commission (PRC);
3. A summary on how the performance of ANS may be measured;
4. An overview of how the quality of ANS may be assessed.

These individual sections have two main objectives, thus:

- To provide a comprehensive synopsis as part of the framework on how ANS may be compared and contrasted by financiers, nations and providers around the world, in addition to the manner in which this is done by the regulatory bodies;
- To develop checklist criteria that can aid CNS/ATM project appraisals in the form of indicators, as drafted in **Section 7.2.3** for ANS provider organisational efficiency and **Section 7.2.4** for the quality of ANS.

The contents of this section form the background to the benchmarking exercise on the level of service provided in **Section 7.3**.

### 7.2.1 Categorisation and classification of ANS

This section provides an assessment of the approaches used by the US Federal Aviation Administration (FAA) and the International Federation of Air Line Pilots' Associations (IFALPA) to categorise and classify Air Navigation Services (ANS) in countries. It cites their respective methods and highlights aspects that are relevant to this analysis of ANS performance and quality. It should be noted that approaches adopted by other associations and organisations are contained in **Section 7.2.2**, which discusses how Eurocontrol measures ANS performance based on procedures developed by numerous bodies. Together, the approaches are indicative of how authorities are starting to realise that the performance of ANS is crucial to its efficient operation. Indeed, the sections emphasise what assessment services are presently available. Therefore, the overviews presented in these sections are important from all stakeholders' perspectives and encapsulate the ethos of a need for improved performance if the implementation of CNS/ATM is to be successful.



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**FAA**


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The Air Traffic Services<sup>1077</sup> (department) of the US Federal Aviation Administration (FAA) has a mission to:

- Ensure the safe, efficient operation, maintenance and use of the air transport system today;
- Maximise the utility of airspace resources;
- Meet tomorrow's challenges to increase system safety, capacity and productivity.

In order to adhere to this mission statement, the FAA has different offices. Three offices play rôles in directly and indirectly assessing the performance of ANS:

1. The *Aviation System Standards* (AVN) office<sup>1078</sup> has total responsibility for managing and administering the FAA's flight inspection programme, which ensures the integrity of instrument approaches and airway procedures. Flight inspections are carried out on international bases through airborne assessments of all space and ground-based instrument flight procedures and the validation of electronic signals that are transmitted;
2. The *System Safety* (ASY) office<sup>1079</sup> has a primary function to develop and implement improved tools and processes, but also serves as a focal point for aviation safety data and information. This latter mission facilitates the development, marketing and promotion of safety information. The office therefore publishes many safety reports and has an access facility to frequently-used aviation safety databases, thus:
  - ASY produces quarterly and annual reports of aviation system and environmental indicators that the FAA has developed to give a broad view of the US aviation system operation and environment. **Appendix 7.1** contains a listing of the system indicators, which include accident and incident rates, in addition to measures of efficiency, compliance and inspector activity. Accordingly, **Appendix 7.2** lists the environmental indicators, which include information providing a perspective of the current and future environment in which the system operates;
  - ASY also operates the Global Aviation Information Network (GAIN), which promotes and facilitates the voluntary collection and sharing of aviation safety information worldwide. This programme is an international co-operative effort involving manufacturers, operators, unions, governments and others in flight and ground operations, maintenance and air traffic control. GAIN was created in response to concern that the worldwide commercial aviation accident rate has been constant for many years. It collects, analyses and disseminates aviation safety information to those in the aviation community who can use it to improve safety;

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<sup>1077</sup> <http://www.faa.gov/ats>

<sup>1078</sup> <http://www.mmac.jccbi.gov/avn>

<sup>1079</sup> <http://www.asy.faa.gov/>

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3. The *Regulation and Certification* (AVR) office<sup>1080</sup> provides, among other services, an International Aviation Safety Assessment (IASA) service. This programme focuses on a country's ability, and not that of its carriers, to adhere to international standards and recommended practices. The main intention of IASA is to ensure that all non-US carriers operating to and from the US are properly licensed, with safety oversight provided by a competent civil aviation authority. Nonetheless, it provides a useful classification methodology, albeit based on a country's entire aviation system and not specifically on its ANS facilities or services. A US federal register exists that defines the policy regarding nations not meeting the International Civil Aviation Organization (ICAO) minimum safety oversight standards, which are used as the basis of the IASA service.

In fact, ICAO has adopted IASA procedures for its Safety Oversight Programme (SOP) to ensure that ICAO-member nations meet their obligations: ironically, the US was subject to its own assessment evaluations in 2000 as part of the ICAO SOP. The US passed<sup>1081</sup>. Accordingly, the ICAO SOP has evaluated other nations, which include Australia<sup>1082</sup> and the United Kingdom (UK)<sup>1083</sup>. Indeed, it should be added that other nations' authorities, such as the UK's Civil Aviation Authority (CAA), perform inspections<sup>1084</sup>.

The FAA's IASA uses the following two-rating criteria to designate the status of nations' aviation systems at the time of the assessment, thus:

- **Cat 1** – complies with ICAO standards;
- **Cat 2** – does not meet ICAO aviation safety standards in all areas, which is divided into two further categories:
  - Countries that have air carriers with existing operations to the US at the time of the assessment. While in **Cat 2** status, carriers from these countries are permitted to continue operations, but under heightened FAA surveillance;
  - Countries that do not have airlines with existing operations to the US at the time of the assessment. Carriers from these countries are not permitted to commence services to the US while the **Cat 2\***<sup>1085</sup> status exists.

Unacceptable ratings apply if the civil aviation authority<sup>1086</sup>:

- Has not developed or implemented laws and regulations in accordance with ICAO standards;

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<sup>1080</sup> <http://www.faa.gov/avr>

<sup>1081</sup> 'FAA meets ICAO international safety standards' – *Air Transport Intelligence*, 11 April 2000.

<sup>1082</sup> 'Australia releases confidential ICAO safety audit' – *Air Transport Intelligence*, 12 May 2000.

<sup>1083</sup> 'International Civil Aviation Organisation Safety Oversight Programme: report of assessment of United Kingdom' – *Safety Regulation Group, Civil Aviation Authority* (<http://www.srg.caa.co.uk>), April 2000.

<sup>1084</sup> 'UK experts declare Hong Kong ATC system safe' – *Air Transport Intelligence*, 11 December 2000.

<sup>1085</sup> This group of countries is designated **Cat 2\***, in contrast with **Cat 2** for the nations with flights to the US.

<sup>1086</sup> 'FAA modifies international safety assessment ratings' – *Air Transport Intelligence*, 25 May 2000.



- Lacks the capability to certify, oversee and enforce air carrier operational requirements;
- Lacks the aircraft maintenance capability to certify, oversee and enforce air carrier maintenance requirements;
- Lacks appropriately trained inspector personnel required by ICAO standards.

These poor ratings may be manifested by the following categories of deficiencies:

- Inadequate, and in some cases non-existent, regulatory legislation;
- Lack of advisory documentation;
- Shortage of experienced airworthiness staff;
- Lack of control on important airworthiness-related items;
- Lack of adequate technical data;
- Absence of Air Operator Certification (AOC) requirements;
- Non-conformance to the requirements of the AOC system;
- Lack or shortage of adequately trained flight operations inspectors, including a lack of type ratings;
- Lack of updated company manuals used by airmen;
- Inadequate proficiency check procedures;
- Inadequately trained cabin and flight attendants.

The classification data is publicly available to enable the travelling US public to make informed choices when flying on non-US airlines. **Appendix 7.3** contains the latest available results of the programme (dated 18<sup>th</sup> January 2001) for just over 100 countries, which represents roughly half the number of nations that this research evaluates. The IASA results show that two-thirds of countries assessed were fully compliant with ICAO standards. The rated nations tend to be from the Americas & Caribbean region, Europe and parts of Asia, because carriers from these countries fly to the US.

It is evident that most nations without **Cat 1** status are located in the Americas & Caribbean region. Indeed, it should be noted that the Bahamas was demoted from **Cat 1** status at the start of 2001<sup>1087</sup>. Accordingly, El Salvador was downgraded to **Cat 2** during 2000<sup>1088</sup>. In addition, Peru was re-assessed in 2000<sup>1089</sup> and nearly received a **Cat 2** designation<sup>1090</sup>. In contrast, the region's Costa Rica was promoted to **Cat 1** in 2000<sup>1091</sup>. These changes demonstrate how countries are continuously subject to re-evaluation. Finally, it should be noted that a lot of industry attention is paid to the results of FAA IASA evaluations: there was concern in Europe when Greece received a **Cat 2** status in 2000<sup>1092</sup> because it is the only nation in the European region to not have **Cat 1** rating.

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<sup>1087</sup> 'FAA downgrades Bahamas to IASA Category 2' – *Air Transport Intelligence*, 15 January 2001.

<sup>1088</sup> 'FAA gives El Salvador Category 2 safety rating' – *Air Transport Intelligence*, 14 June 2000.

<sup>1089</sup> 'FAA to re-assess Peru's Category 1 safety rating' – *Air Transport Intelligence*, 2 May 2000.

<sup>1090</sup> 'Threat of FAA Cat 2 IASA rating removed for Peru, airlines' – *Air Transport Intelligence*, 18 August 2000.

<sup>1091</sup> 'FAA upgrades Costa Rica to Category 1' – *Flight International*, 11 July 2000.

<sup>1092</sup> 'FAA hands Greece poor safety assessment' – *Air Transport Intelligence*, 21 December 2000.



## IFALPA

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Similar to the aforementioned US FAA approach to validating countries' ANS and the method they adopt with ICAO to categorise entire aviation systems, the International Federation of Air Line Pilots' Associations (IFALPA) has developed a methodology for classifying ANS and airports in nations around the world<sup>1093</sup>. It should be noted, also, that the International Air Transport Association (IATA) has a similar system, but does not reveal any details to the public.

Noting that the IFALPA method analyses the airspace and CNS/ATM infrastructure when assessing the ANS, countries that are considered to be deficient are categorised into one of three classes, thus:

- **DEFICIENT (ORANGE STAR) – CLASS 1** include airports and/or airspaces with deficiencies which constitute a hazard to flight operations, such as:
  - ✓ No static free navigation aid or aids sufficiently accurate and positioned to provide a cloud break procedure;
  - ✓ No ILS with co-located DME;
  - ✓ Lacking VASIs, PAPI or ILS on all instrument runways;
  - ✓ Having a runway which is not capable of being used for take-off or landing in either direction without performance restrictions on the aircraft types authorised to use the airport;
  - ✓ Any other deficiency or combination of deficiencies considered sufficiently important to require Class 1 classification.
  
- **SERIOUSLY DEFICIENT (RED STAR) – CLASS 2** are those airports and/or airspaces having deficiencies which constitute a hazard to flight operations, such as one or more of the following:
  - ✓ Absence of airport control, or inadequate services or facilities;
  - ✓ Air traffic congestion or unsafe operational and procedural practices;
  - ✓ Inadequate communications;
  - ✓ Terrain hazards;
  - ✓ Prevalent adverse weather conditions or significant local weather features, which create significant operational difficulties at the airport;
  - ✓ Inadequate standard of crash/fire and rescue equipment for the types of aircraft using the airport, or due to the physical characteristics of the airport;
  - ✓ Arbitrary restriction of a pilot's free choice of the most suitable runway for use for purely environmental reasons;
  - ✓ Any other deficiency or combination of deficiencies considered sufficiently important to require Red Star classification.

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<sup>1093</sup> The methodology is given in the IFALPA Annex 19, Part 3 (REG).



- **CRITICALLY DEFICIENT (BLACK STAR) – CLASS 3** include those airports/airspace that have been recommended by IFALPA's member association of the nation and/or the IFALPA regional vice-president as being critically deficient.

Specifically, the airspace deficiencies may be broadly classified as **Class 1, 2 or 3** respectively on the basis of whether the facilities are:

- Of low capacity, not sufficiently numerous or slow;
- Unreliable, inaccurate or difficult to use;
- Absent, yet a basic necessity within the area.

When an airport or airspace has terrain hazard and/or prevalent adverse weather conditions that create significant operational difficulties, but does not have any of the other listed deficiencies, then it is classified as a **Special Category** airport or airspace. The listing of airports and airspaces under this category alerts users to the special problems or procedures involved until such time as improved technology or procedures are available.

The pilot authority of each nation conducts the assessment, although it is possible for member associations from other countries to recommend the imposition of a deficiency on an airport or airspace not located in their State. Irrespectively, a standard deficiency sheet layout exists, which lists facilities and services under the ICAO headings given in **Appendix 7.4**, and also contains:

- A brief explanation of the reported deficiency;
- Information on whether or not the facility required by IFALPA is in the appropriate ICAO Regional Plan;
- The implementation status, noting that unsatisfactory status is recorded when a particular facility is non-standard, inaccurate, unreliable, on test or unserviceable.

If there is a deficiency in the ANS or at an airport in a country, it is discussed in a paper presented at the annual IFALPA conference. A decision is made regarding its classification and IFALPA then approaches the nation's civil aviation authority to describe the problem(s) in detail, with a view to solving the deficiencies. The country's pilot association establishes procedures to deal specifically with deficiencies in airport and ANS. **Appendix 7.5** contains a list of the priorities for installation, which IFALPA or its member association(s) recommend(s) to the nation.

In the case of a **Class 3** critical deficiency, the IFALPA protocol adopted is for the recommendation to be accepted by the Regional vice-presidents' annual meeting and subsequently approved by the IFALPA annual conference. The conference agrees special measures that are deemed necessary for operation of the airport and/or airspace whilst the critical deficiency is in place. When reliable information has been received that the problem(s) causing the critical deficiency classification no longer exists, the IFALPA principal officers, in consultation with the appropriate regional vice-president and relevant member association(s), recommend a new classification and advise all interested parties accordingly. Approval and confirmation of such a recommendation are obtained by vote at the subsequent annual conference.



Information regarding airports or airspaces classified by IFALPA as Class 1, 2 or 3 deficient is made available by the country's pilot association to its own relevant civil aviation authority and/or airport authority. In the absence of an IFALPA-member association in the nation, the appropriate IFALPA regional vice-president does this. The country's pilot association may only release information that relates to the airport or ANS in its own country. This does not prevent them from distributing to their pilot members information on deficient aerodromes and airspaces into which they operate. Due to the sensitivity of such information, IFALPA has a policy that restricts the availability of the results to the public. Nonetheless, all stakeholders should be aware that this assessment method exists. This applies, in particular, to airline users.

### 7.2.2 Eurocontrol's measures of ANS performance

Even though the European region is perceived to have relatively high standards of Air Navigation Services (ANS), it has a lot of problems, which are mentioned throughout this dissertation. These apply, in particular, to the related issues of capacity and delay<sup>1094</sup>. Although the European Air Traffic Control Harmonisation and Integration Programme (EATCHIP) managed to extract 40% extra capacity from existing CNS/ATM systems, recent summers have experienced the region's worst-ever delays.

Therefore, Eurocontrol established an independent Performance Review Commission (PRC<sup>1095</sup>) in 1998 to "introduce a strong, transparent and independent performance review and target setting system to facilitate more effective management of the European ANS, encourage mutual accountability for system performance and provide a better basis for investment analyses". The main tasks of the PRC that are relevant to this research's framework strategy may be summarised, thus:

- Develop an Air Traffic Management (ATM) performance and target setting system;
- Measure this performance in review reports;
- Propose overall objectives for improvement of European ATM;
- Approve guidelines for economic regulation of ANS service providers;
- Address the proper functioning of Eurocontrol's Performance Review Unit (PRU), which supports the PRC. The PRU is responsible for monitoring and reviewing the performance of European ATM system.

As part of this framework strategy's process to develop performance indicators, this section specifically deals with the first two of the aforementioned objectives, namely:

- The development of ATM performance indicators;
- Measurement of ATM performance.

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<sup>1094</sup> It should be noted that the concepts of capacity and delay are also covered as part of this framework's suggested project appraisal techniques in Section 5.3.

<sup>1095</sup> 'The Performance Review Commission' – Eurocontrol, <http://www.eurocontrol.be/dgs/prc>, 2000.



## ATM Performance indicators

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The PRC published a document in 1999<sup>1096</sup>, which is still current, that proposes Key Performance Areas (KPA) and an initial set of associated Key Performance Indicators (KPI) for assessing the performance of Europe's ATM-related stakeholders, including ANS providers, airspace users, airports and Eurocontrol. Thus, noting the acute relevance to this thesis' framework, this section considers the report's findings. It should also be added that the report is considered to be a living document because analysis of ATM performance is an area that has only recently been researched in detail. Correspondingly, it is considered extremely pertinent to analyse the Eurocontrol methods because the PRC's aim is to be as comprehensive as is practically possible and its methodology incorporates research conducted by the:

- Association of European Airlines (AEA);
- Boeing Company's CNS/ATM Focused Team (C/AFT)<sup>1097</sup>;
- Civil Air Navigation Services Organisation (CANSO);
- International Air Transport Association (IATA);
- MITRE Corporation.

In addition, a large number of stakeholders in Europe were involved in the consultation process which led to the publication of the document. Thus, as with **Section 6.2.5**, Eurocontrol's approach is considered to be an example of best international practice.

In its 'ATM performance measurement system report', the PRC proposes the following key performance areas and respective definitions, thus:

- **Safety** – the conformance of air transport to specified safety targets;
- **Delay** – the time in excess of the optimum time that it takes a user to complete an operation;
- **Cost effectiveness** – the value for money that users receive from the supply of air traffic services;
- **Predictability** – the ability of a user to predict variation and to build and maintain optimum flight schedules;
- **Access** – the accessibility of airspace, ATM services and airport facilities under controllable conditions;
- **Flexibility** – the ability of ATM to accommodate changing user needs in real time and without penalty;
- **Flight efficiency** – the ability of the ATM system to allow a user to adopt the preferred flight profile in terms of flight level and route;
- **Availability** – the availability of critical ATM resources and of the ATM services provided to users;
- **Environment** – the conformance of air transport to environmental regulations;
- **Equity** – equality treatment of flights by all aircraft operators within and between specific classes of users.

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<sup>1096</sup> 'The PRC's European ATM Performance Measurement System' – Edition 1.7, Eurocontrol, June 1999.

<sup>1097</sup> 'Airline metric concepts for evaluating air traffic service performance' – C/AFT Air Traffic Services Performance Focus Group (ATSP FG), 1 February 1999.



The PRC notes that, while it is the aim that ATM performance in general should improve over time, an aircraft operator or service provider may be able to trade certain KPAs against others to optimise their system performance. For instance, an aircraft operator may choose to reduce the delay on a flight by accepting a re-routing or a sub-optimal flight level: this should improve the delay, albeit at the expense of flight efficiency. There are, however, a number of external factors, such as government or safety regulator constraints, which will limit the extent to which KPAs are tradable. To assist the process of assessing the costs and benefits of the aforementioned trade-offs, the PRC believes that it is necessary to have an objective for the ATM system: their proposed aim is “to give users over the long term safe services and the levels of capacity and quality they require, and for which they are prepared to pay, with price based on the costs of efficient operations”.

**Appendix 7.6** contains a list of the PRC’s suggested Key Performance Indicators (KPI), categorised by their respective Key Performance Area (KPA). The KPIs have been developed in conjunction with other Eurocontrol-related entities, such as the independent Safety Regulation Commission (SRC) and the Central Office for Delay Analysis (CODA), to offer indicators from different perspectives. In addition, as cited previously, the KPIs draw on research by the AEA, Boeing, CANSO, IATA and the MITRE Corporation. It is evident that many KPIs are straightforward ratios, formulae or purely indicative values. Some elements have not had associated KPIs drafted yet.

The indicators should be considered at the appropriate levels, whether ECAC-wide, by nation, by flight information region, by ANS provider, by airport, by sector, by time-series, by phase of flight, by city pair, by airspace user or by passenger travelled. However, the present lack of data, particularly regarding airport and terminal airspace operations, means that the indicators are aggregated and that it is often only possible to compute at specific stakeholder levels. Nonetheless, it is consequently important for the future applicability and relevance of indicators as part of this thesis’ framework strategy to develop those that may be suitably applied when data become available. Indeed, ATM performance measurement should be driven by the needs of all users, including commercial, general aviation and military aircraft operators. Therefore, each stakeholder can use key performance indicators to measure their specific activities.

In its ‘ATM performance measurement system report’, Eurocontrol emphasises that, in addition to the aforementioned quantitative measures, there may be a need to evaluate qualitative measures of performance, even though such KPAs would be more subjective (this framework’s guidelines on project appraisal techniques in **Section 5.3** considers qualitative issues): an example, in this case, is users’ satisfaction with the system, which could be ascertained through surveys carried out at regular intervals. Correspondingly, the Performance Review Commission (PRC) mentions that it may be beneficial to develop process KPAs that address the effectiveness of the actual processes. Irrespectively, the PRC has already started to compute some of the KPAs, as described hereunder.



## Measuring ATM performance

Eurocontrol believes that the ability to monitor and analyse the performance of the European ATM system as an overall network will have far reaching effects on its management. Thus, the Performance Review Commission (PRC) produces reports in which it cites statistics based on some of the aforementioned Key Performance Areas (KPA). The performance review reports aim to assist all stakeholders in understanding why, where, when, and possibly how, European ATM performance should be improved. Their objective is not to praise or criticise, but to improve performance in the future. Accordingly, it should be noted that the PRC does not intend to compute and highlight all Key Performance Indicators (KPI) in every report: the aim of the PRR documents is to focus on those indicators that provide the greatest relevant and timely insight into performance. Hence, in order to describe how Eurocontrol measures ATM performance, this section briefly analyses some results from these reports, noting that **Section 7.3** evaluates the reports' results in greater detail, in addition to citing findings from other information sources, as part of its worldwide benchmarking exercise.

The PRC published its initial annual Performance Review Report (PRR1) covering the calendar year 1998 in 1999<sup>1098</sup>. Noting that the PRC produced an interim report on delays during 1999 as PRR2<sup>1099</sup>, the subsequent PRR covering the year 1999 (PRR3) was published in 2000<sup>1100</sup>. The report on 2000 has not yet been produced. Accordingly, due to lack of data availability and time, the PRC confined its reports covering 1998 and 1999 to assessing the performance of European ANS providers, and not other stakeholders, based on three KPAs, as follows:

- **Cost effectiveness** – Based on forecast data for those countries participating in the Eurocontrol Route Charges System, PRR1 cites that, in 1998, en-route charges of \$4,017 million for cumulative distances flown of 5,465 million km render an average European unit cost of \$0.74 per km. The corresponding forecast figures for 1999 in PRR3 indicate that the unit cost reduced in that year. The studies state that there is a general lack of consistent Europe-wide information on ATM costs, which prevents the PRC from making in-depth analyses. Additionally, it should be noted that, where information is available, there are large variations in the selected cost effectiveness performance indicators among European nations;
- **Delays** – According to the PRR1, reactionary delays<sup>1101</sup>, Air Traffic Flow Management (ATFM) delays and ground delays were the largest categories of delays in ECAC airspace during 1998. PRR3 states that the average ATFM delay per flight rose by a significant 48% from 3.6 minutes in 1998 to 5.4 minutes in 1999. Eurocontrol cites the implementation of a new route network and the Kosovo crisis as major factors for this increase. In addition, no measurable increase in overall

<sup>1098</sup> 'First Performance Review Report' – Performance Review Commission, June 1999.

<sup>1099</sup> 'Special Performance Review Report on delays' – Performance Review Commission, November 1999.

<sup>1100</sup> 'Performance Review Report (covering the calendar year 1999)' – Performance Review Commission, May 2000.

<sup>1101</sup> Reactionary delays – whereby late departures are due to late arrivals of inbound aircraft.



system capacity was achieved in 1999, primarily due to a lack of capacity in a small number of sectors. Accordingly, PRR3 states that capacity shortfalls still existed in 1999 and that 20 bottlenecks caused more than 40% of the ATFM delays<sup>1102</sup>, which illustrates the high level of interdependency among Air Traffic Control (ATC) centres, thereby stressing the need for individual service providers to implement capacity plans in order to meet demand. This particularly applies to what the reports refer to as the 'backbone areas' of the upper airspace, namely:

- London Area Control Centre (ACC);
- 'Area North' over the north-east of France, Benelux and western Germany;
- 'Area South' over the south-east of France, northern Italy and part of the Mediterranean.

These three areas caused the majority of delays in 1998 and their restrictions had wide effects across the whole of Europe. It should be noted that France and Switzerland continued to be the major sources of delays in 1999<sup>1103</sup> and 2000<sup>1104</sup>. Therefore, noting PRR2's claims that ATFM delays could be 3 to 5 times worse in 2005, Eurocontrol's strategy action plan should target these areas and remove all bottlenecks. Accordingly, as discussed in Chapter 4, Europe should co-ordinate its traffic to a greater extent by removing the airspace borders that exist:

- **Safety** – PRR1 claims that the lack of available and consistent safety data at a European level prevented meaningful conclusions being drawn on the performance of ATM safety in the ECAC<sup>1105</sup> area. National reporting schemes vary in content and scope, with their results invariably subject to national confidentiality processes. Thus, the report concludes that there was a need to introduce a harmonised approach to national ATM safety performance reporting in Europe, encompassing a harmonised categorisation of safety occurrences. According to PRR3, Eurocontrol's independent Safety Regulation Commission (SRC<sup>1106</sup>) addressed this need by launching the Eurocontrol Safety Regulatory Requirements (ESARR) in 2000, which deal with, among others, the implementation of an occurrence reporting and assessment scheme in ATM. The SRC expects to be able to publish more consistent statistics from 2001.

The reports also consider the reactive nature in which the European ATM system has been managed over the last 15 years. It highlights the cycles of decreasing/increasing unit costs and increasing/decreasing delays that have occurred. PRR1 concludes by stating that "a much more proactive and forward-looking collective management of the European ATM network would appear to be required." Thus, the PRC aims to set "targets for future performance and economic regulation guidelines, which could include incentives to meet those targets". Indeed, the PRC believes that a by-product of

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<sup>1102</sup> It should be added that, in contrast with ATFM delays, the PRC is unable to identify the causes of other delays through lack of data, noting that arrival delay = departure delay + taxi-out delay + airborne delay + taxi-in delay – a buffer. The availability of such data should be enhanced through introduction of Collaborative Decision Making (CDM), as discussed in Chapter 3.

<sup>1103</sup> 'Eurocontrol PRC recommends steps to tackle traffic delays' – *Flight International*, 4 July 2000.

<sup>1104</sup> 'European bottlenecks prevent delay recovery' – *Flight International*, 30 January 2001.

<sup>1105</sup> European Civil Aviation Conference (ECAC): Appendix 3.3 contains a list of member States.

<sup>1106</sup> SRC is a body that is independent from Eurocontrol and separate from the PRC. It was established to ensure consistently high levels of safety in ATM within the ECAC area.



the performance review reports is for Eurocontrol to check whether high-level objectives of its 'ATM Strategy for 2000+' (see **Section 3.5**) are being met, thus:

- **Safety** – to ensure that the number of ATM-induced accidents and serious or risk bearing incidents does not increase, the number of losses of planned separation incidents in the ECAC area should be determined;
- **Total cost** – noting that the total cost incurred by ATM airspace users is made up of direct costs (such as route charges) and indirect costs (avionics and those expenses that may arise due to delay or unpredictability), all costs should be considered and minimised;
- **Meeting the demand** – to portray whether capacity is growing as fast as traffic, whether there is a link between under-spending and delays, in addition to whether direct costs are growing slower than traffic;
- **Airport capacity** – provided that the constraints imposed by safety, environment and equity are met, airport access indicators should be expanded.

Thus, it is evident that the PRC considers capacity, cost, delays and safety to be indicative of ATM performance. **Section 7.3** contains more specific results from the PRC's performance review reports as part of this chapter's aim to develop performance-related parameters for the framework strategy.

### 7.2.3 Performance of ANS provider organisations

With reference to the previous two sections, this section develops methods for assessing the performance of Air Navigation Service (ANS) provider organisations as part of the framework strategy. Performance measurements, which can be divided between the en-route and terminal services of ANS organisations, are useful for all stakeholders because they facilitate:

- Higher levels of organisational productivity and cost effectiveness if integrated as part of a management system;
- Comparisons with other air navigation service providers to determine their relative efficiency, even if some of the facilities or services are provided by a third party (see **Section 5.4**);
- The development of future financial and operational plans in order to meet capacity requirements;
- An assessment of whether employees are being as productive as possible.

It should be noted that the indicators developed in this section produce results, which are heavily dependent on the type of organisational structure that a nation's air navigation service provider(s) and regulator(s) adopt, as per the discussion in **Section 5.4**. In order to develop the appraisal method, it is necessary to:

- Determine suitable measurement characteristics from all pertinent data sources;
- Develop indicators of performance based on these characteristics.



## 1. Measurement characteristics

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In choosing characteristics for measuring performance of ANS organisations, the main factors to be considered are operating statistics and other quantitative measurements such as number of aircraft movements by category handled (landings/take-offs for approach and overflight traffic for en-route), staff used (air traffic controller or unit), distance flown by aircraft and amount of time (calendar month or year).

It is necessary to consider parameters that enable emphasis to be placed on productivity changes, namely those that are subjectively termed input and output, thus:

- Input measurements can have units such as capital, investments, staff numbers (noting that many flight information regions use the same personnel to perform en-route and terminal ATM functions), indirect and operating costs (to provide services, based on the five air navigation service categories cited in **Section 5.4.1**), noting that capital can be measured through the value of assets, that investments are very subjective due to their infrequent requirements and that all monetary measures should be adjusted for inflation when viewed over time;
- Output measurements are usually based on financial aspects and can comprise revenue (which is preferentially segregated by approach and en-route charges) and other ANS revenues such as Aeronautical Information Service (AIS) income from charts or from providing third party services.

It should be noted that, while the wishlist above serves as a guideline regarding those factors and parameters that should be included in such a benchmarking exercise, the availability of data and its comparability are problems when attempting to conduct a worldwide analysis of ANS organisational performance. Thus, given that one of the objectives of this framework is to determine what data sources are available to stakeholders, and acknowledging the aforementioned difficulty with obtaining data, this research discovers that:

- The International Air Transport Association (IATA) has very little relevant information other than city pair and regional traffic data in its annual 'World Air Transport Statistics' (WATS) publications;
- ICAO, the International Civil Aviation Organisation, has useful data, with an annual publication in their Digest Of Statistics series<sup>1107</sup>, which accumulates factors and parameters directly relevant to this analysis of ANS organisational performance. However, it only contains en-route data. Accordingly, countries do not submit all the demanded information and appear to do so on an irregular basis, so information is available for some years and not for others. **Section 7.3.1** contains some benchmarking exercises using this source;
- As cited in **Section 7.2.2**, Eurocontrol has started to assess ATM performance and has conducted evaluations pertinent to this analysis of ANS organisational performance in the area of cost effectiveness. This is dealt with hereunder and their results form part of the benchmarking exercise in **Section 7.3.1**:

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<sup>1107</sup> Entitled 'Airports and route facilities: financial data and summary traffic data'.



- The Civil Air Navigation Services Organisation (CANSO) is currently developing performance measurements and benchmarking methods in conjunction with its member service providers. Having attempted to obtain the information for this research, it should be noted that it is not possible for the public to access the data. It should also be added that CANSO has had much difficulty in benchmarking its member providers<sup>1108</sup>;
- Therefore, the only method of obtaining statistics for a comprehensive assessment of ANS performance is to obtain the figures **directly from the authorities and/or providers**. Noting that some of the aforementioned sources are used to convey the efficiency of ANS organisations in **Section 7.3.1** as part of the benchmarking exercise, direct contact with authorities and/or providers is beyond the scope of this research, but may be more suitable to stakeholders using this framework to apply an evaluation methodology.

In addition, it is very difficult to obtain data that are comparable for all parameters because:

- There is a marked variation in the management and organisational structures of authorities and/or providers at national or international levels, as per **Section 5.4.1**;
- Air navigation facilities and services organisations' accounting practices differ, as do their accounting years;
- Revenue streams are often mixed for airports and air navigation facilities and services;
- Organisations are often government run and there is often little account of funding sources and destinations of revenues;
- Authorities compute distance travelled by aircraft in different manners, if at all;
- Flight Information Region (FIR) boundaries do not always coincide with countries' borders and some nations, as discussed in **Section 5.4**, are not responsible for the provision of ANS in any FIR;
- There are inherent problems with the appropriateness of comparisons: for instance, traffic handled in a region may not directly apply to the apparent level of capital investments.

## **2. Performance indicators**

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Performance indicators must be structured to compare organisations individually and collectively, so that this framework strategy is versatile. It is essential to highlight system indicators that are based on comparable data. Given the aforementioned difficulty with obtaining terminal navigation data and other comparable information, this exercise considers en-route traffic only. However, the same principles apply to approach control should stakeholders wish to apply its methodology.

It should be noted that a list of indicators is never exhaustive and that every one will not be relevant for all ANS providers. In order to benchmark countries' en-route ANS efficiency levels, this framework suggests that performance indicators based on those

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<sup>1108</sup> 'CANSO wrestles with ATC benchmarking' – *Air Transport Intelligence*, 22 September 1999.



factors, input measurements and output measurements cited above, in addition to the Eurocontrol cost effective Key Performance Indicators (KPI) listed in **Appendix 7.6**, could include:

- Size of operations in terms of:
  - ✓ Amount of revenue from en-route air navigation facilities and services;
  - ✓ Number of en-route flights;
  - ✓ Average en-route navigation fee (see **Section 6.3.1**);
  
- Type of company, whether:
  - ✓ National and/or international;
  - ✓ Ownership structure:
    - Government department;
    - Autonomous or corporatised public sector agency;
    - Partially or fully-privatised entity;
  
- Relative cost of providing safe air navigation facilities and services based on:
  - ✓ Total national expenses on en-route traffic per flight handled;
  - ✓ Total national expenses on en-route traffic per member of personnel;
  - ✓ Total national expenses on en-route traffic per kilometre flown;
  - ✓ Administrative overhead costs per flight handled;
  - ✓ Administrative overhead costs per member of personnel;
  - ✓ Administrative overhead costs per total expenses;
  - ✓ Staff costs per total expenses;
  - ✓ Operating costs per total expenses;
  - ✓ Capital cost per flight handled.
  
- Productivity in terms of:
  - ✓ Total revenue from en-route traffic per movement;
  - ✓ Total revenue from en-route traffic per en-route air traffic controller;
  - ✓ Number of flights per air traffic controller;
  - ✓ Distance travelled by en-route traffic per en-route air traffic controller;
  - ✓ Gross capital investments per flight handled;
  - ✓ Average revenue per aircraft type;
  - ✓ Value of fixed assets per movement;
  - ✓ Value of fixed assets per kilometres flown.
  
- Profitability as:
  - ✓ Operating ratio;
  - ✓ Return on capital employed;
  - ✓ Surplus - the difference between total country ANS revenue and cost of service provision.
  
- Ratios of:
  - ✓ Movements to personnel;
  - ✓ Landings to overflights.



Thus, to conduct an assessment using these indicators for all 205 nations, as per the charges survey in **Chapter 6**, the aforementioned ICAO information may be used, which has 1997 data available in detail for 27 countries. In addition, US Federal Aviation Administration and Eurocontrol information may be employed. The survey could be completed through direct contact with organisations, as previously mentioned, but this is beyond the scope of this study and initial research indicates that it is often the same countries that have duly completed the requested ICAO forms that have their statistics readily available to the public. Correspondingly, to provide a set of indicative benchmarking levels, whilst ensuring that data is as comparable as possible, this report conducts a benchmarking analysis of en-route provision of air traffic services in **Section 7.3.1**.

#### **7.2.4 Quality of CNS/ATM**

Given the need for safe air transport operations, it is necessary to establish levels of quality that are or should be achieved in nations' CNS/ATM systems as part of this framework strategy. The industry is very concerned with the safety of systems: from this perspective, airlines constantly complain that the quality of Air Navigation Services (ANS) around the world is not sufficient. Carriers cite examples of Air Traffic Control (ATC) centres frequently not being aware of their arrival and requirements, which is sometimes because the information did not pass successfully through their ground communications systems, or indeed, that the communications do not work at all.

Most of Africa, parts of Asia and some Latin American countries have perceived poor safety levels, but those regions that are considered safe also have their own problems:

- The Eurocontrol Performance Review Commission (PRC) reports mentioned in **Section 7.2.2** demonstrate that delays and other qualitative aspects in the European region have been worsening in recent years, albeit with more positive results for 2000. The reports highlight the fact that the European Air Traffic Management (ATM) system is saturated and urgently requires more capacity. The situation is the source of constant wars of words between the airlines and the regulatory bodies, particularly Eurocontrol. Summer 1999 led to serious questions being asked about Europe's policy towards ATM, with some airlines forced to cut their schedules due to constant delays;
- Parts of the US ATM system are close to gridlock and the en-route portion of the system has been branded "safe, but unreliable" by its own National Transportation Safety Board (NTSB). Correspondingly, US carriers are currently requesting that service quality rules be changed in the US to eliminate false impressions over punctuality caused by air traffic delays: the US Air Transport Association (ATA) is claiming that its Department of Transport's (DoT) rule regarding its Airline Service Quality Performance reports should be changed to fully disclose the nature and sources of delay.

Thus, flight delays are also being increasingly discussed. They are a source of frustration for many people and are financially penalising for all sectors of aviation and



economies in general. Therefore, in contrast with **Section 7.2.3**, which provided information on how the performance of ANS organisations may be measured, this section provides an overview of how the quality of ATM in countries may be assessed, ultimately determining quality indicators for this framework strategy. Development of the quality indicators enables the assessment of service standards provided by nations' ANS organisations to be conducted, as per **Section 7.3.2**. Similar to the analysis of the efficiency of ANS providers, such an exercise enables a comparison of service levels between nations, in addition to providing input to management of ANS organisations and governments for overview of CNS/ATM system requirements and functionality.

Quality indicators, which are more subjective than the quantity-related factors employed to assess ANS organisational performance, may be derived from CNS/ATM aspects that have effects on the service level of a country or region, such as availability and reliability of facilities in terms of airspace complexity. Therefore, this section:

- Identifies pertinent aspects of nations' Communications, Navigation & Surveillance (CNS) technology with regard to its ATM functions;
- Highlights relevant indicators, thereby assessing the provision of ANS.

### **1. CNS/ATM quality aspects**

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In conjunction with the other analyses in this thesis, navigation should be considered separately for en-route and terminal facilities and services, particularly with respect to quality because different criteria often apply. But, certain aspects must be considered when generating quality indicators. They include:

- Availability and provision of CNS/ATM system infrastructure;
- Type of equipment in use and its maintenance standards;
- Systems' differing levels of complexity, thereby necessitating complexity factors;
- Effects such as the nature of traffic, its density, flow, mix, peaks, patterns and volume;
- Number and location of the country's airports;
- Airspace utilisation and organisation;
- Co-ordination procedures between ATC units;
- Presence of SIDs (Standard Instrument Departure procedures) and STARs (Standard Instrument Arrival procedures);
- Staffing levels and the training procedures employed;
- Route network in between city pairs (both national and international);
- System time delays.

To develop and deduce a definitive list of suitable indicators, it is necessary to analyse all relevant information sources and determine whether their content is pertinent. The sources include:

- Countries' Aeronautical Information Publications (AIP), which<sup>1109</sup> are "intended primarily to satisfy international requirements for the exchange of aeronautical information of a lasting character essential to air navigation. They constitute the

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<sup>1109</sup> According to ICAO Annex 15.



basic information source for permanent information". AIPs are usually divided into three parts (general, en-route and airport) and contain information on:

- ✓ The authorities responsible for provision of air navigation facilities and services, based on the categorisation cited in **Section 5.4.1**;
  - ✓ Conditions under which the (en-route) facilities and services are available for national and international use;
  - ✓ National regulations and practices in conjunction with ICAO's Standards and Recommended Practices (SARPs);
  - ✓ The airspace operated by the ANS organisation(s) in terms of its structure, Air Traffic Service (ATS) routes, availability of radio-navigation aids and navigation warnings;
  - ✓ Aeronautical charts for the country's airports;
- Handbooks which detail, among other information, the availability and provision of ATC equipment for pilots, such as **Racal Avionics' Aerad series** or the United Kingdom Royal Air Force's Flight Information Publications. Due to similarity between the two publications, this research concentrates on one type only, the Racal Avionics' Aerad series;
  - **ICAO Air Navigation Plans (ANPs)**, which describe the facilities, services and procedures required for international air navigation within the specified regions. These plans also constitute recommendations for nations to follow regarding operations at airports, on ATS and associated routes, subject to air traffic flow management, using air traffic services and telecommunications facilities;
  - **ICAO Annexes**, in particular:
    - ✓ *Annex 10* on Aeronautical Telecommunications, which contains guidelines on the provision and specifications of radio navigation, communication and surveillance facilities and systems;
    - ✓ *Annex 11* on Air Traffic Services, which covers the application and scope of ATC, flight information, alerting and other air traffic services;
  - Publications such as the **Jane's Information Group's** annual ATC books and their Special Report on the worldwide ATC market;
  - Regional bodies such as **Eurocontrol**, the US Federal Aviation Administration (FAA) and the International Federation of Air Line Pilots' Associations (IFALPA), whose approaches are discussed in **Sections 7.2.1** and **7.2.2**;
  - Industry articles and papers, which may contain financial and technical accounts of countries' and/or providers' CNS/ATM systems;
  - **Part 1 of this dissertation** contains an evaluation of CNS/ATM.

Thus, given that a sizeable amount of relevant information exists, it is imperative to determine what is acutely useful for assessing the quality of nations' CNS/ATM systems. Although somewhat dependent on the size and detail of the evaluation being performed, consider the sources individually for both en-route and terminal navigation facilities and services, thus:

- Based on their obligations as members of ICAO, countries' AIPs should contain comprehensive, useful lists of equipment and services for individual countries that



are updated quite regularly. However, due to inconsistencies with the information, they are not useful for pan-regional or worldwide benchmarking;

- ❑ **Racal Avionics' Aerad series** periodically publish lists by name of communication and navigational aids divided into four worldwide regions;
- ❑ **ICAO Air Navigation Plans (ANP)** provide listings by country of communication and radio navigation aids, but are not up to date, noting that equipment sometimes is not even in service;
- ❑ Regional bodies such as the **FAA** and **IFALPA** grade countries' quality of airports and ATC using air transport body blacklists. **Section 7.2.1** covers their procedures, which are employed in the benchmarking analysis;
- ❑ **Eurocontrol's** method is detailed in **Section 7.2.2** and contains many useful indicators for determining the quality of terminal and en-route ATC;
- ❑ **Jane's annual ATC publications**<sup>1110</sup> and reports<sup>1111</sup> contain listings of current ATC programmes that are useful for cross-referencing or familiarisation purposes, but not for applying quality indicators. Their listings may also be helpful to a stakeholder should they wish to ascertain specific information about a programme;
- ❑ **Industry articles and papers** can be used for cross-referencing and familiarisation purposes where en-route information exists;
- ❑ The evaluation of CNS/ATM in **Part 1** of this dissertation may be used for more specific project analyses.

Whilst many sources exist, it is essential that information is comparable and realistic to facilitate accurate international and interregional comparisons. This limits the scope of data that are available. Additionally, it should be noted that it is possible to analyse the quality of CNS/ATM from the perspectives of different stakeholders.

## **2. Quality indicators**

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In order to develop a framework that indicates the quality of a nation's air traffic services and facilitates international comparisons, a list of measures should be drafted and integrated. Therefore, with reference to the aspects discussed above and information available in the sources, consider the following framework indicators for en-route and terminal navigation under the respective measure headings:

### **General measures**

- Total number of flight hours in the country's aviation system (commercial, military and general aviation);
- Total number of movements per hour;
- Forecast of annual traffic handled at en-route centres and in the terminal environment.

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<sup>1110</sup> Edition analysed was 'Jane's Air Traffic Control' – 6<sup>th</sup> Ed. 1999/2000.

<sup>1111</sup> 'The World Market for ATC Equipment' – Philip Butterworth-Hayes, September 1996.



**Institutional measures**

- ANS organisational performance (see **Section 7.2.3**);
- Situation regarding planning and implementation of new facilities and services;
- Effectiveness of the country's Aeronautical Information Services (AIS).

**Personnel measures**

- Amount of experienced staff and their competence (ability to cope with automated and other complex systems);
- Employee productivities (see **Section 7.2.3**);
- Occurrence of any human factors related errors;
- Number of trained operations inspectors;
- Adequate provision of search and rescue persons;
- Attitudes to discipline;
- Proficiency of spoken English.

**Environmental measures**

- Effects of emissions:
  - *Estimated fuel consumption / optimum fuel consumption;*
  - *Taxi time / optimum taxi time.*

**Availability measures**

- Number of sufficiently accurate navigation aids:
  - *In the airport environment:*
    - Instrument Landing Systems (ILS);
    - Localisers (LLZ) in the horizontal plane only;
    - VOR/DME/NDB<sup>1112</sup> where no ILS or LLZ exists;
    - Augmented satellite facilities;
  - *In the en-route environment:*
    - VOR/DME/NDB ground aids;
    - (Augmented) satellite aids;
- Sufficient provision of airport CNS/ATM services in the terminal area:
  - *Categorised by average number of airports with:*
    - Approach control services;
    - Tower-based aerodrome control services only;
    - Aerodrome flight information services at smaller airports;
    - No ATC at all, other than common traffic advisory facilities;
- Adequate provision of CNS/ATM control in the en-route environment:
  - *Controlled airspace or information-only services;*
  - *Whether procedural or radar-based ANS;*
- Availability of air-ground communications:
  - *Coverage of VHF network and ground-ground connections with AFTN<sup>1113</sup>;*
- Availability of accurate meteorological advice;
- Age, condition and maintenance standard of equipment;

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<sup>1112</sup> VOR/DME/NDB – VHF Omnidirectional Radio Range / Distance Measuring Equipment / Non-Directional Beacon.

<sup>1113</sup> AFTN – Aeronautical Fixed Telecommunications Network.

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- Suitability of equipment location and its housing environment;
- Existence of reliable support and back-up;
- Provision of effective search and rescue equipment;
- Capacity at airports:
  - *Aircraft movements at peak hours / declared capacity;*
- Availability of airspace:
  - *Allowed minimum separation between aircraft;*
  - *Number of routes and level of freedom;*
  - *Ease of access to airspace;*
  - *Number of aircraft operator preferred routes accepted / number of flight plans submitted;*
  - *Availability of airspace for military purposes ~ presence of danger areas;*
- Disruption caused by unavailability:
  - *Number of flights delayed, re-routed, cancelled or diverted as a result of equipment unavailability / number of planned flights;*
  - *Time lost due to any component of the CNS/ATM system being unavailable.*

### Efficiency measures

- Reliability of facilities and services – customer performance requirements;
- Delays:
  - *Causes of delay;*
  - *Tendency for ANS-dependent delays;*
  - *Delay or punctuality rates:*
    - Total number of delayed flights / total number of flights;
    - Total minutes of departure delay / number of delayed flights;
- Capacity management (with respect to delay and traffic volume):
  - *Capacity index;*
- Predictability:
  - *Anticipated delay:*
    - Difference between scheduled and optimum gate-to-gate time;
  - *Variability in arrival delay:*
    - Standard deviation of arrival delay;
- Airspace structure:
  - *Rationalisation of area control centres and communal terminal control centres;*
  - *Management of region's airspace;*
- Ability to meet demand;
- Efficiency of the route structure:
  - *1 - (preferred route length - optimal route length) / optimal route length;*
- Flexibility of the CNS/ATM system to deal with traffic's varying density, flow, mix, peaks, patterns and volume;
- Freedom to change departure time or planned route at short notice:
  - *Number of regulated flights / number of actual flights.*

### Safety measures

- Results from an international safety assessment exercise, such as the FAA's or ICAO's, which are covered in **Section 7.2.1**:
  - *Deviation from recommendations in ICAO Annexes;*



- 
- Whether flight inspections of airway procedures and instrument approaches are conducted;
  - Whether the nation's stakeholders have an opportunity to declare safety information to an agency on a confidential basis;
  - Culture of preventative maintenance;
  - Severity of accurate technical requirements;
  - Degree of compliance with aircraft certification changes;
  - Prevalence of adverse weather conditions or terrain hazards;
  - Standard of search and rescue services;
  - ANS providers' and aircraft operators' perception of CNS/ATM safety;
  - Accident indicators:
    - *Accident rates per airspace user category;*
    - *Number of mid-air collisions;*
  - Incident indicators:
    - *Incident rates per airspace user category;*
    - *Number of near-misses;*
    - *Runway incursion rates;*
    - *Number of air traffic incident reports.*

Depending on the assessment and/or benchmarking exercise being conducted, it should be possible to assess the quality of en-route and terminal facilities and services on an individual stakeholder's basis or by considering the country as a whole, thereby facilitating international and interregional contrasts. Therefore, the aforementioned list of indicators that evaluates quality issues is an important element of this framework strategy, in particular when considered in conjunction with the other list on ANS organisational performance in **Section 7.2.4** and when amalgamated with the (integration management and project appraisal technique) guidelines in **Chapter 5**.

**Section 7.3.2** performs this task for some countries on the availability and provision of countries' en-route navigational facilities and services using some of the data sources cited above. Additionally, it should be noted that a perusal through the findings of the worldwide CNS/ATM system evaluation in **Part 1** of this thesis would facilitate an initial understanding of some quality aspects associated with a nation's or region's CNS/ATM system(s).



## 7.3 Level of ANS provision

This section contains a benchmarking and contrasting analysis of worldwide provision of air navigation facilities and services in terms of:

- Efficiency of countries' Air Navigation Service (ANS) organisations;
- Standard of CNS/ATM in nations.

Split into two parts and based on some of the indicators developed in **Section 7.2**, both parts provide comparisons of service levels between countries from the five regions described in **Chapter 1**, to give an indication of what efficiencies and standards exist, in addition to validating aspects of the framework strategy that this research develops. It should be noted, however, as cited in **Section 7.2** and highlighted in the Eurocontrol performance review reports, that lack of data availability is a major issue. Thus, the benchmarking analysis of this section is not as comprehensive as that in **Section 6.3** because it is not possible to obtain information for all regions that is directly comparable and complete.

Ultimately, however, this section highlights the different levels of ANS that nations around the world provide. Information contained in this section could apply to further indicators, when the requisite data becomes available, or should a stakeholder wish to apply the indicators using in-house information.

### 7.3.1 Efficiency of countries' ANS organisations

This section details, where possible, the values of the performance indicators regarding Air Navigation Service (ANS) providers, which are determined in **Section 7.2.3**. By benchmarking some of the ANS organisational performance measures, it is possible to assess the degree of efficiency variation among countries. This can be used to identify yardstick efficiency standards. Noting that this section concludes with a contrasting analysis of values for the different sources, specific reference is made to:

- The cost effectiveness aspect of Eurocontrol's Performance Review Commission (PRC) reports due to their concentration on ANS providers;
- Manipulation of data from ICAO about financial and traffic levels of countries' route facilities (ICAO only provides en-route data), as covered in **Section 7.2.3**.

Unfortunately, due to the aforementioned lack of data in the public arena, it is only possible to determine a small number of the indicators developed in **Section 7.2.3**. Thus, this framework recommends that stakeholders create databases that harbour data to calculate the indicators.



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## PRC's cost effectiveness results

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As mentioned in **Section 7.2.2**, Eurocontrol's independent Performance Review Commission (PRC) has published its first two Performance Review Reports (PRR) for the 1998 (PRR1) and 1999 (PRR3) calendar years. Both PRRs restrict analyses to ANS providers, based on the three Key Performance Areas (KPA) of cost effectiveness, delays and safety. Noting that the latter two KPAs are assessed in **Section 7.3.2**, this section analyses the cost effectiveness of ANS provision in Europe, which relates to the ability of providers to deliver desired output at least cost. Given the PRC's claim that "there is a general lack of consistent Europe-wide information on Air Traffic Management (ATM) costs", the PRR findings show stakeholders what results exist and act as examples of this framework strategy's applicability.

The PRRs declare that only en-route ATM costs are consistently known across Europe, with little known about airport and terminal ATM costs. At present, the main source of Europe-wide consistent information is the set of data provided by States participating in Eurocontrol's Route Charges System (RCS)<sup>1114</sup>, which is available through their Central Route Charges Office (CRCO). Some forecasting elements had to be applied to obtain the values for countries. Additionally, only limited information is available on present staffing structures and virtually no information is available on present assets, with even less on future plans. Thus, given that Europe is considered to be an example of best international practice, these facts highlight the data availability problems when attempting to conduct such a benchmarking exercise. However, it should be noted that Eurocontrol members have adopted a greater level of economic information disclosure since the start of 2001. Therefore, future reports should contain greater amounts of data.

Nonetheless, the PRC studies facilitate and provide the following discussions, results and conclusions regarding the cost effectiveness of Europe's ANS providers:

- The Eurocontrol national unit rates, which are computed annually for each subscribing country (see **Section 6.2**), are not considered to be good indicators of performance because many variables exist in their determination (not just national costs) that are not relevant to the efficiency of service providers;
- Based on the table contained in **Appendix 7.7**, the total cost relating to en-route facilities in 1998 is \$3,989 million. This includes contributions to Eurocontrol, which accounted for 6.5% of the total when the cost of providing the Maastricht upper airspace facility for the four nations mentioned is excluded. It is evident that half of the cost to run Eurocontrol is incurred by France, Germany and the United Kingdom. It should be noted that the corresponding (forecast) figures for 1999 in PRR3 indicate that the total cost increased in that year to \$4,137 million;
- With reference to the 1998 breakdown values by type of expenditure in **Appendix 7.8**, and noting that PRR3 does not contain the data for 1999, it is possible to:
  - Portray the distribution of cost per type throughout all the nations participating in Eurocontrol's Route Charges System, as indicated in **Figure 7.1** overleaf, noting the significant proportion that accounts for staff expenses.

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<sup>1114</sup> See **Section 6.2.5** for a list of those nations using the RCS.



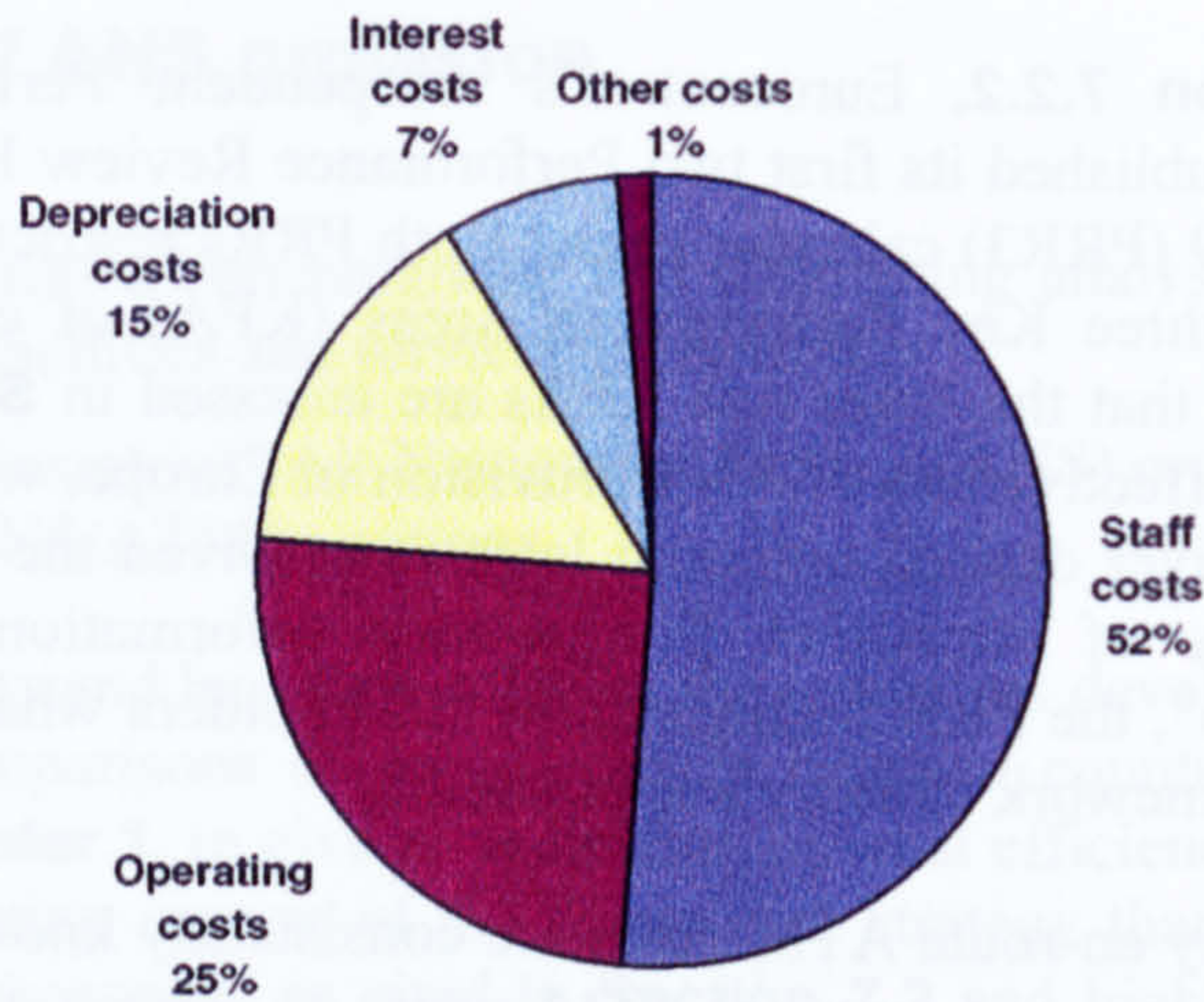


Figure 7.1 – Percentage breakdown of cost per type of expenditure for all Eurocontrol States

- Show the large variation in cost breakdown for each country as per **Figure 7.2**, noting that operating and staff costs relate to normal operating expenditures, and that interest and depreciation costs relate to capital investment:

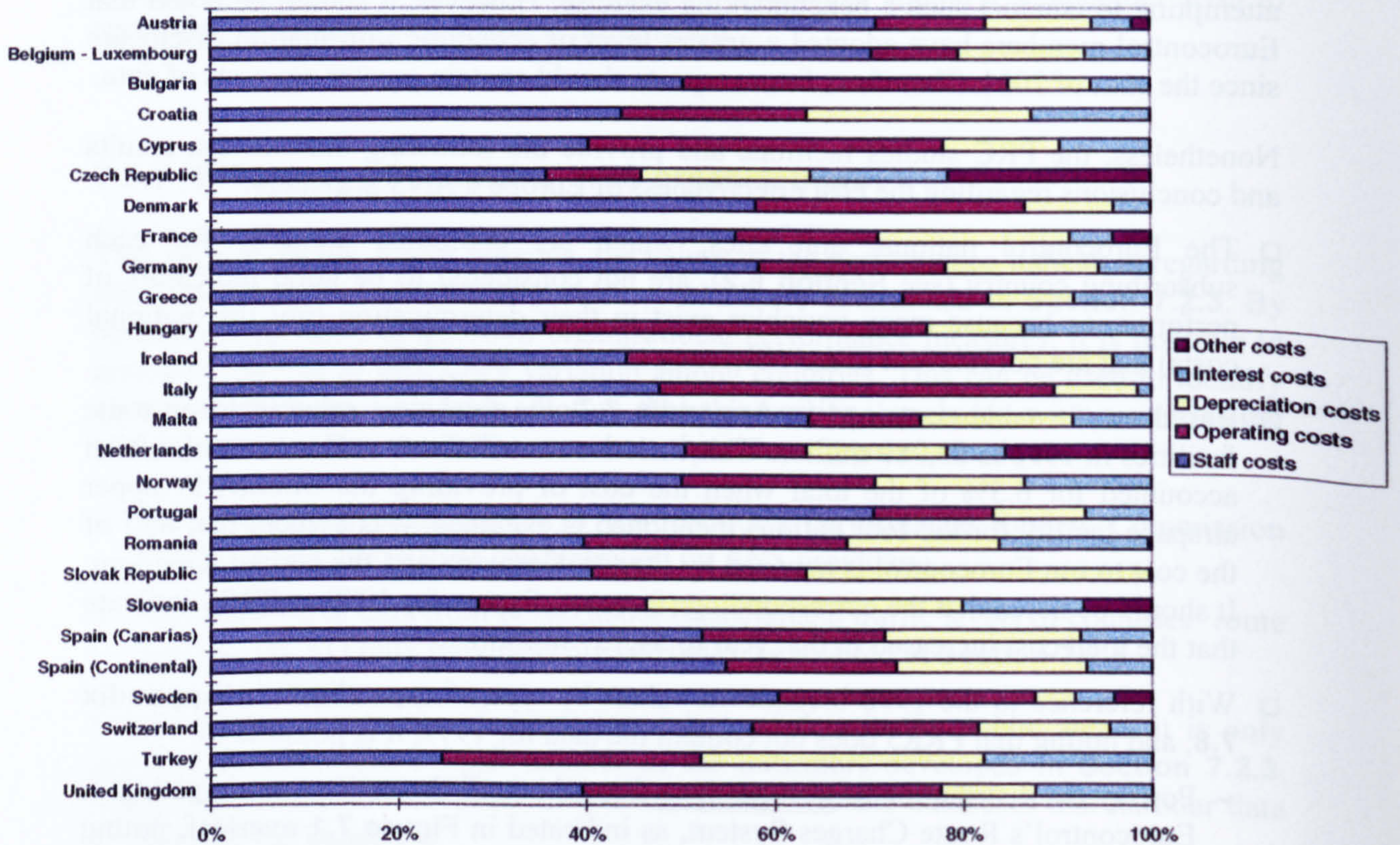
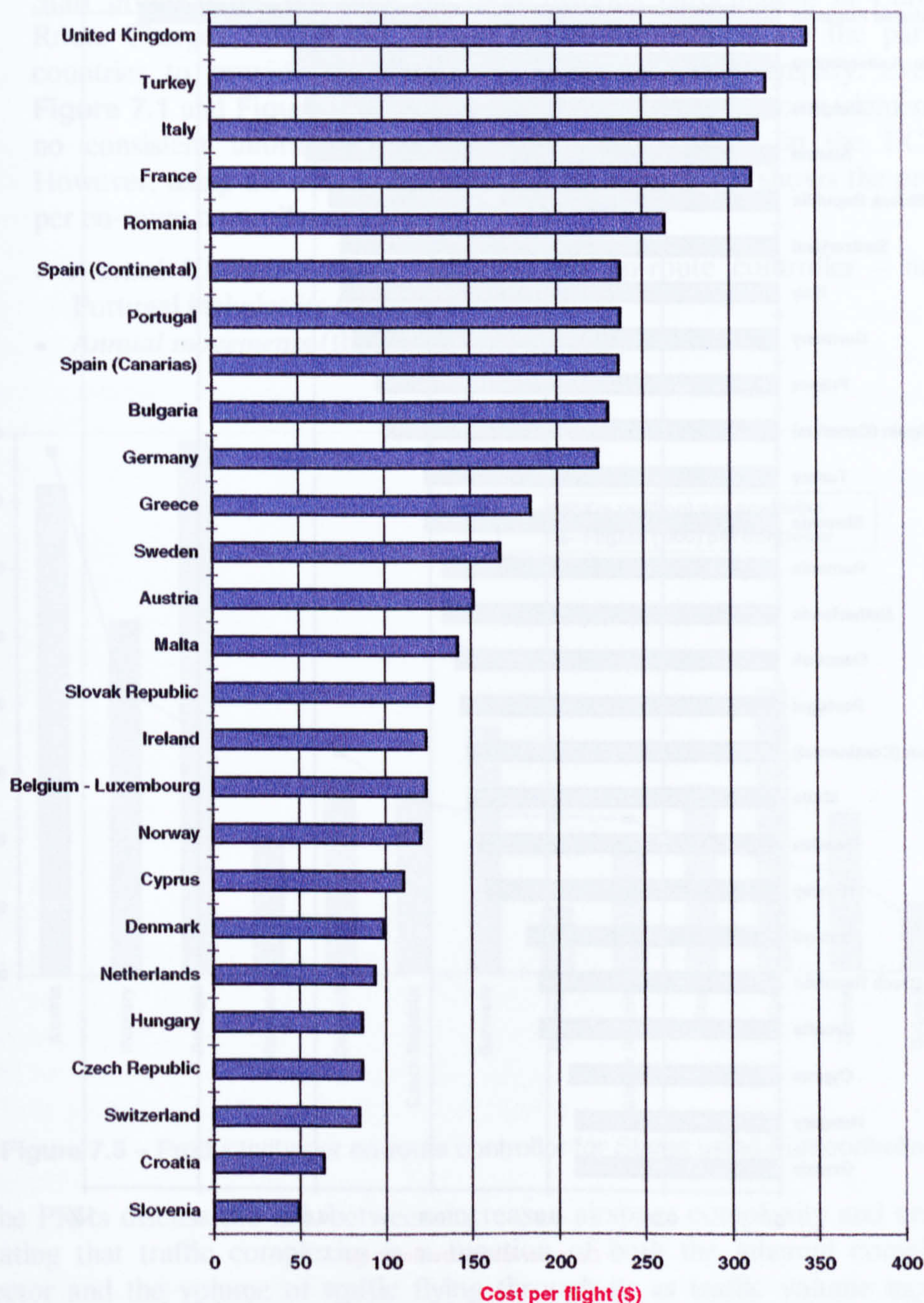


Figure 7.2 – Percentage breakdown of cost per type of expenditure for each Eurocontrol State



- Using the Key Performance Indicator (KPI) data that are summarised in **Appendix 7.9**, the PRC PRR1 report also facilitates calculation of the unit costs for en-route services in 1998, thus:
  - Noting that the accuracy is distorted by non-inclusion of approach and terminal charges, the 1998<sup>1115</sup> cost per flight is indicated in **Figure 7.3**:

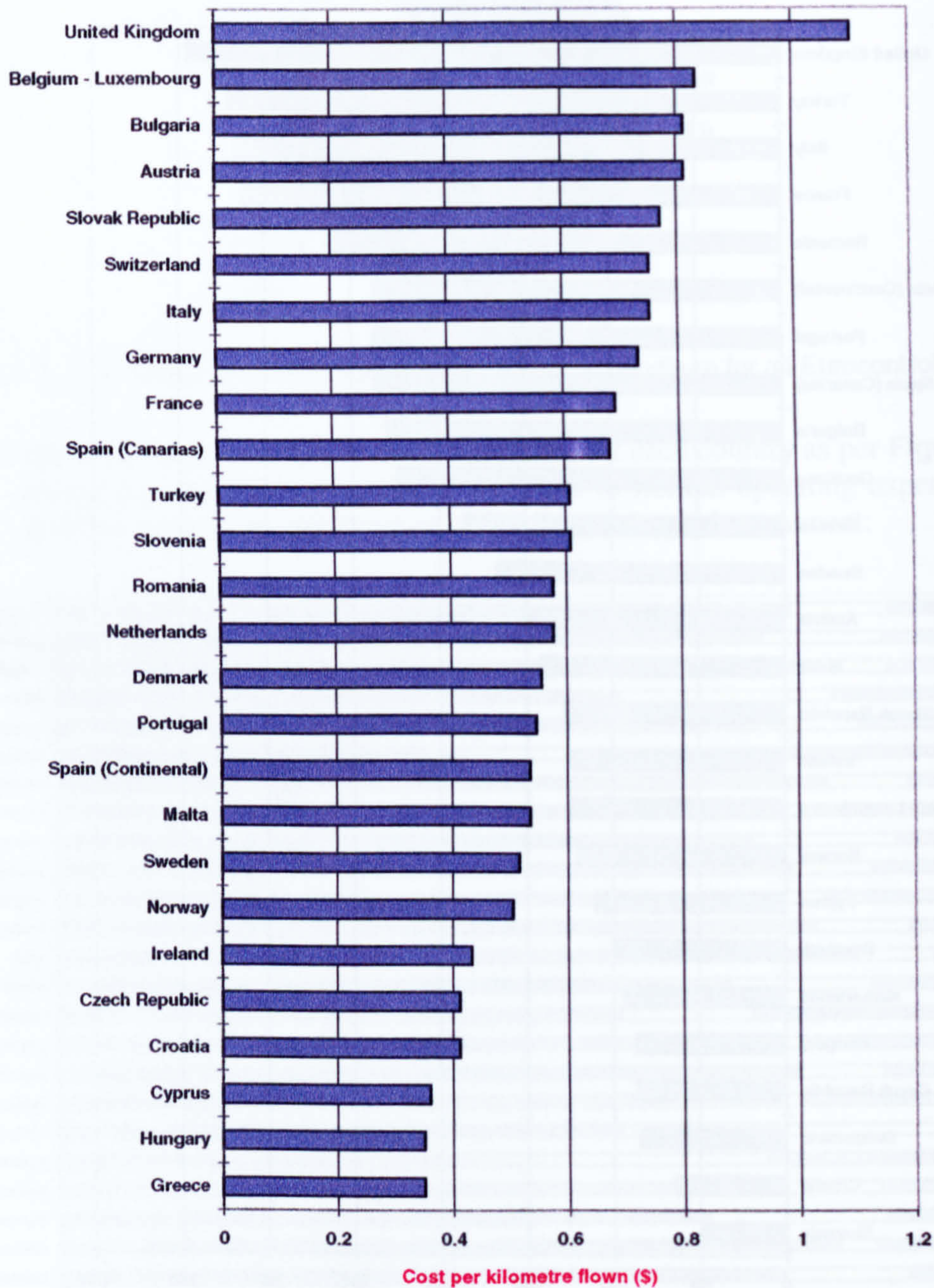


**Figure 7.3 – Cost per flight for each Eurocontrol State**

<sup>1115</sup> It should be noted that PRR3 does not contain 1999 data for nations. Additionally, an analysis of unit cost (per flight) over the period from 1994-1998 for the five largest providers demonstrates that, with the exception of the UK, results were lower in successive years.



- Due to availability of en-route data only, the 1998<sup>1116</sup> cost per kilometre flown is more accurate, although it should be noted that the cost and kilometres flown data might not always be calculated across consistent areas of airspace. **Figure 7.4** portrays the results of this indicator for the Eurocontrol countries, thus:

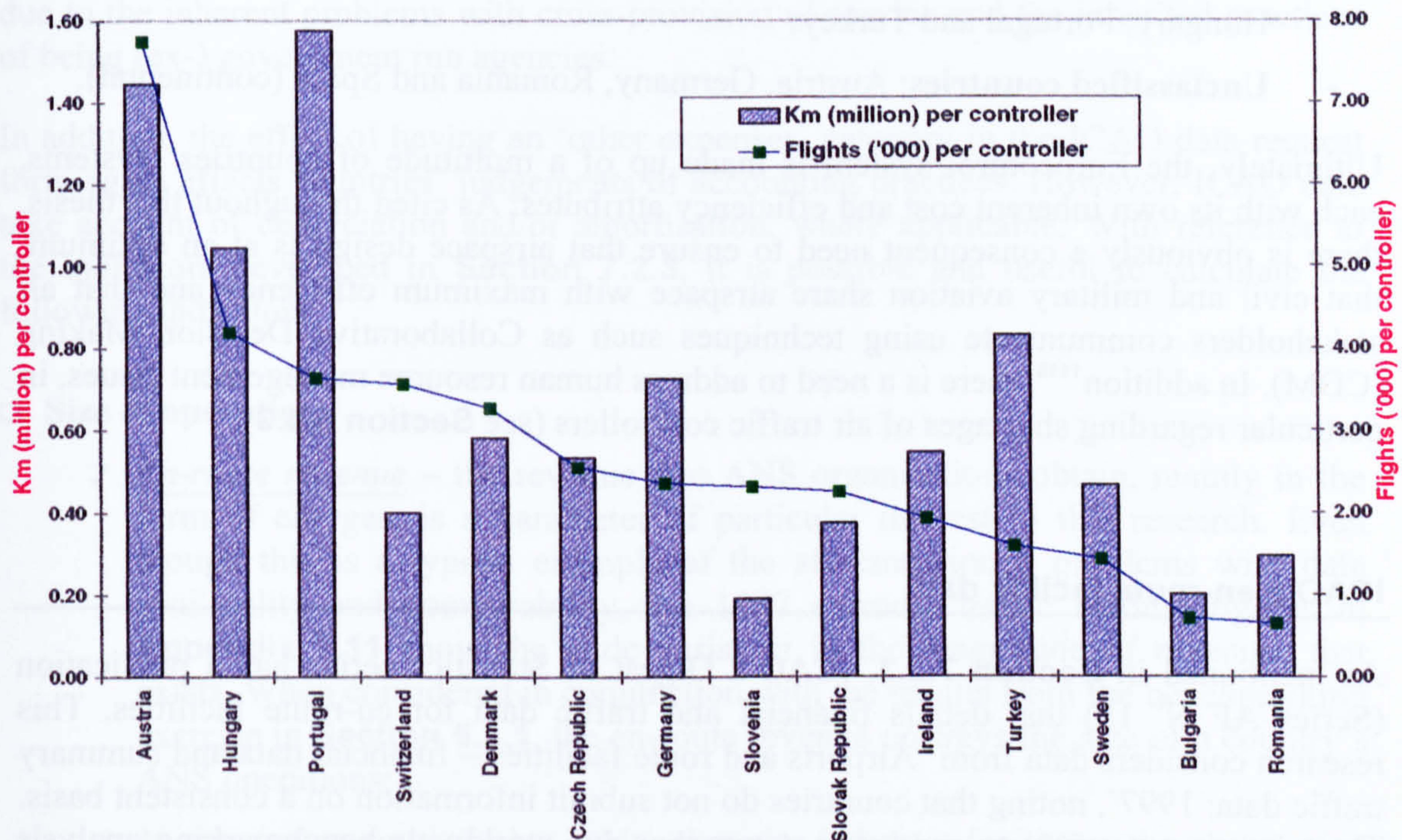


**Figure 7.4** – Cost per kilometre flown for each Eurocontrol State

<sup>1116</sup> The corresponding (forecast) figure for 1999 in PRR3 indicates that the cumulative unit cost (per km) for all member nations reduced in that year. However, PRR3 does not contain 1999 data for all countries. In addition, an analysis of unit cost (per km) over the period from 1994-1998 for the five largest providers demonstrates, with the exception of the UK, a tendency for reduced unit costs.



- Results produced by the PRC include productivity, which is an important element for measuring organisations' effectiveness. Specifically, the PRR reports discuss:
  - Asset productivity, but refers to the fact that there is no requirement for providers to publish balance sheets or investment plans and that companies' annual reports contain little pertinent data. Thus, no numerical results are provided;
  - Staff productivity, but only for those nations participating in Eurocontrol's Route Charges System (RCS) due to the requirement on the part of such countries to provide the number of controllers they employ: even though **Figure 7.1** and **Figure 7.2** above highlight staff as a high cost element, there is no consistent information available for other nations in the ECAC area. However, using the data in **Appendix 7.10**, **Figure 7.5** shows the productivity per en-route controller in terms of:
    - *Annual kilometres flown* (millions) per en-route controller – noting that Portugal includes its Oceanic FIR;
    - *Annual movements* (thousands) per en-route controller.



**Figure 7.5** – Productivity per en-route controller for States using Eurocontrol's RCS

- The PRRs discuss the link between increased airspace complexity and unit costs by stating that traffic complexity is a function of both the inherent complexity of a sector and the volume of traffic flying through it: as traffic volume increases, the complexity also rises. However, unit costs fall since, in the short to medium term, a large portion of the cost is fixed. The reports conclude by claiming that nations can be divided into four groupings, thus:
  - Relatively complex airspace in relatively expensive countries;
  - Relatively complex airspace in relatively inexpensive countries;



- Less complex airspace in relatively expensive countries;
- Less complex airspace in relatively inexpensive countries.

Therefore, there are other reasons for variations in the levels of unit costs with complexity: for instance, the proportion of overflights that a nation controls because a higher proportion of overflights is, in theory, less complex to control than a lower proportion.

Correspondingly, a Eurocontrol Experimental Centre report<sup>1117</sup> identified the following classes of countries using 1998 data:

- **High costs:** Bulgaria, France, Italy, Spain (Canarias) and the United Kingdom;
- **Low costs:** Croatia, Czech Republic, Denmark, Greece, Ireland, Malta, Norway, Slovenia and Sweden;
- **Low cost per flight with relatively high cost per kilometre:** Belgium – Luxembourg, Croatia, Netherlands, Slovak Republic, Slovenia and Switzerland;
- **Relatively high cost per sector compared to the cost per kilometre:** Cyprus, Hungary, Portugal and Turkey;
- **Unclassified countries:** Austria, Germany, Romania and Spain (continental).

Ultimately, the Eurocontrol system is made up of a multitude of countries' systems, each with its own inherent cost and efficiency attributes. As cited throughout this thesis, there is obviously a consequent need to ensure that airspace design is at an optimum, that civil and military aviation share airspace with maximum efficiency and that all stakeholders communicate using techniques such as Collaborative Decision Making (CDM). In addition<sup>1118</sup>, there is a need to address human resource management issues, in particular regarding shortages of air traffic controllers (see Section 5.4.3).

### **ICAO's en-route facility data**

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As mentioned in Section 7.2.3, ICAO's Digest of Statistics series has a publication (Series AF N<sup>o</sup> 15) that details financial and traffic data for en-route facilities. This research considers data from 'Airports and route facilities – financial data and summary traffic data: 1997', noting that countries do not submit information on a consistent basis. Thus, it is not possible to conduct a comprehensive worldwide benchmarking analysis of ANS provider organisational performance either for one particular year or on an evolutionary basis. This latter aspect is essential when considering the effects of investments, due to their inherent nature to be sporadic.

Nonetheless, this section uses the data that are available to illustrate those indicators and their magnitudes that are possible to calculate, in order to provide some approximate

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<sup>1117</sup> 'Cost of the en-route air navigation services in Europe' – Eurocontrol Experimental Centre, June 1999.

<sup>1118</sup> 'Eurocontrol's 1999 Performance Review Commission' – air traffic management, September/October 2000.



regional guidelines. Therefore, with reference to **Appendix 7.11**, consider the following measurements that may be used:

- **En-route revenue;**
- **En-route expenses** – the cost of providing all the facilities and services for en-route ANS in nations, which is broken down into the following categories where possible:
  - *Total;*
  - *Operations and maintenance;*
  - *Administration;*
- **Total flights** – this measurement is useful for linking the en-route revenues and expenses so that the volume of traffic controlled is reflected in the analysis.

Even though the three aforementioned measurements are the only widely available data from the ICAO source, they may lack consistency because the ANS providers usually consist of a multitude of departments, with functions for the provision of en-route and terminal navigation facilities and services apportioned among them. It is probable that accounting practices are not always conducted in strictly accurate and similar manners due to the inherent problems with cross-provision of service and the inherited practices of being (ex-) government run agencies.

In addition, the effect of having an ‘other expenses’ category in the ICAO data request form again affects countries’ judgements of accounting practices. However, ICAO data take account of depreciation and/or amortisation, where applicable. With reference to the indicators developed in **Section 7.2.3**, it is possible and useful to calculate the following indicators:

- **Size of operations**
  - ✓ *En-route revenue* – the revenue that ANS organisations obtain, mainly in the form of charges, is a parameter of particular interest to this research. Even though this is a typical example of the aforementioned problems with data availability and comparability, the 1997 en-route traffic income figures in **Appendix 7.11** show the wide variation in the magnitude of revenues that exists. When considered in conjunction with the results from the benchmarking exercise in **Section 6.3.1**, the en-route revenue portrays the size of a country’s ANS operations;
  - ✓ *Number of en-route flights* – this other size indicator facilitates the observation that there is a large difference in en-route traffic levels among nations.
- **Relative cost of providing en-route facilities and services**
  - ✓ *Total national expenses per flight handled* – which **Figure 7.6** overleaf shows to vary substantially among regions and individual nations within regions. The results for Europe are similar to those in **Figure 7.3**, albeit for two different periods, 1997 and 1998 respectively.



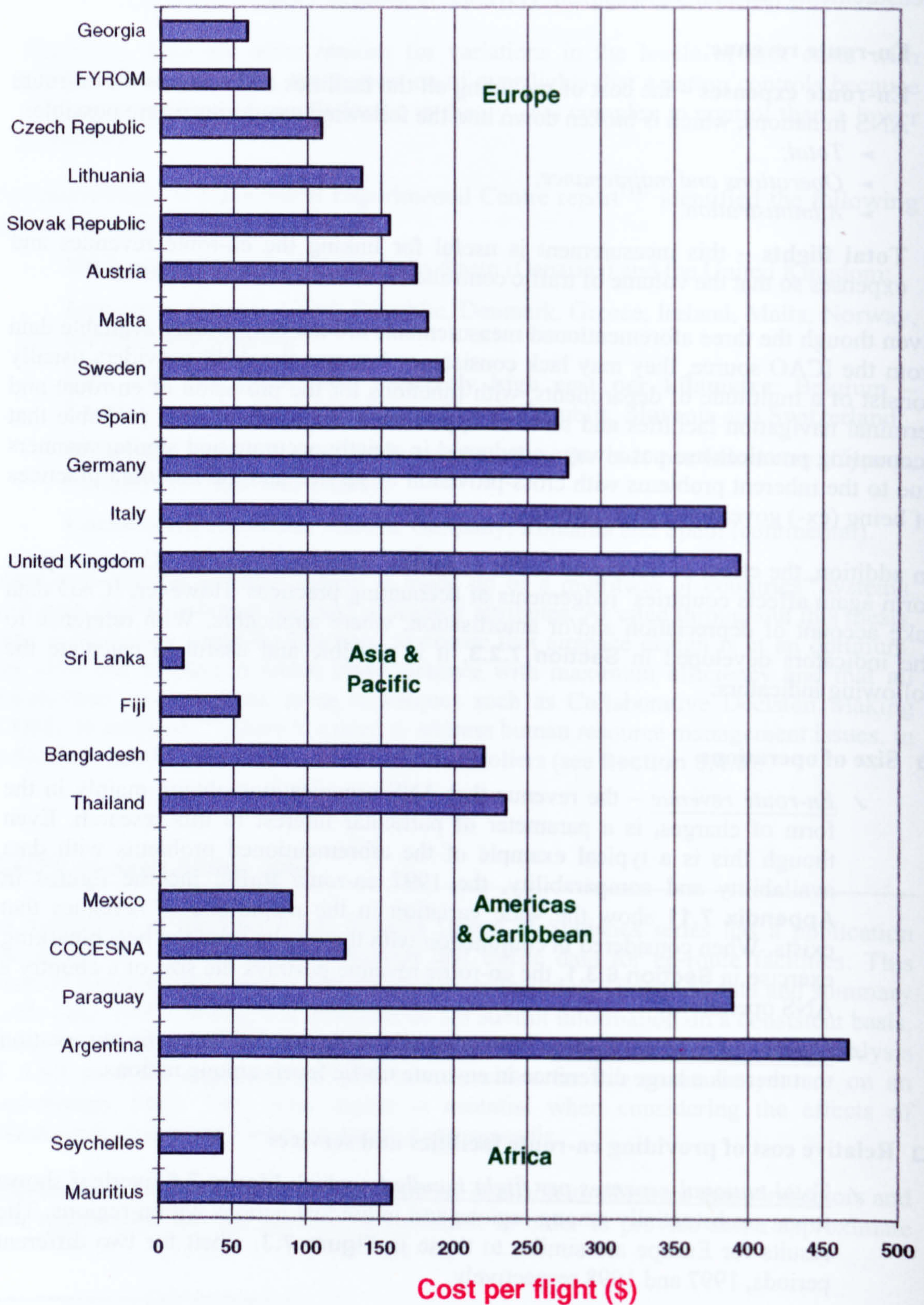
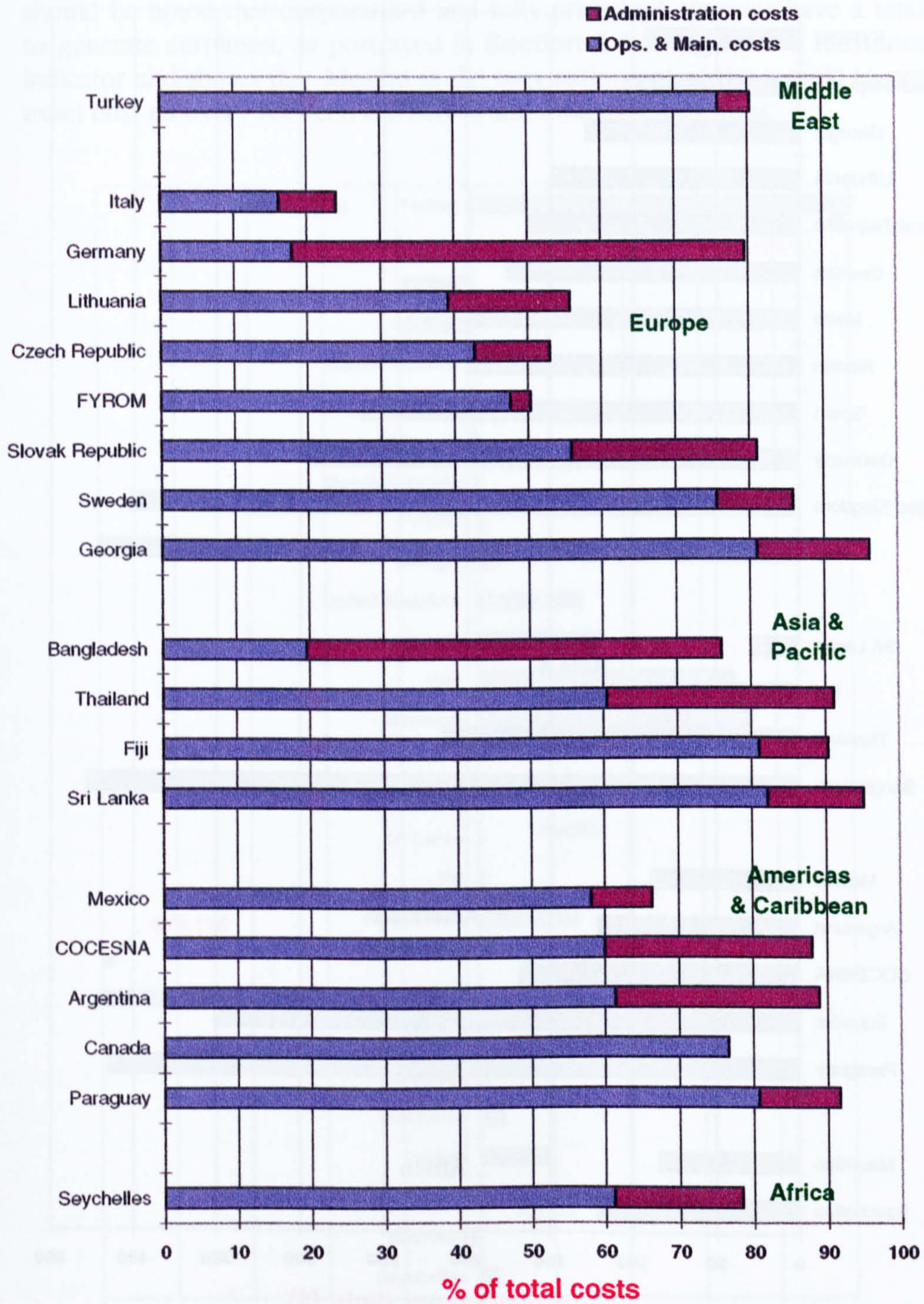


Figure 7.6 – Cost per flight using ICAO data



- Operations and maintenance costs per total national expenses and administration costs per total national expenses, which are both portrayed in **Figure 7.7**, thus:

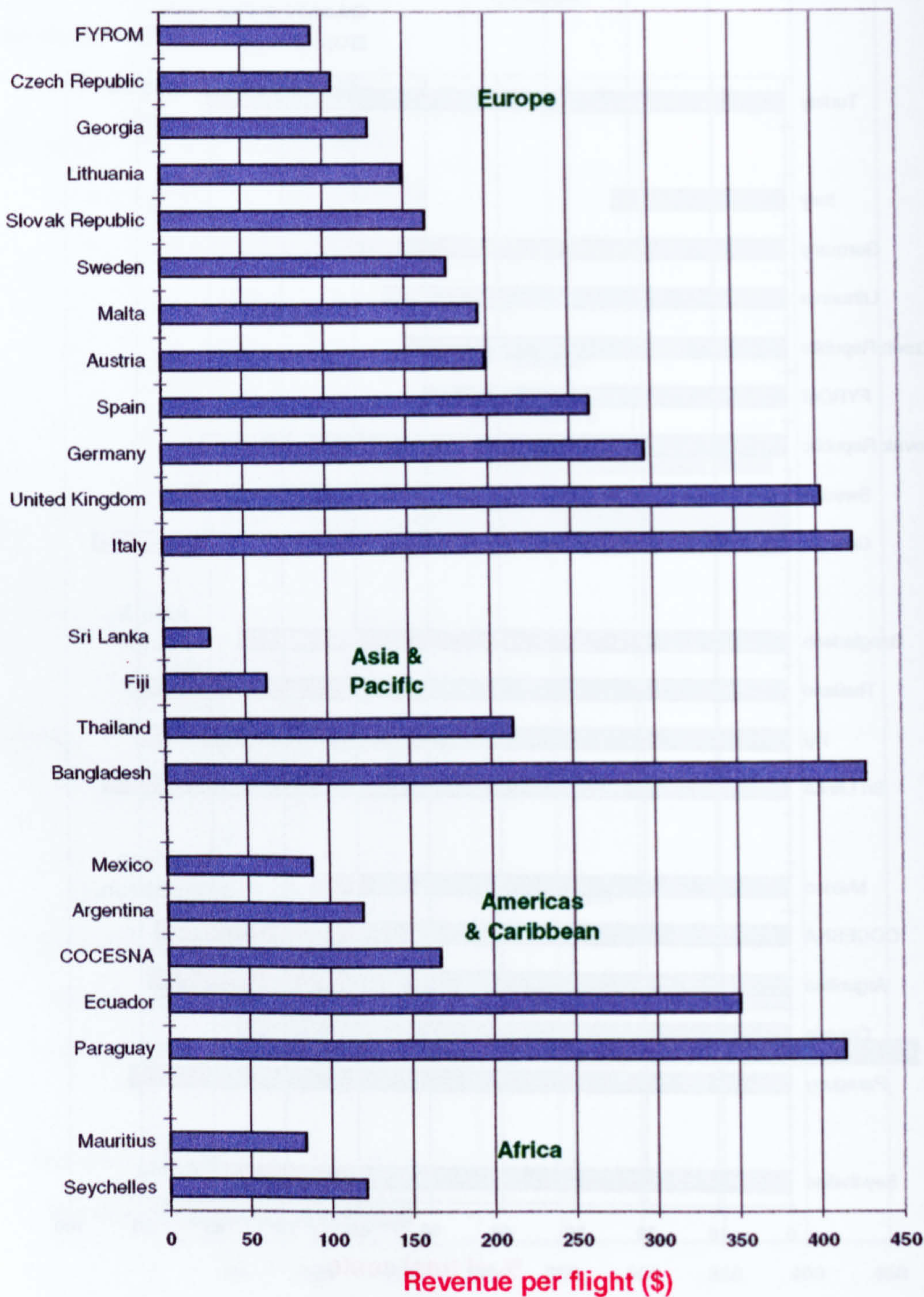


**Figure 7.7** – Percentage breakdown of cost per type of expense using ICAO data



□ **Productivity**

- Total en-route revenue per flight handled – which varies significantly within regions, as portrayed in **Figure 7.8**:



**Figure 7.8** – Revenue per flight using ICAO data



□ Profitability

- *Profit* – the difference between total revenues and costs gives an indication of the degree to which the countries implement ICAO’s cost recovery policies, although the different accounting practices could apportion any surplus to funding future investments, consequently not being in breach of suggestions. It should be noted that corporatised and fully privatised agencies have a tendency to generate surpluses, as portrayed in Section 6.4.1. Figure 7.9 illustrates this indicator and shows that Mexico is the only nation out of the sample to practice exact cost recovery between total costs and total expenses, thus:

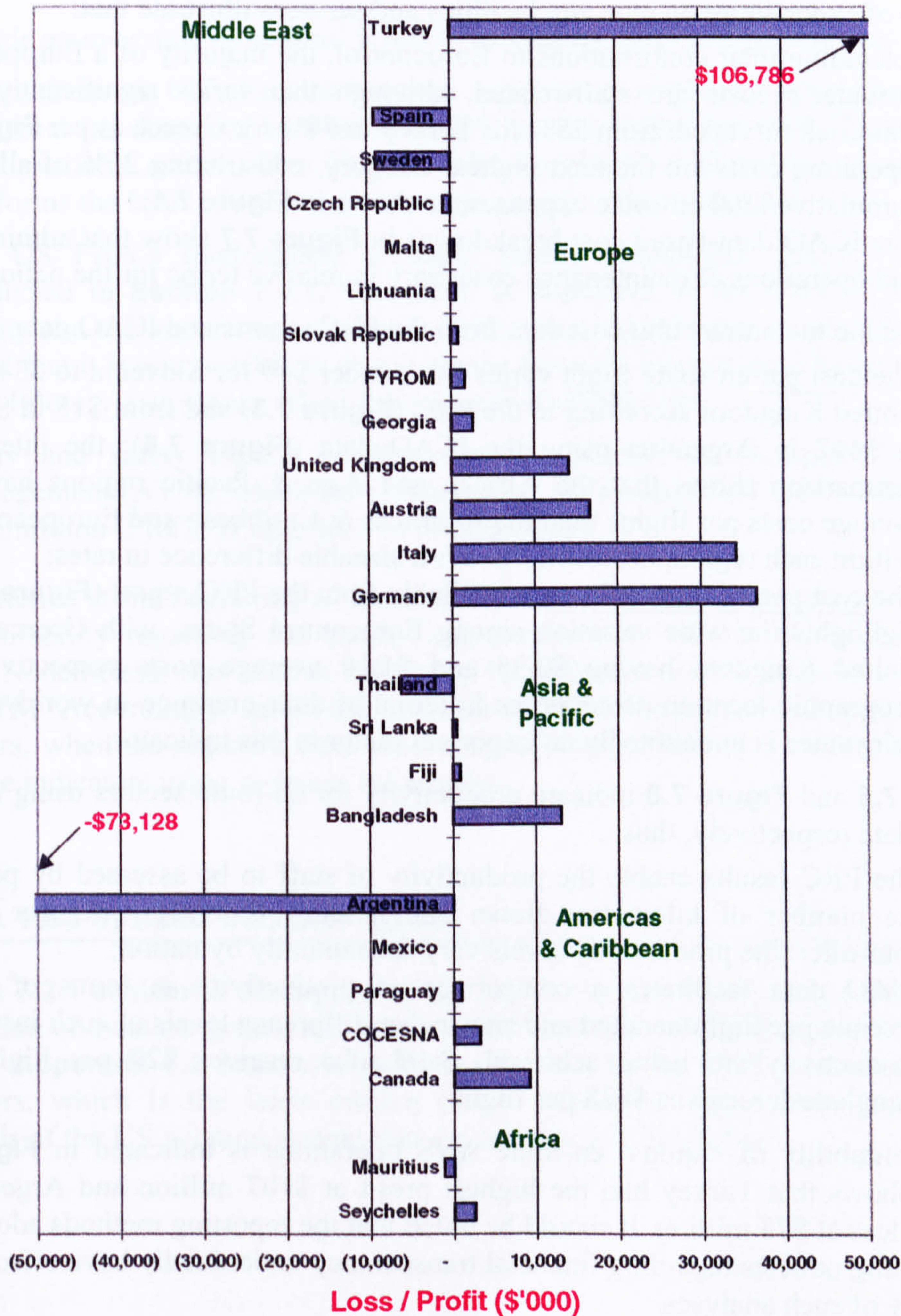


Figure 7.9 – En-route profit using ICAO data



## Comparisons of values

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This section, on the efficiency that countries' ANS organisations manage to achieve, highlights the lack of consistent data that are available from agencies and nations around the world. However, based on the indicators developed in Section 7.2.3, it has been possible to calculate some parameters that portray the organisational performance of countries. Thus, in order to provide a summary of this research's findings on efficiency levels, consider the following points:

- Results from the Eurocontrol PRC's cost effectiveness analyses and the ICAO data by type of expenditure on en-route facilities and services illustrate that:
  - Excluding their contributions to Eurocontrol, the majority of a European ANS provider's costs are staff-related, although this varies significantly for the countries surveyed: from 25% for Turkey to 74% for Greece as per Figure 7.2;
  - Operating costs are the next highest category, constituting 25% of all nations' cumulative total en-route expenses, as shown in Figure 7.1;
  - The ICAO data-based cost breakdowns in Figure 7.7 show that administration and operations & maintenance costs vary in relative terms for the nations;
- It is possible to contrast unit cost data from the PRC reports and ICAO data, thus:
  - The cost per en-route flight varies from under \$49 for Slovenia to \$345 for the United Kingdom according to the PRC (Figure 7.3) and from \$15 in Sri Lanka to \$467 in Argentina using the ICAO data (Figure 7.6): the interregional comparison shows that the African and Asia & Pacific regions have lower average costs per flights than the Americas & Caribbean and European regions. Within each region, however, there is a sizeable difference in rates;
  - The cost per kilometre flown is available from the PRC report (Figure 7.4) and highlights the wide variation among Eurocontrol States, with Greece and the United Kingdom having \$0.35 and \$1.10 average costs respectively. The geographic location of countries in terms of their presence in worldwide city-pair routes is undoubtedly an important factor in this indicator;
- Figure 7.5 and Figure 7.8 indicate productivity for en-route sectors using PRC and ICAO data respectively, thus:
  - The PRC results enable the productivity of staff to be assessed by portraying the number of kilometres flown and amount of movements per en-route controller: the productivity levels vary substantially by nation;
  - ICAO data facilitates a comparison of productivity in terms of en-route revenue per flight handled and shows that difference levels of such institutional productivity are being achieved: Sri Lanka receives \$29 per flight, while Bangladesh receives \$428 per flight;
- The profitability of nations' en-route ANS operations is indicated in Figure 7.9, which shows that Turkey had the highest profit at \$107 million and Argentina the highest loss at \$73 million. It should be noted that the reporting methods adopted and the existing policies regarding financial transparency undoubtedly have effects on the accuracy of such analyses.



### 7.3.2 Standard of countries' CNS/ATM

This section uses sources cited in **Section 7.2.4** to categorise some of the quality indicators developed, in order to ascertain the standard of countries' CNS/ATM systems. Additionally, the range of different aspects considered in the indicators aims to help stakeholders using this framework for the purposes of improving the implementation of future air navigation systems. Indeed, nationally or regionally specific evaluations by stakeholders should use the evaluation of CNS/ATM in **Part 1** of this thesis as a means of comparing activities in the country or region under review.

To provide an overview of nations' CNS/ATM quality, this section considers:

- Results from the US's Federal Aviation Administration (FAA) System Safety office indicators (as discussed in **Section 7.2.1**) annual report for 1998<sup>1119</sup>, which is the latest available edition. This illustrates the magnitude of some indicators in the US and forms the basis of other indicators developed in **Section 7.2.4**;
- The US FAA's International Aviation Safety Assessment (IASA) facility, as conducted in **Section 7.3.1**, because it is indicative of the CNS/ATM system's quality and the importance countries attach to having efficient systems. It should be noted that it is not possible to obtain results from the International Federation of Air Line Pilots' Associations (IFALPA) classification process;
- Delay and safety aspects of Eurocontrol's studies on European Air Traffic Management (ATM), which are conducted by the independent Performance Review Commission (PRC), as described in **Section 7.2.2**.

As mentioned at the beginning of **Section 7.3.1**, there is a distinct lack of comparable data availability regarding the quality and performance of Air Navigation Services (ANS). Nonetheless, this section highlights the different quality standards of nations' CNS/ATM. Accordingly, information contained in this section could apply to further indicators, when the requisite data becomes available, or should a stakeholder wish to apply the indicators using in-house information.

#### US FAA 1998 Systems Indicator report

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**Section 7.2.1** contains a description of the FAA's System Safety office and its annual publication of aviation system and environment statistics, which are listed in **Appendix 7.1** and **Appendix 7.2** respectively. With reference to the 1998 publication of these indicators, which is the latest edition that is available, this section highlights the standards of the US aviation system that are relevant to CNS/ATM.

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<sup>1119</sup> 'Aviation System Indicators: 1998 Annual Report' – US Department of Transportation, FAA, 1999.



Results for 1998 may be portrayed under the following four headings, thus:

### 1. Accident<sup>1120</sup> Indicators

- Large air carrier accident rates:
  - 48 accidents;
  - 0.29 per 100,000 flight hours;
  - 0.47 per 100,000 departures;
- Commuter air carrier accident rates:
  - 8 accidents;
  - 1.56 per 100,000 flight hours;
  - 1.01 per 100,000 departures;
- Air taxi accident rates:
  - 79 accidents;
  - 3.11 per 100,000 flight hours;
- General aviation accident rates:
  - 1,907 accidents;
  - 7.12 per 100,000 flight hours;
- Rotorcraft accident rates:
  - 205 accidents;
  - 8.55 per 100,000 flight hours;
- Mid-air collision accident rates:
  - 15 accidents;
  - 0.032 per 100,000 flight hours.

It should be noted that the causes of accidents are not given in the report, but that the latter indicator, the mid-air collision accident rate, is the most pertinent for CNS/ATM. This result, at approximately  $3 \times 10^{-7}$ , may be equated with the average air transport crash rate of  $5 \times 10^{-7}$ .

### 2. Incident<sup>1121</sup> Indicators

- Aircraft incident rates:
  - not complete;
- Air carrier near mid-air collision rates<sup>1122</sup>:
  - 207 near mid-air collisions;
  - 0.51 near mid-air collisions per 100,000 flight hours;
- Pilot deviation rates:
  - 1,597 pilot deviations;
  - 3.45 pilot deviations per 100,000 flight hours;
- Operational error rates:
  - 898 operational errors;
  - 0.56 operational errors per 100,000 flight hours.

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<sup>1120</sup> An accident is where damage is caused to the aircraft, but not necessarily to its passengers;

<sup>1121</sup> An incident means that little or no damage was caused to the aircraft, but could include passenger injuries or fatalities.

<sup>1122</sup> This indicator can be very subjective, due to reporting rates.



### 3. Efficiency Measures

- Facility/service reliability<sup>1123</sup>:
  - 99.85%;
- Facility/service operational availability<sup>1124</sup>:
  - 99.38%;
- Delay<sup>1125</sup> rates:
  - 314,471 delays;
  - 195.8 delays per 100,000 facility activities;
- Delays due to volume rates
  - 44,932 delays;
  - 28.0 delays per 100,000 facility activities.

Similar to the European situation, which is described hereunder and elsewhere in this dissertation, it should be noted that the level of delays is a major source of concern and consternation for all US stakeholders<sup>1126,1127</sup>. 2000 was one of the worst years in history<sup>1128</sup>, with delays for June 2000 up 16% on 1999 values<sup>1129</sup>. New York LaGuardia airport reported average delays on all flights of 43 minutes<sup>1130</sup>.

### 4. Aviation Environmental Indicators

- Total facility activity<sup>1131</sup>:
  - 160,570,789 facility activities;
- Annual IFR aircraft handled at en-route centres<sup>1132</sup>:
  - 43,200,000 facility activities;
  - 4.41% growth on 1997.

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<sup>1123</sup> This indicator provides an aggregate estimate of the probability that a typical major facility or service will not fail during a 24-hour period based on requirements and procedures set by the US National Airspace Performance System. Use of the facilities and services include automation used to process flight data information, en-route and terminal radar and instrument landing systems.

<sup>1124</sup> This indicator provides an aggregate estimate of the percentage of time a typical major facility or service is available to users of the US National Airspace System (NAS). It is the ratio of total operating facility or service hours to maximum facility or service hours, expressed as a percentage. It is also based on requirements and procedures set by the US National Airspace Performance System. Again, use of the facilities and services include automation used to process flight data information, en-route and terminal radar and instrument landing systems. The result equates to one failure per annum.

<sup>1125</sup> Delays may result from weather, equipment failures or excessive volumes of traffic. Delays occur when an aircraft is delayed by more than 15 minutes due to the volume of aircraft being worked by the US air traffic control system.

<sup>1126</sup> 'Airlines not solely to blame for delays: Carty' – *Air Transport Intelligence*, 28 June 2000.

<sup>1127</sup> 'RAA fights notion that RJs jam up US ATC system' – *Air Transport Intelligence*, 6 November 2000.

<sup>1128</sup> 'FAA figures paint dismal 2000 delay picture' – *Air Transport Intelligence*, 1 February 2001.

<sup>1129</sup> 'US ATC delays soar again' – *Airline Business*, August 2000.

<sup>1130</sup> 'FAA outlines full extent of LaGuardia delay horror story' – *Air Transport Intelligence*, 9 November 2000.

<sup>1131</sup> Facility activity includes the number of en-route aircraft handled and the number of terminal airport/instrument operations.

<sup>1132</sup> The number of IFR aircraft handled at en-route centres is equal to twice the number of departures plus the number of IFR overflights handled by all the US FAA air route traffic control centres.



## **US FAA International Aviation Safety Assessments**

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With reference to the discussions in Section 7.2.1 on the US FAA's International Aviation Safety Assessment (IASA) programme, it is covered here because the IASA results are also indicative of the quality of CNS/ATM systems and the importance countries attach to having systems of high standards. Correspondingly, given that the majority of air navigation systems around the world are still government run, it is considered relevant to equate these results with the standards of nations' CNS/ATM.

Section 7.2.1 describes the IASA process and its relevance to ICAO activities. It uses the following two-rating criteria to designate the status of nations' aviation systems at the time of the assessment, thus:

- **Cat 1 – complies with ICAO standards;**
- **Cat 2 – does not meet ICAO aviation safety standards in all areas, which is divided into two further categories:**
  - **Countries that have air carriers with existing operations to the US at the time of the assessment. While in Cat 2 status, carriers from these countries are permitted to continue operations, but under heightened FAA surveillance;**
  - **Countries that do not have airlines with existing operations to the US at the time of the assessment. Carriers from these countries are not permitted to commence services to the US while the Cat 2<sup>1133</sup> status exists.**

Appendix 7.3 contains the latest IASA results (dated 18<sup>th</sup> January 2001) for just over 100 countries, which represent roughly half the number of nations that this research evaluates. The rated nations tend to be from the Americas & Caribbean region, Europe and parts of Asia because carriers from these countries fly to the US. The IASA results show that two-thirds of countries assessed were fully compliant with ICAO standards. Thus, over 30 countries do not meet FAA/ICAO criteria. Accordingly, it may be concluded that some of their ANS providers do not meet efficiency IASA requirements.

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<sup>1133</sup> This group of countries is designated Cat 2\*, in contrast with Cat 2 for the nations with flights to the US.

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## PRC's delay and safety results

As mentioned in Section 7.2.2, Eurocontrol's independent Performance Review Commission (PRC) published its initial annual Performance Review Report (PRR1) covering the calendar year 1998 in 1999<sup>1134</sup>. Noting that the PRC produced an interim report on delays during 1999 as PRR2<sup>1135</sup>, the subsequent PRR covering the year 1999 (PRR3) was published in 2000<sup>1136</sup>. The report on 2000 has not yet been produced.

PRR1 and PRR 3 restrict analyses to Air Navigation Service (ANS) providers based on the Key Performance Areas (KPA) of cost effectiveness, delays and safety. The former KPA is discussed in Section 7.3.1. This section analyses the results of the delay and safety assessments for the purposes of enhancing this worldwide performance analysis with data for the European region, in addition to demonstrating what statistics are available as part of this framework strategy. Some of the statistics are based on the indicators listed in Section 7.2.4. Accordingly, this section also refers to other Europe air traffic management-related safety and delay findings, which justify the need for a regional solution. Therefore, consider the delay and safety aspects separately, thus:

### 1. Delay

Problems with lack of capacity in European airspace were recognised in the summer of 1987, following excessive delays due to ATC strikes throughout Europe<sup>1137</sup>. Since then, delays in Europe have escalated. The 6<sup>th</sup> Meeting of ECAC Transport Ministers on the Air Traffic System in Europe (MATSE) at the start of 2000 focussed on the severity of European air traffic delays<sup>1138</sup>. The seriousness of the delays has received widespread attention and coverage. Indeed, delay is said to be the best parameter to describe quality of service<sup>1139</sup>.

According to PRR1 and PRR2, reactionary delays<sup>1140</sup>, Air Traffic Flow Management (ATFM) delays and ground delays were the largest categories of delays in the ECAC airspace during 1998 and 1999. Indeed, noting that similar data are not available for 1999, PRR1 cites the following distribution of causes accounts for air traffic delays in the Eurocontrol area during 1998:

- Reactionary delays: 37.7%;
- Air Traffic Flow Management (ATFM): 27.8%;
- Ground Air Traffic Control (ATC) delays: 3.7%;
- Airport (non ATC items): 14.4%;

<sup>1134</sup> 'First Performance Review Report' – Performance Review Commission, June 1999.

<sup>1135</sup> 'Special Performance Review Report on delays' – Performance Review Commission, November 1999.

<sup>1136</sup> 'Performance Review Report (covering the calendar year 1999)' – Performance Review Commission, May 2000.

<sup>1137</sup> 'The feasibility of maintaining regional airline access to congested European airports' – A Jefferson, PhD Thesis, Cranfield University, 1997.

<sup>1138</sup> 'matse/6 focuses on seriousness of delays' – era regional report, March 2000.

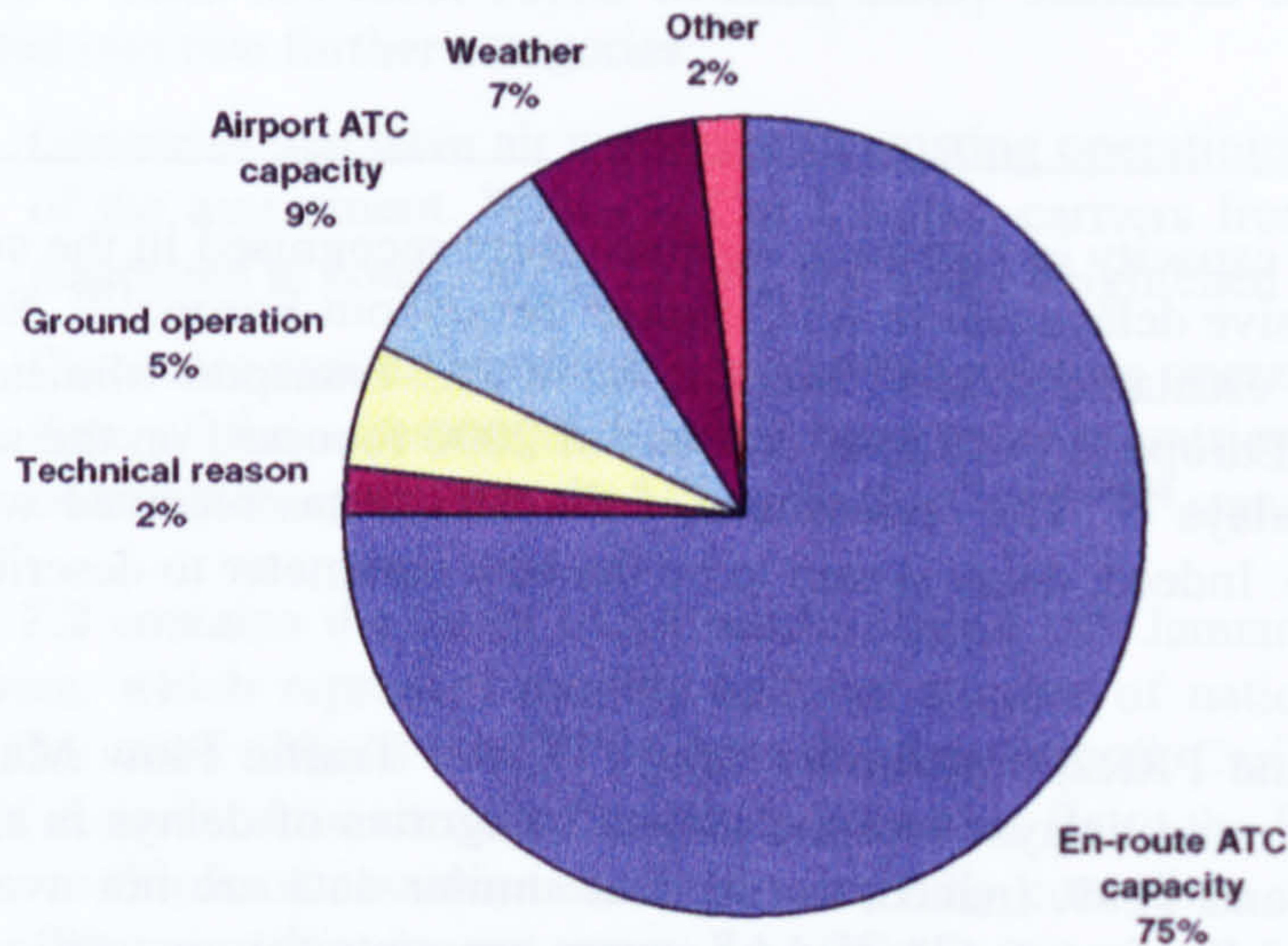
<sup>1139</sup> 'Performance assessment in the European air transportation system' – Journal of ATC, October – December 1999.

<sup>1140</sup> Reactionary delays – whereby late departures are due to late arrivals of inbound aircraft.



- Airline: 12.8%;
- Other: 3.6%.

Very little information is available to break down delays in the airport environment, so the analyses concentrate on ATFM delays: ATFM delays are imposed to a given controlled flight whenever capacities declared by control centres or airports along their routes are exceeded. Eurocontrol's Central Flow Management Unit (CFMU) manages queues for every regulated sector and airport. The ATFM delay for a given flight is that of the most penalising queue it traverses, which implies that any ATFM delay can be attributed to a single congestion origin, namely airport or sector. However, it should be noted that ATFM delay is not a good measure of airport ATM performance because, when airports are closed or capacity is significantly reduced, some or all flights are cancelled, which has a positive impact on delay records because cancellations are not reflected in delay indicators. Additionally, a large part of ATM-related delays at airports, such as holding and taxiing, are not accounted as ATFM delays. Nonetheless, **Figure 7.10** portrays the individual causes of ATFM delay during 1998 and highlights the fact that the primary cause of ATFM delay is a lack of ATC capacity related to en-route services<sup>1141</sup>, which includes both terminal and en-route control sectors.



**Figure 7.10 – ATFM delay distribution by causes**

Using PRC results and the annual Eurocontrol/ECAC report on en-route ATFM delays for 1999<sup>1142</sup> (the edition covering 2000 is not yet available), in addition to industry articles and papers, the following points summarise the evolution and status of ATFM delays in the European region from 1997 to 2000:

- **Total flights:** the number of flights subject to ATFM rose by 5% from 1997 to 1998 and then by 6% during 1999 when compared with 1998;

<sup>1141</sup> Indeed, no measurable increase in overall system capacity was achieved during 1998.

<sup>1142</sup> 'ATFM delays to air transport in Europe: Annual report 1999' – Eurocontrol/ECAC, 2000.



- **Delayed Flights:** An increase of 16.7% was experienced in the total number of delayed flights during 1998 compared with 1997 and a corresponding rise of 34% over 1998/1999;
- **Total delay:** the ATFM system experienced a total delay, in terms of minutes, in 1998 that was 30.7% greater than 1997's. The corresponding change between 1998 and 1999 was +58%<sup>1143</sup>, which equates to 320 aircraft being permanently grounded<sup>1144</sup>. An analysis of the total delay during the period from May-September 2000 with respect to the same interval during 1999 concludes that figures were down by 29%, but still representing a 21% increase on 1997 delays;
- **% Flights delayed:** the proportion of delayed traffic increased from 15.4% of all flights in 1997 to 17.1% in 1998 and 21.7% in 1999. However, the May-September 2000 values show a decrease to 18.9%;
- **Delay per flight:** an average delay value attributed to every flight indicates that 1998's value was 24.5% higher than 1997, noting that the average delay was 46.6% higher during Summer 1998 than 1997, while the equivalent rate for winter was 20.2% greater in 1998 than in 1997<sup>1145</sup>. There was a subsequent, significant increase of 50% during 1998/1999 because 1998's 3.6 minutes result rose to 5.4 minutes in 1999. Indeed, according to PRR2, ATFM delays could be 3 to 5 times worse in 2005;
- **Average delay per delayed flight:** the average delay per delayed flight rose by 12.0% from 1997 to 1998 and then by 18% from 1998 to 1999;
- **Delays > 15 minutes:** the percentage of delays, which were greater than 15 minutes rose by 44% from 8.6% in 1998 to 12.4% in 1999<sup>1146</sup>. Accordingly, delay statistics issued by the Association of European Airlines (AEA) indicate that 30% of its member airlines' departures were delayed, on average, by more than 15 minutes in 1999<sup>1147</sup>. This figure compares with 22.8% in 1998 and 19.5% in 1997<sup>1148</sup>;
- **Vertical distribution of ATFM delays:** this is analysed in PRR2 for the 118 sectors that made up 90% of Europe's ATFM delays in 1999. It indicates that 24% of such delays occurred on the ground, 15% below Flight Level (FL) 245 and 51% above FL245. Accordingly, out of the 15 most delaying sectors, only 2 were at FL245 or below, indicating that the implementation of programmes such as Reduced Vertical Separation Minima (RVSM) is essential in European airspace;

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<sup>1143</sup> Eurocontrol cites the implementation of a new route network and the Kosovo crisis as major factors for this increase. In addition, no measurable increase in overall system capacity was achieved in 1999, primarily due to a lack of capacity in a small number of sectors.

<sup>1144</sup> '1999 delays equivalent to 320 aircraft permanently grounded' – *era regional report*, April 2000.

<sup>1145</sup> Results show that the en-route ATFM delays were concentrated in the summer period during 1998, based on the CFMU definition of the summer season starting on the 4<sup>th</sup> of May and ending on the 1<sup>st</sup> of November. Correspondingly, it should be noted that there is a sharp increase in ATFM delays during weekend periods compared to weekdays.

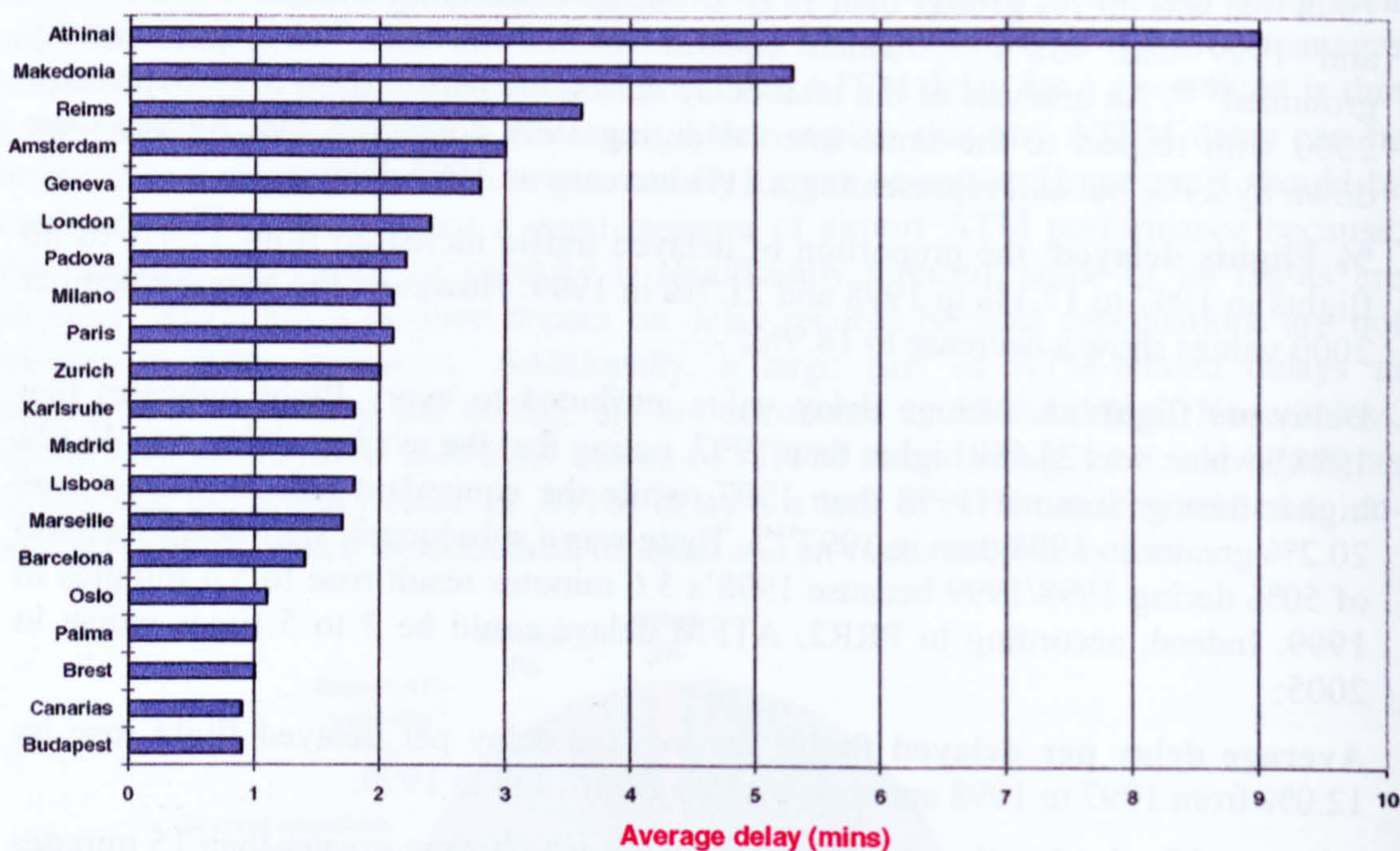
<sup>1146</sup> 'ATM performance review in Europe' – Working Paper 66, ICAO Air Navigation Services Conference 2000.

<sup>1147</sup> 'European airlines hit out over delays' – *Air Transport Intelligence*, 15 February 2000.

<sup>1148</sup> 'Pressure rises over delays' – *Airline Business*, March 2000.



- **Average delay per movement<sup>1149</sup>**: the average delay per movement rose by 50% in 1999 to 6.7 minutes, when compared with 1998's levels. In 1999, 20 bottlenecks caused more than 40% of the ATFM delays. The 1999 results were similar in structure to 1998's, whose top 20 Area Control Centre (ACC) offenders had the profile given in **Figure 7.11**, thus:



**Figure 7.11** – Average ATFM delay per movement for the top 20 ACCs

The diagram indicates that Athens and Macedonia ACCs were the top two offenders in 1998, but it should be added that Greece improved its ATFM delay record in 1999<sup>1150</sup>. Average delay per movement performance targets were set for the first time in 1999 as a result of the PRC reports: Eurocontrol put its peak season<sup>1151</sup> for 2000 average ATFM delay target at 3.5 minutes<sup>1152</sup>. However, the actual result for 2000 was 4.6 minutes<sup>1153</sup>. Therefore, Eurocontrol is retaining its 3.5 minute overall ATFM delay target for Summer 2001<sup>1154</sup>,

- **Ranking by country**: in 1999, France accounted for 23% of all delays, while Italy and Switzerland were responsible for 16.4% and 15.2% respectively<sup>1155</sup>. Despite efforts to reduce bottlenecks in France and Switzerland during Summer 2000, they continued to contribute to delays, albeit with somewhat lower results: France

<sup>1149</sup> Eurocontrol states that one flight passing through 'N' area control centres generates 'N' movements.

<sup>1150</sup> 'Eurocontrol PRC recommends steps to tackle traffic delays' – *Flight International*, 4 July 2000.

<sup>1151</sup> Based on the weekly evolution of average traffic and average en-route ATFM delay spread throughout the year, there is a tendency for ATFM delays to peak around week 26 and decline thereafter.

<sup>1152</sup> 'European bottlenecks prevent delay recovery' – *Flight International*, 30 January 2001.

<sup>1153</sup> 'Eurocontrol fails to hit peak season delay target' – *Air Transport Intelligence*, 16 November 2000.

<sup>1154</sup> 'European punctuality continues to deteriorate' – *Air Transport Intelligence*, 18 May 2000.

<sup>1155</sup> 'Eurocontrol PRC recommends steps to tackle traffic delays' – *Flight International*, 4 July 2000.



accounted for 21.5% and Switzerland 13.3%<sup>1156</sup>. It should be noted that sample Swiss airports (Geneva and Zurich) had over 30% of departures delayed in the first three months of 2000. Results for 1998 show that the UK was a big offender, but a resectorisation of airspace in 1999 led to improved performance. These results correlate with findings in the PRRs that the majority of ATFM delays (53% in 1998) were experienced in the following 'backbone areas' of the upper airspace:

- London Area Control Centre (ACC);
- 'Area North' over the northeast of France, Benelux and western Germany;
- 'Area South' over the southeast of France, northern Italy and part of the Mediterranean.

Restrictions in these three areas have wide effects on ATFM across Europe. For instance, a strike by one nation's controllers is exacerbated on a regional level, with serious consequences on the whole system<sup>1157</sup>, which can result in cancellations of flights by a carrier in another country<sup>1158</sup>. Therefore, Eurocontrol's strategy action plan should target these areas and remove all bottlenecks by maximising capacity in all sectors: there is an economic optimum between capacity and delay costs, where the capacity:demand ratio = 1, which represents the suitable capacity levels that should be applied<sup>1159</sup>. This is achieved through capacity and delay trade-offs<sup>1160</sup>. Accordingly, as discussed in **Chapter 4**, Europe should co-ordinate its traffic to a greater extent by removing the airspace borders that exist because, ironically, "the solution to ATC delays [in Europe] has nothing to do with technicalities ... it is mainly a political problem"<sup>1161</sup>. Nonetheless, the measures being taken, which are described in the aforementioned two chapters, are having a positive effect because it is evident that the 2000 results were better than 1999, albeit still at 1997 values;

- **Cost of delays:** PRR2 provides an analysis of estimated delay costs in 1999, thus:

DOC <sup>1162</sup> to airspace users from primary ATFM delays	\$ 927 million
DOC to airspace users from reactionary ATFM delays	\$ 618 million
ATFM costs to passengers <sup>1163</sup>	\$ 4,326 million
<b>Total costs of ATFM delays</b>	<b>\$ 5,871 million</b>

However, a Eurocontrol-commissioned study<sup>1164</sup> determined that the delay costs for 1999, including environmental<sup>1165</sup> and passenger costs could be anything within the range of \$6.8 to 11.9 billion. Accordingly, the Air Transport Action Group (ATAG) claimed that the ATC delays in Europe during 1999 would cost the industry at least

<sup>1156</sup> 'European bottlenecks prevent delay recovery' – *Flight International*, 30 January 2001.

<sup>1157</sup> 'Airlines face big delays when French controllers strike' – *Air Transport Intelligence*, 23 June 2000.

<sup>1158</sup> 'Looming ATC strike makes KLM cancel French flights' – *Air Transport Intelligence*, 22 June 2000.

<sup>1159</sup> 'Performance assessment in the European air transportation system' – *Journal of ATC*, October – December 1999.

<sup>1160</sup> 'A review of the ATM performance in Europe' – R Cioponea, PRU. *Performance Measurement in Air Traffic Control Conference*, London, October 2000.

<sup>1161</sup> 'Delays of a divided Europe' – *Air Transport World*, January 2000.

<sup>1162</sup> **DOC – Direct Operating Costs.**

<sup>1163</sup> **Based on an average value of passenger time of \$62 per minute that has been derived by the UK's National Air Traffic Services (NATS).**

<sup>1164</sup> 'Cost of air transport delay in Europe' – *Institut du Transport Aérien*, November 2000.

<sup>1165</sup> **Environmental costs may be manifested as aircraft emissions and noise.**



\$10 billion<sup>1166</sup>. In a similar manner, Finnair estimated in 1999 that cancellation of many, but not all, of its services would cost the airline \$5 million per week<sup>1167</sup>. Using such figures, in conjunction with the methodology cited in Section 5.3, European stakeholders should determine whether the cost of improving ATM through capacity increases exceeds this cost.

## **2. Safety**

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With reference to the data availability problems cited throughout this chapter, the safety analyses of the PRC assessments stress that “the lack of consistency and availability of safety data at the European level has prevented meaningful conclusions being drawn on the performance of ATM safety across the ECAC area. National reporting schemes vary in scope and content, and their results are subject to national confidentiality processes”.

Given that acceptable safety performance is an essential prerequisite to the operation of ATM, the PRC obtains such information from the Safety Regulation Commission (SRC). As mentioned in Section 7.2.2, the SRC is a body that is independent from Eurocontrol and separate from the PRC. It was established to ensure consistently high levels of safety in ATM within the ECAC area. For the purposes of the PRC’s report, measurement of safety is the assessment of levels of safety being achieved by the ATM systems.

Based on the data that are currently available within the ECAC area, the following statistics from the aforementioned performance review reports sources were recorded for 1998 and 1999:

### **Accidents**

- *Aviation Safety Net (ASN)* – 8 hull losses in 1998 (of aircraft carrying more than 19 passengers) and 10 in 1999;
- *ICAO ADREP* – 10 hull losses (of airline aircraft over 2,250kg), 6 fatal crashes and 2 Controlled Flight Into Terrain (CFIT) in 1998, with 1999 figures showing increases to 12, 9 and 3 respectively.

### **Incidents**

- *Eurocontrol* – 367 air proximity (airprox) and level busts (where pilots do not maintain their assigned altitude), 15 ground proximity/near CFIT and 40 runways incursions. Data are not available for 1999.

It is not possible to get statistically meaningful conclusions from the data, which are reproduced above for completeness. In particular, little insight is available into how ATM may have contributed. Therefore, the safety analysis of the PRC report emphasises that “there is an urgent need to introduce a harmonised approach to national

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<sup>1166</sup> ‘ATAG attacks Europe’s \$10 billion ATC delays’ – *Flight International* 29 September 1999.

<sup>1167</sup> ‘Finnair: ATC strike to cost \$5 million a week’ – *Air Transport Intelligence*, 2 February 1999.



ATM safety performance reporting, encompassing a harmonised categorisation of safety occurrences, a common approach to confidentiality issues, and a means of identifying causal factors of ATM accidents and incidents.” According to PRR3, the SRC addressed this need by launching the Eurocontrol SAFETY Regulatory Requirements (ESARR) in 2000, which deal with, among others, the implementation of an occurrence reporting and assessment scheme in ATM. The SRC expects to be able to publish more consistent statistics from 2001.

Correspondingly, it should be noted that the European Commission believes that there is a need for a confidential Europe-wide airline ATM incident reporting system. The EC sees the ESARR mechanism as a possible route to safety regulation by the planned European Aviation Safety Authority (EASA)<sup>1168</sup>. However, doubts exist whether EASA will ever be given power over ATM safety regulation, noting that EASA will initially be concerned with aircraft certification and operation. EASA’s establishment will involve a transformation of the joint Aviation Authorities (JAA) into an agency of the European Commission<sup>1169</sup>. It is unlikely that EASA will be functioning until 2002<sup>1170</sup>.

### Comparisons of values

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In conjunction with much of the analysis in this chapter, this section on the standard of countries’ CNS/ATM reinforces the lack of consistent data that are available. However, it has been possible to portray results using some of the indicators developed in **Section 7.2.4**. In order to provide a summary of this research’s findings on standard levels, consider the following points:

- The US FAA has more information available about the accident and incident rates in the US than Eurocontrol’s Safety Review Commission does in Europe. Results from the Aviation Systems report for 1998 illustrate the scope and detail of data available regarding accident and incident rates;
- Correspondingly, other indicators that are produced in the FAA Aviation Systems report and are relevant to this analysis of CNS/ATM standards include:
  - Reliability and operational availability of facilities and services, based on statistics covering facility activity levels;
  - Delay rates and delays due to volume rates;
- The performance review reports by Eurocontrol’s Performance Review Commission (PRC) possess information on delays, but not on the availability and reliability of equipment. In comparison with the FAA’s national delay statistics, the PRC data is broken down into sectors and also highlights the alarming increase in overall delays during recent years, albeit with improvements in 2000. In addition, results indicate that lack of sufficient en-route ATC capacity accounts for the largest proportion of ATFM delays and that the summer periods instigate more severe delays;
- The US FAA International Aviation Safety Assessments (IASA) programme indicates lower standard levels in African and Latin American nations.

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<sup>1168</sup> ‘Europe reviews air traffic safety’ – *Flight International*, 28 November 2000.

<sup>1169</sup> ‘European safety agency set to be adopted by EU’ – *Flight International*, 26 September 2000.

<sup>1170</sup> ‘EASA delayed by debate over powers’ – *Airline Business*, April 2000.



## 7.4 Route Performance Analysis

The main objectives of future air navigation systems include maximised air transport safety, accommodation of demand for Air Navigation Services (ANS), reduced flight delays and lowered costs, so that all stakeholders can maintain efficient and safe operations. Methods of fulfilling these aspirations are covered throughout this dissertation as part of its framework strategy. In conjunction with the strategy's performance parameters, which are developed in this chapter, this section briefly discusses and evaluates air navigation route performance<sup>1171</sup>, noting that some indicators developed in **Section 7.2** are also applicable to flight analyses.

Accordingly, it should be noted that the following issues, which are discussed in **Section 7.2**, are factors that affect the performance of aircraft and air navigation routes:

- **Safety** – safety forms the basis of performance requirements;
- **Delay** – delays should be minimised though the implementation of CNS/ATM technologies and procedures;
- **Cost** – from the perspective of all stakeholders, operating and other expenses should be controlled;
- **Predictability** – as a result of minimised delays, airspace users should be able to predict any variation that may affect their optimum flight schedules;
- **Access** – using indicators that are developed in **Section 7.2.4**, users' accessibility to airspace affects route performance levels;
- **Flexibility** – the performance of CNS/ATM-based air navigation routes should be flexible to accommodate all users' needs in real time and without penalty (as greater distances travelled incur larger fuel costs);
- **Flight efficiency** – the ease with which users can adopt preferred flight profiles in terms of flight level and route are indicative of an airspace region's performance;
- **Availability** – the availability of CNS/ATM equipment affects ANS provided to users. **Part 1** of this thesis discusses provision tendencies in various regions;
- **Environment** – performance of routes should accommodate environmental effects;
- **Equity** – all aircraft operators should have equal status.

These factors are dependent on determinants that affect whether an airspace region has a propensity for facilitating high levels of performance. The determinants may be grouped under the headings of the other parameters that are developed as part of this framework strategy, namely:

- **Integration management:** the manner and extent to which an airspace region has been developed will affect its performance in terms of the aforementioned factors;

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<sup>1171</sup> Route performance encompasses aircraft and airspace efficiencies, noting that future air navigation systems, by definition, are often not manifested by routes.



- **Project appraisal techniques:** similar to integration management, the manner in which an airspace region has been evaluated and planned will affect performance;
- **Institutional issues:** the tendency for a country to commercialise or outsource the provision of ANS, in addition to the level of automation that is adopted, will greatly affect the performance of routes in its airspace regions;
- **Mandatory matters:** a multitude of points covered in these sections of the framework has significant implications on the performance of aircraft within the airspace region. For instance, the level of equipment that has been deemed essential for operations and other regulatory aspects impact the aircraft population's ability to avail of high performance CNS/ATM technologies and procedures;
- **Financial factors:** phenomenally high charges would discourage operators from flying through an airspace region, thereby improving performance for the resultant aircraft in terms of flight efficiency and availability of infrastructure, but not in terms of cost effectiveness. Additionally, the funding given to an airspace region determines the CNS/ATM equipment that is present, thereby having an effect on the region's performance.

Therefore, airspace planners, providers, users, financiers and any other stakeholders should consider the indicators and parameters discussed throughout this thesis when conducting analyses of route performance. In addition, they should refer to information provided hereunder, which complements the indicators and performance parameters developed in this chapter. Indeed, this section is provided for completeness and does not intend to reproduce many facts or material that exist elsewhere. Correspondingly, this section conducts a short case study analysis of route performance by evaluating the new civil aviation operations in the North Polar Region (NPR), thus:

- **Part 1** of this thesis demonstrates that the NPR is characterised by poor provision of Communications, Navigation & Surveillance (CNS) facilities. Indeed, the NPR is known as a 'compass unreliable' area and it is stated that satellite-based CNS/ATM systems may not be used in many parts of this region, although some lower NPR routes<sup>1172</sup> (up to 82°N) enable satellite communications<sup>1173</sup>. Nonetheless, other CNS systems are useable and Air Traffic Management (ATM) techniques are based on fixed tracks that are navigated using a grid structure superimposed on polar stereographic projection charts;
- The regional evaluation of CNS/ATM implementation in **Section 4.7** and its related **Appendix 4.6** provides the background to civil air transport operations in the NPR. It should be noted that proving flights have been completed from 1998<sup>1174</sup> to date, with numerous carriers conducting trials. Airlines had hoped to launch continuous operational flights on four Polar routes by 1999, but unopened points along the routes and the loss of Iridium communications have delayed the situation<sup>1175</sup>. In

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<sup>1172</sup> Four Polar routes have been planned in the NPR, Polar-1, -2, -3 and -4. It should be noted, however, that other routes exist in the vicinity of these polar routes, such as the Russian Far East routes and potential routings between Europe and Asia (Arctica routes): see Figure 7.12.

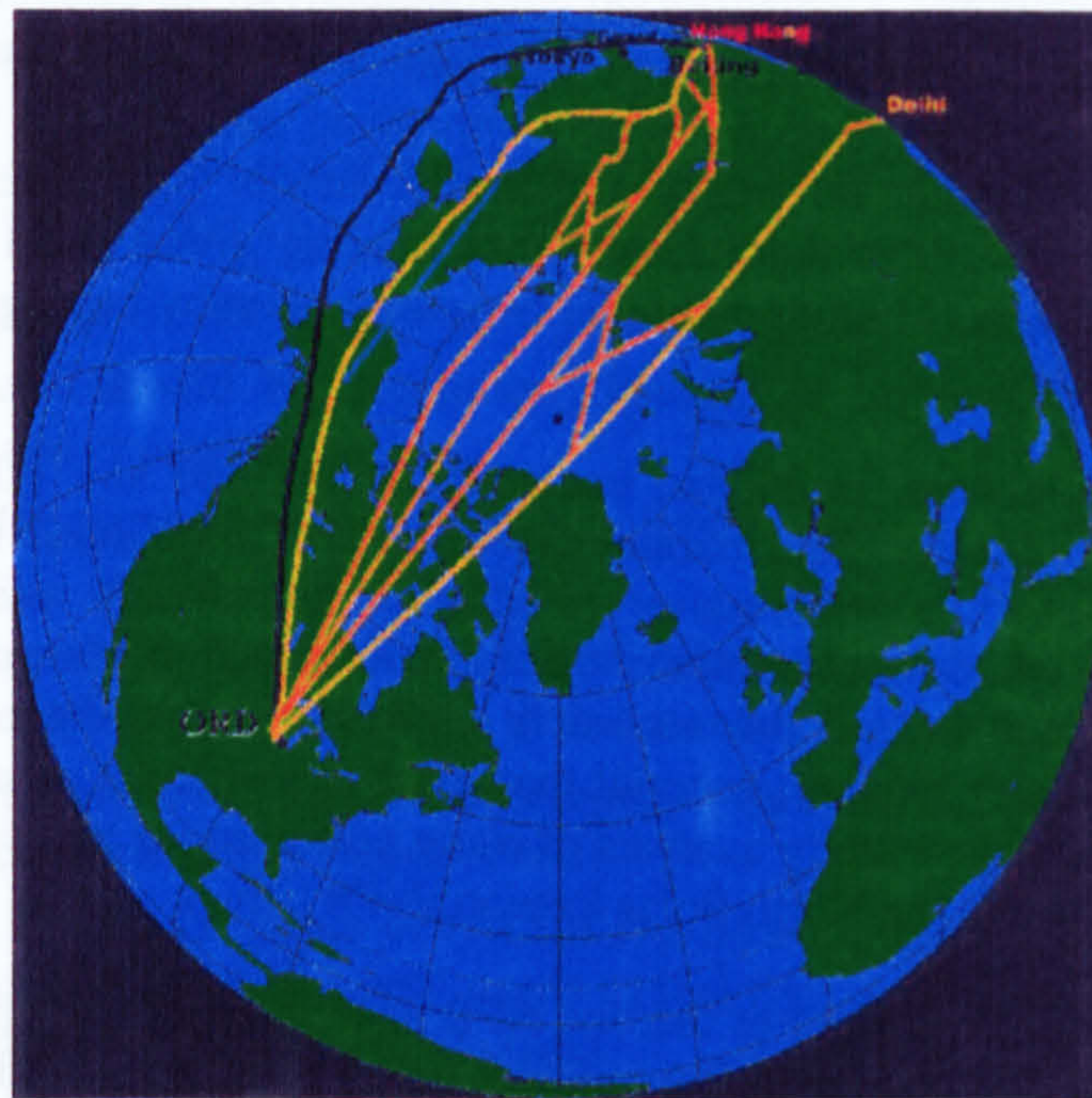
<sup>1173</sup> 'Polar operations an "unqualified success" says UAL' – *Air Navigation International*, 7 July 2000.

<sup>1174</sup> 'Pole stars' – *air traffic management*, July/August 1998.

<sup>1175</sup> 'Ice-breaking' – *air traffic management*, September-October 1999.



addition, Russia had, and still has, restrictions in place: current limits are 2 aircraft per hour. Nonetheless, noting that the four routes have been approved by ICAO<sup>1176</sup>, the situation is improving<sup>1177</sup>: Continental Airlines, Northwest Airlines and United Airlines each presently operate one route over the Pole, noting that United will add another on the 1<sup>st</sup> of April 2001. Accordingly, other (Asian and North American) carriers plan to start this year<sup>1178</sup>, although it is thought that the opening of all 4 Polar routes to flights will not occur before 2003<sup>1179</sup>. **Figure 7.12** indicates the geographic location of the routes. Phased introduction is planned thereafter until full-CNS/ATM operations are available on entire routes, allowing up to 6 flights per hour<sup>1180</sup>. This should happen by 2006;



**Figure 7.12** – Layout of trans-polar routes from Chicago (ORD) to Asia  
**Source** – United Airlines

- Noting that a British Airways study reveals that operations through the NPR could cut its Boeing 747 London – Tokyo flight times by an average 15 minutes eastbound and 35 minutes westbound if allowed to use the Arctica 1 route<sup>1181</sup>, the following airlines were among those involved in NPR operational trials, with corresponding results:
  - **Cathay Pacific** flew an Airbus 340 between Toronto and Hong Kong (6,737nm) in 15h: 17min, which represents 3 hour time<sup>1182</sup> and 30 tonnes fuel savings<sup>1183</sup>;

<sup>1176</sup> 'ICAO over the pole' – *Flight International*, 6 February 2001.

<sup>1177</sup> 'IATA sees progress on Arctic routes' – *Air Transport Intelligence*, 14 November 2000.

<sup>1178</sup> 'Polar services bear fruit' – *Flight International*, 20 March 2001.

<sup>1179</sup> 'Polar route openings two years away: IATA' – *Air Transport Intelligence*, 26 January 2001.

<sup>1180</sup> 'Polar thaw' – *air traffic management*, November/December 2000.

<sup>1181</sup> 'Arctica 1 links Europe to Japan via North Pole' – *Flight International*, 2 May 2000.

<sup>1182</sup> 'Polar route viability set to soar' – *Flight International*, 23 May 2000.



- **Continental Airlines** flew a Boeing 777 between Newark and Hong Kong (6,332nm) in 16h: 30min, constituting a 3 hour block time saving<sup>1184</sup>;
  - **Delta Air Lines** used a Boeing 777 between New York and Beijing (6,559nm), with a 13h: 47 min flight time, to bring 1h: 10mins saving<sup>1185</sup>;
- Even though operational proving flights have occurred successfully, the following operational concerns should be noted as part of this route performance analysis:
- **Emergency:** in terms of Search And Rescue (SAR) services and provision of sufficient diversion airfields (within a maximum of two hours), noting that Extended Twin-engine OperationS (ETOPS) have more stringent requirements. ETOPS criteria are acutely relevant because many (US) operators wish to fly their Boeing 777 aircraft on the routes. ETOPS ratings of 207 minutes are now being considered for the region;
  - **Fuel:** JET A fuel, which can become too viscous to flow at low temperatures, is currently rated to be used down to  $-40^{\circ}\text{C}$ . However, Outside Air Temperature over the pole at Flight Level (FL) 350 has been measured in trials at  $-45^{\circ}\text{C}$ . Flights in other regions of the world move fuel between tanks or reduce their altitude to warm fuel. However, this is not an option in the NPR, although flying at a faster airspeed would also warm the fuel. Therefore, a new fuel sampler is being developed to check the freezing point of JET A fuel, which may be able to facilitate a lower rating of  $-58^{\circ}\text{C}$ ;
- With reference to the determination of costs in **Section 5.3**'s project appraisal method, it is possible to identify the provider costs for developing the routes using data gathered as part of a joint study by Nav Canada and the Federal Aviation Authority of Russia in 2000<sup>1186</sup>. Additional investment is required to handle the traffic and increase capacity: in addition to new infrastructure, Russia requires many new controllers. Other operating costs will also rise. Nav Canada has agreed to help the Russians secure funds<sup>1187</sup>, with the European Bank for Reconstruction and Development (EBRD) being approached for a bridging loan. Additionally, Nav Canada is proposing that 10 airlines form a special-purpose company, Polar Bridge, to upgrade Siberian ATC infrastructure, in order to increase flights to 25 per hour. Nav Canada would be the project manager<sup>1188</sup>. The only real extra cost for airlines, in addition to route certification and proving expenses, would be due to potentially higher fuel reserve requirements, meaning that more contingency fuel must be carried on polar flights than over the Pacific. However, this cost would be offset by fuel savings (see hereunder);

<sup>1183</sup> 'Flight over the pole easy, but encore will be costly' – *Aviation Week & Space Technology*, 5 June 2000.

<sup>1184</sup> 'Russian deal key to Hong Kong route' – *Airline Business*, September 2000.

<sup>1185</sup> 'Delta 777 to cross North Pole on New York - Beijing flight' – *Flight International*, 20 February 2001.

<sup>1186</sup> **The study identified 33 potential city-pairs (between 11 US, 1 Canadian and 8 Asian airports), which could benefit from establishment of the 4 Polar routes.**

<sup>1187</sup> 'Russia and Canada team to target Polar route profits' – *Flight International*, 24 October 2000.

<sup>1188</sup> 'Polar services bear fruit' – *Flight International*, 20 March 2001.



- With reference to the determination of benefits in Section 5.3's project appraisal methods, it is possible to identify benefits for airlines using PNR routes, thus:
  - **Flight time:** flight times are drastically reduced due to flying a more direct, Minimum Time Route (MTR) and not having to stop for fuel (see aforementioned examples);
  - **Fuel savings:** considerable fuel savings per flight are possible from a greater opportunity to fly direct routings nearer optimum profile over shorter time and distance;
  - **Other cost savings:** other than fuel, operating cost savings include lower airport fees from not having to land at a fuel stop and potentially reduced navigation charges from flying shorter distances (although the latter may be increased by ANS providers to recoup costs). In addition, crew duty expenses will be lower, as will maintenance or depreciation costs from reduced aircraft utilisation;
  - **Revenue Enhancement:** airlines will improve their revenues through greater aircraft utilisation, which should be possible due to lower sector times through optimum aircraft scheduling. In addition, certain passenger types will choose to fly with an airline that has lower sector times rather than another with a fuel stopover. Accordingly, aircraft may be able to carry extra cargo;

Additionally, benefits exist for stakeholders, thus:

- **Passengers:** time savings attributed to passengers have cost saving implications (see Section 5.3 and Appendix 5.5);
  - **Capacity:** increased capacity on normal Pacific routes;
  - **Environment:** lower fuel consumption is a benefit to the environment;
  - **Providers:** the aforementioned Canada-Russia study estimates that projected air navigation revenues will cover their costs<sup>1189</sup>. Accordingly, IATA understands that there will be charge increases to meet funding requirements<sup>1190</sup>, thereby justifying the cost recovery logic of this framework strategy for financing CNS/ATM equipment purchases, which is cited in Chapter 6:
- A final step in this route performance analysis is to quantify the costs and benefits that have been identified:
    - **Costs:** Nav Canada needs to spend \$7 million over four years, while Russian authorities must spend \$33 million<sup>1191</sup>. Accordingly, IATA predicts that Russia could make \$75 million annually in air navigation charges from cross-polar flights. Other estimates are more conservative: the aforementioned Polar Bridge proposal believes that the \$33 million loan could be paid off in 5 to 6 years, after which the company would be shut down. This also justifies the framework's cost recovery recommendation in Chapter 6. Airline data are unavailable for route certification and proving expenses. With respect to the penalty for having to carry greater contingency fuel, noting that extra fuel means extra weight with

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<sup>1189</sup> 'Polar routes study identifies big potential savings' – Air Navigation International, 16 October 2000.

<sup>1190</sup> 'IATA sees progress on Arctic routes' – Air Transport Intelligence, 14 November 2000.

<sup>1191</sup> 'Russian-Canadian study confirms polar route benefits' – Air Transport Intelligence, 11 October 2000.



consequently higher average fuel burn, it is possible to state that fuel mileage charts are dependent on many factors, including wind speeds, altitude and aircraft weight. Thus, the penalty is a quantity that is specific to inherent aircraft, in addition to the circumstances and conditions of every flight;

- **Benefits:** airline operational benefits may be estimated in monetary terms using the average fuel costs given for airports worldwide in **Appendix 5.6** if the fuel savings are known. Otherwise, it is possible to apply an approximate value for the Direct Operating Costs (DOC) of a long-range aircraft (\$100 per minute<sup>1192</sup>) to time saving figures. Therefore, the time saved must be ascertained. Sector distances and times are published for many city-pairs, but time savings require more detailed analysis. Accordingly, noting that the example data in the previous list of proving flights contains time savings based on different criteria, consider the comparable data that have been produced by the aforementioned Canadian-Russian study, which may be manipulated to provide guidelines of potential benefits. The methodology of this data manipulation is to initially compute the airborne time savings for the various city-pairs, which exclude time at refuelling stops, where applicable, and then apply the \$100 per minute factor to the time savings. **Figure 7.13** portrays the results, thus:

<i>Data per flight</i>	New York Hong Kong	Houston Seoul	New York Singapore	Vancouver Beijing	Los Angeles Delhi
Current distance (nm)	8,060	6,825	9,884	5,409	8,011
Polar route distance (nm)	6,997	6,112	8,278	4,584	6,948
<b>Distance saving (nm)</b>	<b>1,063</b>	<b>713</b>	<b>1,606</b>	<b>825</b>	<b>1,063</b>
Time saving (min)	138.65	93.00	209.48	107.61	138.65
<b>DOC cost saving (\$)</b>	<b>13,865</b>	<b>9,300</b>	<b>20,948</b>	<b>10,761</b>	<b>13,865</b>

**Figure 7.13 – Financial savings on trans-polar routes**

It is evident that considerable financial savings, ranging to over \$20,000 in DOCs for the sample city-pairs, are attainable by flying on the North Polar routes. It should be noted that most aircraft types do not have to sacrifice seats in order to carry any increased fuel requirements. In addition, noting that the Canadian-Russian study based its time data on the Boeing 747-400 aircraft, the numbers in **Figure 7.13** may be used to determine that the average saving per nautical mile (nm) is approximately \$13.

In conclusion, this section demonstrates how a route performance analysis could be undertaken. Using data for the North Polar Region, it suggests that all stakeholders will benefit positively from the opening of more routes in that area. The route performance analysis also validates the framework's cost recovery recommendation in **Chapter 6**.

<sup>1192</sup> 'Flying the Silk road' – *Airline Business*, September 2000.



## 7.5 Summary

In addition to conducting route performance analyses, this chapter develops and computes criteria that assess the performance of ANS provision as part of this thesis' framework. Indicators are considered in terms of:

- The performance of ANS organisations;
- The quality of CNS/ATM that they provide.

**Section 7.3** applies the indicators and criteria drafted in **Section 7.2** to nations, split by the regional categories defined in **Chapter 1**, to provide an overall analysis of their ANS providers' organisational efficiencies and standards of the countries' CNS/ATM systems. This further develops the thesis' framework strategy by validating the criteria developed, providing results from a survey of nations or providers and supplying information that may be added to the other framework guidelines. **Section 7.4** complements **Section 7.3** with a case study analysis of airline route performance.

The route performance analyses demonstrate that advances with air navigation facilitate cost savings for all stakeholders. Accordingly, results from the analyses show that a large variance exists in the performance of countries' ANS organisations and the quality of CNS/ATM systems around the world. Specifically, it is discovered that:

- The efficiency of countries' ANS organisations varies in terms of:
  - Percentage breakdowns of their cost structures;
  - Unit cost levels per flight and per kilometre flown;
  - Productivities per controller and per flight;
  - Their profitabilities;
- The standard of nations' ATM fluctuates in terms of:
  - Accident and incident indicators;
  - Operational availability or reliability of facilities and services;
  - International safety assessment ratings;
  - Delay rates.

Ultimately, this chapter contains much information and benchmarked data that may be used for analytical, referencing or strategic purposes by CNS/ATM stakeholders. All stakeholders should be able to draw from this material as part of the framework strategy to swiftly develop their individual strategies to assessing performance of CNS/ATM, in addition to stating their minimum acceptable or expected efficiencies and standards. Accordingly, ANS providers, financiers, national or regional authorities and users should be able to apply the experiences cited in **Section 7.4** to other route developing areas. Correspondingly, this chapter considers many sources and discovers that there is a distinct lack of comparable data and information that facilitate the assessment of CNS/ATM performance and quality. Nonetheless, this chapter contains listings of numerous data sources and their applicability for this task.



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**CHAPTER 8**

**CONCLUSIONS & RECOMMENDATIONS**

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## 8.1 Introduction

It is stated in **Chapter 1** that the ultimate aim of this thesis on worldwide introduction of CNS/ATM systems is two-fold, namely:

- 1 To provide a comprehensive evaluation of CNS/ATM systems and a determination of the degree to which future air navigation systems have been implemented to date around the world;
- 2 To develop a framework strategy that improves worldwide introduction of future air navigation systems. Noting that many stakeholders are involved with CNS/ATM systems, the framework strategy should allow for use by any industry player.

**Chapter 1** also discusses methodologies employed and mentions how both objectives are conducted separately in two distinct parts, noting that the second aim is reliant on the first. Accordingly, this dissertation performs the analysis to fulfil the first objective in **Chapter 2** to **Chapter 4** inclusive, while **Chapter 5** to **Chapter 7** inclusive contain the research to realise the second aim. Therefore, a useful analytical tool, which was previously unavailable, now exists for all involved with the worldwide integration of CNS/ATM systems.

This chapter concludes the dissertation with an analysis of the findings from **Part 1** and **Part 2**. in addition to discussing recommendations that arise from this thesis and citing areas of potential further study related to the worldwide implementation of future air navigation systems.

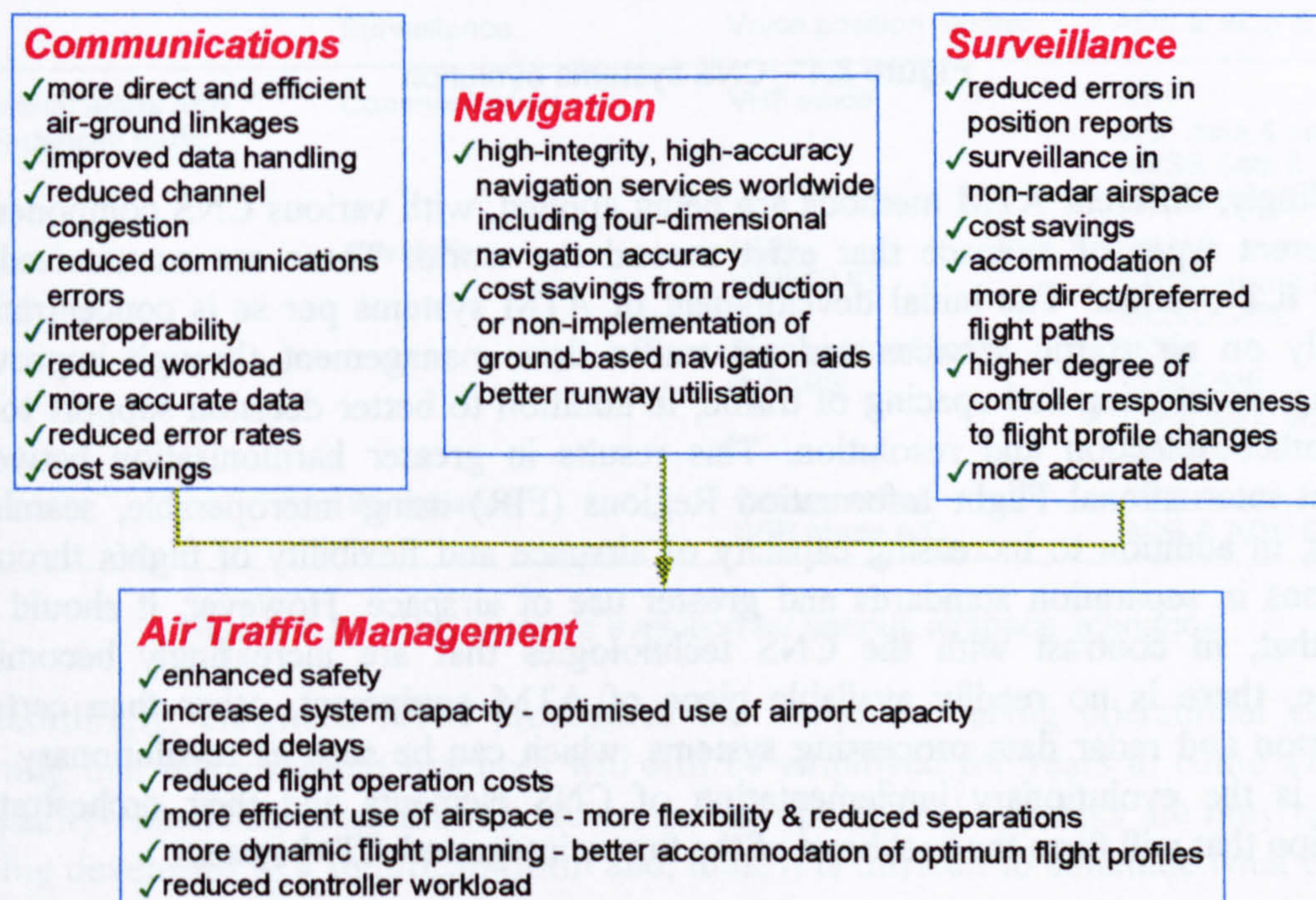


## 8.2 Summary of Part 1

It is emphasised in this dissertation that the plethora of future air navigation systems that exist have inherent capabilities to solve congestion and safety-related problems around the world. However, it is also stressed that a comprehensive evaluation of CNS/ATM systems, which includes an assessment of the current status of their worldwide implementation, has not yet been completed in an independent manner. Accordingly, this becomes the objective of **Part 1**, which is fulfilled by conducting an examination using a multitude of reference sources so that the analysis is detailed and encompasses a diverse range of activities around the world.

**Chapter 2** and **Chapter 3** evaluate Communication, Navigation & Surveillance (CNS) technologies and Air Traffic Management (ATM) concepts respectively. A contrasting approach between current and future systems is adopted in both chapters, given that the present methods will remain for some time. Indeed, by definition, transitional periods have aspects of present infrastructure and techniques. It may be concluded that CNS/ATM environments optimise the potential of airport and airspace resources so that their capacity, flexibility and safety are maximised, with delays and operating costs minimised. Automated CNS technologies provide enhanced ATM by availing of continuous information on aircraft positions and intentions, thereby allowing for a reduction in aircraft separation without compromising safety requirements.

In summary, both chapters discover that CNS/ATM systems provide the following benefits:





Specifically, **Chapter 2** concludes that CNS technologies will evolve as portrayed in **Figure 8.1**, noting that certain existing systems, such as Secondary Surveillance Radar (SSR) Mode A/C, also form part of the future arrangement. Accordingly, some versions of the future systems are already in operation, albeit limited to certain regions and particular applications of each technology.

### Communications

- ✗ Very High Frequency (VHF) voice
- ✗ High Frequency (HF) voice



- ✓ VHF voice and data
- ✓ Aeronautical Mobile Satellite Service (AMSS) - voice & data
- ✓ Secondary Surveillance Radar (SSR) Mode S data link
- ✓ Aeronautical Telecommunication Network (ATN)
- ...leading to *Required Communication Performance (RCP)*

### Navigation

- ✗ MNPS
- ✗ Omega & Loran-C
- ✗ Nondirectional Beacon (NDB)
- ✗ VHF Omnidirectional Range (VOR)
- ✗ Barometric altimetry
- ✗ Inertial Navigation System (INS)
- ✗ Instrument Landing System (ILS)



- ✓ Area Navigation (RNAV)
- ✓ Global Navigation Satellite System (GNSS)
- ✓ Barometric altimetry
- ✓ GNSS altitude
- ✓ Inertial Navigation System (INS)
- ✓ GNSS landing system
- ...leading to *Required Navigation Performance (RNP)*

### Surveillance

- ✗ Primary Radar
- ✗ Secondary Surveillance Radar (SSR)
- ✗ SSR Mode A/C
- ✗ Voice position reports



- ✓ Automatic Dependent Surveillance (ADS)
- ✓ ADS-B (Broadcast)
- ✓ SSR Mode A/C or Mode S
- ...leading to *Required Surveillance Performance (RSP)*

**Figure 8.1 – CNS systems evolution**

Accordingly, different ATM methods are being applied, with various CNS components, to different types of airspace that exist around the world. These are summarised in **Figure 8.2** overleaf. The initial development of ATM systems per se is concentrating primarily on air traffic services and air traffic flow management through improved metering, sequencing and spacing of traffic, in addition to better decision support tools for conflict detection and resolution. This results in greater harmonisation between different international Flight Information Regions (FIR) using interoperable, seamless systems, in addition to increasing capacity of airspace and flexibility of flights through reductions in separation standards and greater use of airspace. However, it should be noted that, in contrast with the CNS technologies that are increasingly becoming available, there is no readily available piece of ATM equipment, other than certain automation and radar data processing systems, which can be seen as revolutionary. In fact, it is the evolutionary implementation of CNS elements and their orchestrated interaction that will form the backbone of the future integrated ATM system.



Airspace	Function	Current System	Future system
<i>Continental and oceanic en-route airspace with low-density traffic</i>	Communication	VHF data & voice HF data & voice	ATN VHF data & voice AMSS data & voice HF data, in particular at North and South poles
	Navigation	OMEGA/LORAN-C NDB VOR/DME Barometric altimetry INS/IRS	RNAV GNSS (using EGNOS, MSAS or WAAS) Barometric altimetry GNSS altitude INS/IRS
	Surveillance	Primary radar/SSR Voice position reports	ADS& ADS-B
<i>Continental airspace with high-density traffic</i>	Communication	VHF voice	VHF data & voice AMSS data & voice SSR Mode S datalink
	Navigation	OMEGA/LORAN-C NDB VOR/DME Barometric altimetry INS/IRS	RNAV GNSS (using EGNOS, MSAS or WAAS) Barometric altimetry GNSS altitude INS/IRS
	Surveillance	Primary radar SSR Mode A/C	SSR (Mode A/C or S) ADS & ADS-B
<i>Oceanic airspace with high-density traffic</i>	Communication	HF data & voice	AMSS data & voice
	Navigation	MNPS OMEGA/LORAN-C Barometric altimetry INS/IRS	RNAV GNSS (using EGNOS, MSAS or WAAS) Barometric altimetry GNSS altitude INS/IRS
	Surveillance	Voice position reports	ADS & ADS-B
<i>Terminal areas with high-density traffic</i>	Communication	VHF voice	ATN VHF data & voice AMSS data & voice SSR Mode S datalink
	Navigation	NDB VOR/DME ILS Barometric altimetry INS/IRS	RNAV GNSS (using LAAS) MLS/DGPS NDB VOR/DME Barometric altimetry INS/IRS
	Surveillance	Primary radar SSR Mode A/C	SSR (Mode A/C or S) ADS & ADS-B

**Figure 8.2** – CNS systems evolution for various airspace scenarios

Accordingly, enhanced ATM procedures are introduced using operational concepts, noting that many current practices will still be employed for years to come as part of capacity-enhancing programmes. However, the operational concepts are only presently being developed in a significant form and, thus, it is difficult to conclude what concepts



will be in place in the next decade. Nonetheless, **Chapter 3** considers the three main ATM concepts that have been developed to date, namely:

- ICAO's global ATM;
- Europe's initiatives, which are encompassed in the ATM Strategy for 2000+;
- The US alternative approach, Free Flight.

It may be concluded that **Chapter 2** and **Chapter 3** ascertain what CNS technologies and ATM methods make up CNS/ATM systems, in addition to describing the systems and providing stakeholders with much information on what future air navigation systems are available presently or should be offered during and beyond this decade. Indeed, both chapters contain detailed specifics about system(s). Accordingly, the findings from both chapters are amalgamated to form the basis of the evaluation in **Chapter 4** on the current status of CNS/ATM systems implementation around the world. The integration status of CNS technologies and ATM procedures is determined by assessing many different sources of information, which enable a detailed evaluation of each CNS/ATM system component to be carried out. It should be noted, however, that there is no unique CNS/ATM solution: all circumstances are different. Thus, the introduction of CNS/ATM systems should be the result of all implementation projects.

In summary, **Chapter 4** finds that progression with the implementation of CNS/ATM systems, where planned, has not progressed as fast or as far as had originally been envisaged. The plethora of delays and poor safety in various airspace regions are testament to this point. All stakeholders and users of CNS/ATM systems are frustrated in many world areas. However, **Chapter 4** highlights the fact that many technologies and procedures are nearly ready for mainstream implementation. Advances have been made with datalink applications and satellite-based communications facilities. GPS-enhanced navigation procedures in all flight phases are becoming more mature, while the concept of RNP is aiding airspace planning and facilitating adherence to standards in many regions. Correspondingly, the success of surveillance systems, such as ADS, is encouraging. Additionally, enhanced ATM procedures, such as automated sequencing tools and dynamic aircraft re-routing, are currently operational. In contrast, many other technologies (such as Mode S datalink and ADS-B) will also become available later.

Even though the development of CNS systems and their technical standards (Standards And Recommended Practices, SARPs) has proceeded relatively well, the lack of a global operational concept that provides a detailed vision of an ATM system means that there is little detail on how the new technologies should lead to a more effective ATM system. It is for this reason that the EU and US have worked on their respective operational concepts, in addition to the fact that the air traffic systems in Europe and the US are in desperate need of improvement. Indeed, both ATM concepts have been tailor-made to suit their specific environments and they constitute each region's tentative plans for increasing capacity and flexibility, whilst maintaining safety standards. However, neither has been very successful with their concept solutions thus far, so many sections in this thesis refer to other methods that should improve the implementation of CNS/ATM systems. Indeed, Europe and the US must stringently adhere to their plans so that their current delays are sorted out in the next 5 years. Both



should simultaneously apply other recommendations, which are mentioned throughout this dissertation (see **Section 8.4**). It should be noted, however, that their concepts refer mostly to the future and that, therefore, it is difficult to assess their success accurately.

The CNS/ATM implementation activities of other nations and regions are appraised through a worldwide survey in **Chapter 4**, which also mentions national or regional future air navigation system plans. It should be remembered that the need to implement CNS/ATM varies throughout the world, based on safety and efficiency needs of a particular country or region. The pressure points on the system result from particular situations in different geographical scenarios. For example, high-density traffic areas would find certain CNS/ATM applications, such as Mode S surveillance, more useful than low-density airspace regions, where applications such as ADS would be more applicable. Thus, different solutions apply to various regions, although there is usually the requirement for improved capacity and flexibility of airspace regions because there is always scope for savings in fuel and time.

Correspondingly, it is evident that many countries and regions have not developed CNS/ATM plans for the future: hence the need to develop a framework, as conducted in **Part 2** of this thesis. It may also be observed that major air traffic routes and areas based on CNS/ATM systems have been identified. Some have already started operations. Thus, implementation programmes are starting to gather greater momentum, although many trials are still taking place (for instance, see **Appendix 4.2** for a list of European CNS/ATM projects). However, noting that CNS/ATM requires a global, or certainly regional, approach, there is a need to ensure that the process is conducted and guided correctly. This is another justification of the need to develop the framework for improved introduction of CNS/ATM in **Part 2**.

Therefore, given the increasing availability and reliability of CNS/ATM systems, in addition to the sense of urgency for improvement that exists around the world, it would appear that the CNS/ATM arena is at a crossroads and that a much higher level of systems introduction may be expected during this decade. Indeed, the integration and operation of CNS/ATM systems has started. Correspondingly, the survey of equipment manufacturers in **Chapter 4** highlights the fact that many different systems are being developed, which should create a vibrant market place. **Chapter 4** also portrays that interim spending on CNS/ATM systems will be sizeable. Coupled with the positive experiences that airlines have had with FANS-1/A packages on existing and new routes, it is possible to conclude that they should act as stepping-stones to dedicated CNS/ATM airspace regions, although it should be noted that FANS-1/A can only provide marginal benefits in terminal airspace.

Ultimately, in addition to facilitating the aforementioned conclusions, **Chapter 4** advises analysts or stakeholders what trials, programmes and operational experiences have been conducted for all CNS/ATM systems. **Chapter 4** also assesses the planned integration of CNS/ATM systems in the future and provides much information on CNS/ATM equipment for the benefit of this study and those that use it. Thus, analysts or stakeholders can consult this information and learn from previous occurrences, in addition to liaising with stakeholders that have previously implemented the system(s).



### 8.3 Summary of Part 2

In order to solve the congestion and safety problems of the world's airspace regions, there is a desperate need to improve the introduction of CNS/ATM systems around the world over the next two decades. **Part 1** of this thesis concludes that their integration is far from complete. Thus, the objective of **Part 2** is to develop a framework strategy for worldwide implementation of future air navigation systems that may be used by all CNS/ATM-related stakeholders. This aim, which is presently lacking in the CNS/ATM arena, is achieved through consideration of different industry players' perspectives to form a set of methods and options, based on computed data and other information, for successful implementation of CNS/ATM at national, regional and global levels.

The framework strategy is structured so that each stakeholder should benefit from its recommendations, which are developed and discussed in separate sections. Suggestions on how to improve the specific problem(s) and guide implementation are generated as components, which are based on stumbling blocks to successful implementation that are identified using **Part 1**'s findings. Components are divided into the following sections:

- Integration management;
- Project appraisal techniques;
- Institutional issues;
- Mandatory matters;
- Financial factors;
- Performance parameters.

Accordingly, it is possible to conclude from **Part 2** that the worldwide implementation of CNS/ATM technologies and procedures should be accomplished and expedited if one or more of the framework strategy suggested methodologies is employed. Given its handbook-style, it is possible for any analyst or stakeholder to consult relevant sections of the framework to obtain advice on introduction of their CNS/ATM system(s). Each section usually contains references to other sections, so the analyst or stakeholder can maximise their use of the framework. The advice, which often consists of alternative strategies, is substantiated and supported by a wealth of information that is provided in many cases for individual nations. Indeed, benchmarked indicators are established and computed, where possible, to help stakeholders. The benchmarked data for key elements are coupled with best practice examples, which act as proof-of-concept evidence, to validate framework strategy components.

Correspondingly, an analysis of the solution methods for comprehensive introduction of CNS/ATM systems, which are produced as the framework strategy in **Chapter 5** to **Chapter 7** inclusive, leads to conclusions that are divided into the aforementioned component sections, thus:

- **Integration management** of CNS/ATM projects is best performed at four distinct levels (global, regional, national and project) using evolutionary introduction rather than a 'big bang' approach. Lack of co-ordinated management for introduction of



CNS/ATM is a significant obstacle to comprehensive integration, so this aspect of the framework's suggested formula fulfils one of the urgent guidance requirements. To conclude, the framework recommends different strategies for the four levels, thus:

- *Global management* – The International Civil Aviation Organisation (ICAO) should act as the co-ordinating body, ensuring that safe regional plans are harmonised, standardised and implemented in an expeditious manner. Given that global management requires harmonised implementation of CNS/ATM systems, the other components of this framework should be consulted because the introduction of future air navigation systems is ultimately a voluntary choice and change may require impetus to start, which could be acquired through economic incentives such as the accommodation of efficient flight trajectories, with resultant fuel savings and time-optimised operations from gate to gate;
  - *Regional management* – The ICAO Planning and Implementation Regional Groups (PIRG) should co-ordinate integration of CNS/ATM in the ICAO regions, but with an emphasis on maximum co-ordination with all stakeholders through the ALLPIRG, which is the ICAO interregional advisory group, and other multi-stakeholder bodies, such as the CNS/ATM Focused Team (C/AFT), the Civil Air Navigation Service Organisation (CANSO) and the FANS Stakeholders' Group (FSG). This point about inter-stakeholder co-operation is very important. Accordingly, regional agencies such as ASECNA or Eurocontrol should also influence decisions. Indeed, such agencies should be given decision-making powers by their member countries. This should ensure that regional implementation occurs as quickly as possible through general consensus. Noting that each stakeholder, including ICAO, has its own agenda and preferences, there is a need to establish an independent governing body with leadership status, whose objective is to expedite the process. Finally, it should be noted that **Section 5.2.2** develops specific stakeholder actions to expedite the regional process, which is the key for successful implementation of CNS/ATM systems;
  - *National management* – All countries are responsible for the provision of air navigation facilities and air traffic management in their airspace. Therefore, each nation should establish a CNS/ATM planning group, with the requisite regulatory powers, whose members represent all the country's stakeholders. The planning group's aim should be to develop a national plan for CNS/ATM systems and subsequently manage its related integration projects. **Section 5.2.3** provides a methodology for developing national plans, which should be co-ordinated on a regional basis;
  - *Project management* – Given the project-oriented nature of CNS/ATM systems implementation, **Section 5.2.3** suggests a formula for orchestrating projects efficiently;
- **Project appraisal techniques** are crucial for ensuring that the chosen path to follow is the most suitable option for the particular application. The framework strategy concludes in **Section 5.3** that it is better to conduct economic project appraisals rather than purely financially based evaluations. However, it should be noted that the former do encompass financial assessments, which are essential due to ever-



increasing need to prepare a business case for the particular CNS/ATM application. Using the cost-benefit approach, the framework strategy develops suggested methodologies for assessing projects' economic drivers. It may be concluded that many different types of costs and benefits exist, so project appraisals should be conducted with acute attention to detail;

□ **Institutional issues** are considered as framework components in terms of:

- *Organisational structures of national ANS providers* – Given their extremely relevant rôle in the efficient operation of CNS/ATM, the framework suggests that Air Navigation Service (ANS) providers should optimise the structure of their organisations if the provision of ANS is performed at a national level. **Section 5.4.1** concludes that countries differ in their propensity to provide the services by using a government department or commercialised structure. The strategy determines that the commercialised type is becoming increasingly employed and notes that such providers adopt a structure that is either (part) privatised or corporatised, where the latter is manifested by the nation retaining ownership of the provider. A list of suggested guidelines for altering the structure from being government-run mentions the improved efficiencies and other advantages that are associated with commercialised entities;
- *International co-operation* – Various sections of this thesis conclude that co-operative ventures among countries and/or other stakeholders improve the integration of CNS/ATM systems. **Section 5.4.2** cites that two methods of international co-operation are the provision of ANS and operational or technical advice. With reference to the former, the section concludes that countries' providers have the opportunity to share facilities and services or to create an autonomous operating agency. It also determines that ventures such as co-operation among African countries lead to economies of scale and scope, in addition to operational synergies. Accordingly, the analysis recognises that the provision of international satellite services usually requires co-operation on an international scale. The second form of international co-operation that is considered, advice, leads to the conclusion that there is a requirement for an international database that houses operational and technical information, which stakeholders could use for their particular projects. The framework recommends that ICAO house the database or, at least, a catalogue of advisory sources;
- *Human factors* – Noting the importance of human-related aspects with respect to the worldwide introduction of CNS/ATM systems, the strategy concludes that human-machine interfaces must be designed in optimum manners and that all stakeholders should address their training needs immediately because lead times can be at least five years;

□ **Mandatory matters** are other components of this framework that facilitate the following conclusions, which are divided into four distinct areas, thus:

- *Standardisation and certification* – All aspects of CNS/ATM must adhere to regulations: communication, navigation and surveillance equipment is certified and standardised; correspondingly, ATM is subject to regulated procedures. It is



stated that the integration of CNS/ATM around the world will only be achieved if equipment and procedures are standardised to similar specifications. In addition, **Section 5.5.1** believes that equipment will be more intercompatible and interchangeable, meaning that procedures should have greater levels of similarity. Therefore, it is concluded that there is a need to list specifications for equipment or procedure development. Indeed, it is noted that greater levels of international co-ordination are occurring with development of specifications. Accordingly, the framework strategy refers to the essential requirement for harmonised certification processes and suggests an outline structure that could be adopted by stakeholders, noting that international co-operative ventures would be beneficial to the worldwide implementation of future air navigation systems;

- *Regulation* – Given the propensity for CNS/ATM systems to be operated by ANS providers that are not government-run, there is a need for regulation of the airspace and safety standards. In addition, the strategy suggests that economic regulation of providers is essential when management migrates from government. **Section 5.5.2** also observes that economic regulatory control may be exercised by capping a provider's charging levels. The strategy suggests that the Retail Price Index (RPI-X) formula is applied. Finally, regulatory aspects of the framework strategy conclude that new approaches to rule making should expedite the introduction of CNS/ATM systems;
- *Political* – Many different framework strategy components contain elements that exhibit the effect of politics on the worldwide implementation of future air navigation systems. Additionally, it is claimed in **Section 5.5.3**, that the issue of national airspace sovereignty affects the progression towards CNS/ATM environments. However, the framework concludes that, in order to enhance international or regional co-operation, countries need to become less obsessed with strict sovereignty matters. Indeed, it notes that co-operative ventures cited throughout the dissertation are indicative of the fact that nations do not lose the essence of sovereignty by entering into international agreements that improve ANS provision;
- *Legal* – Even though the Chicago Convention, which applies to civil aviation, is one of the world's most widely accepted international legal instruments, each nation has other inherently individual national laws that they apply. For instance, each country defines its own legal standards and notifies ICAO accordingly. Together, they form a complicated law structure that controls air navigation. In contrast, noting the global nature of CNS/ATM systems, it is stated in **Section 5.5.4** that a unified set of legal rules based on a new Convention or Treaty, which limits the provider's liability and sets service obligations, would be necessary to ensure that future air navigation systems are implemented in a comprehensive manner. The section concludes that it would appear logical to base CNS/ATM legal stipulations on existing tools and that any legal changes should be incremental rather than fundamental;



- **Financial factors** are included because all CNS/ATM projects have funding requirements, whether government run or orchestrated solely in the private sector. In addition, lack of finance is often cited as the reason for not being able to implement future air navigation systems. However, **Chapter 6** concludes that this is usually a false perception by analysing:
  - *Charging systems* – A theoretical assessment of charging mechanisms based on an overview of ICAO guidelines on Air Navigation Service (ANS) charging policies, principles for allocation of costs, charging methods and the billing process discovers that ANS providers are allowed to set the level of their fees so that their provision costs may be recovered. It should be added that **Section 6.2** provides analysts or stakeholders with alternative strategies for setting ANS charges, having identified the structure of fees for those nations in a sample set of 205 countries that levy charges. Accordingly, the existence of regional en-route provision agencies is emphasised;
  - *Worldwide charging levels* – A benchmarking exercise of air navigation fees in 205 countries, where applied, reveals that a wide range of charges exists. The fees fluctuate wildly both between and within specific regions. All stakeholders may employ this comprehensive survey to ascertain their average regional fee, among other criteria. Accordingly, nations and/or ANS providers should apply formulae that they consider to be more pertinent for their operation and, correspondingly, users may realise that alternative routes might mean lower navigation charges;
  - *Alternative methods for funding* – Having noted the broad range of cost levels that applies to CNS/ATM projects, **Section 6.4** evaluates finance sources by conducting an assessment of methods that may be applied to CNS/ATM systems. It is concluded that non-user stakeholders, including the equipment manufacturers, should maximise their revenue through cost recovery principles, while users should be aware of the other financing methods that exist. Noting the increasing tendency for ANS providers to commercialise their operations, the framework recommends that stakeholders are aware of their ability to borrow funds that bridge the gap between incurring expenses for implementation of CNS/ATM equipment and receiving revenues from those using the systems. This satisfies users' concerns that they could be pre-financing projects. Correspondingly, the analysis of funding methods concludes that accountancy and other business practices in the CNS/ATM arena should be changed;
- **Performance parameters** are becoming increasingly relevant through the greater need for CNS/ATM systems to be efficient in terms of capacity, cost-effectiveness and flexibility. Accordingly, air navigation systems must maintain the same safety standards, even though traffic levels and throughput rates are higher. Thus, **Chapter 7** develops indicators to assess the performance of ANS providers and quality of CNS/ATM, in addition to computing the values where data exist and assessing the parameters involved in flight analyses. The performance components that are created



enable analysts or stakeholders to apply appraisal criteria to CNS/ATM projects. The chapter's contents facilitate conclusions, which may be split into sections as follows:

- *Drafting indicators* – An assessment in **Section 7.2** of current stakeholder performance appraisal methods and available information is merged with a criteria wishlist to provide indicators that evaluate the performance of ANS organisations and the quality of CNS/ATM. It is possible to conclude that there is a distinct lack of data globally, but that appraisal criteria developed in the framework strategy enable analysts or stakeholders to determine specific ANS provider performance levels and CNS/ATM system quality standards if they adopt a case study approach. Therefore, the indicators are important components of the framework. Accordingly, it is evident that there is a need to accumulate an interregional database of certain criteria, which should make comparisons easier in the future;
- *Computing indicators* – **Section 7.3** applies the indicators and criteria drafted in **Section 7.2** to nations to provide an overall analysis of their ANS providers' organisational efficiencies and standards of their CNS/ATM systems. With reference to the number of countries for which data were available, which rises to approximately 100 for some evaluations, the section concludes that there is a wide variation in provider efficiency and in the standard of nations' CNS/ATM systems. Similar to other analyses, this benchmarking exercise provides analysts and stakeholders with invaluable information relating to the worldwide implementation of future air navigation systems. In addition to validating the criteria developed. It should be noted that there is a need for ICAO and other bodies to improve their data publishing material. In order to facilitate more in-depth appraisals. As an addendum, the survey of national and regional system quality emphasises the severity of the air traffic control problems in Europe and the US, thereby justifying the development of this framework;
- *Route performance analysis* – The worldwide integration of future air navigation systems is intended to maintain or improve safety standards, reduce flight delays and lower costs, in addition to enabling aircraft to transit airspace regions that were previously impassable. The assessment of route performance, which is conducted in **Section 7.4**, discovers that CNS/ATM systems do fulfil these intentions. By analysing existing efforts to make (North) Polar operations a permanent reality. The evaluation also demonstrates the magnitude of savings that are available to stakeholders by altering existing air navigation methods.

Ultimately, it may be concluded that **Part 2** meets its objective, in addition to providing benchmarked data and information, which may be used for referencing purposes by analysts or CNS/ATM stakeholders. ANS providers, airports, nations, regulators and users alike should be able to draw from this material to swiftly develop their individual strategies for implementing their air navigation system(s). Indeed, the framework strategy should act as a catalyst to further and guide integration as the potential for CNS/ATM becomes more apparent, noting that introduction of such systems requires incentives, which may be developed through some of the strategy's components. Accordingly, there should be continual consultation among all stakeholders.



## 8.4 Conclusions

With reference to **Section 8.2**, consider the following conclusions from this research's evaluation of CNS/ATM and its worldwide implementation status:

- ❑ CNS/ATM environments optimise the potential of airport and airspace resources so that their capacity, efficiency, flexibility and safety are maximised, with delays and operating costs minimised;
- ❑ Automated CNS technologies already provide enhanced ATM by availing of continuous information on aircraft positions and intentions, thereby allowing for a reduction in aircraft separation without compromising safety. Enhanced ATM procedures include automated sequencing tools and dynamic aircraft re-routing;
- ❑ Worldwide progression with the implementation of CNS/ATM systems, where planned, has not progressed as fast or as far as had originally been envisaged. The plethora of delays and poor safety standards in various airspace regions are testament to this point. All stakeholders are frustrated in many world areas;
- ❑ However, many technologies and procedures will soon be ready for mainstream implementation.

Accordingly, the summary in **Section 8.3** provides the following conclusions relating to the framework for improved worldwide implementation of CNS/ATM systems:

- ❑ Management collaboration is needed at global, national, regional and project levels. Greater decision-making processes are required;
- ❑ Projects should be appraised from economic perspectives using business case approaches;
- ❑ Cost and efficiency of air navigation service provision may be improved through commercialisation of providers and international co-operation;
- ❑ Standardisation of systems and their certification processes, in addition to suitable regulation methods, should expedite the introduction of CNS/ATM systems;
- ❑ Few legal problems exist with future air navigation systems;
- ❑ Implementation of CNS/ATM can, for most nations, be self-financing through user charges, although a bridging loan is usually required. Many funding methods exist. Accordingly, the framework discovers that there are large differences in average fees for air navigation services around the world;
- ❑ Using the framework strategy, it is possible to measure performance of air navigation service providers and CNS/ATM equipment. Results from a benchmarking exercise demonstrate that a wide variation in provider efficiency and equipment quality exists;
- ❑ New routes bring efficiencies in terms of increased capacity, reduced journey times and lower costs;
- ❑ Ultimately, each stakeholder should benefit from methods and options in the framework strategy, resulting in improved implementation of CNS/ATM systems if suggestions are followed. Indeed, the strategy should act as a catalyst to further and guide integration of systems.



## 8.5 Recommendations

This section lists some recommendations emanating from this research. It should be noted, however, that suggestions are spread throughout the text. Thus, it is not possible to comprehensively cite all advice and proposals in this section. Nonetheless, consider the following recommendations:

- One important suggestion is that **all analysts and stakeholders should use Part 1 of this thesis as a compendium or handbook on future air navigation systems** and their current implementation status by reading about their particular system or the whole arena. If all players with a vested interest have a thorough knowledge of CNS/ATM systems, then the introduction of CNS/ATM should progress at a faster rate. In a similar manner, analysts and stakeholders should use **Part 2** to guide their decision-making and CNS/ATM systems introduction processes. This dissertation has adopted a truly worldwide perspective, so use of the survey results and other findings should be maximised. Therefore, it is recommended that **analysts or stakeholders access the benchmarked indicators and other information that are provided**, having familiarised themselves with CNS/ATM systems and their success to date in **Part 1**. Worldwide implementation of future technologies and procedures should be accomplished and expedited if one or more of the framework strategy suggested methodologies is employed;
- Accordingly, remembering that CNS/ATM systems have the capability to reduce delays and maintain safety levels, it is recommended that **stakeholders should complete programmes or trials. Once the programmes or trials are completed, it is recommended that technologies and procedures be brought into widespread operation with immediate effect to realise near-term benefits.** Correspondingly, it is suggested that **industry makes a concerted effort to ensure that all other technologies, which are still in the development process, are certified and introduced in a timely manner.** Only technology that is genuinely required should be produced. Ultimately, future air navigation systems optimise the potential of airspace resources so that their capacity, flexibility and safety are maximised, with delays and operating costs minimised. This should be a sufficient catalyst to warrant their implementation:
- In order to increase the possibility of realising its seamless, gate-to-gate CNS/ATM concept, it is recommended that the International Civil Aviation Organisation (ICAO) **should swiftly complete its global ATM operational concept** because a definitive concept will become increasingly elusive with time as the European and US models are perfected. In addition, ICAO should finish all the Standards And Recommended Practices (SARPs) for CNS/ATM systems. Accordingly, the ICAO process should harmonise VHF DataLink (VDL) Mode 3 and 4, noting that it is developing SARPs for both modes. **ICAO should also stay focused on achieving its Aeronautical Telecommunications Network (ATN),** which should be achievable when the advances in Internet technology during recent times are considered. In a similar manner, it is recommended that **all stakeholders should liaise with ICAO to complete the ATN,** noting that industry has been able to further the introduction and



standardisation of In-Flight Entertainment (IFE) technologies during the past decade. Ironically, the same companies are often involved in CNS/ATM and IFE equipment manufacturing. Accordingly, **work should be conducted on integrating FANS-1/A into the ICAO CNS/ATM concept.** Finally, **ICAO should consider implications of all future air navigation systems:** for example. Controller Pilot DataLink Communications (CPDLC) will undoubtedly have adverse knock-on issues such as reduced pilot situational awareness due to being unable to hear the instructions given to other aircraft. In a similar manner, it is recommended that the **industry prepare itself for debating the issue of transferring responsibility for aircraft separation from the ground to the cockpit,** noting that it is a little premature to plan for pilot-less passenger aircraft. Ultimately, CNS/ATM provides ICAO with the opportunity to realise its original aim, which was set when the organisation was formed in 1944, namely to harmonise international aviation. **ICAO recognises that its process is very slow, so it should accept collaboration offers from industry;**

- Noting that there is no unique CNS/ATM solution due to circumstances being different, and that the global ATM operational concept is unavailable at present, it is recommended that **the introduction of future air navigation systems in other countries or regions should be the result of implementation projects by all stakeholders.** For many, this will be a venture into uncharted waters. Given the variety of CNS/ATM-related implementations that could be conducted and acknowledging the need for all stakeholders to refocus on their CNS/ATM strategy, it is recommended that **stakeholders make definitive decisions immediately with respect to their CNS/ATM system requirements for this decade,** if they have not already done so. remembering that **Part 1** contains a lot of information about the systems and that CNS/ATM implementation activities of nations and regions are appraised through a comprehensive worldwide survey in **Section 4.7.** The latter evaluation also mentions national or regional future air navigation system plans. It should be remembered that CNS/ATM provides a timely opportunity for developing nations with poor CNS equipment to enhance their infrastructure so that they may handle additional traffic safely with minimal investment. Accordingly, future air navigation systems are useful for all airspace regions:
  
- Correspondingly, it should be noted that the need to implement CNS/ATM varies throughout the world, based on safety and efficiency needs of a particular country or region. Thus, different solutions apply to various airspace areas, although, in addition to a continual need for enhanced safety, there is usually the requirement for improved capacity and flexibility because there is always scope for extra savings in fuel and time. However, there may be a certain irony to providing more capacity in the hope of increasing flexibility because this could activate increased use of the airspace, resulting in the capacity being taken. Nonetheless, it is recommended that **all airspace regions should be optimised to accommodate demand,** which may mean, among many suggestions in this thesis, increased automation of systems or limiting the number of slower aircraft in certain areas at particular times so that throughput is maximised. This could be achieved through mandatory measures or financial penalties. In contrast, it is possible that aircraft operators may seek to transit airspace



regions that have previously remained unused. For instance, the case study on North Polar operations indicates that many economic and financial incentives exist for users to fly in this region:

- Additionally, noting that short- and long-term planning can occur simultaneously, it is recommended that **stakeholders should start thinking of their overall, long-term future CNS/ATM strategies as soon as possible**. There is a need to plan ahead because it is nearly 20 years since the first ICAO FANS Committee was formed (see **Section 1.3.1**) and the CNS/ATM industry is not exactly renowned for adhering to implementation schedules. Hence, in order to make their short- and long-term decisions, it is recommended that **stakeholders use the framework strategy in Part 2 as intended, namely to improve the worldwide introduction of future air navigation systems**. The framework has been structured so that the perspectives of different stakeholders are incorporated. **This analytical tool is recommended to the stakeholders because it offers alternative strategies that aim to incentivise and act as catalysts for comprehensive application of future technologies and procedures that increase efficiency and lower operating costs**. Specifically, it is suggested that they **consult Section 8.2 and Section 8.3, which summarise the framework strategy's suggestions**. This should lead to better integration management of projects, with multiple stakeholders working together to expedite the introduction of systems on regional bases. Everyone is currently waiting for other stakeholders to act, so this approach means that a consensus is achieved faster. Groups that are presently inactive with CNS/ATM, such as aircraft leasing companies, should become involved. Accordingly, the framework's recommended **project appraisal techniques should accommodate the fact that the systems must be implemented in an evolutionary manner, using business case attitudes**. Correspondingly, given the need for a reduction in the number of diverse CNS/ATM systems, the suggested options on commercialising ANS providers and co-operating internationally should fulfil this necessity. In addition, suggestions on **mandatory matters should ensure that standardisation and certification processes are improved at interregional level, while regulatory recommendations should maintain economic stability between providers and users**. The latter would be even more content if the charges were linked to ANS provider and CNS/ATM system performance. It is recommended that **charging policies should be adapted to include an element of satisfaction**. In addition to enhancing the safety of airspace regions, this would have the knock-on effect of allowing the cost recovery principle to be utilised because aircraft operators would be willing to pay increased fees for improved CNS/ATM services. It is, after all, a major recommendation of this framework strategy.

Ultimately, if stakeholders implement the aforementioned recommendations, in addition to others from the framework strategy and elsewhere in this dissertation, the worldwide implementation of future air navigation systems should be improved. Accordingly, the present delay and safety problems should be alleviated, with sufficient planning for the future. However, the next two decades will undoubtedly be fraught with unpleasant experiences for many different stakeholders.



## 8.6 Further research

Due to inherent limitations associated with research on a worldwide scale, there is undoubtedly a need for further analysis on many specific issues at more concentrated levels. Therefore, with particular reference to implementation of future air navigation systems, consider the following topics that warrant more detailed evaluation:

- **Implications of congestion**: The interrelationships between capacity, congestion, delays and demand, in addition to economic impacts of congestion. This would address issues such as separation standards and flexibility of flight;
- **Multi-stakeholder CNS/ATM groups**: Optimum compositions and structures of the groups, in addition to the possibility of assigning powers to such organisations;
- **CNS technologies**: Ensuring that such systems can guarantee safety standards and their stated performance levels, in addition to developing new CNS technologies;
- **ATM concepts**: Validation of the ICAO global ATM operational concept when it becomes available, in addition to drafting addenda for the existing European and US concepts. Accordingly, it could be possible to study the applicabilities of specific ATM methods to particular airspace regions, noting that this research states the applicabilities using some examples. It would also be beneficial to appraise flight profiles to determine optimum (4-Dimensional) trajectories for improved aircraft economics, in terms of reduced fuel and time;
- **Status of CNS/ATM implementation**: Constant monitoring and updating of the evaluation that is conducted in **Chapter 4**, in order to ensure that the introduction of future air navigation systems progresses as required;
- **CNS/ATM equipment**: Assessment of the multitude of products using the survey in **Chapter 4** as the basis, which could classify systems for particular applications;
- **National and regional CNS/ATM activities**: In addition to updating the survey in **Chapter 4**, identify those nations or regions where greater synergies may exist with their implementation processes. Indeed, there is untold opportunity within this area for more detailed national or regional planning using this thesis as a reference source, including the integration management guidelines in **Chapter 5**;
- **Project appraisal techniques**: Drafting a range of strategies for a CNS/ATM system using the framework strategy's project evaluation guidelines in **Chapter 5**;
- **Institutional issues**: Reassessing the extent of air navigation service provider commercialisation in a few years' time or using this section of the framework as the start of a study on human factors' aspects of CNS/ATM;
- **Mandatory matters**: Optimised standardisation and certification processes or drafting CNS/ATM regulatory legislative guidelines, in addition to improving legal processes;
- **Financial factors**: Development of new charging formulae and funding methods;
- **Performance parameters**: Generation of an information database, which should include application of the indicators that are developed in **Chapter 7**. Additionally, identification of areas eligible for CNS/ATM routes, similar to the North Pole.



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## APPENDICES

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## ***APPENDIX 1.1***

### **LIST OF COUNTRIES BY REGION**



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**LIST OF COUNTRIES BY REGION**


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<b>Africa</b>	<b>Americas &amp; Caribbean</b>
Algeria	Anguilla
Angola	Antigua
Benin	Argentina
Botswana	Bahamas
Burkina Faso	Barbados
Burundi	Belize
Cameroon	Bermuda
Cape Verde	Bolivia
Central African Republic	Brazil
Chad	British Virgin Islands
Comoros	Canada
Congo, PR	Cayman Islands
Congo, DR	Chile
Cote d'Ivoire	Colombia
Djibouti	Costa Rica
Egypt	Cuba
Equatorial Guinea	Dominica
Eritrea	Dominican Republic
Ethiopia	Ecuador
Gabon	El Salvador
Gambia	French Guyana
Ghana	Greenland
Guinea Bissau	Grenada
Guinea Conakry	Guadeloupe
Kenya	Guatemala
Lesotho	Guyana
Liberia	Haiti
Libyan Arab Jamahiriya	Honduras
Madagascar	Jamaica
Malawi	Martinique
Mali	Mexico
Mauritania	Montserrat
Mauritius	Netherlands Antilles
Morocco	Nicaragua
Mozambique	Panama
Namibia	Paraguay
Niger	Peru
Nigeria	Puerto Rico
Reunion	St. Kitts & Newis
Rwanda	St. Lucia
Sao Tome & Principe	St. Maarten
Senegal	St. Vincent & Grenadines
Seychelles	Surinam
Sierra Leone	Trinidad & Tobago
Somalia	Turks & Caicos
South Africa	Uruguay
Sudan	US Virgin Islands
Swaziland	USA
Tanzania	Venezuela
Togo	
Tunisia	
Uganda	
Zambia	
Zimbabwe	

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Asia & Pacific		Europe	
	Afghanistan		Albania
	Australia		Armenia
	Bangladesh		Austria
	Bhutan		Azerbaijan
	Brunei		Belarus
	Cambodia, Kingdom of		Belgium
	China, PR		Bosnia and Herzegovina
	Cook Islands		Bulgaria
	Fiji		Croatia
	Guam		Cyprus
	Hong Kong		Czech Republic
	India		Denmark
	Indonesia		Estonia
	Japan		Finland
	Kazakhstan		France
	Kiribati		FYROM
	Korea, Democratic PR of		Georgia
	Korea, Republic of		Germany
	Kyrgyzstan		Greece
	Laos		Hungary
	Malaysia		Iceland
	Maldives		Ireland
	Marshall Islands		Italy
	Mongolia		Latvia
	Myanmar		Lithuania
	Nauru		Luxembourg
	Nepal		Malta
	New Caledonia		Moldova
	New Zealand		Monaco
	Pakistan		Netherlands
	Papua New Guinea		Norway
	Philippines		Poland
	Singapore		Portugal
	Solomon Islands		Romania
	Sri Lanka		Russian Federation
	Taiwan, ROC		Slovak Republic
	Tajikistan		Slovenia
	Thailand		Spain
	Tonga		Sweden
	Turkmenistan		Switzerland
	Tuvalu		Ukraine
	Uzbekistan		United Kingdom
	Vanuatu		Yugoslavia
	Vietnam		
	Western Samoa		



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<b>Middle East</b>	Bahrain
	Iran
	Iraq
	Israel
	Jordan
	Kuwait
	Lebanon
	Oman
	Qatar
	Saudia Arabia
	Syria
	Turkey
	United Arab Emirates
	Yemen, Republic of

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## ***APPENDIX 1.2***

### **LIST OF COUNTRIES PARTICIPATING IN REGIONAL EN-ROUTE AGENCIES**



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**LIST OF COUNTRIES PARTICIPATING IN REGIONAL EN-ROUTE AGENCIES**


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*Source: IATA Airport & en-route aviation charges manual.*

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**ASECNA - Agence pour la Sécurité de la Aérienne en Afrique et à Madagascar.**


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Benin	Gabon
Burkina Faso	Madagascar (incl. Comores & Reunion)
Cameroon	Mali
Central African Republic	Mauritania
Chad	Niger
Congo	Senegal
Côte d'Ivoire	Togo
Equatorial Guinea	

---

**COCESNA - Corporacion Centroamericana de Servicios de Navigacion Aérea.**


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Belize	Guatemala
Costa Rica	Honduras
El Salvador	Nicaragua

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**EUROCONTROL - European Organisation for the Safety of Air Navigation.**


---

Austria	Luxembourg
Belgium	Malta
Bulgaria	Monaco
Croatia	Netherlands
Cyprus	Norway
Czech Republic	Portugal
Denmark	Romania
France	Slovak Republic
FYROM	Slovenia
Germany	Spain
Greece	Sweden
Hungary	Switzerland
Ireland	Turkey
Italy	United Kingdom

---

**PIARCO FIR**


---

Antigua	Montserrat
Barbados	St. Kitts & Nevis
Dominica	St. Lucia
Grenada	St. Maarten
Guadeloupe	St. Vincent & Grenadines
Martinique	Trinidad & Tobago

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**ROBERTS FIR**


---

Guinea Conakry
Liberia
Sierra Leone

---



## ***APPENDIX 1.3***

### **DESCRIPTIONS OF REGIONAL EN-ROUTE AGENCIES**



---

## DESCRIPTIONS OF REGIONAL EN-ROUTE AGENCIES

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*Sources: Eurocontrol & ICAO.*

### **ASECNA - Agence pour la Sécurité de la Aérienne en Afrique et à Madagascar.**

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ASECNA (founded in 1959), constituted as a public body with legal status and financial autonomy, is operated by 15 States in Africa, as listed in **Appendix 1.2**, and France, which is also a member. Its functions on their behalf include the provision and operation of air traffic control (ATC) services, communications facilities and meteorological services for both route and approach/landing purposes in the 15 African States. In addition, the Agency may be entrusted by each of the States with the management or maintenance of any operation serving an aeronautical purpose, under individual contracts. The Agency may also be authorised to establish special equipment programmes for a particular State, especially with regard to the operation of its terminal aids or any special tasks entrusted to the Agency. The Agency is governed by a Ministerial Committee, composed of the ministers responsible for civil aviation in the signatory States, which defines general policy. It is administered by an Administrative Council, composed of one representative from each signatory State, assisted by a Director General. The Agency employs its own staff, but it can also have staff from signatory States seconded to it. ASECNA headquarters are located in Dakar, Senegal. In accordance with the provisions of Article 15 of the Chicago Convention, the Agency may not extend to any user, directly or indirectly, or in any form whatsoever, benefits not offered to other users availing themselves, under the same conditions, of the facilities under its management.

#### **□ Methods of financing**

At present, the Agency is totally financed from its own operating income. It is authorised to levy charges to offset the financial obligations it assumed in the performance of the tasks entrusted to it and in return for services rendered to users. The Agency is also authorised to collect all income that the property under its management generates in the course of serving aeronautical purposes.

### **COCESNA - Corporación Centroamericana de Servicios de Navegación Aérea**

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COCESNA, the Central American Air Navigation Services and Facilities Corporation, founded in February 1960, has 6 member States, namely Belize, Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua. The Corporation is an integrated, international, Central American autonomous organisation. According to its Charter, the Corporation has exclusive rights to provide air traffic services, aeronautical telecommunications and radio navigation aids for international civil aviation in the territories of the contracting parties. In practice, however, it provides services in the upper airspace (above flight level 200) and co-operates only partially with contracting governments in the provision of air traffic services in the lower airspace. It may also provide to other States, through agreements, the aforementioned services and aids specified in the ICAO regional Air Navigation Plan (ANP). Furthermore, it may also provide services and radio aids of the type mentioned above that are not specified in the ICAO Regional Plan within the territories of the contracting parties, by means of contracts with public or private entities.

#### **□ Methods of financing**

In addition to working capital, the contracting parties also agreed to acquire, when necessary, and concede the use and possession of, at no cost to the Corporation, certain equipment listed in the Charter, as well as to provide the land on which the equipment was situated, as well as all other property or furnishings directly related to the discharge of its functions. In order to maintain financial equilibrium and provide for the development and expansion of its aeronautical services, the Corporation is authorised to levy charges on facility users. By this means, COCESNA is at present wholly financed from its own operating income.

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## **EUROCONTROL - European Organisation for the Safety of Air Navigation**

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Eurocontrol has 28 member States, as listed in **Appendix 1.2**. Founded in 1960 for overseeing ATC in the upper airspace of member States, it provides the necessary expertise and operational, experimental and training facilities to assist the expansion of air traffic control capacity in Europe. Its functions include:

- ❑ the management of the European Air Traffic Control Harmonisation and Integration Programme (EATCHIP) on behalf of States belonging to the European Civil Aviation Conference (ECAC);
- ❑ the implementation of short and medium-term action to improve the co-ordination of ATC systems in Europe;
- ❑ the provision of air traffic control services in the upper space of Belgium, Luxembourg, the Netherlands and northern Germany;
- ❑ the operation of a single European Central air traffic Flow Management Unit (CFMU) to make optimum use of European airspace and to prevent air traffic congestion;
- ❑ the conduct of research and development work aimed at increasing air traffic control capacity in Europe;
- ❑ the provision of support on advanced and specialist ATS training.

Eurocontrol also operates a route facility charges collection scheme for its member and non-member States, as described in **Chapter 1** of this dissertation. The States participating in the scheme determine the level of charges and moneys, which are collected and disbursed to them. The governing body of the Organisation is the Permanent Commission assisted by an Agency comprising the Committee of Management and the Director General. The Commission and Committee are composed of member States' representatives, with voting strength weighted according to each State's annual contribution to the Organisation. Both bodies are enlarged to include non-member States' representatives when matters relating to the route charges collection scheme are addressed.

### **❑ Methods of financing**

The Organisation is financed by contributions from its Member States, except for the costs of its route charges collection scheme, which are recovered from airspace users through a supplement included in the charges.

## **PIARCO FIR**

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PIARCO FIR consists of 12 Eastern Caribbean States, who have centralised their en-route air navigation activities in Trinidad & Tobago. The provision of the facilities and services are conducted in Port-of-Spain, where the charges are also levied. Therefore, any aircraft entering the FIR is subject to just one charge, irrespective of which countries it actually flew over.

### **❑ Methods of financing**

The agency may retain all the charges to finance its equipment, staff and all other costs.

## **ROBERTS FIR**

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ROBERTS FIR is an en-route agency that combines the provision of such air navigation services with the billing and collection of charges for Guinea Conakry, Liberia and Sierra Leone in Africa. The centre of these facilities is currently located in Guinea Conakry.

### **❑ Methods of financing**

The agency may retain all the charges to finance its equipment, staff and all other costs.



***APPENDIX 2.1***

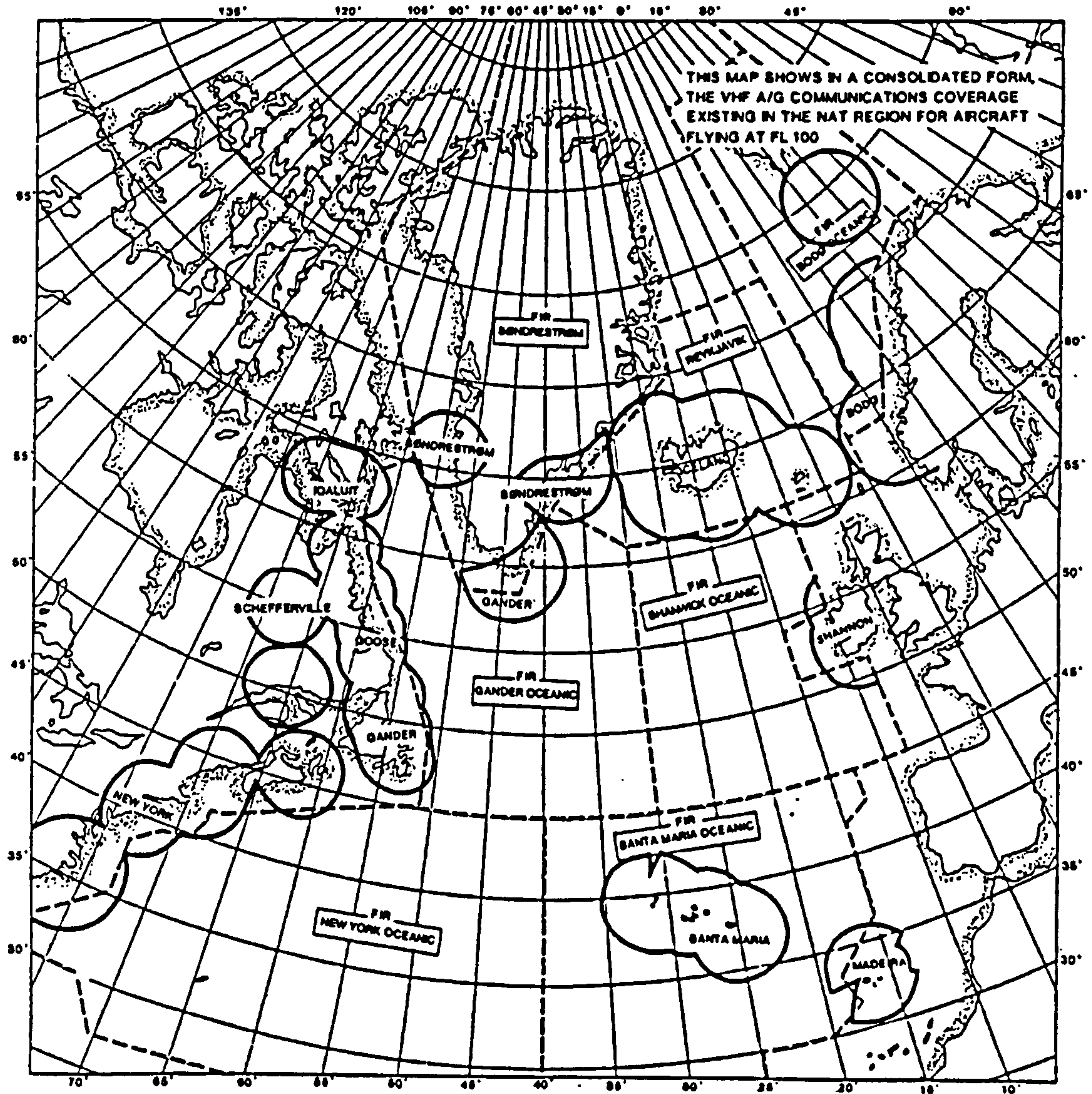
**NORTH ATLANTIC OCEAN  
VHF COVERAGE CHARTS**



## NORTH ATLANTIC OCEAN VHF COVERAGE CHARTS

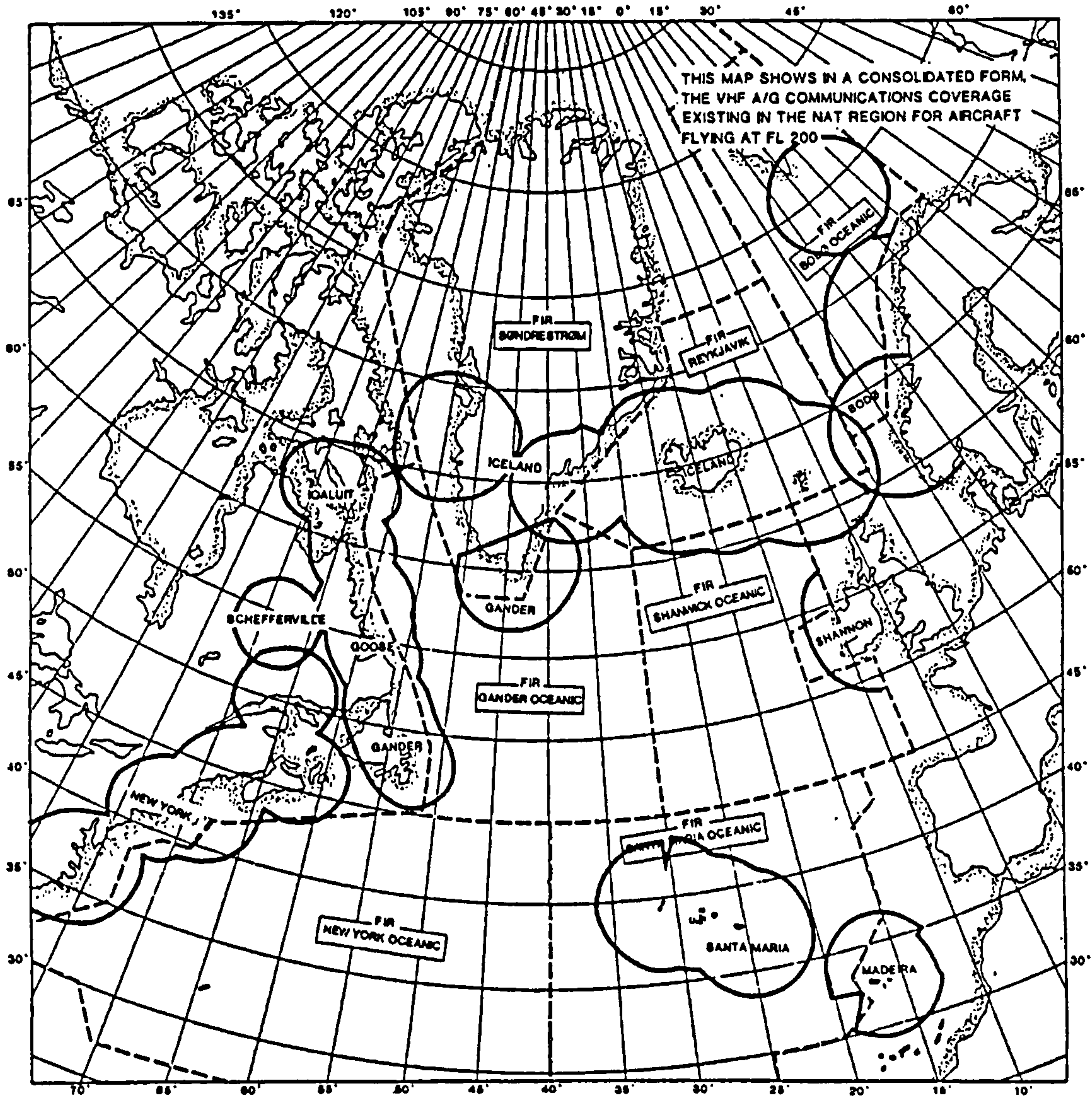
Source: 'Guidance and Information Material concerning Air Navigation in the North Atlantic Region' – ICAO. Interim 7<sup>th</sup> Ed., September 2000.

### VHF AIR/GROUND COMMUNICATIONS COVERAGE EXISTING IN THE NAT REGION AT FL 100



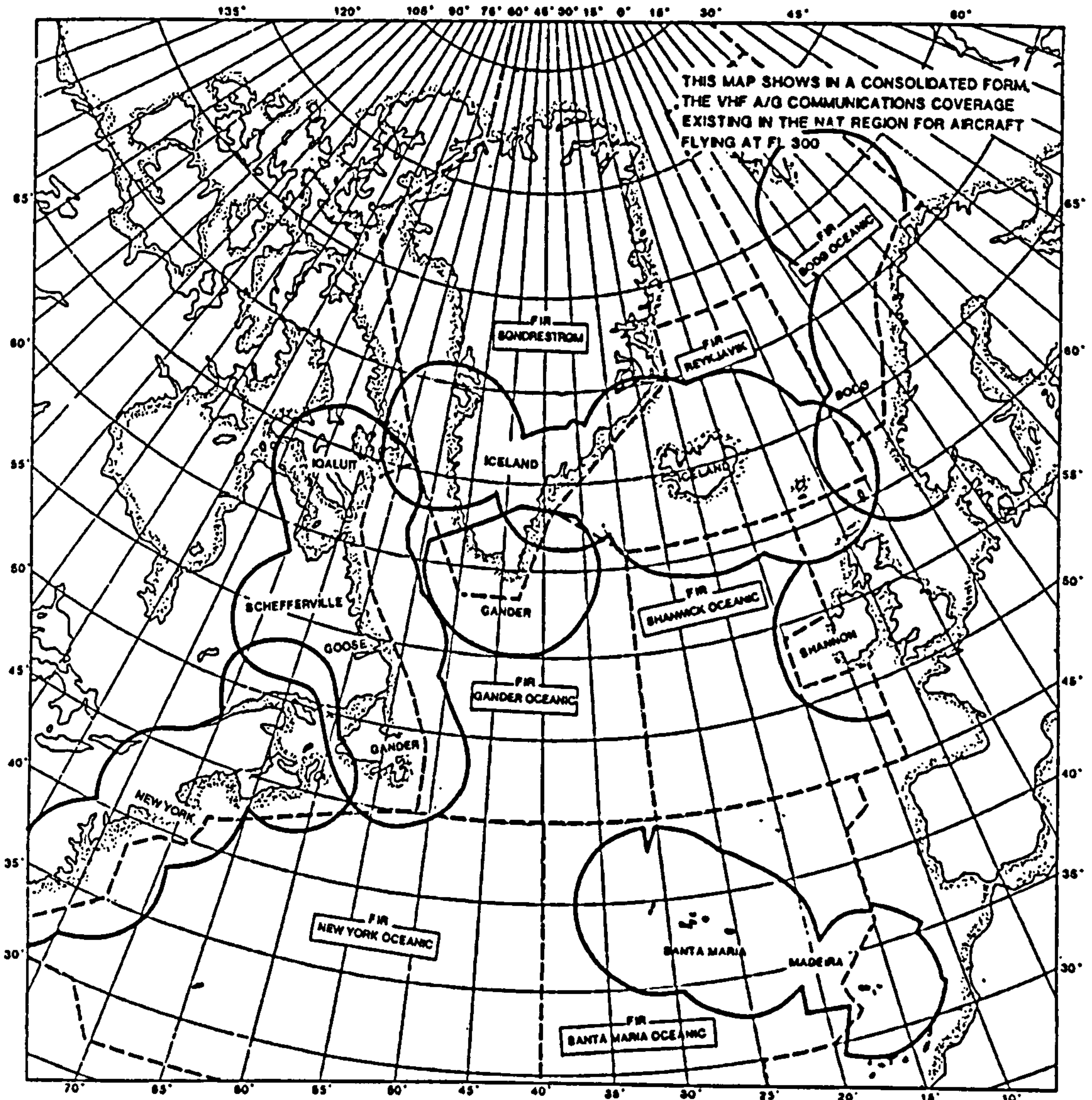


**VHF AIR/GROUND COMMUNICATIONS COVERAGE  
EXISTING IN THE NAT REGION AT FL 200**





**VHF AIR/GROUND COMMUNICATIONS COVERAGE  
EXISTING IN THE NAT REGION AT FL 300**





***APPENDIX 3.1***

**ANNEXES TO THE CONVENTION  
ON INTERNATIONAL CIVIL AVIATION**



## **ANNEXES TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION**

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**Source: ICAO**

The following ICAO Annexes exist:

- Annex 1 – Personnel Licensing;
- Annex 2 – Rules of the Air;
- Annex 3 – Meteorological Service for International Air Navigation;
- Annex 4 – Aeronautical Charts;
- Annex 5 – Units of Measurement to be Used in Air and Ground Operations;
- Annex 6 – Operation of Aircraft:
  - Part I: International Commercial Air Transport – Aeroplanes
  - Part II: International General Aviation – Aeroplanes;
  - Part III: International Operations – Helicopters;
- Annex 7 – Aircraft Nationality and Registration Marks;
- Annex 8 – Airworthiness of Aircraft;
- Annex 9 – Facilitation;
- Annex 10 – Aeronautical Telecommunications:
  - Volume I: Radio Navigation Aids;
  - Volume II: Communication Procedures, including those with PANS status;
  - Volume III:       Part I – Digital Data Communication Systems;  
                          Part II – Voice Communication Systems;
  - Volume IV: Surveillance Radar and Collision Avoidance Systems;
  - Volume V: Aeronautical Radio Frequency Spectrum Utilisation;
- Annex 11 – Air Traffic Services;
- Annex 12 – Search and Rescue;
- Annex 13 – Aircraft Accident and Incident Investigation;
- Annex 14 – Aerodromes:
  - Volume I: Aerodrome Design and Operations;
  - Volume II: Heliports;
- Annex 15 – Aeronautical Information Services;
- Annex 16 – Environmental Protection:
  - Volume I: Aircraft Noise;
  - Volume II: Aircraft Engine Emissions;
- Annex 17 – Security;
- Annex 18 – The Safe Transport of Dangerous Goods by Air.



## ***APPENDIX 3.2***

### **BENEFITS OF CNS/ATM SYSTEM FOR DIFFERENT AIRSPACE TYPES**



## **BENEFITS OF CNS/ATM SYSTEM FOR DIFFERENT AIRSPACE TYPES**

Source: ICAO's Global Air Navigation Plan for CNS/ATM systems (1<sup>st</sup> Ed. 2000).

### **Oceanic/continental en-route airspace with low-density traffic**

<b>Functions</b>	<b>ATM Procedures</b>	<b>ATM benefits</b>
<i>Communications</i>	<ul style="list-style-type: none"> <li>• Datalink handling procedures                             <ul style="list-style-type: none"> <li>• Message format</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Improved tactical control</li> <li>• Improved pilot/controller communications</li> <li>• Facilitate ATC/FMS dialogue</li> </ul>
<i>Navigation</i>	<ul style="list-style-type: none"> <li>• Navigation procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Improved airspace utilisation</li> </ul>
<i>Surveillance</i>	<ul style="list-style-type: none"> <li>• Surveillance procedures                             <ul style="list-style-type: none"> <li>• Message format</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Reduction of R/T workload</li> <li>• Improved situational awareness</li> </ul>
<i>Automation</i>	<ul style="list-style-type: none"> <li>• Automation procedures and algorithm development                             <ul style="list-style-type: none"> <li>• Message format</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Increase in direct routings</li> <li>• Improved conflict prediction and resolution</li> </ul>



**Oceanic en-route airspace with high-density traffic**

<b>Functions</b>	<b>ATM Procedures</b>	<b>ATM benefits</b>
<i>Communications</i>	<ul style="list-style-type: none"> <li>• Separation criteria</li> <li>• Datalink handling procedures</li> <li>• Message format</li> </ul>	<ul style="list-style-type: none"> <li>• Improved tactical control</li> <li>• Improved pilot/controller communications</li> <li>• Facilitate ATC/FMS dialogue</li> </ul>
<i>Navigation</i>	<ul style="list-style-type: none"> <li>• Navigation procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Increase airspace capacity by reduction in separation minima due to increased positional accuracy</li> <li>• Improved airspace utilisation</li> </ul>
<i>Surveillance</i>	<ul style="list-style-type: none"> <li>• Surveillance procedures</li> <li>• Message format</li> </ul>	<ul style="list-style-type: none"> <li>• Increased airspace capacity by reduction in separation minima due to improved conformance monitoring</li> <li>• Improved airspace utilisation</li> <li>• Reduction of R/T workload</li> <li>• Improved situational awareness</li> </ul>
<i>Automation</i>	<ul style="list-style-type: none"> <li>• Automation procedures and algorithm development</li> <li>• Message format</li> </ul>	<ul style="list-style-type: none"> <li>• Increase in direct routings</li> <li>• Increase in user-preferred flight profiles                             <ul style="list-style-type: none"> <li>• Increased capacity</li> </ul> </li> <li>• Improved tactical planning</li> <li>• Improved conflict prediction and resolution</li> <li>• Improved trajectory planning</li> </ul>



**Continental en-route airspace with high-density traffic**

<b>Functions</b>	<b>ATM Procedures</b>	<b>ATM benefits</b>
<i>Communications</i>	<ul style="list-style-type: none"> <li>• Separation criteria</li> <li>• Datalink handling</li> <li>• Message format</li> </ul>	<ul style="list-style-type: none"> <li>• Improved pilot/controller communications</li> <li>• Facilitate ATC/FMS dialogue</li> <li>• Complement VHF coverage</li> <li>• Reduction of R/T workload</li> </ul>
<i>Navigation</i>	<ul style="list-style-type: none"> <li>• Navigation procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Increase airspace capacity by reduction in separation minima due to increased positional accuracy</li> <li>• Improved airspace utilisation</li> </ul>
<i>Surveillance</i>	<ul style="list-style-type: none"> <li>• Surveillance procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Increased airspace capacity by reduction in separation minima due to improved conformance monitoring</li> <li>• Improved airspace utilisation</li> <li>• Reduction of R/T workload</li> <li>• Improved situational awareness</li> <li>• ADS (and ADS-B) complement to and possible backup for SSR                             <ul style="list-style-type: none"> <li>• Reduced need for PSR</li> </ul> </li> </ul>
<i>Automation</i>	<ul style="list-style-type: none"> <li>• Automation procedures and algorithm development                             <ul style="list-style-type: none"> <li>• Message format</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Improved traffic planning</li> <li>• Improved conflict prediction and resolution</li> <li>• Improved trajectory planning                             <ul style="list-style-type: none"> <li>• Increase in direct routings</li> </ul> </li> <li>• Increase in user-preferred flight profiles</li> </ul>



**Terminal areas with high-density traffic**

<b>Functions</b>	<b>ATM Procedures</b>	<b>ATM benefits</b>
<i>Communications</i>	<ul style="list-style-type: none"> <li>• Separation criteria</li> <li>• Message format</li> <li>• Datalink procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Improved pilot/controller communications</li> <li>• Facilitate ATC/FMS dialogue</li> <li>• Complement VHF coverage</li> <li>• Reduction of R/T workload</li> </ul>
<i>Navigation</i>	<ul style="list-style-type: none"> <li>• Approach procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Increase airspace capacity by reduction in separation minima due to increased positional accuracy</li> <li>• Improved airspace utilisation</li> </ul>
<i>Surveillance</i>	<ul style="list-style-type: none"> <li>• Surveillance procedures development</li> </ul>	<ul style="list-style-type: none"> <li>• Increased airspace capacity by reduction in separation minima due to improved conformance monitoring</li> <li>• Improved airspace utilisation</li> <li>• Reduction of R/T workload</li> <li>• Improved situational awareness</li> <li>• ADS (and ADS-B) complement to and possible backup for SSR               <ul style="list-style-type: none"> <li>• Reduced need for PSR</li> </ul> </li> </ul>
<i>Automation</i>	<ul style="list-style-type: none"> <li>• Automation procedures and algorithm development               <ul style="list-style-type: none"> <li>• Message format</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Increase in direct routings</li> <li>• Improved sequencing and flight profiles</li> <li>• Improved trajectory planning               <ul style="list-style-type: none"> <li>• Improved traffic planning</li> </ul> </li> <li>• Improved conflict prediction and resolution</li> </ul>



**Terminal areas with low-density traffic**

<b>Functions</b>	<b>ATM Procedures</b>	<b>ATM benefits</b>
<i>Communications</i>	<ul style="list-style-type: none"> <li>• Datalink procedures</li> <li>• Message format</li> </ul>	<ul style="list-style-type: none"> <li>• Improved pilot/controller communications</li> <li>• Facilitate ATC/FMS dialogue</li> <li>• Complement VHF coverage</li> </ul>
<i>Navigation</i>	<ul style="list-style-type: none"> <li>• Approach procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Improved airspace utilisation</li> </ul>
<i>Surveillance</i>	<ul style="list-style-type: none"> <li>• Surveillance procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Improved airspace utilisation</li> <li>• Improved situational awareness                             <ul style="list-style-type: none"> <li>• Reduced need for PSR</li> </ul> </li> </ul>
<i>Automation</i>	<ul style="list-style-type: none"> <li>• Automation procedures and algorithm development                             <ul style="list-style-type: none"> <li>• Message format</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Increase in user-preferred flight profiles</li> <li>• Improved traffic planning</li> <li>• Improved conflict prediction and resolution</li> </ul>



### **APPENDIX 3.3**

## **LIST OF ECAC AND EUROCONTROL MEMBER COUNTRIES**



## LIST OF ECAC AND EUROCONTROL MEMBER COUNTRIES

Source: ECAC & Eurocontrol

The European Civil Aviation Conference (ECAC) and Eurocontrol are composed of the following member States:

Country	ECAC	Eurocontrol
Albania	X	
Armenia	X	
Austria	X	X
Belgium	X	X
Bulgaria	X	X
Croatia	X	X
Cyprus	X	X
Czech Republic	X	X
Denmark	X	X
Estonia	X	
Finland	X	X
France	X	X
FYROM	X	X
Germany	X	X
Greece	X	X
Hungary	X	X
Iceland	X	
Ireland	X	X
Italy	X	X
Latvia	X	
Lithuania	X	
Luxembourg	X	X
Malta	X	X
Moldova	X	X
Monaco	X	X
Netherlands	X	X
Norway	X	X
Poland	X	
Portugal	X	X
Romania	X	X
Slovak Republic	X	X
Slovenia	X	X
Spain	X	X
Sweden	X	X
Switzerland	X	X
Turkey	X	X
Ukraine	X	
United Kingdom	X	X



## ***APPENDIX 3.4***

### **CHANGING RÔLES AND RESPONSIBILITIES**



## CHANGING RÔLES AND RESPONSIBILITIES

Source: Eurocontrol's ATM Strategy for 2000+

The following table highlights some of the key evolutions regarding rôles and responsibilities:

Period	Pilot	Controller	Aircraft Operators
Up to 2005	<p><b>Responsible for:</b></p> <ul style="list-style-type: none"> <li>- conduct of flight;</li> <li>- instigating changes to plan.</li> </ul> <p><b>In an environment with:</b></p> <ul style="list-style-type: none"> <li>- navigation based RNAV systems;</li> <li>- greater choice of flight trajectory available on free routes in upper airspace for suitably equipped aircraft;</li> <li>- RT used as main communications with controller, but initial air-ground datalink applications;</li> <li>- improved cockpit HMI, with some automated inputs into FMS.</li> </ul>	<p><b>Responsible for:</b></p> <ul style="list-style-type: none"> <li>- separating aircraft;</li> <li>- a defined fixed airspace sector.</li> </ul> <p><b>In an environment with:</b></p> <ul style="list-style-type: none"> <li>- a largely unchanged control team;</li> <li>- some (co-ordination &amp; transfer automated) tasks;</li> <li>- RT as main communications means with pilot, but initial air-ground datalink applications;</li> <li>- electronic flight strips in many units;</li> <li>- increasing reliance on computer tools for monitoring and alerting;</li> <li>- growing emphasis on de-confliction planning;</li> <li>- arrival manager for sequencing aircraft at major airports.</li> </ul>	<p><b>Responsible for:</b></p> <ul style="list-style-type: none"> <li>- pre-planning of flights.</li> </ul> <p><b>In an environment with:</b></p> <ul style="list-style-type: none"> <li>- some automated links with CFMU, MET and AIS;</li> <li>- more choice on re-routings;</li> <li>- early CDM operations.</li> </ul>
Up to 2010	<p><b>Responsible for:</b></p> <ul style="list-style-type: none"> <li>- conduct of flight and negotiating changes to trajectory with the ground controller, in some instances in conjunction with the Aircraft Operations Centre (AOC);</li> <li>- separation in some defined circumstances (climb, same-way routes) in suitably equipped aircraft.</li> </ul>	<p><b>Responsible for:</b></p> <ul style="list-style-type: none"> <li>- separating aircraft except in limited and defined circumstances;</li> <li>- defined airspace sector, but boundaries are subject to change to reflect traffic patterns.</li> </ul>	<p><b>Responsible for:</b></p> <ul style="list-style-type: none"> <li>- pre-planning of flights and diversions;</li> <li>- also involved in route choices and in-flight trajectory changes;</li> <li>- additionally, some operators will directly negotiate dynamic route and timing changes with ATC and aircraft</li> </ul>



Period	Pilot	Controller	Aircraft Operators
<i>Up to 2010 cont'd</i>	<p><b><i>In an environment with:</i></b></p> <ul style="list-style-type: none"> <li>- less reliance on RT and many routine messages exchanged via datalink;</li> <li>- greater reliance on 4D flight trajectories and navigation techniques using satellite systems;</li> <li>- integrated FMS with route change inputs automated on many aircraft;</li> <li>- early introduction of ASAS capabilities with improved situational awareness displays on some aircraft;</li> <li>- greater reliance on cockpit systems for airport surface movement.</li> </ul>	<p><b><i>In an environment with:</i></b></p> <ul style="list-style-type: none"> <li>- progressive emphasis on planning rather than tactical intervention;</li> <li>- less reliance on RT and many routine messages exchanged via datalink;</li> <li>- most inter-unit data exchange automated and electronic flight strips at most ATC units;</li> <li>- growing reliance on planning tools and computer generated resolution advice;</li> <li>- controller relying on automated slot sequencing for arrivals and departures at most major airports.</li> </ul>	<p><b><i>In an environment with:</i></b></p> <ul style="list-style-type: none"> <li>- automated links with CFMU, MET, AIS, ATC and airports.</li> </ul>
<i>Up to 2015</i>	<p><b><i>Responsible for:</i></b></p> <ul style="list-style-type: none"> <li>- conduct of flight and negotiating changes to trajectory in conjunction with the Aircraft Operations Centre (AOC);</li> <li>- maintaining own separation in designated free route airspace using ASAS.</li> </ul> <p><b><i>In an environment with:</i></b></p> <ul style="list-style-type: none"> <li>- routine messages passed by datalink, with much reduced use of RT;</li> <li>- most trajectory monitoring and change automated within FMS;</li> <li>- automated systems used for airport surface movement.</li> </ul>	<p><b><i>Responsible for:</i></b></p> <ul style="list-style-type: none"> <li>- separating aircraft in managed airspace;</li> <li>- managing the organisation of traffic to ensure a smooth flow, particularly in border areas between free and managed airspace.</li> </ul> <p><b><i>In an environment with:</i></b></p> <ul style="list-style-type: none"> <li>- emphasis on automated medium-term planning over a number of sectors and monitoring of de-conflicted trajectories;</li> <li>- routine messages passed by datalink, with much reduced use of RT;</li> <li>- controller relying on automated slot sequencing for arrivals and departures at major airports.</li> </ul>	<p><b><i>Responsible for:</i></b></p> <ul style="list-style-type: none"> <li>- pre-planning of flights and diversions;</li> <li>- also involved in direct negotiation with ATC and aircraft on dynamic route and timing changes;</li> <li>- changes to aircraft landing and take-off times negotiated directly with ATC, CFMU and airports.</li> </ul> <p><b><i>In an environment with:</i></b></p> <ul style="list-style-type: none"> <li>- automated down-linking of flight parameters from aircraft in-flight and dynamic optimisation of trajectories passed directly to aircraft.</li> </ul>



## ***APPENDIX 3.5***

### **THE TARGET CONCEPT STATEMENT**



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## THE TARGET CONCEPT STATEMENT

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**Source: Eurocontrol's ATM Strategy for 2000+**

The target concept, which should be viewed as the goal that the future ATM network is aiming towards, is predicated on layered planning, based around a strategically driven daily airspace plan, with Collaborative Decision Making (CDM) between the involved parties and with an evolving change to managing resources rather than demand. The concept incorporates a mix of route structuring, free routings and autonomous aircraft operations to answer the needs of a diverse user community. It also involves, among other changes cited in **Section 3.5**, a more dynamic and flexible management of airspace. The main objectives and focus of the concept are also given in **Chapter 3**.

This appendix summarises the target concept statement, which reads ...

***“A collaborative and layered planning system, strategically co-ordinated and operating gate-to-gate, incorporating capacity management and based on three airspace régimes with shared responsibilities for separation assurance involving changes to rôles and responsibilities under-pinned by enhanced computer support”***

... indicating that the following components exist, with associated explanations given:

- ❑ *Collaborative and layered planning system* – the exchange of current, relevant data between ATM, airports, Airline Operations Centres (AOC) and aircraft, to enable the different system layers to support flexible decisions where needed, taking advantage of the availability of a common information pool, enhanced equipment, computer tools and operating procedures designed to increase capacity, efficiency and safety;
- ❑ *Strategically co-ordinated* – co-ordinated strategic planning involving ATM, airports and airspace users to balance and match capacity and demand;
- ❑ *Operating gate-to-gate* – starting at the moment in a flight when the user first interacts with ATM and ending with engine shut-down, it also includes the process of charging users for ATM services;
- ❑ *Capacity management* – evolving to managing capacity rather than demand, based on service quality agreements and layered sets of planning functions;
- ❑ *Three airspace regions* – the following three types will exist:
  - **UnManaged AirSpace (UMAS)** – unknown traffic environment with rules of the air;
  - **Managed AirSpace (MAS)** – known traffic environment with 3D routes and routings that have separation governed from the ground;
  - **Free Flight AirSpace (FFAS)** – known traffic environment that is based on free routings and autonomous operations;
- ❑ *Rôles and responsibilities* – with humans still ultimately responsible for tactical separation, revised individual and team rôles will provide enhanced planning on multi-sector bases with extensive computer support and tools;
- ❑ *Separation assurance* – that is allied to the airspace régime.

The sections hereunder concentrate on those ATM aspects not covered in great detail in **Section 3.5**:

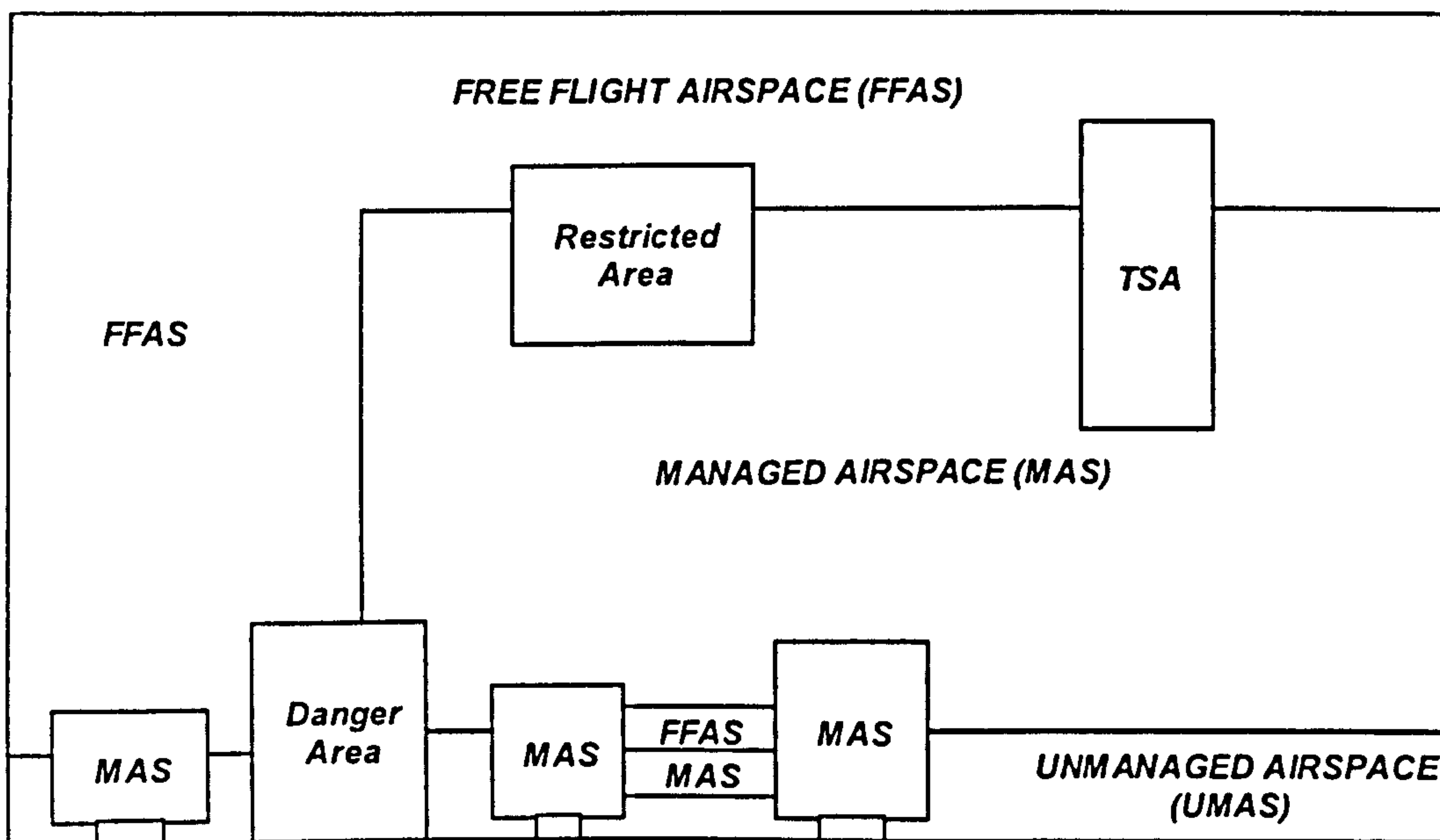
### **1. Airspace Management**

AirSpace Management (ASM) and planning will become a more integrated and collaborative function that will support all aspects of planning, design, maintenance, updates, civil-military co-ordination, regulation and airspace legislation. The main objective will be to optimise the



airspace structure of the entire ECAC airspace for the benefit of all users at both the strategic planning and tactical levels. As part of ASM, the development of the airspace structure will consider the ATM requirements for CNS performance and the corresponding impact of available CNS techniques, systems and infrastructures.

Airspace divisions will be based on ATM needs rather than on national boundaries, but without compromising sovereignty. They will consist of the three aforementioned different types of airspace régimes, namely UnManaged AirSpace (UMAS), Managed AirSpace (MAS) and Free Flight AirSpace (FFAS). The vertical, lateral and time boundaries of the régimes will be determined during the airspace planning phases, taking into consideration air traffic flow forecasts and the corresponding aircraft capabilities. It will be possible to dynamically readjust the boundaries between MAS, FFAS and UMAS in accordance with the needs of en-route operations. ATM will have the responsibility to make the information on the extent of MAS and FFAS operations available to all users before and on the day of operation. The following plan view diagram details the overall layout of the régimes:



Unmanaged airspace in 2015 will be equivalent to today's regions that are outside controlled airspace, with similar rules to those that presently exist. However, there will be harmonisation of airspace categories and uniformity of rules across the ECAC region, with easier access to more accurate information, including the ability of equipped aircraft to negotiate and agree separation action. There will be no interaction with ATM for aircraft operating in UMAS, except for those aircraft that wish to notify their presence by filing a flight plan or by broadcasting their position through electronic means.

In contrast, managed airspace in 2015 will consist of airspace that requires traffic structuring at peak times in the form of structured routes and facilitates user-preferred trajectories at other times, using the free-routing concept. The latter will always exist in those airspace regions that are not subject to phenomenal demand at peak times. Thus, greater flexibility will be possible in the less congested airspace of some ECAC regions. In both cases, the responsibility for separation assurance will remain with the ground ATM organisations. Consider structured routes and the free-routing concept separately, thus:

- Structured routes – operations within these routes will be optimised using the benefits of RNAV and the FMS, with structures tailored to accommodate traffic flows and take advantage of Special Use Airspace (SUA). Route structures will be dynamically sized and optimised to increase flight economy, with sectorisation based on traffic flow demands and workload factor considerations. The capability of more accurate navigation by aircraft will



reduce the horizontal separation standards, enabling more closely spaced routes and corresponding increases in airspace capacity;

- *Free-routing* – such operations will use current developments with direct routings, whereby aircraft will fly their own user-preferred trajectories outside the structured routes, subject to any overriding airspace restrictions such as danger areas, restricted areas or Temporary Segregated Airspace (TSA). ATM intervention will be by exception and will use CDM principles. The development of automated support systems will aid the provision of free-routing.

In the terminal area, operations will vary according to the complexity of the airspace and the amount of traffic that must be handled. The emphasis will remain on the establishment of RNAV and FMS routes to enable flexible routes with dynamic route restructuring and terminal area resizing in response to traffic flows. More accurate navigation capabilities will facilitate closer separation standards and routes. Integrated Departure and Arrival Management Systems (DMS & AMS) will assist accurate flight monitoring and improved prediction of 3D trajectory information. In complex terminal areas with high traffic levels, a number of constraints will probably still affect aircraft operations in 2015 by limiting the flexibility of dynamic routes, similar to today's instrument departures and terminal arrival routes.

Free flight airspace will be determined by airspace planning and management services on a daily basis. The volumes of airspace allocated as FFAS will be promulgated to reflect the expected demand patterns. This will take account of the traffic forecasts and the capability of the aircraft. Indeed, the aim will be to maximise the benefits for capable aircraft, thereby providing operators with incentives to fit the requisite avionics. Suitably equipped flights will be able to fly user-preferred 3D and 4D-routings. The routings chosen by aircraft will be for short-term, long-term or strategic reasons. Operators will benefit in terms of fuel economy and flexibility. Responsibility for separation assurance from other aircraft will rest with the aircraft in almost all circumstances, with some responsibility undertaken on the ground in emergencies, for instance. In addition to the alerting service, the ground ATM network will also provide a Flight Information Service (FIS).

## **2. Air Traffic Flow Management**

Air Traffic Flow Management (ATFM) exists to support ATC with preventing system overloads and to ensure optimum flow of air traffic to, from, through and within defined areas during times when demand exceeds, or is expected to exceed, the available capacity of the system. In the future, the emphasis will be on responsive capacity management, with demand management applied as a result of physical airport or airspace limitations, unexpected events or abnormal traffic peaks. Thus, the aim is to develop airspace capacity to such an extent that flow regulation will only be needed in exceptional circumstances. In this context, the emphasis of future flow control will move from adapting demand to a fixed capacity limit, to optimising the capacity of the system to meet the predicted demand.

The new term for ATFM, Flow and Capacity Management (FC&M), will deliver an increase in capacity through a service quality plan for preparing, co-ordinating and managing the service quality plans. The plans will define specific user demands, the quality of service to be achieved and the planning responsibilities of each party. These plans will form a central platform for strategic planning activities. In addition, the required performance of the system will be part of the service quality contract. Implementation of the contract will be based on main principles that include co-ordinated timetables, optimised time of arrival and minimum in-flight delay.

FC&M will concentrate on two factors, flight punctuality and efficiency, which will be optimised through the use of a layered set of scheduling and planning functions. Each layer will operate as a filter for the next and the process will involve:

- *Strategic flow scheduling* – which emanates from airlines' needs to publish their schedules before each season. The output will be a set of daily operations plans that will balance the expected demand and forecast available capacity;



- Optimal flow regulation – due to the schedule changes and subsequent filing of flight plans by other types of operator, optimal flow regulation will refine the details of the original plan over time and prepare an optimised and detailed operational plan one day in advance of the implementation date for airspace configuration;
- Tactical flow planning – its rôle will be to implement and supervise the daily operations plans and to apply any refinements needed in light of real-time events, with the intention being to ensure as little disruption to the daily airspace plan as possible. The need to adapt from the original plan may be due to significant weather phenomena or unexpected infrastructure changes.

### 3. Air Traffic Services

Traditionally, Air Traffic Services (ATS) have had a leading rôle in progressing, developing, maintaining and managing the overall actions related with the provision of safe services. The target operational concept for future ATM in Europe continues to view ATS as the most important element of ATM due to the safety implications of the services provided. However, it should be noted that the other elements will gain in importance. ASM and ATFM rôles will be to anticipate, identify, organise and prepare the implementation of strategic planning in order to provide a high quality of service to airspace users and to minimise the tactical implementation risks related to real-time operation.

Thus, ATS will only change in order to respond promptly to real-time scenario variations using advanced and integrated data information exchange and computer support. It will still consist of the following primary elements:

- ATC service – whose objective is to maintain a safe, expeditious and orderly flow of air traffic. Thus, ATC will prevent collisions within the parameter of gate-to-gate operations using the aforementioned F&CM techniques to maintain an orderly and expeditious flow of traffic;
- Flight Information Service (FIS) – whose objective is to provide advice and information for the safe and efficient conduct of flights. FIS will be complemented by a trajectory monitoring service to maintain situational awareness in the event that an aircraft requires assistance from the ground when in FFAS;
- Alerting service – whose purpose, to notify appropriate organisations regarding aircraft in need of search and rescue support and assistance, will remain as it currently is, but will benefit from the availability of more timely and integrated information.

### 4. Aeronautical Information Services

Aeronautical Information Services (AIS) collect and disseminate information relating to the structure and composition of the ATM physical environment and thereby provide essential support for virtually all aeronautical activities and programmes. The objective of AIS is to ensure the satisfactory flow of information necessary for safety, regularity and efficiency of international air navigation. In the future, European AIS will be improved and developed to provide a single, harmonised, co-ordinated service delivering quality-assured information to all phases of flight, both in the context of the gate-to-gate concept and in support of CNS. This one source aims to provide meteorological<sup>1196</sup>, flight plan and other related information such as NOTices To AirMen (NOTAM) in addition to the AIS. It is intended to conduct the AIS in a paperless format, incorporating the use of electronic Aeronautical Information Publications (AIP) and charts.

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<sup>1196</sup> High quality information from METeorological (MET) information services is a pre-requisite for a safe and efficient ATM network as a basis for pre-flight CDM and calculation of trajectories.



## ***APPENDIX 3.6***

# **THE EUROPEAN RULE-MAKING PROCESS**



## THE EUROPEAN RULE-MAKING PROCESS

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*Source: Eurocontrol's ATM Strategy for 2000+*

Nine steps have been identified for future ATM rule-making within Europe, thus:

- Identification of the Strategic Direction and associated decisions by the Eurocontrol Council and General Assembly;
- Identification of the work programme to meet the strategic direction;
- Identification of options and establishing consensus around proposed solutions;
- Identification of costs and benefits;
- Publication of first draft text;
- Consultation process with stakeholders;
- Revision of text following comment and evaluation;
- Approval of rule by the Eurocontrol Council and General Assembly;
- Publication of rule and configuration control where appropriate.

These steps are followed by implementation and enforcement where appropriate. They necessitate a definite commitment on the part of countries, their ATM service providers and airspace users, to implement the changes as stipulated in the rule.

Uniformity embodies the application of common ATM rules and core functions across all European airspace. This calls for inter-operable systems and agreed common rules, standards and practices, which will establish acceptable tolerances for performance and safety levels to cater for operational circumstances that may arise throughout the European air and ground ATM system.

A uniform European ATM network requires a number of standards that bring benefits when implemented. The global importance of ICAO's Standards and Recommended Practices (SARPs), frequently referred to in **Chapter 3**, is recognised in all States and will remain as definitive statements of operational practice in Eurocontrol's ATM Strategy for 2000+. European rules, standards and practices will be developed as a complementary programme so that a foundation for uniform performance across European airspace can be established and implemented.

Emphasis in Europe will be placed on the de facto, or voluntary, standardisation process. Mandatory standards should be limited to performance and inter-operability requirements. Irrespective of whether de facto or mandatory, the process should ensure that the industry is able to participate in the development of the standards, helping to achieve realistic and cost-efficient specifications that relate to agreed ATM requirements. Standardisation should rely as much as possible on available commercial standards.

Mechanisms are required which, in all cases, signify compliance with adopted and promulgated rules by certification and qualification. The former will be used in the case of ATM service provision safety rules; the latter for harmonisation, technical performance or inter-operability through standards, whereby qualification demonstrates compliance with the rules. Additionally, the need for a clear notification system during the rule-making process is part of the European Notice of Proposed Rule-Making (ENPRM).

The main initiators of rule-making activities that have been identified in the revised Eurocontrol Convention include the States, their ATM service providers, in addition to the Director General of Eurocontrol and its associated Safety Regulation and Performance Review Commissions. Any rules proposed by these parties will be submitted for adoption to the Eurocontrol General Assembly and its Council.



***APPENDIX 4.1***

**CNS/ATM SYSTEM IMPLEMENTATION**



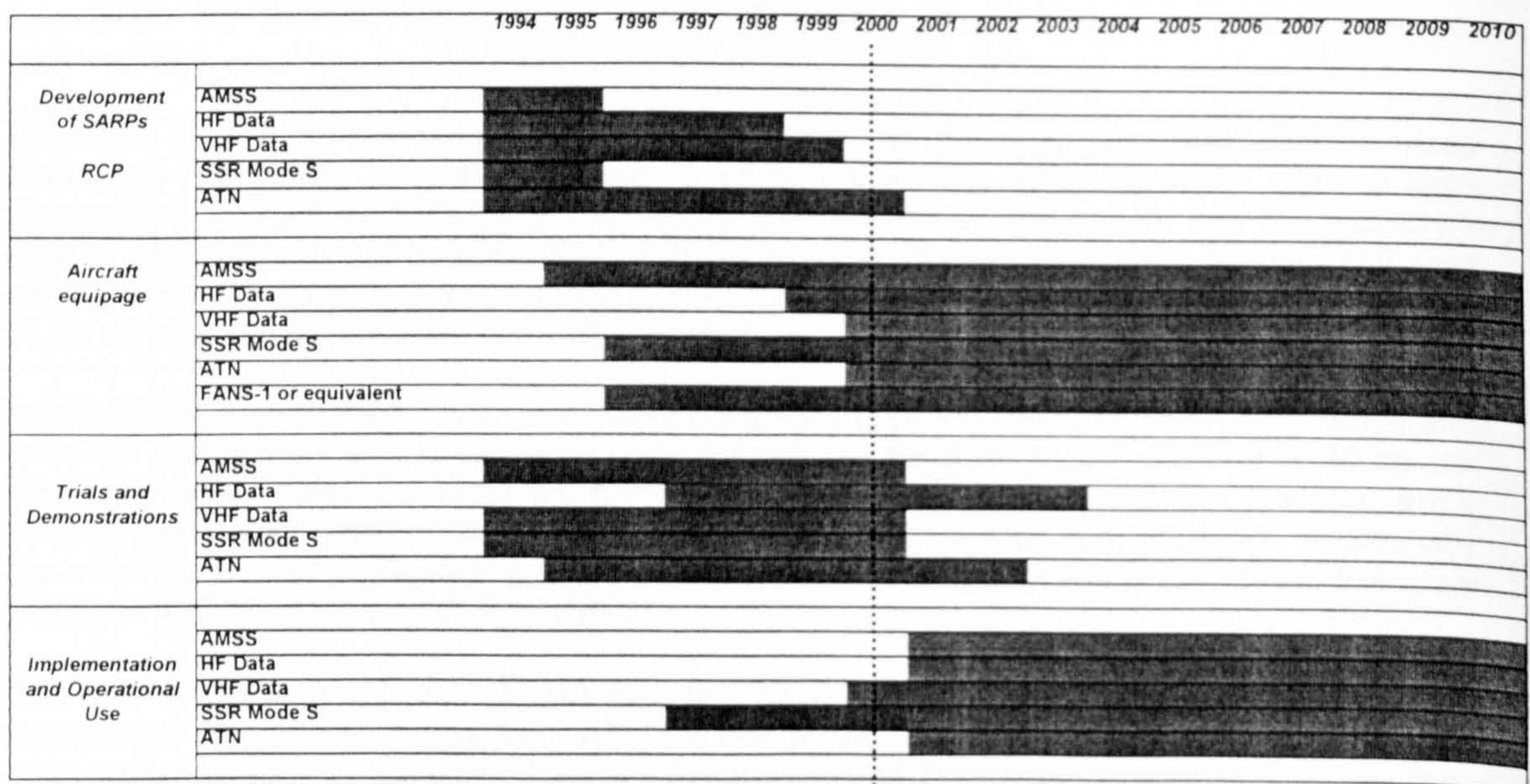
## CNS/ATM SYSTEM IMPLEMENTATION

Source: ICAO's Global Air Navigation Plan (1<sup>st</sup> Ed. 2000).

This appendix contains the projected timelines of ICAO's CNS/ATM System implementation, as described in **Section 4.5.2**. Reference is made in the diagrams to the year 2000, when the plan was published. Abbreviations are as follows:

- ❑ ABAS – Aircraft Based Augmentation System
- ❑ ADS – Automatic Dependent Surveillance
- ❑ ADS-B – ADS Broadcast
- ❑ AIDC – ATS Inter-facility Data Communications
- ❑ AMSS – Aeronautical Mobile Satellite Service
- ❑ ATFM – Air Traffic Flow Management
- ❑ ATN – Aeronautical Telecommunications Network
- ❑ ATS – Air Traffic Services
- ❑ FANS – Future Air Navigation System
- ❑ GBAS – Ground Based Augmentation System
- ❑ GNSS – Global Navigation Satellite System
- ❑ GPS – Global Positioning System
- ❑ HF – High Frequency
- ❑ NPA – Non Precision Approach
- ❑ RCP – Required Communication Performance
- ❑ RNAV – aRea NAVigation
- ❑ RNP – Required Navigation Performance
- ❑ RSP – Required Surveillance Performance
- ❑ SBAS – Satellite Based Augmentation System
- ❑ SSR – Secondary Surveillance Radar
- ❑ VHF – Very High Frequency

### Communication System implementation:





Navigation System implementation:

		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010		
Development of SARPs	RNP	En-route																		
		Terminal/NPA																		
		Precision approach																		
	GNSS	GNSS performance criteria to support operational requirements																		
		Development of GNSS NPA procedures																		
		Use of GNSS with augmented systems																		
		Long-term satellite navigation system																		
Datalink for navigation (Mode 4)																				
Availability	GPS																			
	GLONASS																			
	Imarsat Overlay																			
	SBAS																			
	GBAS																			
Aircraft equipage	GNSS + ABAS																			
	GNSS + ABAS/SBAS/GBAS																			
Trials and Demonstrations	GNSS + ABAS																			
	GNSS + ABAS + SBAS																			
	GNSS + ABAS + GBAS																			
Implementation and Operational Use	WGS-84																			
	En-route																			
	Terminal/NPA																			
	Precision Approach																			

Surveillance System implementation:

		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010		
Development of SARPs	RSP	ADS																		
		ADS-B																		
		SSR (Mode S)																		
Aircraft equipage	ADS																			
	ADS-B																			
	SSR (Mode S)																			
Trials and Demonstrations	ADS																			
	ADS-B																			
	SSR (Mode S)																			
Implementation and Operational Use	ADS																			
	ADS-B																			
	SSR (Mode S)																			



**Air Traffic Management System implementation:**

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Development of SARPs	RTSP	Global ATM																
		Functional integration of flight operations																
		ATM requirements for CNS																
		Separation between aircraft																
		ATS Inter-facility Data Communications (AIDC)																
		ATFM procedures and systems																
Aircraft equipage	Flight operations	RNP certification/approval																
		Functional integration of airborne systems with ground systems																
Implementation and Operational Use	Regional ATM Operational Concept	Determination of major traffic flows																
		Identification of ATM objectives based on these traffic flows																
		Development of regional strategic airspace CNS infrastructure plan based on ATM requirements																
	Airspace Management	Optimised sectorisation																
		Fixed RNAV ATS routes																
		Contingency RNAV routes																
		Random RNAV routes																
		Airspace desegregation / Flexible Use of Airspace																
		Application of RNP																
		Application of RCP																
	Application of RSP																	
	Air Traffic Services	Trajectory Conformance Monitoring																
		Minimum safe altitude warning																
		Conflict prediction																
		Conflict alert																
		Conflict resolution advice																
		Functional integration of ground systems with airborne systems																
		Dynamic accommodation of user-preferred flight profiles																
		Reduced vertical separation																
		Reduced longitudinal separation																
Reduced lateral separation																		
Independent IFR approaches to closely-spaced runways																		
RNAV SIDs and STARs																		
Curved and segmented approaches																		
Arrival metering, sequencing and spacing																		
Air Traffic Flow Management	A-SMGCS																	
	ATS Inter-facility Data Communications (AIDC)																	
	Application of datalink																	
	Centralised ATFM																	
	Inter-regional co-operative ATFM																	
	Establishment of ATFM databases																	
	Application of strategic ATFM planning																	
Application of pre-tactical ATFM planning																		
Application of tactical ATFM planning																		



## **APPENDIX 4.2**

### **EUROPEAN CNS/ATM PROJECTS**



## EUROPEAN CNS/ATM PROJECTS

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Sources: <http://www.eurocontrol.be>;

Other publications – as referenced hereunder.

This appendix lists Eurocontrol's current projects, in addition to describing some past and present European CNS/ATM projects that are referred to in this dissertation, thus:

### 1. Listing of current Eurocontrol projects

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#### Central Flow Management Unit (CFMU)-related project

- SRS – Standard Routing Scheme

#### ATM Strategy 2000+ and European ATM Programme (EATMP)-related projects

- ACAS – Airborne Collision Avoidance System
- ADB – Airports DataBase
- ARDEP – Analysis of Research & Development in Eurocontrol Programmes
- ASE – overall CNS/ATM architecture for EATCHIP
- CARE – Co-operative Actions of R&D in Eurocontrol
- CBA – Cost Benefit Analysis
- CIP – Convergence and Implementation Programme
- EATMS – the future European ATM System Operational Concept Document (OCD)
- EGD – Generic Specifications For EAS Supported Projects
- FAA/EURO – The FAA/EUROCONTROL R&D Committee
- FREER – Free Route Experimental Encounter Resolution
- ODT – Operational requirements and Data processing systems Team
- RVSM – Reduced Vertical Separation Minima in Europe
- Skylink – provides to the Airspace Users high-level information on EATCHIP projects
- URD – ATM User Requirement Document

#### Other current CNS/ATM projects

##### *Communication*

- 8.33 kHz – 8.33 kHz Channel Spacing
- ASTERIX – All purpose STructured Eurocontrol Radar Information eXchange
- CST – Technical Concept Development
- FDE ICD – Flight Data Exchange on the Web
- FVHF – Future VHF system study
- LINK 2000+ – Implementation of Operational Air-Ground Datalink Services in Europe
- ODIAC – Operational Requirements for ATM air-ground Data Communications Services.
- PETAL II – Preliminary Eurocontrol Test of Air-ground dataLink project
- SPG – Aeronautical Radio Spectrum Protection
- VDL Mode2
- WACS – Wireless Airport Communication System (Wireless Gatelink)

##### *Navigation*

- ICARD – ICAO Five-Letter Name-Code And Route Designator System
- WGS84 – World Geodetic System 1984



### Surveillance

- ADS – Automatic Dependent Surveillance as part of ADS Europe project
- ARTAS – ATM surveillance Tracker And Server system
- Mode S – Secondary Surveillance Radar (SSR) Mode Select
- SASS-C – Surveillance Analysis Support System for ATC-Centre
- SASS-S – Surveillance Analysis Support System for use at a radar Site

### ATM

- AIS – Aeronautical Information Services
- EAD – European AIS Database
- EFDP – European Flight Data Processing
- FRAP – 8-states Free Routes Airspace Project
- HFI – Human Factors Integration
- HMI – EATCHIP Phase 3 Human Machine Interface
- PHARE – Programme for Harmonized ATM Research in EUROCONTROL

## **2. Description of past and present European CNS/ATM projects**

**AATMS** (Airborne Air Traffic Management System) – work focused on datalink, communications management and onboard CNS/ATM functions, including flight plan negotiation and 4-D planning/guidance, which are compatible with the future European air traffic environment.

**AFAS** (Aircraft in the Future ATM System)<sup>1197</sup> – this 3-year programme, comprising 15 aviation stakeholders, started in 2000 to devise operational ATM concepts for European airspace and develop a validated Airbus-based avionics platform to support them. AFAS aims to create an integrated avionics package that will be ready in 2005.

**A-SMGCS** (Advanced Surface Movement Guidance and Control System) – an STDMA system has been tested and used mainly for A-SMGCS applications, whereby data fusion occurs between ADS-B information, ground radar and other sensors.

**BRAHMSS** (Business Requirements for Aeronautical High-Speed Mobile Satellite Services) – this 9-month study launched by the European Space Agency in 2000 aims to examine future wideband aeronautical services requirements<sup>1198</sup>.

**CASCADE** (Contribution for Assessment of Common ATM Development in Europe) – it ran in 1996 to make an inventory of ATM validation tools available in Europe.

**CCC** (Cellular CNS Concept) – has been developed for demonstration of a regional or global CNS/ATM implementation option based on GNSS and STDMA. NEAN and NEAP projects (see hereunder) incorporate most features developed in the CCC.

**DADI-2** (Datalinking of Aircraft-Derived Information-2) – successor to DADI, which finished at the end of 1999, DADI-2 is a datalink evaluation programme aimed at increasing airspace capacity and safety.

**EAD** (European AIS Database)<sup>1199</sup> – this programme aims to create a homogeneous, consistent database for Aeronautical Information Services across a streamlined network that sorts out the present inefficient jumble of European aeronautical information<sup>1200</sup>.

<sup>1197</sup> 'Big European avionics programme starts shortly' – *Air Transport Intelligence*, 30 March 2000.

<sup>1198</sup> 'European team to study future broadband satcom needs' – *Air Transport Intelligence*, 26 September 2000.



**EOLIA** (European pre-Operational dataLink Applications) – completed in 1998 by Sofréavia, this project developed the following pre-operational datalink applications<sup>1201,1202</sup>:

- Acquisition of aircraft position;
- Clearance and information communication;
- Downstream clearance delivery and request;
- Transfer of communication;
- Delivery of ATIS to aircrew;
- Flight plan consistency checking;
- Route navigation aid.

**ESCORT** – this European GNSS Datalink Certification Project aimed to address issues associated with the certification of GNSS receivers and their datalinks through the UK CAA.

**FARADEx** (Functional Architecture Reference for ATM systems and Data EXchange) – ran in 1997 to define the functional architecture of overall ATM systems.

**FARAWAY** – objectives of this project were to investigate enhanced operational performance of ground surveillance and aircraft navigation made possible through fusion of radar and ADS data and the use of ADS-B/two-way datalink based on STDMA technology. The project covered Italian airspace and connected with the NEAN network in FARAWAY II (see hereunder). Completed in 1998.

**FARAWAY II** – this project is extending the ground infrastructure to give complete ADS-B coverage in Italian airspace. ADS-B coverage will then be used to augment radar coverage. The local cellular network in Italy will then be connected to NEAN in order to extend the European infrastructure as part of the EU's Trans European Network (TEN) programme.

**FREER** (Free Route Experimental Encounter Resolution) – a Eurocontrol project that is incorporated in the ATM Strategy for 2000+, FREER investigates the transfer of some ATC functions to the cockpit and the potential of trajectory negotiation to increase airspace capacity, maximise flexibility and support the implementation of Free Flight. Three sub-projects exist<sup>1203</sup>:

- FREER-1*: airborne autonomous mode, where ATC is fully delegated to the aircraft in European Air Traffic Management System (EATMS) Free Flight Airspace;
- FREER-2*: ground-air co-ordinated mode, where ATC is partially delegated in high-density airspace, EATMS Managed Airspace, but responsibility for separation remains with ATC;
- FREER-3*: experimental trial of airborne conflict detection and resolution with VDL Mode 4.

**GENOVA** (General Overall Validation for ATM) – when completed in 1997, it had defined a generic approach to the ATM validation process with the description of the validation activities, their inputs and outputs.

**JANE** (Joint Air Navigation Experiments) – to identify operational improvements that are needed to overcome constraints on capacity and efficiency within Europe's airspace<sup>1204</sup>. JANE was decided upon in 1996 to demonstrate and evaluate the feasibility and potential benefits of a

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<sup>1199</sup> 'Information unification' – air traffic management, July-August 1999.

<sup>1200</sup> 'Pan-European AIS database enters design phase' – Air Transport Intelligence, 9 March 2000.

<sup>1201</sup> 'Demonstrating the Benefits of Air-Ground Data Communications' – J Lutz, Sofreavia. Air Traffic Management: Prospects for Free Flight Conference, London, 1999.

<sup>1202</sup> 'ATN team aims for Paris flight demonstration' – Flight International, 9 June 1999.

<sup>1203</sup> 'Towards Freedom of Movement for Airspace Users – Free Flight or Freer Flight?' – V Duong. Eurocontrol. 4<sup>th</sup> Air Navigation Conference, Amsterdam. September 1998.

<sup>1204</sup> 'Free Flight in Europe: Lessons learnt from JANE' – K Platz, DFS. Air Traffic Management in Europe: The business case for CNS/ATM Conference, London, 1997.



future ATM system. This involves assessment of the limits of the free flight and free route concepts in respect to transition areas. It will enable evaluation of the rôle of certain elements.

**LINK 2000+** – programme that started in 2000, which is part of datalink's certification for ATC and AOC services<sup>1205</sup>. Link 2000+ is based on VDL Mode 2 and hopes to be implemented at airports by 2003 and ATC centres in 2005. It is on course for start of implementation in 2002<sup>1206</sup>. It covers most of Europe, except the Iberian Peninsula.

**MAGNET A** (Multi-modal Approach for GNSS-1 in European Transport A) – when run from 1996 to 1998, its objectives were to develop user segments prototypes of GNSS-1, in addition to assessing their performance in terms of availability, accuracy, integrity and continuity of service.

**MAGNET B** (Multi-modal Approach for GNSS-1 in European Transport B) – also completed in 1998, its aim was to develop GNSS-1 user segments, in addition to assessing their capability to meet the most demanding aviation requirements and to evaluate the benefits that users can achieve from the integration of GNSS-1 with a ground-based datalink (STDMA) for the three transport domains of air, rail and sea.

**MAICA** – a theoretical study focusing on the use of VDL Mode 4/STDMA for development of new simulation models for future EU ATM projects.

**MA-AFAS** (More Autonomous Aircraft in the Future ATM System)<sup>1207</sup> – 50% funded by the EU's New Perspectives in Aeronautics programme, the objective of MA-AFAS is to transform European research results into airborne ATM techniques with the potential to radically improve the European ATM scenario in the near term. A shift in responsibility from controller to pilot is seen as one of the most important factors in coping with the gradual overcrowding of European skies.

**NAAN** (North Atlantic ADS-B Network) – this project establishes a cellular ADS-B infrastructure across the North Atlantic based on VDL Mode 4.

**NEAN** (North European ADS-B Network)<sup>1208</sup> – under the auspices of the EU's Trans European Network (TEN), NEAN's aim is to develop, evaluate and demonstrate the benefits of a common ADS-B network for CNS in future European ATM<sup>1209</sup>, in addition to validating STDMA technology for ADS-B. The cellular VDL Mode 4 network, which extends over Denmark, Germany and Sweden<sup>1210</sup>, provides the capability to monitor aircraft through a gate-to-gate flight path from a PC. Indeed, the project has demonstrated the benefits of implementing a harmonised pan-European CNS/ATM concept on a gate-to-gate basis<sup>1211</sup>. NEAN installed the necessary CNS tools to provide ADS-B and DGNSS data.

**NEAP** (North European ADS-B Applications Project) – an EU-funded project based on the infrastructure implemented in the NEAN project, to test, develop and demonstrate user applications and end-to-end CNS/ATM functions based on ADS-B and VDL Mode 4 (STDMA) datalink to demonstrate the feasibility of providing cost-effective CNS/ATM systems serving all phases of flight. It was completed in 1998.

**NUP** (Network Update Programme) – new system of North European ADS-B (see NEAN and NEAP)<sup>1212</sup>.

<sup>1205</sup> 'Eurocontrol presents Link plan' – *Flight International*, 11 April 2000.

<sup>1206</sup> 'Link 2000+ approval paves way to mobile Euro datalink' – *Flight International*, 14 November 2000.

<sup>1207</sup> 'Aircraft autonomy' – *Air Traffic Technology International* 2001.

<sup>1208</sup> 'NEAN: a European ADS-B initiative' – *Journal of ATC*, January-March 1998.

<sup>1209</sup> 'Airbus to support key European ADS-B programme' – *Air Transport Intelligence*, 8 March 1999

<sup>1210</sup> 'NEAN Status Report' – P Ahl, SAS. *Air Navigation Conference*, Amsterdam. 1997.

<sup>1211</sup> 'SAS demonstrates gate-to-gate CNS/ATM concept' – *Air Navigation International*, 25 January 1999.

<sup>1212</sup> 'Freeing up the skies' – *Airline Business*, November 1999.



**PETAL** (Preliminary Eurocontrol Test of Air-ground dataLink) – concluded that datalink is useful for strategic communications, but not for tactical aircraft separation<sup>1213</sup>. **PETAL II**, which is a continuation of the EATCHIP PETAL project, aims to investigate Controller Pilot DataLink Communications (CPDLC) and its application to ATM. It utilises the VDL Mode 4 infrastructure of the NEAN project for CPDLCs by digital datalink. Latest achievements include the clearing of Lufthansa A340<sup>1214</sup> and B747 aircraft through Maastricht Upper Airspace entirely via datalink. The project also involves the development of controller workstations to support CPDLC operations. Preliminary results emphasise that pilots and controllers need to know that sent messages are received and understood. The PETAL II programme is now being conducted during routine flights handled by Eurocontrol's Maastricht Upper Area Control Centre<sup>1215</sup>. Many CPDLC test flights by numerous airlines have occurred in the PETAL II programme trials<sup>1216</sup>. The programme is scheduled to begin conducting datalink trials using the ATN as a medium in 2001.

**PHARE** (Programme for Harmonised ATM Research in Europe) – this experimental programme was sponsored by Eurocontrol and some European air navigation service providers. The research initially validated several new technologies and computer-assisted tools, with integration of airborne and ground-based systems successfully demonstrated. One goal of PHARE was to develop computerised datalinks to enable controllers to safely handle increasing amounts of traffic, with minimum intervention<sup>1217</sup>. Much like Free Flight, aircraft crews selected a preferred flight path that was transmitted to ground controllers, who would intervene if there was a conflict with other aircraft. Another aim was the Experimental Flight Management System (EFMS) that makes use of GPS and other distance measuring equipment to determine an aircraft's position.

**PROATN** (Prototype Aeronautical Telecommunications Network) - an ATN prototype in close co-operation with the ATM application development in the EOLIA project (see above) until its completion in 1998.

**SUPRA** (Support for the Use of Presently unseRved Airspace) – when operational in 1997, it focused on the use of (STDMA) datalink technology and Cockpit Display of Traffic information (CDTI) for GA aircraft and airport ground support vehicles. An STDMA ground station was necessary for reception and processing of surveillance data.

**VICTORIA** – a 3-year programme launched recently by Europe's main aerospace companies and research organisations to derive standardised avionics systems for future generation aircraft<sup>1218</sup>. Falling within the EU's 5<sup>th</sup> Framework Programme, its cost is 50:50 split between the EU and industry. The project is a direct follow-on from the 2-year Prospective Analysis for Modular Electronic Integration (PAMELA), which investigated the potential of new onboard electronic technology<sup>1219</sup>.

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<sup>1213</sup> 'PETAL-II' – R Mead, Eurocontrol. 4<sup>th</sup> Air Navigation Conference, Amsterdam. September 1998.

<sup>1214</sup> 'Lufthansa A340 first to use FANS-A in datalink trial' – Air Transport Intelligence, 1 November 2000.

<sup>1215</sup> 'United joins PETAL II datalink trials' – Flight International, 5 May 1999.

<sup>1216</sup> 'PETAL trial sees surge in controller-pilot datalink use' – Air Transport Intelligence, 11 August 2000.

<sup>1217</sup> 'Europe tests core of new ATM systems' - J.D. Morrocco, Aviation Week & Space Technology, 3 June 1996

<sup>1218</sup> 'Thales leads EC avionics drive' – Flight International, 23 January 2001.

<sup>1219</sup> 'VICTORIA to standardise advanced avionics' – Air Transport Intelligence, 19 January 2001.



**APPENDIX 4.3**

**EUROPE'S ATM  
STRATEGY 2000+ TIMELINE**



## EUROPE'S ATM STRATEGY 2000+ TIMELINE

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Source: 'ATM Strategy 2000+', Eurocontrol, 1998.

This appendix summarises the timeline for Eurocontrol's ATM Strategy 2000+, which is discussed in Section 3.5 and Section 4.5.3. The following three steps outline the stages for improving performance:

### Step 1 – up to 2005

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This first period will concentrate on improving capacity as a priority, and enhancing efficiency wherever possible, by concentrating on changes to airspace organisation and current procedures. Simultaneously, existing systems will be prepared for further integration to meet traffic increases and new features will be introduced into Flight Data Processing Systems (FDPS).

Step 1 will include the full deployment of a number of harmonisation and integration measures that have already been developed in order to improve performance and offer the following operational improvements:

- *safety* – enhanced safety nets and tools;
- *capacity* – enhancement of ground-based planning during all phases of flight; route structure and sector optimisation based on RNAV techniques and the introduction of RVSM; progressive improvement to surface movement control and airside capacity management;
- *efficiency and flexibility* – initial implementation of free-routing airspace and operations in the upper airspace; improved flexibility in the use of airspace; improved re-routing; optimisation of human resource management.

The associated changes in ATM systems will consist of FDPS upgrades to support advanced data processing and flexible route operations; progressive deployment of arrivals and surface management tools at major airports; implementation of Enhanced Tactical Flow Management System (ETFMS); and initial introduction of system-wide information management techniques.

The accompanying avionics requirements will be:

- Basic aRea NAVigation (B-RNAV) to RNP-5;
- Reduced Vertical Separation Minima (RVSM) for all aircraft wishing to fly above FL280;
- Mode S transponder, with Level 2 being the minimum standard;
- 8.33KHz voice channel spacing for all aircraft wishing to fly in such airspace;
- Airborne Collision Avoidance Systems (ACAS) type II;
- VHF DataLink (VDL);
- Aircraft Communications And Reporting System (ACARS), the Aeronautical Telecommunications Network (ATN) and Multi-Mode Receiver (MMR) as optional.

The combination of these changes aims to provide an estimated increase in capacity of up to 60% by 2005, in comparison with 1995 levels, a reduction in fuel burn per flight of ca. 3% and a 15 to 30% reduction in ground movement emissions. Safety levels will also benefit from the extended introduction of ACAS II. This first step involves complex changes with Air Operators' Certificates (AOC) and FDPS systems.



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## Step 2 – 2005 to 2010

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This second period hopes to see an acceleration of ATM information integration with other related information systems and the optimisation of airspace use and airport resources. Improved integration of the aircraft operator and ATM processes based on enhanced information systems and management, together with increasing use of data communication links, will facilitate Collaborative Decision-Making (CDM). Suitably equipped aircraft should be able to exercise autonomous separation under prescribed circumstances or in certain airspace regions, with AirSpace Management (ASM) and organisation becoming more dynamic and flexible.

Step 2 aims to offer the following operational improvements:

- *Safety* – further deployment of safety improvements;
- *Capacity* – enhancement conflict prediction and trajectory planning with air-ground collaboration supported by datalink communications; integrated arrival and departure management; enhanced Air Traffic Flow Management (ATFM) procedures and initial capacity management; improved airport surface movement ground control and planning;
- *Efficiency and flexibility* – enhanced airspace flexibility and sectorisation changes; collaborative civil-military airspace planning for all airspace regions; extended free-routing airspace and operations; limited transfer of separation responsibilities from the ground to the air; collaborative flight planning procedures; continuing improvement in human resource management.

The associated changes in ATM systems will consist of FDPS and Collision Warning System (CWS) replacements for free route sectors, with just FDPS upgrades in other sectors. The accompanying avionics requirements will be:

- ATN;
- Enhanced Flight Management System (FMS) capabilities and new Human Machine Interface (HMI);
- RNAV RNP-1 or better as optional, depending on the user's availing of Global Navigation Satellite System (GNSS);
- Surveillance system options using ADS-B, ADS-Contract (ADS-C) and ground surveillance support system capabilities.

The Step 2 changes aim to provide capacity increases of 20 to 40% in addition to those in Step 1 and a further fuel burn reduction of 2 to 3% per flight. Target levels of safety will also be enhanced and further benefits should be achievable due to the increasing modernisation of ground ATM infrastructure.

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## Step 3 – 2010 to 2015 and beyond

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This third stage hopes to fully adopt the target concept. Tasks will most likely be redistributed between humans and machines to improve productivity levels. Co-operative ATM will be implemented through integrated air-ground data communications and surveillance, including airborne situational awareness. Based on the availability of more accurate data and other technical improvements, procedures, processes and computer support tools will be optimised. Additionally, flights will be managed on 'gate-to-gate' bases and airspace will be considered as a continuum for planning and management purposes. It is hoped that the majority of flights will be able to fly fuel-efficient routes and that it will be possible to apply autonomous separation in appropriate airspace regions.

Step 3 aims offer the following operational improvements:

- *Safety* – continued improvement of safety;



- *Capacity* – enhanced all-weather airside capacity operations at all major airports; extensive use of computer tools for sequencing and separation; optimised capacity management;
- *Efficiency and flexibility* – collaborative planning involving all European airspace; gate-to-gate planning and conduct of flights; introduction of autonomous aircraft operations.

The associated changes in ATM systems will consist of optimised 4D-ATM tools and the implementation of multi-sector planning. The accompanying avionics requirements will be:

- 4D trajectory exchange and negotiation capability;
- Airborne Situational Awareness Systems (ASAS).

The Step 3 changes aim to provide the potential for additional capacity gains in the region of 20 to 40% in addition to those in Step 2 and the foundations for further capacity increases in line with traffic growth beyond 2015. ATM penalties should be reduced to their minimum level and the principles of 'intervention by exception' will become the norm. It is thought that environmental and runway saturation factors will limit future improvements. Indeed, several nations and organisations participating in the ATM 2000+ airports group expressed concern over the provision of adequate future capacity at airports<sup>1220</sup>.

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<sup>1220</sup> *'Concerns raised over ATM 2000+ airport capacity' – era regional report. May 1998.*



**APPENDIX 4.4**

**SUPPLIERS OF CNS/ATM EQUIPMENT**



## SUPPLIERS OF CNS/ATM EQUIPMENT

**Sources: Civil Air Navigation Services Organisation (CANSO);  
Internet & Publication search;  
'Jane's Air Traffic Control' – 6th Edition, 1999-2000;  
Product brochures.**

This appendix contains the results from a survey of CNS/ATM equipment providers and their products:

Company	COM	NAV	SURV	ATM
ACI - Aeronautical Communication International	X			
ACS Communication Inc	X			
Ad Opt Technologies Inc				X
Adacel				X
Advanced Integrated Recorders (AIR)			X	
Advanced Navigation & Positioning Corporation (ANPC)		X		
Advanced Technology Ltd (ATL)			X	
AEG Mobile Communication GmbH	X			
Aerodata Flugmesstechnik GmbH		X		
Aeronautical & General Instruments Ltd		X		
Aerospace Engineering & Research Associates			X	
AEROTHAI - Aeronautical Radio of Thailand Ltd	X	X		X
Air-A-Plane Corporation	X			
Airport Information Systems				X
Airport Systems International		X		
Airsys ATM	X	X	X	X
Airtel ATN	X			
AIT Recorders Ltd	X		X	
Alcatel	X	X		
Alenia Marconi Systems	X	X	X	X
ALES as			X	
Alifabs Design and Construction Ltd	X			
Alusett Ltd			X	
Amphitech			X	
Amtech Systems			X	
Andrew Canada Inc			X	
ANS Technics			X	
ARINC	X	X		X
ARNAV Systems Inc	X			
ASC telecom Ltd	X			
Atis GmbH	X			
Audiosoft	X			
Audor Communications Inc	X	X		
AverStar Inc		X		



Company	COM	NAV	SURV	ATM
Avidyne			X	
Avionitek	X	X		
AWA Plessey Aerospace	X	X		
Aydin Corporation Systems Group			X	
BAE Systems Canada	X	X		
Baker Audio/Telecom	X			
Ball Aerospace and Technologies Corp	X			
BARCO NV			X	
Barton ATC Inc	X			
BBN Systems and Technologies			X	
Becker Flugfunkwerk GmbH	X	X		
Beel Technologies			X	
BFGoodrich Aerospace		X		
Bharat Electronics			X	
Boeing Air Traffic Management				X
Boeing Australia Ltd	X			
British Aerospace Systems and Equipment (BASE)	X			
BURAN			X	
Bytron Ltd				X
CAL Corporation	X			
Calibre UK Ltd			X	
CEA Technologies Pty			X	
CelsiusTech Systems AB		X	X	X
CERME Groupe SFIM			X	
CET Technologies Pte Ltd	X			
Chelton Avionics Inc	X	X		
Claddagh Inc			X	X
Clement Clarke Communications	X			
CML ATC Technologies Inc	X			
Codan Pty Ltd	X			
Computer Sciences Corporation			X	X
Comsoft			X	X
Communication Systems Technology Inc (CSTI)	X			
Comverse Infosys	X			
Conrac Elektron GmbH			X	
Copperchase Ltd				X
CORIS	X			
Craig Systems Corporation	X			
Crenio Inc			X	
Crimp A/S				X
CS - Compagnie des Signaux	X		X	
Cubic Communications	X		X	
CVDS Inc	X			
Daco Scientific			X	
DaimlerChrysler Aerospace AG		X	X	



Company	COM	NAV	SURV	ATM
Dansk System Elektronik A/S				X
Data Communications Specialties Inc	X			
Data Systems Analysts Inc				X
debis Systemhaus GmbH				X
Delta Information Systems			X	
Denbridge Digital			X	
Denro	X			
Devtek Electronic Packaging Systems			X	
Dictaphone Corporation	X			
Diem Electronic SA	X			
Dimensions International			X	
Drake Electronics Ltd	X			
DSNP			X	
EASAMS			X	X
Easat Antennas Ltd	X		X	
ECI TeleSystems Ltd	X			
EDS - Electronic Data Systems			X	X
EIAr Electronics Ltd			X	
ELDIS sro			X	
Electronics Corp. of India Ltd.			X	X
ELSA - Pt Elektrindodaya Pakarnusa	X		X	X
Elta Electronics Industries Ltd			X	
ENA Telecomunicaciones SA	X			
Enator Telub AB			X	X
ERA as			X	
Evans			X	
EYP Telecom				X
Fernau Avionics	X	X		
FIAR - Fabbrica Italiana Apparecchiature Radioelettriche			X	
Flight Refuelling Ltd			X	
Folknoil Ltd	X			
Francis & Lewis International Ltd	X			
Frequentis	X		X	X
Gallium Software			X	
Garex	X			
Garmin International		X		
Giese GmbH				X
Global Simulation Systems		X		
Global Weather Dynamics Inc				X
GP&C Sweden AB		X		
GTE Information Systems Division	X			
Gujurat Communications and Electronics Ltd (GCEL)		X		
Hand GmbH			X	
Harris Corporation	X		X	X
Headset Services Ltd	X			
Hessing Telecommunicatie BV	X			
Hindustan Aeronautics Ltd (HAL)	X		X	
HITT			X	
Honeywell	X	X	X	X
HSI - High Speed Information Inc				X
HTT-TESLA Pardubice			X	
IER			X	
IFR Ltd		X		
Il Morrow Inc	X	X	X	
Ilog			X	
Image Systems Corporation			X	
Incotel Inc				X



Company	COM	NAV	SURV	ATM
Indian Hydraulic Industries Pvt Ltd (IHI)	X			
Indra DTD, Sociedad Anonima	X		X	X
INFRANAV Industria e Comercio Ltda	X	X		
IN-SNEC Intertechnique Group		X		
Intek Global USA	X			
Intelcan Technosystems Inc				X
Intelect Network Technologies	X			
Intersoft Electronics			X	
Interstate Eletronics Corporation		X		
Intertechnique		X		
ISIS			X	
ISN - Information Systems and Networks Corporation	X		X	
ITT Avionics		X		
ITT Gilfillan			X	
Japan Radio Co (JRC)	X	X	X	
Jotron Electronics AS	X			
JTA - Jerry Thompson & Associates			X	
Kayser-Threde GmbH			X	
Kollmorgen Artus		X		
L-3 Communications, ESSCO			X	
Lamda System Engineering			X	
Lansec Ltd	X			
Lee-Dickens Ltd		X		
Litton Denro Inc	X			X
LNS Systems Inc	X			
Lockheed Martin ATM	X	X	X	X
Logical Ltd			X	
MacDonald Dettwiler & Associates Ltd				X
Magellan Systems Corporation		X		
Magnavox				X
Mann Avionics Ltd		X		
Marconi Aerospace Systems		X		
MCI WorldCom Government Markets	X			
Mentor Radio Company	X			
Midland Land Mobile Radio	X			
Midwest Air Traffic Control Services Inc	X			
Miles Air Products Ltd	X			
MiTech Incorporated		X		
Mitsubishi Electric Corporation			X	
Motorola	X			
Narco Avionics		X		
Nardeux SA	X			
Nautel Ltd		X		
Navia Aviation AS	X	X	X	
Navis		X		
Navstar Systems Ltd	X			



Company	COM	NAV	SURV	ATM
Neal Recording Systems	X			
NEC Corporation	X	X	X	X
New Bedford Panoramex Corporation (NBP)		X		
Nice Systems Ltd	X	X		
Nice-Fix		X		
Nordic Aviation Resources			X	
Normarc Flight Inspection Systems AS		X		
Nor-Tech A/S		X		
Northrop Grumman Corporation			X	X
Northstar Avionics		X		
Novation Ltd		X		
Oracle Telecomputing			X	X
Ortel Corporation	X			
Orthogon GmbH			X	
OTE SpA	X			
PA Communications Ltd				X
PAE - Park Air Electronics Ltd	X			
PAGE	X			
Palomar Display Products	X		X	
Park Air Electronics	X			
Pelorus Navigation Systems Inc		X		
PIT - Przemyslowy Instytut Telekomunikacji			X	
PixelVision			X	
Plantronics Inc	X			
Primagraphics			X	
Prince Cladding BV	X			
PRIOR				X
Prior Data Sciences			X	
Punjab Wireless Services Ltd (Punwire)	X			
Radamec Defence Systems			X	
Raytheon	X	X	X	X
Real Time Engineering Ltd				X
Redflex Systems Pty Ltd	X			
Redifon MEL Ltd	X			
Reunert Defence ESD			X	
RGB Spectrum			X	
Rickard Miller Ltd			X	
Rockwell Collins	X	X	X	
Rohde & Schwarz GmbH	X	X		
RSI Technical Products			X	
SAF - Systemes et Audio Frequences	X			
Sagem SA		X		
Saphire International ATC Engineering Co			X	
Sascal Displays			X	
SBFI			X	
Schmid Telecommunication	X			
Scientific Radio Systems Inc (SRS)	X	X		
Sensis Corporation			X	
Servo Corporation of America		X		
Sierra Data Systems Inc		X		



Company	COM	NAV	SURV	ATM
SITA	X			
SITTI SpA	X			
Skyforce Avionics		X		
SL Corporation			X	
SMA - Segnalamento Marittimo ed Aereo SpA			X	
Smiths Industries		X		
Sofreavia	X		X	X
Sony Corporation			X	
Southern Avionics Company		X		
Stento ASA	X			
Stonefield Systems plc		X		
Storacall Attachments Ltd	X			
SYSECA				X
Systemintegrering AB			X	
Systems Atlanta Inc				X
Tait Electronics Ltd	X			
Technology Service Corporation (TSC)			X	
Tech-Source Inc			X	
Tectelcom Aeroespacial Ltda	X	X		
Telebit Communications A/S	X			
Telegenix Inc	X			
Telephonics	X		X	X
Telerad	X	X		
Telex Communications Inc	X			
Ten-XJ Electronics Ltd			X	
TERMA Elektronik			X	X
Tex ATC Ltd	X			
Textron Systems		X		
Thales	X	X	X	
The Lane Group	X			
The Preston Group			X	
Tianjin Broadcast Equipment Corporation		X		
Ticon Radomes A/S			X	
TIMSAN	X			
Toshiba Corporation	X	X	X	
Transcon Elektronik Systems		X		
Trimble Navigation Ltd		X		
Troy Systems Ltd	X			
TRW				X
UFA				X
Ultra Electronics	X			
Unitech	X			
Universal Avionics Systems Corporation	X	X	X	
Vaisala Oy				X
Visolux Ltd			X	
Vitrociset SpA	X	X		
W & J Tod			X	
Walter Dittel GmbH	X			
Wavionix				X
YDAB AB		X		
Zepter Flugtechnik GmbH	X			
Zycomm Electronic Ltd	X			



## ***APPENDIX 4.5***

### **COUNTRY SURVEY OF CNS/ATM IMPLEMENTATION**



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## COUNTRY SURVEY OF CNS/ATM IMPLEMENTATION

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**Sources: 'Jane's Air Traffic Control' – 3rd, 4th, 5th & 6th Editions, 1996-2000;  
Numerous other publications – as referenced hereunder.**

In addition to a multitude of references in the main text, this appendix completes the survey of CNS/ATM systems' integration around the world, thus:

### **Afghanistan**

The country's Civil Aviation and Tourism Authority signed a contract with IATA in 1998 for refurbishment of the country's air traffic services facilities<sup>1221</sup>. Noting that there was a distinct lack of communications facilities, the satellite-based system, SkyWAN, is being implemented<sup>1222</sup>.

### **Algeria**

The air navigation authority, ENNA, intends to transition to a CNS/ATM environment, ATM system under the project TRAFCA. Five key airspace control centres are being upgraded<sup>1223</sup>.

### **Angola**

As part of South Africa's Very Small Aperture Terminal (VSAT) system concept, Luanda airport received much improved communications and navigation in 1998.

### **Argentina**

Through the country's National Radarization Programme (NRP), new air surveillance systems are being implemented. But a change of leadership recently threatened the programme<sup>1224</sup>. In addition, the Ezeiza FIR recently started operating with a new airspace management system that acts in co-operation with a Uruguayan radar to provide automatic flight plan processing and flown management<sup>1225</sup>.

### **Armenia**

Armenia has begun the changeover from its former Soviet Union airspace management system with the implementation of ICAO vertical separation standards using a new ATM system, which is intended to improve capacity for flights from Europe to the Near East and Asia<sup>1226</sup>.

### **Australia**

The Australian Advanced Air Traffic System (TAAATS)<sup>1227</sup>, which is a complete upgrade of the country's civil ATS that supports ADS, CPDLC radar and flight plan tracks<sup>1228</sup>, became formally fully operational in 2000<sup>1229,1230</sup>, even though it had experienced development problems to date<sup>1231</sup>: given its original implementation date of 1995, TAAATS was late and ran over budget<sup>1232</sup>. The new technology links ground ATM automation systems with airborne avionics computers, thereby increasing flight path flexibility and providing more time for decision-

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<sup>1221</sup> 'Flying the Silk road' – *Airline Business*, September 2000.

<sup>1222</sup> 'Satellite communication for ATC' – *Air Traffic Technology International* 2001.

<sup>1223</sup> 'Algerian air traffic control to undergo modernisation' – *Air Transport Intelligence*, 28 September 2000.

<sup>1224</sup> 'Agonizing over Argentina' – *air traffic management*, November-December 1999

<sup>1225</sup> 'Buenos Aires ATC system goes operational' – *Air Transport Intelligence*, 20 November 2000.

<sup>1226</sup> 'Armenia in airspace management system upgrade' – *Flight International*, 22 August 2000.

<sup>1227</sup> 'Turning on TAAATS' – *air traffic management*, March-April 2000.

<sup>1228</sup> 'Australia defends Advanced Air Traffic System' – *Air Transport Intelligence*, 29 July 1999.

<sup>1229</sup> 'Australia's TAAATS formally commissioned' – *Air Transport Intelligence*, 1 March 2000.

<sup>1230</sup> 'Australia's TAAATS put into full use' – *Air Transport Intelligence*, 15 February 2000.

<sup>1231</sup> 'Software failure hits new Australian Air Traffic System' – *Air Transport Intelligence*, 16 July 1999.

<sup>1232</sup> 'Australian air traffic system late, overbudget: opposition' – *Air Transport Intelligence*, 19 August 1999.



making<sup>1233</sup>. Correspondingly, Australia is part of the ADS and Datalink Interim System (ADIS) project, which incorporates ADS and CPDLC, with Boeing, Fiji and New Zealand. In addition, Australia has conducted ADS trials with India. It should be noted that, in 1998, CASA decided not to make transponders mandatory in certain airspace areas<sup>1234</sup>. Australia has developed its transition programme to GNSS under ICAO guidelines, based on 3 phases: limited approval for GPS/GLONASS; a WAAS; and then a LAAS. Australia uses GPS for en-route IFR and non-precision approaches<sup>1235</sup>. Australia's Civil Aviation Safety Authority (CASA) has endorsed a trial of new remote air traffic communications services to provide enhanced information to pilots<sup>1236</sup>. The US FAA is trying this new radio communications system that CASA operates at some remote airports in Australia<sup>1237</sup>. Airservices Australia has withdrawn a proposal to reduce or transfer to local ownership a number of navigational aids throughout the country<sup>1238</sup>. The plans to scrap 200 of Australia's 1,200 ground-based navigational aids in 2000 met with vigorous opposition<sup>1239</sup> and were subsequently abandoned<sup>1240</sup>. RVSM is due in 2001<sup>1241</sup>.

### **Austria**

Vienna's ATC centre is the best in Europe, according to a 1998 study by the Association of European Airlines (AEA)<sup>1242</sup>.

### **Azerbaijan**

The national Air Navigation System is being upgraded with a new ATC centre.

### **Bahamas**

The government recently awarded a contract to install radar and an automated airspace management system at Nassau International airport, with initial operational capability scheduled for August 2001<sup>1243</sup>.

### **Bahrain**

Planning CNS/ATM system trials, in particular using datalinks to send messages in fixed formats.

### **Bangladesh**

New communications equipment is being installed in Bangladesh.

### **Bosnia-Herzegovina**

In 1998, Eurocontrol and NATO established a formal Letter of Agreement to open four specific air routes in the no-fly zone above the country that allowed civil flights above FL330<sup>1244</sup>.

### **Botswana**

Raytheon is providing radar data processor and tower systems at Gaborone International Airport<sup>1245</sup>.

### **Brazil**

According to Embraer<sup>1246</sup>, noting that Brazil follows ICAO recommendations, the country's CNS/ATM implementation situation is that a Data Telecommunication Network (DATACOM),

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<sup>1233</sup> 'Air-ground datalinks bring enhancements to Australian air traffic management' – ICAO Journal, May 2000.

<sup>1234</sup> 'Class warfare' – air traffic management, May/June 1998.

<sup>1235</sup> 'Transition to the Global Navigation Satellite System (GNSS) in Australia' – Journal of ATC, July-September 1998.

<sup>1236</sup> 'Airport radio service trial launched in Australia' – Air Transport Intelligence, 17 September 1999

<sup>1237</sup> 'FAA endorses trials of Australian airport radio system' – Air Transport Intelligence, 9 June 2000

<sup>1238</sup> 'Airservices Australia drops navaid reduction proposal' – Air Transport Intelligence, 15 February 2000.

<sup>1239</sup> 'Australian navaid plan under fire' – Air Navigation International, 21 February 2000.

<sup>1240</sup> 'Airservices drops navaid reduction plan' – Air Navigation International, 20 March 2000.

<sup>1241</sup> 'South China Sea, Australian RVSM set for next year' – Air Transport Intelligence, 22 March 2000.

<sup>1242</sup> 'Vienna tops European ATC chart' – Air Transport Intelligence, 4 June 1998.

<sup>1243</sup> 'Bahamas awards ATC radar contract' – Air Transport Intelligence, 28 November 2000.

<sup>1244</sup> 'Recovery of Civil Aviation in Bosnia-Herzegovina' – N Angelo & R Motzko, 43<sup>rd</sup> Annual Air Traffic Control Association Conference Proceedings, November 1998.

<sup>1245</sup> 'New ATM system for Botswana' – Air Navigation International, 3 April 2000.



which is similar to SITA's Aircom<sup>1247</sup>, is being implemented as an initial step to the ATN. It will gradually cover all continental routes, noting that VHF datalink communications started in 1997. GPS navigation has been allowed as a supplementary means since 1995: the airline, Rio-Sul, uses it and was involved with Embraer and Honeywell in evaluating DGPS. In the surveillance arena, some ADS tests have been performed. In terms of ATM, Brazil is working on the implementation of an Air Traffic Flow Management (ATFM) system. Brazil became the first South American country to purchase the Total Airspace & Airport Modeler (TAAM) ATM software in 2000<sup>1248</sup>.

### Bulgaria

New radios and equipment for the Bulgarian ATS Authority are being supplied by Par Air Electronics to reconfigure area coverage for en-route communications<sup>1249</sup>.

### Cameroon

ILS is being implemented as part of the ASECNA central African navigation upgrade programme.

### Canada

NavCanada is implementing the Canadian CNS/ATM Transition Plan, which is being co-ordinated with, and consolidated into, a North American tri-partite plan involving Canada, Mexico and the US. Work was recently completed<sup>1250</sup> on the equipment for the new Canadian Automated Air Traffic System (CAATS), which claims to be the world's most advanced<sup>1251</sup>. Installation of the system at ATC centres throughout Canada is now starting, with full integration expected by the start of 2003<sup>1252</sup>. However, a \$27 million upgrade project that was announced towards the end of 1999<sup>1253</sup> faced a potential strike<sup>1254</sup> and airline retribution due to increases in charges<sup>1255,1256</sup> earlier that year. It should be noted that the Gander Automated Air Traffic System (GAATS) already has ADS/CPDLC capability<sup>1257</sup>: NavCanada accommodates VHF and HF datalink. ADS/CPDLC is scheduled to be in place in the Northern and Arctic areas by 2005, although this date could be brought forward due to airline pressure. NavCanada is concentrating on ensuring that the ADS/CPDLC interfaces with their neighbours are harmonious. CPDLC will be introduced in other areas where the use of voice communications is inefficient. NavCanada is also participating in initial trials of FANS-1/A waypoint position reporting over the North Atlantic in conjunction with the Irish Aviation Authority (IAA) and the UK's NATS. The trials, which use ARINC facilities for distribution over the AFTN, have been underway since 1999. It should be noted that GPS was first approved for en-route, terminal and non-precision approaches in 1993. Indeed, GPS is almost always used now for guidance: there is widespread use of GPS for RNAV routes, which is beneficial for remote operations. GPS is also being encouraged so that expensive ground aids can be removed. Correspondingly, Canada is participating with WAAS trials. The earliest that a LAAS system will be installed in Canada is 2005<sup>1258</sup>. Toronto Pearson International airport is being equipped with a new surface-guidance system based on multilateral use of, for example, Mode S or ADS-B<sup>1259</sup>.

<sup>1246</sup> 'CNS/ATM for regionals' – R Penido, Embraer. Air Navigation Conference, Amsterdam. 1997.

<sup>1247</sup> 'Brazil – CNS/ATM in action' – W Machado, Directorate of Electronics and Flight Protection, Global Navcom 97.

<sup>1248</sup> 'Brazil taps Preston Group for ATM software' – Air Transport Intelligence, 18 February 2000.

<sup>1249</sup> 'Bulgaria enhances ground-to-air comms' – Air Navigation International, 7 February 2000.

<sup>1250</sup> 'Automated ATC system passes Nav Canada acceptance tests' – Air Transport Intelligence, 7 December 2000.

<sup>1251</sup> 'Canada moves ahead' – Jane's Airport Review, October 1997.

<sup>1252</sup> 'CAATS paves the way for integration during 2001' – Flight International, 19 December 2000.

<sup>1253</sup> 'NavCanada to spend \$27m on upgrades' – Air Transport Intelligence, 22 October 1999.

<sup>1254</sup> 'Last minute accord averts Canadian ATC strike' – Air Transport Intelligence, 10 June 1999

<sup>1255</sup> 'Air Canada CEO slams huge domestic user fee increases' – 5 May 1999.

<sup>1256</sup> 'NavCanada to cut ANS charges after criticism' – Air Transport Intelligence, 14 May 1999

<sup>1257</sup> 'Technology solutions' – Air Traffic Technology International 2001.

<sup>1258</sup> 'LAAS but not least' – air traffic management, July/August 2000.

<sup>1259</sup> 'Toronto to install new surface-guidance technology' – Air Transport Intelligence, 6 September 2000.



### **Chad**

Due to the efforts of ASECNA and IATA, at least 75% of airspace was covered by VHF communications in 1998, with 90% expected by 2000<sup>1260</sup>. In addition, new ILSs are being implemented as part of the ASECNA central African navigation upgrade programme.

### **Chile**

Noting that Chile is responsible for ATS over a very large part of the southern Pacific and Antarctic airspace, the country's CNS/ATM study was completed in 1998. Datalink is already operational for pre-departure clearances and GPS is used as the primary means of navigation. Indeed, Chile has worked with the US on WAAS, with two satellite navigation testbed reference stations to support WAAS installed in 1998<sup>1261</sup>, linked to a main WAAS station in the US. Oceanic ADS is not necessary because the traffic isn't dense. Correspondingly, RVSM is not required. In contrast with its Latin American counterparts, Chile has a high safety record<sup>1262</sup>.

### **China**

China plans to spend \$1.2 billion on a major upgrade of ATM systems between 1999 and 2009<sup>1263</sup>. For instance, new ATC automation systems are operating at the new Shanghai airport<sup>1264</sup>; Raytheon installed the first ATC centre in the region with a modernised system during 2000<sup>1265</sup>; and radar coverage has been extended in China's busy southern airspace<sup>1266</sup>. Regarding the latter, Hong Kong and China subsequently signed a new co-operation agreement, with new, improved co-ordination procedures<sup>1267</sup>. Accordingly, China has opened its first CNS/ATM route, in addition to extending FIR boundaries and reducing the number of ATC centres in China from 34 to 10<sup>1268</sup>. This followed heavy lobby over a number of years by European companies<sup>1269</sup>. ARINC supports the new western CNS/ATM flight path over the Himalayas<sup>1270</sup>. In addition, a Network Management Data Processing System is being integrated with ARINC systems for digital datalink in Eastern China and trials using VHF datalink to process ADS messages are occurring in Beijing with Air China and United Airlines. Other ATM system upgrades include Xi'an International airport, which is installing a new VHF air-ground radio network that is software controlled and incorporates digital technology<sup>1271</sup>; Shuangliu International airport is installing a new ATM system manufactured by Airsys ATM<sup>1272</sup>; and Nanchang's new Changbei airport has been equipped with a terminal airspace automation system<sup>1273</sup>.

### **Congo (Republic of)**

ILS is being implemented as part of the ASECNA central African navigation upgrade programme.

### **Cook Islands**

A \$1.7 million programme has been announced for GPS-based systems, including differential GPS.

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<sup>1260</sup> 'Safer skies' – *Flight International*, 10 June 1998.

<sup>1261</sup> 'Two begin battle to direct Latin American navigation' – *Flight International*, 11 April 2000.

<sup>1262</sup> 'Controlling Chile' – *Flight International*, 7 July 1999.

<sup>1263</sup> 'China plans \$1.2b air traffic management upgrade' – *Air Transport Intelligence*, 24 February 1999

<sup>1264</sup> 'ATC systems accepted ahead of Shanghai airport opening' – *Air Transport Intelligence*, 2 September 1999.

<sup>1265</sup> 'New ATC system accepted at Kunming airport' – *Air Transport Intelligence*, 4 February 2000.

<sup>1266</sup> 'New radar cuts separation in southern China' – *Air Transport Intelligence*, 6 January 2000

<sup>1267</sup> 'HK, South China sign new ATC co-operation pact' – *Air Transport Intelligence*, 27 January 2000

<sup>1268</sup> 'Qantas ponders new China CNS/ATM route' – *Orient Aviation*, November 1999.

<sup>1269</sup> 'Aérospatiale talks to China about FANS' – *Flight International*, 19 March 1997.

<sup>1270</sup> 'Business in China' – *air traffic management*, July/August 2000.

<sup>1271</sup> 'China modernises VHF network at Xi'an airport' – *Air Transport Intelligence*, 4 December 2000

<sup>1272</sup> 'Chinese airport opts for European ATC upgrade' – *Air Transport Intelligence*, 13 September 2000.

<sup>1273</sup> 'China accepts new US air traffic system' – *Air Transport Intelligence*, 25 April 2000.



**Croatia**

The country is implementing international technical standards and recommendations within the context of Euro-Atlantic integrations<sup>1274</sup>.

**Cyprus**

Radar, which is designed to be upgradeable to full ModeS operation, is being introduced.

**Czech Republic**

Drafting a new CNS/ATM plan.

**Denmark**

Their nationwide upgrade plan (DKATMS) incorporates GNSS RNAV procedures. Additionally, Denmark is conducting trials on continuous aircraft position reposting via ADS and VHF with Germany, Sweden and the UK.

**Ecuador**

Nav aids are being upgraded.

**Egypt**

The Egyptian CAA has signed a contract with Airsys ATM for the first phase modernisation programme of the Cairo Air Navigation Centre, which will have an ADS/CPDLC system. Northrop Grumman was awarded the second phase of the modernisation.

**El Salvador**

A countrywide ATC modernisation programme is underway.

**Equatorial Guinea**

ILS is being implemented as part of the ASECNA central African navigation upgrade programme.

**Fiji**

Fiji has pioneered civilian use of satellite navigation<sup>1275</sup>; since 1994, it has had GPS en-route instrument procedures<sup>1276</sup>. ATC provides VOR/DME standard separations using GPS bearing and distance information. This is also applicable in the terminal area, where augmented GPS is provided in parallel with ILS at Nadi. Fiji hopes to use satellite-based CNS/ATM for all flight phases by 2010. In addition, Fiji's oceanic services are able to deal with the FANS-1 package, noting that it is involved in the ADS and Datalink Interim System (ADIS) with Australia, Boeing and New Zealand. Accordingly, Fiji is one of the lead nations in the South Pacific Forum, which is trying to unify airspace above the South Pacific Ocean<sup>1277</sup>. In addition, Fiji has upgraded the AFTN links with high-speed datalinks to enable swift message transfers.

**France**

France recently became the first European country to make Pre-Departure Clearance (PDC) via datalink available to all interested parties in 2000<sup>1278</sup>. This stems from its project, CLAIRE, which developed a datalink system that provides departure clearance automatically, so that pilot and pre-flight controller workloads are reduced. In addition, France is involved with transition from ADS to radar airspace for North Atlantic Oceanic traffic.

<sup>1274</sup> 'Croatian ATC system development within European Integration Programmes' – S Steiner, B Galović & Č Ivaković, 43<sup>rd</sup> Annual Air Traffic Control Association Conference Proceedings, November 1998.

<sup>1275</sup> 'Asia/Pacific leads global modernization demand' – Aviation Week & Space Technology, 27 January 1997

<sup>1276</sup> 'Fiji pioneers satellite navigation' – Integrating Global Air Traffic Management, ISC & ICAO, 1998

<sup>1277</sup> 'Fijian rôle is key to South Pacific airspace revamp' – Air Transport Intelligence, 24 September 1999.

<sup>1278</sup> 'France to authorise departure clearance by datalink' – Air Transport Intelligence, 6 October 2000.



### Georgia

The ATC authority has accepted its new \$16m airspace management system at the main Tbilisi control centre<sup>1279</sup>.

### Germany

Germany's air traffic services provider, DFS, has initiated the first phase in its nationwide airspace restructuring effort to improve capacity and reduce flight delays<sup>1280</sup>. DFS has conducted a lot of satellite tests, including field trials for GPS non-precision approaches, with subsequent published procedures for such approaches, in addition to permitting GPS as a supplementary means of en-route navigation. DFS has also been involved with trials on continuous aircraft position reporting via ADS and VHF with Denmark, Sweden and the UK. Correspondingly, the P1 ATC Automation System (P1/ATCAS) was declared operational in 2000<sup>1281</sup>. DFS is interested in forming a strategic alliance with the UK's NATS<sup>1282</sup>.

### Ghana

Noting that Ghana is aiming to become an example of best practice in Africa<sup>1283</sup>, a new AFTN system was integrated at its main airport in 1999 as part of a modernisation programme<sup>1284</sup>.

### Greece

A new ATC centre, built by Thompson-CSF, opened near Athens in 1999<sup>1285</sup>. However, Greece still lacks full radar coverage of its airspace and continues to use procedural ATM in some sectors<sup>1286</sup>. Its airspace has been a bottleneck in summer time over recent years<sup>1287</sup>. The Greek airspace was nearly downgraded<sup>1288</sup> in 1998 by IFAPLA<sup>1289</sup> for being "seriously deficient"<sup>1290,1291</sup>. However, its ICAO safety classification was recently reduced to Class 2 status, the first time that this has happened to a Eurocontrol State.

### Guatemala

Honeywell is installing its Satellite Landing System at four airports<sup>1292</sup>.

### Hong Kong

Its Civil Aviation Department sought approval and funding from China for its CNS/ATM trial programme, which is the start of Hong Kong's 18-year CNS/ATM installation project<sup>1293</sup>. The trials began in 2000 with ADS and CPDLC assessments<sup>1294</sup>. Other ADS trials had started in 1995. Additionally, when opened in 1998, the new Hong Kong airport required a redesigning of the FIR's airspace that had to incorporate the closeness of several airports in the vicinity of the Pearl River delta<sup>1295</sup>.

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<sup>1279</sup> 'Georgia accepts new air traffic management system' – *Air Transport Intelligence*, 2 August 2000.

<sup>1280</sup> 'Germany begins major airspace restructuring project' – *Air Transport Intelligence*, 23 May 2000.

<sup>1281</sup> 'New German ATC system declared operational' – *Air Navigation International*, 7 February 2000.

<sup>1282</sup> 'Germany's DFS eyes Euro ATC liberalisation and NATS tie-up' – *Flight International*, 14 July 1999.

<sup>1283</sup> 'Plan to provide 'showpiece' African airport' – *air traffic management*, May-June 1999.

<sup>1284</sup> 'CNS studied' – *air traffic management*, March-April 1999.

<sup>1285</sup> 'Cautious welcome for new Greek ATC centre' – *Air Transport Intelligence*, 2 March 1999.

<sup>1286</sup> 'Light shines at end of Greek air traffic tunnel' – *Flight International*, 10 February 1999.

<sup>1287</sup> 'New Greek ATC system faces summer challenges' – 12 May 1999.

<sup>1288</sup> 'Pilots attack 'inadequate' ATC in Greece' – *Flight International*, 18 March 1998.

<sup>1289</sup> 'Acropolis now' – *air traffic management*, July/August 1998.

<sup>1290</sup> 'Greek airspace remains seriously deficient' – *Air Navigation International*, 29 June 1998.

<sup>1291</sup> 'Grim news from Greece' – *ATAG News*, December 1998.

<sup>1292</sup> 'Four airports to have D-GPS' – *air traffic management*, March-April 1999.

<sup>1293</sup> 'China to trial CNS/ATM' – *air traffic management*, May-June 1999.

<sup>1294</sup> 'Hong Kong to launch CNS/ATM system trials' – *Air Transport Intelligence*, 7 September 2000.

<sup>1295</sup> 'Hong Kong's new international airport required major restructuring of surrounding airspace' – *ICAO Journal*, May 2000.



### Hungary

Hungary's service provider, LRI, needs to introduce a new ATM system to handle increased flights<sup>1296</sup>. It has, however, inaugurated a new ATC centre at Budapest airport<sup>1297</sup> and is modernising the airport's ground movement guidance system.

### Iceland

Iceland has conducted a number of HF and VHF datalink trials, which includes transmission of ADS messages. In addition, the country has been host to a number of EGNOS/WAAS interoperability trials.

### India

India plans major improvements in ATC for the early part of this decade<sup>1298</sup>. For instance, satellite communications are planned for introduction through the Remote Area Business Management Network (RABMN) and integration into AFTN. Accordingly, ATC modernisation is occurring at Delhi and Mumbai, with new centres operational shortly. Their FIRs are having NDBs replaced with VORs. In addition, CNS/ATM equipment is being purchased for the Calcutta FIR. An interim ATM system in the densely packed Bay of Bengal region is being used prior to implementation of a FANS system, which is under development: ADS trials have been conducted on the Bay of Bengal FANS-1 route and in Madras. The contract for a wide-area VHF voice communications system for en-route traffic over the Indian sub-continent was recently awarded<sup>1299</sup>. A single radio frequency can be used to provide VHF coverage over a large area due to the 'offset carrier' technique, which enables transmission to take place from two or more radio sites simultaneously, without the risk of interference<sup>1300</sup>. India hopes to replace its terrestrial ATC system with GNSS-based CNS/ATM by 2015. Mode S capability has been available at airports since the mid-1990s and transponders are now mandatory on all aircraft using Indian airspace.

### Indonesia

The Jakarta Automated ATC system was completed in 1997<sup>1301</sup>, which enables ADS via AFTN. VDL en-route was expected in 1998, ModeS datalink in 2005. In addition, France provided Indonesia with a soft loan to help fund an ATS project<sup>1302</sup>.

### Iran

Iran had planned to open a FANS route for transiting traffic by 1998<sup>1303</sup>, noting that its CNS/ATM workstation became operational in March 1999.

### Ireland

Ireland is testing the integration of HF reports, radar data and position reports delivered by ACARS and displayed in graphical form on a workstation. It is therefore involved with ARINC HFDL trials<sup>1304</sup>. The Irish Aviation Authority (IAA) is also participating in initial trials of FANS-1/A waypoint position reporting over the North Atlantic in conjunction with NavCanada and the UK's NATS. The trials, which use ARINC facilities for distribution over the AFTN, have been underway since 1999. The IAA announced a new ATC centre at Shannon in 1997, due in 2001<sup>1305</sup>. However, its status has since slipped.

<sup>1296</sup> 'Hungary rapped over air traffic control safety risk' – *Flight International*, 8 December 1999.

<sup>1297</sup> 'East Europe leads move towards seamless AT' – *Flight International*, 28 March 2000.

<sup>1298</sup> 'Millennium facelift for Indian ATC' – *Air Transport World*, March 2000.

<sup>1299</sup> 'Park Air enhances VHF communications facilities to support India's Air Traffic control operations' – *ATC e-zine*, 8 August 2000.

<sup>1300</sup> 'India to modernise air-ground radio network' – *Air Transport Intelligence*, 4 July 2000.

<sup>1301</sup> 'Jakarta ATC System Faces Operational readiness demo' – *ATC Market Report*, 15 May 1997.

<sup>1302</sup> 'France firms \$54m loan for Indonesian ATS project' – *Air Transport Intelligence*, 15 February 2000.

<sup>1303</sup> 'Iran plans CNS/ATM investment' – *Jane's Airport Review*, June 1997.

<sup>1304</sup> 'Company News' – *air traffic management*, March/April 1997.

<sup>1305</sup> 'Changing the guard' – *air traffic management*, September/October 1997.



### **Israel**

The Israel Airport Authority completed an evaluation of an advanced Area Control Centre (ACC) ATC system in 1999<sup>1306</sup>.

### **Italy**

An ADS trial is underway to demonstrate technologies needed to fill ATC surveillance gaps in the Mediterranean area. Italy's air navigation provider, ENAV<sup>1307</sup>, officially opened its new Rome area control centre in 1999<sup>1308</sup>.

### **Jamaica**

Jamaica intends to modernise its ATC VHF communications network by installing radio systems capable of handling digital communications<sup>1309</sup>. It is also upgrading its ATM computer systems.

### **Japan**

An ADS satellite datalink experimental programme for ADS-derived position reports is being conducted, noting that Japan commenced operational use of ADS and CPDLC in 1998. In addition, the MTSAT wide area Satellite Augmentation System (MSAS) is under development. However, the MTSAT-1 navigation satellite was destroyed in an aborted launch during November 1999. It is being replaced by MTSAT-1R<sup>1310</sup>, which is due to be delivered in 2002.

### **Kazakhstan**

Kazakhstan has been awarded a grant by the US Trade and Development Agency for a feasibility study on upgrading the country's ATC system<sup>1311</sup>. The ATC upgrade programme includes new radars.

### **Kuwait**

Kuwait is introducing new weather radar for severe weather warnings, such as windshear and sand storm tracking.

### **Laos**

An ADS satellite navigation system is being installed.

### **Latvia**

The Latvian air navigation system modernisation has been completed<sup>1312</sup>, with the Riga area control centre using radar that had been developed for the Swedish CAA<sup>1313</sup>. Controllers for the Riga FIR have consequently started using a paperless air traffic control system<sup>1314</sup>, which also features multi-radar tracking, advanced flight plan data integration, predicted flight trajectories, On-Line Data Interchange (OLDI) and silent co-ordination<sup>1315</sup>.

### **Liberia**

Liberia is adding a new ATM system to Roberts FIR that provides en-route radio communications using South Africa's VSAT concept (see hereunder).

### **Macedonia**

Macedonia is implementing an ATM system for flight data processing.

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<sup>1306</sup> 'Israel Airport Authority completes evaluation of new ATC system' – *Air Navigation International*, 25 January 1999.

<sup>1307</sup> 'ENAV undergoes a personality change' – *Airports International*, June 1997.

<sup>1308</sup> 'Into the ark' – *air traffic management*, May-June 1999.

<sup>1309</sup> 'Jamaica to install digital radios for ATC' – *Air Transport Intelligence*, 2 November 2000.

<sup>1310</sup> 'Japan orders replacement for lost ATC satellite' – *Air Transport Intelligence*, 27 March 2000.

<sup>1311</sup> 'Kazakhstan to study ATC system upgrade' – *Air Transport Intelligence*, 28 April 2000.

<sup>1312</sup> 'Latvian Air Navigation System' – *Journal of ATC*, January-March 2000.

<sup>1313</sup> 'Phasing in Latvia's new look' – *air traffic management*, November-December 1999.

<sup>1314</sup> 'Riga claims paperless ATC first' – *air traffic management*, March-April 1999.

<sup>1315</sup> 'Working model' – *Air Traffic Technology International* 2001.



**Malaysia**

ADS trials are under way. Even though research has shown that the Malaysian ATM system capacity will not be able to cope with the demand in the year 2010<sup>1316</sup>, the Malaysian government wants to regain control over airspace run by Singapore<sup>1317</sup>.

**Mali**

ILS is being implemented as part of the ASECNA central African navigation upgrade programme.

**Mauritius**

A project is under way to replace existing communications equipment with satellite-based technologies for CNS/ATM<sup>1318</sup>.

**Mexico**

Mexico has CNS/ATM modernisation programmes on AFTN, satellite links, GNSS, Mode-S and ADS<sup>1319</sup>. These include studies on putting WAAS stations around the country. Mexico has standardised its ATC infrastructure, thereby laying solid foundations for implementation of CNS/ATM. Mexico's ATS provider, the government-owned Servicios a la Navegacion en el Espacio Aereo Mexicano (SENEAM), owns a network of 23 satellite earth stations that has virtually unlimited access to the government's satellite and a dedicated transponder. Therefore, it already has continuous radar coverage via satellite<sup>1320</sup>.

**Mongolia**

A countrywide CNS/ATM programme is under way, with a ground network already acquired. The CAA is extending its VHF radio network to cope with increased traffic between Asia and Europe, in addition to that on future polar tracks<sup>1321</sup>. Correspondingly, its VHF datalink coverage area is also being extended, ahead of an expected rise in the number of aircraft using FANS routes<sup>1322</sup>.

**Myanmar**

Communications have evolved from HF to VHF, complete with realigned direct speech ground-ground circuits.

**Namibia**

The Windhoek ATC centre was due to be linked with 14 other Sub-Sahara Africa centres through a satellite-based communications link.

**Netherlands**

The Amsterdam Advanced Air Traffic Control (AAA) System at Schiphol Airport has been commissioned and is in operation<sup>1323</sup>.

**New Zealand**

New Zealand plans to implement CNS/ATM by: commissioning its new Oceanic Control System<sup>1324</sup>, which is similar to Australia's TAATS; implementing 1,000ft RVSM between FL 290 and 390 from 2000; introducing domestic RNP-1 and beginning a phased removal of NDBs in 2001; initial air-ground datalink and introduction of ADS by 2002; commencing domestic RNP-0.3 by 2004; and replacing the domestic ATM system by 2005 (Lockheed Martin signed an

<sup>1316</sup> 'A study of the Malaysian Air Traffic Management System' – ZFM Wahi, Cranfield University MSc thesis, September 1997.

<sup>1317</sup> 'Controlling interests spark conflict' – Orient Aviation, November 1998.

<sup>1318</sup> 'Mauritius FIR upgrade planned' – Air Navigation International, 27 July 1998.

<sup>1319</sup> 'Mexico CNS/ATM developments' – AA Rodriguez, Seneam SCT, Global Navcom '97.

<sup>1320</sup> 'Mexico modernises in preparation for CNS/ATM' – Airports International, July/August 1997.

<sup>1321</sup> 'Mongolia plugs gaps in VHF radio coverage' – Air Transport Intelligence, 13 September 2000.

<sup>1322</sup> 'Mongolia extends VHF datalink coverage' – Air Transport Intelligence, 24 May 2000.

<sup>1323</sup> 'Amsterdam Advanced ATC System up and running' – ATC Market Report, 9 July 1998.

<sup>1324</sup> 'US, Canadian and NZ companies team for oceanic ATM' – Air Transport Intelligence, 25 October 1999.



agreement with Airways Corporation in 2000 to upgrade the ATM system<sup>1325</sup>). Additionally, New Zealand has been involved in the ADS and Datalink Interim System (ADIS) surveillance and communication link with Australia, Boeing and Fiji.

#### Norway

Norway has been instrumental with modified-ADS for monitoring helicopters in the North Sea. In addition, the Norwegian CAA has completed evaluation trials of a DGPS landing system for complex precision approaches using a Cat I landing system at Bodo Airport<sup>1326</sup>. It is also doing a test on augmented GPS navigation for air, land and sea use that broadcasts errors over AM/FM. The tower at Oslo's new airport, Gardermoen, is the first in the world to integrate all aspects of airside and groundside operations necessary for gate-to-gate ATM<sup>1327</sup>.

#### North Korea

In 1996, North Korea signed an agreement, which will permit flights to operate through its airspace, and part of which plans to improve communications support for FANS-1 equipped aircraft. ICAO secured an agreement between North and South Korea that allows international flights to cross adjacent FIRs<sup>1328</sup>. The relevant FIRs opened in 1998<sup>1329</sup> and a new air route from North Korean airspace over South Korea, which promised to save 12 minutes on flights between North America and Asia, was due to open in October 2000<sup>1330</sup>. ADS-compatible ATM consoles were planned for 1998, having started CPDLC link ADS trials in 1997.

#### Papua New Guinea

Germany's Development Bank, the Kreditanstalt für Wiederaufbau (KIW) is funding an ATS upgrade<sup>1331</sup>. A study is under way to examine transition to CNS/ATM. The PNG government had decided to implement a radar network across the country, which was abandoned<sup>1332</sup>. However, the country will not hand over control of its upper airspace for international flights to an overseas-based ATS provider<sup>1333</sup>.

#### Peru

Northrop Grumman started Peru's ATC modernisation programme in 1997<sup>1334</sup> and finished in 1998<sup>1335</sup>. RNAV FMS trials have taken place using GPS approaches into Lima.

#### Philippines

The first installation outside the US of a Transponder Landing System (TLS) occurred in 1998 at the Philippines' Subic Bay International Airport.

#### Poland

The country is upgrading its Airspace Management System.

#### Portugal

Portugal is using VHF datalink for oceanic clearance transmissions.

#### Romania

New ATC centres and other infrastructure investments have aided Romania's entry into Eurocontrol<sup>1336</sup>.

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<sup>1325</sup> 'Lockheed Martin to upgrade NZ ATM system' – *Air Transport Intelligence*, 8 May 2000.

<sup>1326</sup> 'Norway completes evaluation of landing system' – *Flight International*, 34 March 1998.

<sup>1327</sup> 'Norway's tower ATC automation system enables total gate-to-gate control' – *Journal of ATC*, October-December 1998.

<sup>1328</sup> 'CNS on its way' – *air traffic management*, November/December 1997.

<sup>1329</sup> 'Bad weather prevents first North Korean overflights' – *Air Transport Intelligence*, 23 April 1998.

<sup>1330</sup> 'New Korea air route to cut time from US-Asia flights' – *Air Transport Intelligence*, 11 August 2000

<sup>1331</sup> 'PNG to upgrade air traffic systems' – *Orient Aviation*, November 1999.

<sup>1332</sup> 'Government cancels controversial radar network project' – *air traffic management*, January-February 1999.

<sup>1333</sup> 'PNG rejects IATA call for airspace control transfer' – *Air Transport Intelligence*, 30 July 1999

<sup>1334</sup> 'Peru ATC modernization – into the 21<sup>st</sup> century' – *Journal of ATC*, April-June 1997.

<sup>1335</sup> 'Northrop Grumman ATC system declared operational in Peru' – *Air Navigation International*, 25 January 1999.

<sup>1336</sup> 'Opening up new airspace' – *Jane's Airport Review*, March 1997.



### Russian Federation

With ARINC, Russia is planning ADS-B as the principal means of surveillance and VHF datalink over the vast regions of the Russian North, Siberia and Far East: a programme is underway to implement ADS-B by VHF datalink Mode 4 as the primary means of surveillance in Russian airspace by October 2005<sup>1337</sup>. The Russians therefore plan to reduce reliance on radar<sup>1338</sup>. ADS/CPDLC trials have been conducted for aircraft transiting its airspace. In addition, analyses of Advanced Surface Movement Guidance and Control System (A-SMGCS) using ADS-B are also being conducted. ARINC has developed a communications suite in the Magadan ACC, where Russian controllers receive ADS and CPDLC training whilst tracking FANS-1 aircraft in the Pacific<sup>1339</sup>. The Russian Federation has made Siberia available and hopes to have CNS/ATM phased in by 2005. A number of CNS/ATM specific routes linking North America, Europe and the Orient over the Russian Far East, which require the FANS-1 package, have already been developed and flight-tested<sup>1340</sup>. Russia's Federal Aviation Service (FAS) aims to turn all the projected international air routes in its airspace into CNS/ATM tracks<sup>1341</sup>. However, progress has been slow<sup>1342,1343</sup>. It should be noted that Russia's Federal Service of Air Transport (FSVT) was dissolved in 2000 and was reintegrated into the Ministry of Transport as the State Civil Aviation Service (GSGA)<sup>1344</sup>. Russia is involved with Eurocontrol to improve air traffic flow management between the two areas, in addition to addressing critical safety issues<sup>1345</sup>.

### Rwanda

Rwanda is introducing a new long-range air route surveillance radar system<sup>1346</sup>.

### Saudi Arabia

Saudi Arabia is involved in CNS/ATM trials that are applicable to the desert environment, with experiments using GPS receivers and DGPS station at Jeddah. In addition, there is an ADS capabilities research programme. At Dhahran King Fahd International Airport (KFIA), a customised ATC system that supports Aeronautical Information Display System (AIDS), anti-collision and minimum safe altitudes, was installed at the end of 1999<sup>1347</sup>.

### Seychelles

The country is seeking to upgrade its aeronautical operational data processing system to have FANS (ADS) capability. The Seychelles also has plans to purchase pseudo-sub radar displays and software accessories to suit ADS.

### Singapore

Singapore has been involved with CPDLC trials since 1994. The country has created its second-generation Long Range radar And Display System (LORADS II), which processes and presents ADS data received via satellite. Indeed, Singapore has been involved in ADS trials with Australia, Hong Kong and Indonesia. It should be noted that Malaysian proposals to ICAO in 1998 requested that Malaysia regain control of the airspace that Singapore currently controls<sup>1348</sup>.

<sup>1337</sup> 'VDL Mode 4 and ADS-B – implementation in Russia' – *Flight Deck International*, April 2000.

<sup>1338</sup> 'From under the rouble' – *air traffic management*, September-October 1999.

<sup>1339</sup> 'Negotiating new routings in the Far East' – G Birutis, ARINC. *The Airline Navigation Conference '95*, Amsterdam, September 1995.

<sup>1340</sup> 'Airlines face traffic jams over Russian airspace' – *Jane's Airport Review*, October 1997.

<sup>1341</sup> 'Russia plans more polar routes shortly' – *Air Transport Intelligence*, 22 January 1999.

<sup>1342</sup> 'United polar route launch awaits Russian go-ahead' – *Flight International*, 14 April 1999.

<sup>1343</sup> 'Carriers put transpolar plans on ice' – *Flight International*, 14 July 1999.

<sup>1344</sup> 'Russia edges closer to civil aviation authority reform' – *Flight International*, 22 August 2000.

<sup>1345</sup> 'Eurocontrol, Russia to sign landmark agreement' – *Air Transport Intelligence*, 17 August 2000.

<sup>1346</sup> 'Rwanda commissions Northrop Grumman radar system' – *Air Transport Intelligence*, 10 May 2000.

<sup>1347</sup> 'KFIA one of the region's most modern airports' – *Air Navigation International*, 27 December 1999.

<sup>1348</sup> 'Singapore faces airspace loss' – *air traffic management*, September/October 1998.



### **Slovak Republic**

Having upgraded much of the air navigation infrastructure and implemented significant changes under Europe's EATCHIP, Slovakia continues to focus on integration with Europe's ATC system<sup>1349</sup>.

### **South Africa**

Restructuring of the country's service provision by 2003 is being achieved through establishment of RNAV (RNP) routes along major traffic flows and random routing outside these areas; use of a CFMU for flexible use of airspace; remote VHF; reducing the number of ATC sectors; and ADS/CPDLC, which are currently being tested at Johannesburg airport. Trials of ADS and CPDLC systems were also conducted within the Indian Ocean RNAV area and over parts of Africa, where there is no conventional ground-based surveillance<sup>1350</sup>. The authorities recently announced that they will create a country-wide ADS-B network using VDL Mode 4 by 2005<sup>1351</sup>. In addition, South Africa's Air Traffic Navigation Services (ATNS) has reported successful trials of its Very Small Aperture Terminal (VSAT) concept, which involves the use of satellite communications to link ATC centres in neighbouring States<sup>1352</sup>.

### **South Korea**

A major upgrade of South Korea's ATC centre, due for completion at the end of 2000, was held up because the contractors wanted to be paid in US dollars and not in won<sup>1353</sup>.

### **Spain**

Installation and evaluation of fixed satellite links, VDL, GNSS and ADS are scheduled for completion in 2001. Indeed, the Spanish navigational authority, Aena, joined ADS Europe trials, connecting Madrid ATC with ADS/SATCOM-equipped aircraft of the ADS Europe Consortium. Aena recently split its airport and air traffic control activities<sup>1354</sup>.

### **Sweden**

Sweden has been heavily involved in (STDMA VDL Mode 4) datalink trials with common technical platform for multiple CNS applications. This has included tests on continuous aircraft position reporting via ADS and VHF with Denmark, Germany and the UK.

### **Switzerland**

A DGPS ground station has been ordered for Lugano. Due to Kosovo and other problems, Swisscontrol has suffered poor performance in recent years<sup>1355</sup>.

### **Tahiti**

An oceanic datalink system was installed during 1996.

### **Taiwan**

At Taiwan's Chiang Kai Shek International airport, where a Singapore Airlines Boeing 747 crashed in 2000 whilst taking-off, the authorities are installing ground radar<sup>1356</sup>. A Satellite Landing System (SLS) is also being introduced in 2001<sup>1357</sup>. In addition, improved weather radar is being implemented.

### **Thailand**

Thailand plans VHF and SSR ModeS datalink, noting that the country has implemented a new VHF network for ADS trials. In addition, it has participated in GNSS trials. DGPS has been

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<sup>1349</sup> 'Slovakia moves forward with plans to achieve ATC modernisation and harmonisation' – ICAO Journal, May 2000.

<sup>1350</sup> 'South Africa centre to trial European ADS' – air traffic management, May/June 1997.

<sup>1351</sup> 'Russia begins deploying ADS-B network' – Air Transport Intelligence, 21 December 2000.

<sup>1352</sup> 'Airlines may link on African ATC problems' – Flight International, 26 November 1997.

<sup>1353</sup> 'South Korean ATCC upgrade plan in disarray' – Air Transport Intelligence, 16 March 1998

<sup>1354</sup> 'Spain's Aena splits airports and ATC activities' – Air Transport Intelligence, 28 November 2000.

<sup>1355</sup> 'Nerve centre' – air traffic management, September-October 1999.

<sup>1356</sup> 'Taipei airport to get ground radar in wake of SIA 747 crash' – Air Transport Intelligence, 20 November 2000.

<sup>1357</sup> 'Taiwan opts for Honeywell Satellite Landing System' – Air Navigation International, 6 March 2000.



ordered for an undisclosed Thai airport. The European Investment Bank recently provided a \$23 million loan for the ATC equipment at Bangkok's new international airport<sup>1358</sup>.

### Tonga

Tonga is purchasing communications equipment, which is compatible with the satellite environment.

### Tunisia

Tunisia is implementing new radar capabilities.

### Turkey

Turkey claimed in 1999 that it should take charge of Greece's ATC from Athens because the latter were "incapable" of providing necessary ATC<sup>1359</sup>.

### UK

By 2015, the UK aims to have implemented RTHM between ADS-equipped aircraft; direct CPDLC; and full conformance monitoring based on periodic ADS reports. Trials on continuous aircraft position reporting via ADS and VHF are being conducted by the UK's National Air Traffic Services (NATS), in conjunction with Denmark, Germany and Sweden. In addition, there is concern about the amount of traffic in UK airspace<sup>1360</sup>, certainly in the south-eastern region. The UK's airspace was therefore re-organised in 1999, which has reduced delays in the previously saturated Clacton sector<sup>1361</sup>. NATS experienced repeated computer failures at its London ATC Centre (LATCC) during 2000, which caused severe delays<sup>1362</sup>. Part-privatisation of NATS was confirmed<sup>1363</sup> and decided recently: this process is discussed in **Part 2** of this dissertation, with particular analysis in **Appendix 5.7**. Additionally, NATS's New En-route ATC Centre (NERC) has been the subject of much discussion over the last decade<sup>1364,1365&1366</sup>; after years of delay, NATS announced in 1998 that the NERC at Swanwick would be operational by early 2000<sup>1367</sup>. It was subsequently revealed that NERC was unlikely to open until 2002<sup>1368</sup> and again predicted as the winter of 2002/3<sup>1369</sup>. Thus, NATS was asked to ensure that the London ATC Centre (LATCC) could cope with its responsibilities until NERC is opened<sup>1370</sup>. However, Swanwick was integrated into the NATS network for controller training purposes at the end of 2000 and Swanwick is now expected to take over from LATCC on 20 January 2002<sup>1371</sup>. Similar to the NERC saga, NATS said in 1998 that the initial operation date of its New Scottish ATC Centre (NSC)<sup>1372</sup>, which was due in 2001/2<sup>1373</sup>, would be at least 2004<sup>1374</sup>. This date was then revised to 2005/6<sup>1375</sup>. However, changes of software provider for the new Flight Data Processing System (FDPS) from EDS<sup>1376</sup> to Lockheed Martin were cleared in 2000<sup>1377</sup>. The NSC was supposed to be a Private Finance Initiative (PFI) project, but announcement of the part privatisation process

<sup>1358</sup> 'Europe gives loan for ATC at new Bangkok airport' – *Air Transport Intelligence*, 16 January 2001

<sup>1359</sup> 'Row erupts over FIR control' – *air traffic management*, January-February 1999.

<sup>1360</sup> 'Level busts in the UK bust the record books' – *Flight International*, 2 September 1998.

<sup>1361</sup> 're-organisation of UK airspace increases capacity and cuts delays' – *Air Navigation International*, 8 February 1999.

<sup>1362</sup> 'NATS probes second London ATC breakdown' – *Air Transport Intelligence*, 19 June 2000.

<sup>1363</sup> 'NATS gets go-ahead as AMS and Boeing mull fresh bids' – *Flight International*, 5 December 2000.

<sup>1364</sup> 'Moving target' – *Flight International*, 21 May 1997.

<sup>1365</sup> 'Controlling the future' – *Flight International*, 20 May 1998.

<sup>1366</sup> 'Swanwick: the world's most advanced air traffic control centre' – NATS brochure, 1997.

<sup>1367</sup> 'Delayed UK en-route centre is set for clearance' – *Flight International*, 15 April 1998.

<sup>1368</sup> 'Minister says Swanwick now likely to open in 2002' – *Air Transport Intelligence*, 22 October 1998

<sup>1369</sup> 'NSC delay forces upgrade for Scottish ATC' – *Flight International*, 22 February 2000.

<sup>1370</sup> 'The Future of National Air Traffic Services' – *Third Report by the House of Commons' Environment, Transport and Regional Affairs Committee. Session 1998-99.*

<sup>1371</sup> 'NATS' Swanwick air traffic control centre is 'live' – *Flight International*, 2 January 2001.

<sup>1372</sup> 'UK report slams Swanwick ATC centre delays' – *Air Transport Intelligence*, 7 April 1998

<sup>1373</sup> 'NATS suspends EDS' delayed oceanic ATC upgrade' – *Air Transport Intelligence*, 17 July 2000

<sup>1374</sup> 'Scottish ATC centre three years late – magazine' – *Air Transport Intelligence*, 19 May 1998.

<sup>1375</sup> 'NATS contracts Sky Solutions for new Scottish ATC' – *Air Transport Intelligence*, 4 August 1999.

<sup>1376</sup> 'NATS suspends oceanic ATC contract with EDS' – *Flight International*, 25 July 2000.

<sup>1377</sup> 'Lockheed awarded \$80m New Scottish Centre contract' – *Air Transport Intelligence*, 14 February 2000



lead to NATS abandoning its PFI plans<sup>1378</sup>. Thus, NATS has adopted a two-centre strategy to consolidate UK ATC at both centres in order that the air traffic growth until 2020 is accommodated<sup>1379</sup>.

#### Uruguay

Capability will be provided for future expansion to Mode S and ADS with neighbouring ACCs.

#### US

Noting that the CNS/ATM activities of this country are analysed throughout this thesis and, particularly in Section 4.5.4, it is possible to observe that the US government and its FAA continue their move towards increased dependence on satellite technology. For instance, it is fervently developing LAAS and WAAS, in addition to having completed the first fully-certified local-area differential GPS (LADGPS) precision approach in 1998. Many other CNS/ATM programmes, such as the ADS-B trials, are being conducted. However, many delays are being experienced: for instance, a 24-hour Oceanic DataLink (ODL) service at the Oakland Air route traffic control centre was only ready at the end of 1999<sup>1380</sup>, even though it was supposed to have opened in 1996. This has delayed implementation of ADS and CPDLC in the Pacific Oceanic region<sup>1381</sup>.

#### Uzbekistan

The country's airspace management system is being modernised, with a completion time in 2001<sup>1382</sup>.

#### Venezuela

As part of its modernisation programme for new ATS infrastructure, the government has selected a consortium led by Boeing to conduct a study into migrating its radar-based ATC infrastructure towards satellite-based systems<sup>1383</sup>.

#### Yugoslavia

The Yugoslav Air Traffic Controllers Association recently warned that the ATC equipment in use is too old and unreliable<sup>1384</sup>.

#### Zimbabwe

In 1998, the International Federation of Air Traffic Controllers Associations (IFATCA) was concerned about controller training standards and the country's ATM infrastructure, which was allegedly poorly maintained even though it was relatively new<sup>1385</sup>.

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<sup>1378</sup> 'NATS privatisation hits Scottish ATCC' – *Flight International*, 4 August 1999.

<sup>1379</sup> 'Scotch off the rocks' – *air traffic management*, September-October 1999.

<sup>1380</sup> 'Raytheon data link system operational at Oakland centre' – *Air Transport Intelligence*, 15 November 1999.

<sup>1381</sup> 'FAA works on solution to Pacific ATM problem' – *Air Navigation International*, 11 January 1999.

<sup>1382</sup> 'First western CIS system starts operations' – *air traffic management*, May/June 1997.

<sup>1383</sup> 'FI2000: Boeing team to study Venezuelan ATC upgrade' – *Air Transport Intelligence*, 27 July 2000.

<sup>1384</sup> 'Yugoslavia gets warning over unreliable ATC' – *Flight International*, 7 November 2000.

<sup>1385</sup> 'IFATCA criticises Zimbabwe's ATC service' – *Air Navigation International*, 26 January 1998.



**APPENDIX 4.6**

**REGIONAL CNS/ATM ACTIVITIES**



## REGIONAL CNS/ATM ACTIVITIES

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**Sources: ICAO's 'Global Air Navigation Plan for CNS/ATM Systems' (1<sup>st</sup> Ed. 2000);  
Numerous publications – as referenced hereunder.**

This appendix contains the appraisal of regional CNS/ATM activities, which is referred to in Section 4.7, thus:

### 1. Africa

The African countries are acutely aware that CNS/ATM provides developing nations with a timely opportunity to improve their notoriously poor Air Traffic Management (ATM). Indeed, the African region is used for case study purposes in Part 2 of this dissertation. The ICAO AFI regional group has the responsibility for driving the implementation process through its Implementation Coordinating Groups (ICGs), which are composed of Air Traffic Service (ATS) providers, IATA and ICAO, to ensure a harmonised development. A CNS/ATM task force has created an implementation plan for the region. Noting that South Africa has a relatively well-developed infrastructure and system, two ICGs have been established: one for the Southern Africa interface; another for the African-European traffic flow. A summary of the current status and strategy of the AFI region's CNS/ATM activities follows, thus:

**Communications** – due to rapid increase in flights over the region, use of the IATA Inflight-reporting frequency on 126.9MHz was reduced to 5 minutes in 1996<sup>1386</sup>. The IATA frequency is used by airlines to self-control their migration through the region, in addition to communicating with ground control centres where possible. Air Afrique, ASECNA, Rockwell-Collins and SITA have conducted extensive ADS trials<sup>1387</sup>.

**Navigation** – IATA and ICAO want to assess whether the implementation of GNSS wide-area augmentation would be cost-effective and decide accordingly on its integration<sup>1388</sup>. Correspondingly, local area augmentation may be introduced where cost efficiency has been demonstrated in selected terminal areas. Ten major traffic flows or routing areas have been identified<sup>1389</sup> in the AFI region, thus:

1. Europe to South America (oceanic routes);
2. Atlantic Ocean;
3. Europe to Eastern Africa;
4. Europe to Southern Africa;
5. Gulf of Guinea (coastal routes);
6. Iberian Peninsula to Canaries;
7. North AFI coastal and Europe/AFI interface routes;
8. Continental Southern Africa;
9. Trans-Sahelian;
10. Trans-Indian Ocean.

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<sup>1386</sup> 'Pilot worries' – *Flight International*, 10 April 1996.

<sup>1387</sup> 'Africa responds to critics' – *Jane's Airport Review*, March 1997.

<sup>1388</sup> 'CNS/ATM implementation: progress and priorities from a user perspective' – J White. IATA. 4<sup>th</sup> Air Navigation Conference, Amsterdam. September 1998.

<sup>1389</sup> 'A landmark regional air navigation meeting for Africa' – *Integrating Global Air Traffic Management*. ISC & ICAO, 1998.



**Surveillance** – the region is renowned for its lack of surveillance. Various ventures, which are described hereunder, are bringing ADS to Africa<sup>1390</sup>.

**ATM** – an ICAO Task Force has been created to achieve RVSM implementation at the earliest possible stage. ICAO's regional air navigation meeting in 1997 concluded with a set of recommendations, such as ATM co-operation, aimed at improving compliance with SARPs<sup>1391</sup>. The meeting was considered to be a landmark event because the International Federation of Air Line Pilots' Associations (IFALPA) had publicly denounced African airspace as very dangerous the previous year<sup>1392</sup>. The ICAO Indian Ocean Air Traffic Services Co-ordinating Group is looking at a CNS/ATM route from Asia to Mauritius and South Africa<sup>1393</sup>. The Common Market for Eastern and Southern Africa (COMESA), a conglomerate of 21 African States<sup>1394</sup> and industry, agreed in August 1999 to jointly invest in a system to manage their upper airspace regions above FL240 in a seamless manner using automated ATM and satellite links, with reduced need for ground infrastructure<sup>1395</sup>. Talks between COMESA regional implementation groups and the Safe African Skies Group (SASG) were due to start towards the end of 2000<sup>1396</sup>. This system is expected to be operational in late 2002<sup>1397</sup>. The SASG was commissioned to assess the feasibility of the project. Control will be provided by two ATC centres in the region and the cost of the system will be recovered through user costs. The project will cover 60% of African landmass and interface with a similar venture being proposed by the French-speaking ASECNA States. It should also be noted that the US government has set up a campaign, known as 'Safe Skies for Africa', whose objectives are, among others, to improve regional communications and navigation using satellite technology, in addition to increasing the number of sub-Saharan African countries that meet ICAO safety standards<sup>1398</sup>.

## 2. Americas & Caribbean

ICAO's activities are co-ordinated in this region by the North American Planning Group (NAMPG) and the CARibbean/South American (CAR/SAM) Regional Planning and Implementation Group (GREPECAS). The NAMPG is concerned with the introduction of CNS/ATM in Canada and the US. **Appendix 4.5** cites the happenings in Canada, which are heavily reliant on those in the US. The latter are the subject of much discussion in this dissertation and their present position is discussed in **Section 4.5.4**. Hence, they are not reproduced here. This section consequently summarises the current status and strategy of the CAR/SAM region's CNS/ATM activities, thus:

**Communications** – the lack of reliability in air-ground communications is being addressed through greater use of satellite communication facilities and datalinks.

**Navigation** – even though no persistent aircraft departure delay problems exist in the region, some congested ATS routes and areas have been identified. This is being alleviated by a greater number of RNAV routes joining densely travelled city-pairs. However, there is a lack of radio navigation coverage on some segments, so most countries are approving GPS as a supplementary means of navigation. GPS is already in frequent use in the Eastern Caribbean<sup>1399</sup>. Correspondingly, the region is focusing on the early introduction of GNSS-based

<sup>1390</sup> 'African nations to finance CNS/ATM system' – *Flight International*, 25 August 1999.

<sup>1391</sup> 'Africa moves closer to ICAO' – *Jane's Airport Review*, July/August 1997.

<sup>1392</sup> 'A landmark regional air navigation meeting for Africa' – *Integrating Global Air Traffic Management, ISC & ICAO*, 1998.

<sup>1393</sup> 'Asia-Pacific pathfinders' – *Flight International*, 21 January 1998.

<sup>1394</sup> Angola, Burundi, Comoros, Congo, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Namibia, Rwanda, Seychelles, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe.

<sup>1395</sup> 'Jane's Air Traffic Control' – 6<sup>th</sup> Edition, 1999-2000.

<sup>1396</sup> 'African states begin talks on joint CNS/ATM approach' – *Flight International*, 27 June 2000.

<sup>1397</sup> 'Step by step' – *Flight International*, 22 September 1999.

<sup>1398</sup> 'The Safe Skies for Africa initiative' – M Kenney, 43<sup>rd</sup> Annual Air Traffic Control Association Conference Proceedings, November 1998.

<sup>1399</sup> 'CNS/ATM progress in the Eastern Caribbean' – C Outram, Technical Director – Aviation, Barbados. *Global Navcom '97*.



routes: IATA tested five GPS RNAV routes between the US and South America. The US FAA's Caribbean RNAV programme, which is developing a more efficient route system for RNAV-equipped aircraft, progressed to its second stage at the end of 1998<sup>1400</sup>. Implementation of the WGS-84 geodetic co-ordinate system remains a stumbling block to the development of GPS-based non-precision approaches in the region: most countries did not comply with the 1998 deadline. Raytheon Systems has conducted talks with some Latin American countries' authorities to develop satellite-based en-route and precision approach navigation systems for the region<sup>1401</sup>.

**Surveillance** – the region is characterised by large areas of airspace not covered with adequate radar surveillance due to topographical difficulty in implementing the systems. GREPECAS is carrying out a study of radar systems in the region. Primary and SSR Mode C radar will continue to be used in terminal areas, while SSR Mode C will be used to a greater extent in high traffic density continental areas for en-route ATC. The region is also preparing for SSR Mode S in these areas. In addition, ADS is being progressively used in oceanic and remote airspace regions.

**ATM** – even though some improvements have occurred, there are still significant deficiencies to overcome, which include a lack of optimum flight profiles and a lack of ground system capacity. The International Federation of Air Traffic Controllers' Associations (IFATCA) has said<sup>1402</sup> that a "lack of air traffic management in the airspace over South America and parts of Central America and the Caribbean is endangering the safety of airlines and their passengers." Therefore, IATA and ICAO joined forces with aviation organisations and airframe manufacturers to establish a new safety group, the Pan American Aviation Safety Team (PAAST), which is aiming to implement flight safety improvements in Latin America and the Caribbean<sup>1403</sup>. The region needs to address ATM issues, but does not require RVSM<sup>1404</sup>. It has been necessary to address harmonisation of adjacent Flight Information Regions (FIR), in addition to intra- and inter-regional harmonisation<sup>1405</sup>. The ICAO Implementation Committee responsible for introduction of CNS/ATM in the region has yet to develop its plan in full, although it should be noted that a new CAR/SAM Regional ANP was produced in 1999, which was the first to be structured in the new format of Basic ANP and Facilities and Services Implementation Document (FASID)<sup>1406</sup>.

### 3. Asia & Pacific

ICAO's activities are co-ordinated in the region by the ASIAPAC Air Navigation Planning and Implementation Regional Group (APANPIRG). Noting that the region is well advanced in CNS/ATM implementation<sup>1407</sup>, the current status and strategy of the region's CNS/ATM activities may be summarised, thus:

**Communications** – due to the high levels of HF usage with pilot reports, with the consequent inefficient use of airspace, the region has been implementing ADS and CPDLC, in addition to SSR Mode S datalink. Datalink ground systems are in operation across the region, with more being implemented in China, Hong Kong, India, Japan, Malaysia and Singapore.

**Navigation** – there has been progressive introduction of RNAV capability in compliance with RNP criteria and use of GNSS for aircraft navigation. Some progress has been made in opening the CNS/ATM route between Kuala Lumpur and Bhubaneshwar over the Bay of Bengal.

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<sup>1400</sup> 'FAA launches phase two of Caribbean RNAV programme' – *Air Navigation International*, 25 January 1999.

<sup>1401</sup> 'Two begin battle to direct Latin American navigation' – *Flight International*, 11 April 2000.

<sup>1402</sup> 'Attention shifts to South America' – *Airports International*, March 1997.

<sup>1403</sup> 'New safety initiative for Latin America and Caribbean' – *Air Transport Intelligence*, 23 August 2000

<sup>1404</sup> 'Controlling Chile' – *Flight International*, 7 July 1999.

<sup>1405</sup> 'ICAO Regional CNS/ATM Transition Planning – GREPECAS' – *PI Hegedus, Global Navcom '97*.

<sup>1406</sup> 'New Air Navigation Plan provides greater efficiency and economy in air services' – *ICAO News Release PIO 13/99* 1999.

<sup>1407</sup> 'Improving capacity – implementation of FANS CNS/ATM system in the Asia/Pacific region' – *Developing the Future Aviation System*, R Baldwin. 1998.



Commercial flight trials occurred in 2000 under the auspices of the FANS Action Team for the Bay of Bengal (FAT-BOB), which hopes to permanently implement new FANS routes to remove choke points for flights between Europe and Asia<sup>1408</sup>. This region has been very active in starting satellite navigation services<sup>1409</sup>. RNP-10 was introduced in the North and Central Pacific, on the fixed Polar routes in the Anchorage and Tokyo FIRs, thereby enabling the removal of composite separation. The following routes were identified by IATA's Asia-Pacific regional co-ordinating group<sup>1410</sup> for the purposes of defining CNS/ATM-based RNAV air traffic flows:

1. North America to Australia/New Zealand and South Pacific islands (via South Pacific);
2. Asia to North America (via North Pacific and Russian Far East);
3. North America to Asia (via Central Pacific, which includes traffic from Canada and the US to North and East Asia);
4. Asia to Europe (north of the Himalayas);
5. Asia to Europe (south of the Himalayas);
6. Australia/New Zealand to Asia (and Indonesia to Tokyo);
7. SE Asia to NE Asia (China and Japan);
8. Australia/NZ to South America.

**Surveillance** – the region is characterised by the use of SSR Mode A, C and, shortly, Mode S in some terminal areas and high-density continental airspace. In addition, ADS is being employed and there is diminishing use of primary radar. However, there are poor levels of surveillance in some areas.

**ATM** – the lack of surveillance, poor quality communications facilities and language difficulties in the present system are being alleviated through: improved handling and transferring of information between operators, aircraft and ATS units; the aforementioned extended surveillance using ADS; and advanced ground-based data processing systems that allow for greater levels of user-preferred flight profiles. FANS routes using FANS-1/A in the South Pacific have been in use for over five years<sup>1411</sup> and are discussed in Section 4.6.1. Indeed, the Pacific has demonstrated that FANS-1 works in low-density airspace<sup>1412</sup>. Dynamic Airborne Route Planning (DARP), which uses ADS through the Flight Management System's GPS and CPDLC abilities, is employed in the North Pacific Oceanic region to replan a flight after departure. However, it is not being frequently used<sup>1413</sup>. RVSM was introduced during 2000<sup>1414</sup> in the Pacific Oceanic FANS-1/A environment: it will be implemented in Australian airspace during 2001<sup>1415</sup> and the South China Sea in 2002<sup>1416</sup>. Due to efforts by IATA<sup>1417</sup>, the reopening of Russian and North Korean FIRs has resulted in saving for the carriers. Correspondingly, noting that proving flights have been completed from 1998<sup>1418</sup> to date, with numerous carriers conducting trials. Airlines had hoped to launch continuous operational flights on four Polar routes by 1999, but unopened points along the routes and the loss of Iridium communications have delayed the situation<sup>1419</sup>. In addition, Russia had, and still has, restrictions in place: current limits are 2 aircraft per hour. Nonetheless, noting that the four routes have been approved by ICAO<sup>1420</sup>, the situation is improving<sup>1421</sup>. Continental Airlines, Northwest Airlines and United Airlines each presently operate one route over the Pole, noting that United will add another on the 1<sup>st</sup> of April

<sup>1408</sup> 'IATA, ICAO work to open Bay of Bengal FANS routes' – *Air Transport Intelligence*, 11 August 2000.

<sup>1409</sup> 'Asia/Pacific leads global modernization demand' – *Aviation Week & Space Technology*, 27 January 1997.

<sup>1410</sup> 'Asia-Pacific pathfinders' – *Flight International*, 21 January 1998.

<sup>1411</sup> 'Examples of early implementation of CNS/ATM systems for air traffic services in Asia Pacific' – W Lang, CAE Electronics. *Airline Navigation '96*, Amsterdam. October 1996.

<sup>1412</sup> 'Work in Russia' – P Hogge, IATA. *Airline Navigation '96*, Amsterdam. October 1996.

<sup>1413</sup> 'DARP little used despite successful trials' – *Air Navigation International*, 18 September 2000

<sup>1414</sup> 'Pacific RVSM implementation set for next week' – *Air Transport Intelligence*, 18 February 2000.

<sup>1415</sup> 'South China Sea, Australian RVSM set for next year' – *Air Transport Intelligence*, 22 March 2000.

<sup>1416</sup> 'RVSM to be extended in Asia-Pacific in 2001 and 2002' – *Air Transport Intelligence*, 11 August 2000.

<sup>1417</sup> 'Taking pole position' – *Flight International*, 5 August 1998.

<sup>1418</sup> 'Pole stars' – *air traffic management*, July/August 1998.

<sup>1419</sup> 'Ice-breaking' – *air traffic management*, September-October 1999.

<sup>1420</sup> 'ICAO over the pole' – *Flight International*, 6 February 2001.

<sup>1421</sup> 'IATA sees progress on Arctic routes' – *Air Transport Intelligence*, 14 November 2000.



2001. Accordingly, other (Asian and North American) carriers plan to start this year<sup>1422</sup>, although it is thought that the opening of all 4 Polar routes to flights will not occur before 2003<sup>1423</sup>. Section 7.4 contains an analysis of the North polar routes. Correspondingly, airlines have been quite good at implementing technology in this region and are extremely frustrated over lack of flexible routings<sup>1424</sup>. Some, however, have been using flight-planning programmes to identify optimum routes that accommodate minimum fuel, time or cost<sup>1425</sup>. The South Pacific Forum has been working on plans about co-operative airspace management as one FIR over its sixteen Pacific Ocean country members since 1998<sup>1426</sup>, which have been postponed<sup>1427</sup>. Correspondingly, the Informal South Pacific ATC Coordination Group (ISPACG) has been active in the region. The ISPACG consists of airlines (in particular Japan Airlines, Qantas Airways and United Airlines), Boeing, in addition to the Civil Aviation Authorities and ATS Providers from Australia, Fiji, French Polynesia, New Zealand, Papua New Guinea and the US. A sub-group of the ISPACG, the Southern PACific (SOPAC) FANS Interoperability Teams (FIT), has concluded that ADS/CPDLC performance in the region is adequate, but that significant operating benefits continue to elude operators<sup>1428</sup>. This may be due to the fact that ADS/CPLDC service at the US Oakland Air route traffic control centre has only been operational since the end of 1999<sup>1429</sup>, even though it was supposed to have opened in 1996. Noting that the Asia-Pacific regional CNS/ATM plan has been developed and is being continuously implemented, the experience has shown that introduction of CNS/ATM must be based on realistic ATM goals and timeframes<sup>1430</sup>. Additionally, ICAO recently brokered a deal between China and Vietnam to double capacity across the South China Sea, with the new routes starting in November 2001<sup>1431</sup> for a 3-year trial<sup>1432</sup>. These new routes will complement other trans-Asia FANS routes<sup>1433</sup>.

#### 4. Europe

The ICAO European Air Navigation Planning Group (EANPG) carries out the regional strategy for planning and implementation of CNS/ATM systems in the European region, which comprises 49 States. It should be noted that the European Civil Aviation Conference (ECAC), Eurocontrol and the Joint Aviation Authorities (JAA) State groupings exist (see the list of their Member States in Appendix 3.3). However, coordination is required by the EANPG to ensure that they all remain within the framework of the Global Plan.

Given the large variance in geographic characteristics and air traffic density in the region, ICAO agreed that, considering the complexity and diversity of the region, air navigation planning could be best achieved if it was organised in homogeneous areas of common interests and requirements. It is for this reason that Eurocontrol orchestrates the implementation plans of the region's western part, while ICAO helps the other (Eastern European and Soviet) States. The former is the subject of much coverage in this thesis, in particular as Section 4.5.3, and is not repeated here.

Regarding the remaining part of the European region, work is in progress through the Group for Air Traffic Management to keep pace with developments and to ensure coherent planning and implementation of CNS/ATM systems, taking into account the interfaces with other regions.

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<sup>1422</sup> 'Polar services bear fruit' – *Flight International*, 20 March 2001.

<sup>1423</sup> 'Polar route openings two years away: IATA' – *Air Transport Intelligence*, 26 January 2001.

<sup>1424</sup> 'FANS delay fears in US' – *Orient Aviation*, December 1997 – January 1998.

<sup>1425</sup> 'Air carrier modernizes its flight planning system to maximise operational flexibility' – *ICAO Journal*, March 1998.

<sup>1426</sup> 'IATA readies single South Pacific FIR proposal' – *Air Transport Intelligence*, 9 February 1999.

<sup>1427</sup> 'South Pacific nations defer discussion on single FIR' – *Air Transport Intelligence*, 20 September 1999.

<sup>1428</sup> 'FANS 1/A works but benefits remain elusive, FIT finds' – *Air Navigation International*, 18 September 2000.

<sup>1429</sup> 'Raytheon data link system operational at Oakland centre' – *Air Transport Intelligence*, 15 November 1999.

<sup>1430</sup> 'Success in the Pacific' – P Woodbury, Airways Corporation of New Zealand. *Airline Navigation '96*. Amsterdam, October 1996.

<sup>1431</sup> 'South China Sea routes agreed' – *Flight International*, 19 December 2000.

<sup>1432</sup> 'China, Vietnam agree major airspace reorganisation' – *Air Transport Intelligence*, 12 December 2000.

<sup>1433</sup> 'Approval expected soon for new trans-Asia routes' – *Air Navigation International*, 7 June 1999.



## 5. Middle East

The ICAO MID regional group has agreed that the FANS-1/A navigation package will be accommodated in the region. Indeed, Iran and Saudi Arabia are in the process of installing the requisite ground equipment. ICAO's activities are co-ordinated in the region by the Middle East Air Navigation Planning and Implementation Regional Group (MIDANPIRG), which established a CNS/ATM sub-group to review, monitor and identify any shortcomings or deficiencies in the development of the ICAO global plan. The current status and strategy of the region's CNS/ATM activities may be summarised, thus:

**Communications** – at present, air-ground communication in the region is provided by VHF voice, with some HF activity. It is thought that the use of VHF data and SSR Mode S datalink will continue to increase. The Middle East States wish for ARABSAT communication satellites to be used for providing communication and augmentation. IATA considers this neither realistic nor desirable.

**Navigation** – the current infrastructure of navigational aids within the region is considered adequate to service the foreseeable future requirements and that RNAV capability will be progressively implemented. A blanket RNP-10 has been agreed.

**Surveillance** – the region has good radar coverage in most areas, but is being improved with SSR Mode A/C in terminal areas and high-density continental airspace. The use of primary radar will decrease.

**ATM** – in general, with reference to the earlier CNS sections, the region has good radar coverage, but with few RNAV routes. RVSM is cautiously being assessed. The region's airspace has been divided into two, based on identified CNS/ATM major traffic flows that facilitate optimum flight paths to serve the region and provide linkages with adjacent regions and main trunk routes. Regional timescales for the introduction of the various ATM elements have not yet been definitively produced.

## 6. North Atlantic Ocean

ICAO's activities are co-ordinated in the region by the North Atlantic Systems Planning Group (NATSPG). The current status and strategy of the region's CNS/ATM activities may be summarised, thus:

**Communications** – current communication is via HF voice, although VHF datalinks are being used for some ATS clearances. Due to the current HF network's saturation level, CPDLC is the planned primary means for routine communications, with satellite voice used for emergencies. Trials are being conducted in the West Atlantic region<sup>1434</sup>. Although this requires the ATN as an end-state, provisions have been made to accommodate FANS-1/A. The ATN was still being developed in 1997<sup>1435</sup>, but has been slowed down of late due to problems with the new Flight Data Processing System 2 (FDPS2) at the Scottish Oceanic Area Control Centre<sup>1436</sup>.

**Navigation** – much of the region's traffic travels through the Minimum Navigation Performance Specification Area (MNPSA), whereby aircraft must achieve a navigation performance of RNP-12.6 to sustain lateral separation. Longitudinal separation is achieved using the Mach Number Technique, as described in Section 3.2.2. Navigation requirements will continue to become more stringent as the region implements the ATM improvements, as discussed hereunder. Use

<sup>1434</sup> 'New York centre prepares for Atlantic datalink' – *Air Transport Intelligence*, 2 May 2000.

<sup>1435</sup> 'NATS will introduce North Atlantic ATN' – *Flight International*, 8 January 1997

<sup>1436</sup> 'Scottish ATC centre three years late – magazine' – *Air Transport Intelligence*, 19 May 1998.



of satellite-based navigation will increase. It is thought that ADS may make reduced lateral and longitudinal separation possible.

**Surveillance** – mostly conducted via position reports delivered over HF voice, the region plans to commence ADS Waypoint Position Reporting (WPR) through FANS-1/A services and subsequently over the ATN<sup>1437</sup>. ADS WPR has fewer errors than HF position reporting. ADS operations in the NAT region were planned for July 2000<sup>1438</sup>, but were postponed following technical problems with the infrastructure<sup>1439</sup>. In March 2001, carriage of ACAS II became mandatory<sup>1440</sup>.

**ATM** – the aforementioned lack of communications and surveillance facilities limit the airspace capacity. The system must accommodate two major traffic axes: one between Europe and North America; the other between the Caribbean/South America and North America. The overall goal is to make the oceanic ATM operations as flexible as possible in accommodating users' preferred trajectories. Future operations will use aviation weather system improvements and collaborative decision-making. These new capabilities will permit flexible routing and dynamic modifications to aircraft routes in response to changes in weather and traffic conditions. NATSPG drafted its CNS/ATM plans during the last decade in conjunction with IATA, IFALPA, IFATCA and the ATS Providers of many countries. With implementation strategies until 2015, they were the first based on ICAO's CNS/ATM concept<sup>1441</sup>. ICAO's North Atlantic Implementation Management Group (NAT/IMG) has developed a programme, summarised in the North Atlantic Implementation Document, which aims to provide enough capacity and flexibility in the system<sup>1442</sup>. In addition, the NAT/IMG has approved a programme that calculates the benefits of NAT developments to facilitate the users and providers' scope and expectation for more fuel and time efficient routings and profiles. This region was identified as best suited for RVSM due to the one-way nature of its traffic and the height keeping accuracy of its aircraft population: RVSM was fully implemented in 1998<sup>1443,1444</sup>. RVSM has doubled the capacity of the region's Minimum Navigation Performance Specification (MNPS) airspace. The height-monitoring programme that keeps track of airframes, approved for RVSM operations in the region, has shown that the accuracy of aircraft systems' performance was well within the target level of safety<sup>1445</sup>. This bodes well for introduction of RVSM in other regions: for instance, the South and West Atlantic areas are presently implementing RVSM<sup>1446,1447</sup>, noting that the Western Atlantic Route System is due to begin its first phase in October 2001. RHSM was planned for introduction in early 2000<sup>1448</sup>, but has not materialised yet. Increases in flexibility through On Track Flexibility, Direct Routes and Free Flight are due to subsequently occur. Improved OTS, which is a programme that aims to reduce the OTS design and meteorological forecast penalties, is presently being conducted.

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<sup>1437</sup> 'An analysis of air traffic flow optimisation in the North Atlantic Region' – C Whelan, Cranfield University MSc thesis, September 1996.

<sup>1438</sup> 'ADS on the North Atlantic' – H Martin, NavCanada. Inmarsat Aero Conference, May 2000

<sup>1439</sup> 'Technical problems delay North Atlantic ADS debut' – Air Transport Intelligence, 14 August 2000.

<sup>1440</sup> 'Guidance and Information Material concerning Air Navigation in the North Atlantic Region' – ICAO. Interim 7<sup>th</sup> Edition, September 2000.

<sup>1441</sup> 'Air Navigation Plan - North Atlantic Region'. ICAO. Trial Edition. 1995.

<sup>1442</sup> 'North Atlantic Development' – J Nordbo, NATS. Air Navigation Conference, Amsterdam 1997

<sup>1443</sup> 'RVSM comes of age after trial period' – Flight International, 24 December 1997.

<sup>1444</sup> 'Maximizing Minima – air traffic management, September/October 1998.

<sup>1445</sup> 'Data from NAT height monitoring programme points to better than acceptable risk level' – ICAO Journal, April 1999.

<sup>1446</sup> 'ARINC's safety assessment is part of South Atlantic RVSM program' – ATC Market Report, 20 July 2000.

<sup>1447</sup> 'RVSM to extend to South and West Atlantic' – Air Transport Intelligence, 4 July 2000

<sup>1448</sup> 'Success for trans-Atlantic ADS trial' – Air Navigation International, 8 December 1997



***APPENDIX 5.1***

**ICAO'S POLICY ON  
CNS/ATM SYSTEMS**



## ICAO'S POLICY ON CNS/ATM SYSTEMS

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*Source: Statement of ICAO Policy on CNS/ATM Systems Implementation and Operation. ICAO, 1994.*

In continuing to fulfil its mandate under the Chicago Convention on International Aviation by developing principles and techniques of international air navigation, ICAO has created a policy on CNS/ATM systems, which stipulates that the implementation and operation of CNS/ATM systems will adhere to the following precepts:

1. **Universal accessibility** – the provision of air navigation services using CNS/ATM systems should not discriminate against any users;
2. **Sovereignty, authority and responsibility of ICAO-contracting countries** – nations will remain in charge of air navigation and the enforcement of safety regulations in their jurisdiction;
3. **Responsibility and rôle of ICAO** – ICAO shall continue to discharge the responsibility for the adoption and amendment of Standards And Recommended Practices (SARPs) and procedures governing the CNS/ATM systems. ICAO shall co-ordinate and monitor the implementation of such systems on a global basis in accordance with ICAO regional air navigation plans and the global co-ordinated plan. In addition, ICAO shall facilitate the provision of assistance to States regarding technical co-ordination aspects of implementation;
4. **Technical co-operation** – in the interest of global, harmonious implementation of CNS/ATM systems, ICAO will play a central rôle in co-ordinating technical co-operation arrangements. The ICAO Council directed the new ICAO Objectives Implementation Mechanism to pay special attention to assistance requirements of countries. Additionally, ICAO believes that its Technical Co-operation Programme should be complemented and strengthened at national and regional levels for the effective implementation of SARPs and ANPs;
5. **Institutional arrangements and implementation** – existing institutional arrangements and legal regulations will continue to be employed, with emphasis placed on global implementation in an evolutionary manner. In the implementation of CNS/ATM systems, advantage shall be taken of rationalisation, integration and harmonisation of systems;
6. **Global Navigation Satellite System** – GNSS should be implemented as an evolutionary progression from existing systems towards an integrated GNSS;
7. **Airspace organisation and utilisation** – airspace shall be organised to provide maximum service efficiency. However, ICAO states that, “while no changes to the current flight information region organisation are required for implementation of the CNS/ATM systems, States may achieve further efficiency and economy through consolidation of facilities and services”;
8. **Continuity and quality of service** – continuous availability of service from the CNS/ATM systems shall be assured. Quality of system service “shall comply with ICAO standards of system integrity and be accorded the required priority, security and protection from interference”;
9. **Cost recovery** – in order to achieve a reasonable cost allocation between all users, recovery of costs incurred in the provision of CNS/ATM services shall be in accordance with the Chicago Convention's rules: see Chapter 6.



## ***APPENDIX 5.2***

### **EXAMPLE OF REGIONAL CONCEPTS AND IMPLEMENTATION STRATEGIES**



## EXAMPLE OF REGIONAL CONCEPTS AND IMPLEMENTATION STRATEGIES

Source: Adapted from ICAO information.

Noting that Section 3.2.2 discusses operations in the North Atlantic (NAT) region, this appendix overviews the ICAO NAT region's plans for CNS/ATM, which were drafted in the mid-1990s, as an example of the regional planning process. As mentioned in Section 5.2.2, it should be noted that they were the first set of CNS/ATM regional plans and that the NATSPG is in charge of overseeing introduction of the future changes in the region. The NAT Implementation Strategy<sup>1449</sup> is to exploit CNS improvements and facilitate progressive reductions in separation minima, with increased flexibility in aircraft operations. It consists of three overlapping phases<sup>1450</sup>:

1. **1990 to 2000**: improve the overall efficiency and capacity of the ATS system;
2. **1995 to 2005**: to progressively implement satellite technology for the provision of CNS. This includes the implementation of Reduced Vertical Separation Minima (RVSM), Automatic Dependent Surveillance (ADS), Controller Pilot DataLink Communications (CPDLC) and the initial stages of Reduced Horizontal Separation Minima (RHSM). It should be noted that, as mentioned in the regional analysis of Appendix 4.6, RVSM was introduced successfully and ADS has recently gone live;
3. **2000 to 2015**: to fully implement the future concepts and withdraw current systems. The former are extensions of today's situation and those new developments planned for introduction prior to 2000.

Therefore, the overall implementation strategy is to reduce separation minima and increase levels of flexibility:

- Reductions in **separation minima** increase the number of slots available and consequently the chance of obtaining an available slot that is closer to an aircraft's optimal route profile. The four planned levels of separation minima are:
  - *Current*;
  - *Reduced Vertical (RVSM)* to 1000ft above FL290;
  - *Reduced Horizontal (RHSM)* to 30nm lateral and 5 minutes longitudinal;
  - *Further Reduced Horizontal (F-RHSM)* to 15nm both lateral and longitudinal.

The separation minima reductions and increased flexibility have been, are being, or will be implemented in the following chronological order:

1. *reduced vertical separation minima (1000ft from FL290 to FL410);*
2. *reduced intersecting track separation minima (from 15 to 10 minutes);*
3. *reduced longitudinal separation minima (from 10 to 7 minutes);*
4. *further reduced longitudinal separation minima (from 7 to 5 minutes);*
5. *reduced lateral separation minima (from 60 to 30nm);*
6. *further reduced lateral separation minima (from 30 to 15nm);*
7. *further reduced intersecting track separation minima.*

- **Increased flexibility** in the system will improve service by offering users more choice. The five planned levels of increased flexibility are:
  - *Current*: a fixed Organised Track Structure (OTS) with minimal scope for in-flight changes;
  - *On Track Flexibility*: a fixed OTS, but with a capability for aircraft to request and receive level, speed and track changes in the absence of conflicting traffic;

<sup>1449</sup> 'The North Atlantic Oceanic Concept and Requirements Document' – 1<sup>st</sup> Ed. Appendix C. NAT IMG/4.

<sup>1450</sup> 'The North Atlantic Implementation Document' – North Atlantic Systems Planning Group (NATSPG).



- *Improved OTS*: a significant reduction of the OTS;
- *Direct routes*: no promulgated OTS and all traffic flying random tracks;
- *Free Flight*: where each aircraft has the freedom to continuously optimise its flight profile, subject only to maintaining separation from other traffic.

The development sequence, structured to provide progressively more optimal routes and profiles for the predicted traffic levels, has the following stages of development:

### **1. Reduced Vertical Separation Minimum (RVSM)**

The concept of RVSM is well established and has reduced the vertical separation to 1,000ft from FL290 to a new level of FL410, making 6 additional flight levels available, with choice of optimum levels widened. The strategy's timeframe was over three overlapping steps, which provided progressive increases to the capacity, based on the following schedule:

1. *System verification trials*: from April 1996, the 2,000-ft VSM was maintained. The height-keeping performance of RVSM-approved operators was checked with ground and airborne equipment to ensure that NAT system safety goals were met, and to gather statistics;
2. *Operational trials*: the reduction of the vertical separation to 1000ft in a portion of the Minimum Navigation Performance Specification (MNPS) airspace from FL330 to FL370 for one year from March 1997 so that RVSM-specific air traffic control and operational procedures could be assessed;
3. *Full operational capability*: occurred in 1998.

The RVSM approval process for aircraft and operators involved satisfying many stipulated criteria, similar to obtaining ETOPS approval, including:

- Equipment Requirements** in the form of an enhanced Minimum Equipment List (MEL), which includes:
  - Two independent altitude measurement systems (meeting the RVSM requirements, which are that the worst-case residual altimeter static source error plus the worst-case avionics errors be no more than 160ft);
  - One Secondary Surveillance Radar (SSR) altitude reporting transponder;
  - One altitude alert system which must sound within 300ft;
  - One automatic altitude control system with capability to 65ft of the assigned altitude.
- Airworthiness Approval**, which involves:
  - Mean Altimetry System Error (ASE) < 80 ft for normal operation conditions;
  - Mean ASE plus 3 standard deviations < 200 ft for normal operation conditions;
  - Automatic altitude control system capable of controlling altitude within a tolerance band of  $\pm 65$  ft.
- State Approval of Aircraft and Operators and Flight Crew Procedures**, noting that a joint FAA/JAA effort was undertaken to develop international aircraft frame and operator approval guidelines<sup>1451</sup>. Each State adapted the guidelines into its regulating material. Airworthiness approval and flight crew operating procedures are outlined in the NAT Guidance Material and the FAA Interim Guidance. Operators without the appropriate State approval were, and continue to be, excluded from RVSM airspace.
- System Performance Verification and Monitoring**, which consisted of an overall assessment of the height-keeping performance of RVSM-approved operators. Compliance with airworthiness and operational approval requirements for altimetry and altitude-keeping

<sup>1451</sup> 'Interim Guidance on Aircraft and Operator Approval for RVSM Operations Above FL290/91-RVSM' – ICAO North Atlantic document 002.



systems was checked using a combination of fixed-base Mode C Height Monitoring Units (HMUs) and GPS-based Height Monitoring Units (GMUs). To be eligible for approval, operators had to overfly a HMU or arrange for the carriage of a GMU. The overall system consisted of 2 HMUs and 40 GMUs: the ground-based HMUs were accurate over a 10-mile radius. Each HMU-sensor consisted of four receivers that measure actual height to within 25ft. The HMUs were jointly financing by the NAT provider States; the airborne GMUs used two GPS antennae placed on aircraft windows and measurements recorded by laptop computer.

ICAO<sup>1452</sup> then required States to pass details of aircraft issued with RVSM airworthiness approval to the Central Monitoring Agency (CMA). All RVSM-approved aircraft are checked every two years. The CMA is responsible for determining whether an operator's fleet has demonstrated acceptable performance.

## **2. Reduced Horizontal Separation Minima (RHSM)**

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The authorities intend to reduce lateral separation to the previously specified levels of 30nm laterally and 5 minutes longitudinally. RHSM will lead to a slimmer OTS, leaving room for more random tracking. RHSM and On Track Flexibility (see hereunder) both need ADS for the increased frequency of accurate position reports, an advanced Flight Data Processing System (FDPS2 is being developed to enable Air Traffic Controllers to make use of the ADS position reports) and CPDLC, which are all fundamental to NAT concepts. ADS is presently going live and will provide the surveillance, whilst CPDLC will enable corrective action in the event of ADS showing an aircraft to be deviating off-track. This should reduce the number of Gross Navigation Errors (GNE) that exist in the region. It should be noted, however, that there are no plans to make ADS and CPDLC obligatory. With separation reduced to 30nm, corresponding to a ½° of latitude, the waypoints will have to assume a different incremental approach.

## **3. On Track Flexibility (OTF)**

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Although the present system allows for flight level, speed or track changes, requests are rarely permitted. OTF will be facilitated by the introduction of RVSM and RHSM. However, the key enabler will be reliable and timely communications between the Oceanic Area Control Centres and the flight crew via datalink using ADS and CPDLC.

## **4. Improved OTS**

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The objective of this development is to find ways of reducing the OTS design and METeorological (MET) forecast penalties within an RVSM and RHSM environment, short of dispensing with an OTS altogether<sup>1453</sup>. It is seen as an interim stage to a Direct Routes concept. According to ICAO, the three basic concepts are:

- to base the OTS on more accurate and/or timely MET forecasts;
- to reduce or minimise the extent and/or duration (hours of promulgation) of the OTS, with a view to allowing a greater proportion of aircraft to fly direct;
- to improve the alignment of the OTS with the major city (or region) pairs by allowing the OTS tracks to merge or cross where appropriate.

Hence, more frequent or time-specific weather forecasts are needed, as is an algorithm to generate the OTS itself.

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<sup>1452</sup> As related in a letter dated 2<sup>nd</sup> July 1996 from the ICAO European and North Atlantic Office representative to NAT provider and user States and international organisations regarding the phased implementation of RVSM's approval process' modifications.

<sup>1453</sup> 'The North Atlantic Oceanic Concept and Requirements Document' – NATSPG, NAT IMG/4 App C.



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## 5. Direct Routes and Free Flight

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These two concepts are discussed together because both involve similar issues, with Free Flight essentially being a development of Direct Routes. They will be enabled through the introduction of ADS, CPDLC, enhanced weather data, improved aircraft capability, advanced FDPS, and the further reductions in horizontal separation.

In the Direct Routes concept, no OTS would be needed and all traffic would fly random tracks. Free Flight would add flexibility to the nature of the aircraft's clearance, providing the aircraft with some manoeuvring space around its requested track and profile. This would allow its Flight Management System (FMS) to continuously optimise the flight, subject to maintaining separation from other traffic. This will support variable height such as cruise climbing and variable speed operations, thereby saving time, fuel and money.

The implementation of Direct Routes, expected by 2005, will increase the percentage of traffic flying random tracks from its present level of 40% to 100% of the traffic. However, will the congestion effects be so large as to question the need for Free Flight? The answer would be the establishment of different routes, which is what the OTS is. Indeed, similar to that discussed in **Chapter 3**, with Free Flight perceived as the ultimate NAT concept, a lot more development of FDPS and FMS technology is required to fully optimise the relationship between its cost and potential benefits. Datalinks will be crucial for both improving the speed and clarity of clearance messages and for automatic aircraft position reporting. Until decisions are made about which link to use, Free Flight cannot progress very far.



## ***APPENDIX 5.3***

### **SUMMARY OF CNS/ATM SYSTEMS**



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## SUMMARY OF CNS/ATM SYSTEMS

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This appendix summarises the CNS/ATM technologies and procedures that should be operational by 2010 and are consequently currently available for decision purposes, thus:

### Communications

*Ground-ground:* AFTN upgrades in the short-term only  
ATN

*Air-ground:* ACARS and FANS-1/A where possible in the short-term only  
VHF data and voice (in low-density en-route and terminal environments)  
Satellite data and voice (in oceanic and polar regions)  
HF data (in oceanic and polar regions)  
Mode S data (high-density en-route and terminal environments)  
ATN  
8.33kHz channel spacing

### Navigation

*Co-ordinates:* WGS-84 system

*GNSS:* GPS for (continental and oceanic) en-route and non-precision approaches  
GLONASS to a lesser extent

*Augmentation:* EGNOS, LAAS, WAAS for enhanced en-route and precision approaches in the long-term

*Land-based aids:* ILS/MLS for precision in the near-term only and GPS for non-precision

### Surveillance

*Surface:* A-SMGCS if complex layout and high traffic density

*Radar:* PSR in the near-term only  
SSR Mode A/C in the near-term only  
SSR Mode S (high-density en-route continental areas)

*ADS:* ADS via VHF, HF or satellite in the near-term (for oceanic/polar regions and low traffic density en-route continental areas)  
ADS-B in the long-term

### Air Traffic Management

*Airspace Management:* Optimised sectorisation  
DARPs  
FUA  
RNP  
RNAV route networks

*Air Traffic Services:* Reduced separation standards (RHSM, RVSM)  
Automation systems  
A-SMGCS

*Air Traffic Flow Mgmt:* Planning (strategic and tactical)  
Co-ordination (with neighbouring and/or regional countries)

**Note** – the *Glossary* contains explanations of the abbreviations.



## ***APPENDIX 5.4***

### **EXAMPLE OF NATIONAL CONCEPTS AND IMPLEMENTATION STRATEGIES**



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## EXAMPLE OF NATIONAL CONCEPTS AND IMPLEMENTATION STRATEGIES

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*Source: Adapted from ICAO information.*

This appendix discusses the planning process adopted by the Republic of Cape Verde as an example of national concepts and implementation strategies. The authorities are using the introduction of CNS/ATM technologies and procedures as a reason to renovate the ATS provision systems.

Initially, they conducted a survey of the present situation:

1. Analysed aeronautical infrastructure – all major islands are served by air transport and a new airport terminal is being constructed with updated navigation facilities;
2. Assessed airspace organisation – Cape Verde manages a large portion of the Atlantic Ocean airspace and has domestic terminal airspace;
3. Evaluated the communications infrastructure – en-route VHF stations have been implemented and the AFTN is intact;
4. Observed that the WGS-84 co-ordination system was implemented on time in 1998;
5. Characterised air traffic as arriving/departing national or international flights and overflights;
6. Conducted traffic forecasts until 2010;
7. Listed ATM by traffic operating along ATS routes, noting that a fully random flight trajectory ATM system is not presently possible. Separation minima are 100nm laterally and 10 minutes using Mach Number Technique (see **Section 3.2.2**). Airspace areas are starting to adopt RNP values. The authorities have established a task force to examine RVSM.

They correspondingly drafted their CNS/ATM requirements, which include a renovated operational display and control ATC system with Flight Data Processing System (FDPS) that integrates ADS to provide enhanced conflict prediction, alert and assisted resolution. In addition, a new, dedicated air navigation building needs to be constructed.

A draft transition plan was then developed, with the following CNS/ATM programme objectives:

**Phase 1 - Trials and demonstrations** to be carried out in close co-operation with IATA, with progress reports published frequently to ensure that all stakeholders are in the picture. Specifically, it includes:

- **Communications:** assess the availability and reliability of air-ground datalink via satcom, VHF and HF;
- **Navigation:** use of GNSS as primary and/or supplemental means of navigation during the en-route phase of flight to meet specific RNP values, in addition to use of GNSS as supplemental and/or stand alone means of navigation for terminal operations and for (near) Cat-1 landings;
- **Surveillance:** assess the operational impact of ADS and determine the operational requirements for display of ADS/non-ADS aircraft;
- **Air Traffic Management:** determine operational models and validate options for integration of ADS/non-ADS equipped aircraft, including operational scenarios and ATS tools required. Additionally, identify achievable horizontal minima in the new CNS/ATM environment.

**Phase 2 – The reporting phase** will be aimed at validating operational/ technical options and on agreeing an implementation methodology. Prior to submission of the CNS/ATM plan to APIRG, the ICAO Planning and Implementation Regional Group (PIRG) for the African region, the Cape Verde authorities will co-ordinate its conclusions with other ATS providers in the region.

**Phase 3 – Operational**, which will see gradual application of the decided options.



## ***APPENDIX 5.5***

### **STANDARD COST VALUES**



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**STANDARD COST VALUES**


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*Source: Eurocontrol CBA Group*

This appendix quotes a set of values that have been developed for a variety of costs, thus:

Type of cost and its stakeholder	Year	Value
<b>Delay costs</b>		
Ground delay per minute	1995	21
Airborne delay per minute	1995	36
Passenger delay per hour (airborne and ground)	1998	3,507
<b>Cancellations costs</b>		
Cost to airline per cancellation	1998	5,760
Cost to passenger per cancellation	1998	12,926
<b>Diversion costs</b>		
Cost to airline per diversion	1998	15,926
Cost to passenger per diversion	1998	15,248
<b>Replacement and restoration costs</b>		
Replacement for damaged air carrier	1995	8,520,527
Restoration for damaged air carrier	1995	1,107,668
Replacement for damaged General Aviation aircraft	1995	159,566
Restoration of damaged General Aviation aircraft	1995	24,012
Replacement for damaged military aircraft	1980*	1,400,000
Restoration of damaged military aircraft	1980*	470,000
<b>Aircraft variable operating costs</b>		
All General Aviation	1995	102
<b>Other costs</b>		
Value of time to air-traveller per hour	1995	34
Value of a statistical life	1980*	530,000
Value of a flight	1998	449 - 19,459

*Note - all currencies are Euro, except those marked \*, which are US Dollar.*



## ***APPENDIX 5.6***

### **FUEL COST VALUES**



## FUEL COST VALUES (US¢ PER GALLON)

Source: ICIS-LOR

This appendix quotes a set of values (in US¢ per gallon) for fuel costs at airports around the world during July 2000, thus:

Africa	Airport	Price	Airport	Price
	ABIDJAN (ABJ)	107-109	HARARE (HRE)	199-201
	ACCRA (ACC)	118-120	JO'BURG (JNB)	88-94
	B'VILLE (BZV)	63-65	KINSHASA (FIH)	165-167
	CAPE TOWN (CPT)	66-68	LAGOS (LOS)	124-126
	DAKAR (DKR)	92-94	L'VILLE (LBV)	82-84
	DURBAN (DUR)	66-68	NAIROBI (NBO)	109-111
Americas & Caribbean	Airport	Price	Airport	Price
	CALGARY (YYC)	90-92	TORONTO (YYZ)	97-99
	MONTREAL (YMX)	94-96	VANCOUVER (YVR)	104-106
	ANCHORAGE (ANC)	87-89	M'POLIS (MSP)	85-87
	ATLANTA (ATL)	82-84	N.ORLEANS (MSY)	82-84
	BOSTON (BOS)	86-88	NEW YORK	82-84
	CHICAGO (ORD)	82-84	ORLANDO (MCO)	85-87
	DALLAS (DFW)	81-83	P'DELPHIA (PHL)	82-84
	DENVER (DEN)	84-86	PHOENIX (PHX)	85-87
	DETROIT (DTW)	84-86	PITTSBURGH(PIT)	82-84
	HONOLULU (HNL)	89-91	S.DIEGO (SAN)	85-87
	HOUSTON (IAH)	80-82	S.FRISCO (SFO)	84-86
	LAS VEGAS (LAS)	85-87	SEATTLE (SEA)	85-87
	L.ANGELES (LAX)	83-85	TAMPA (TPA)	82-84
	MIAMI (MIA)	83-85	WASHINGTON(IAD)	83-85
	ARUBA (AUA)	110-112	MEXICO CTY(MEX)	84-91
	BOGOTA (BOG)	109-111	MONTEVIDEO(MVD)	101-102
	B.AIRES (EZE)	91-92	PANAMA (PTY)	104-105
	CARACAS (CCS)	105-107	PORT SPAIN(POS)	86-91
	CURACAO (CUR)	105-107	QUITO (UIO)	105-107
	GUATEMALA (GUA)	115-116	RD.JANEIRO(GIG)	117-118
	HAVANA (HAV)	114-116	SAN JUAN (SJU)	92-94
	KINGSTON (KIN)	85-90	SANTIAGO (SCL)	101-106
	LIMA (LIM)	109-111	S.DOMINGO (SDQ)	115-117



Asia & Pacific	Airport	Price	Airport	Price
	AUCKLAND (AKL)	77-78	KARACHI (KHI)	103-106
	BANGKOK (BKK)	73-74	K. LUMPUR (KUL)	74-77
	BEIJING (PEK)	106-110	MANILA (MNL)	78-81
	BOMBAY (BOM)	123-124	MELBOURNE (MEL)	75-76
	BRISBANE (BNE)	74-74	PERTH (PER)	78-78
	COLOMBO (CMB)	110-110	PHNOM PENH(PNH)	148-148
	DHAKA (DAC)	181-184	SEOUL (SEL)	78-79
	HANOI (HAN)	104-104	SINGAPORE (SIN)	72-76
	HO CHI MINH	104-104	SYDNEY (SYD)	72-73
	HONG KONG (HKG)	74-75	TAIPEI (TPE)	85-85
	JAKARTA (JKT)	86-100	TOKYO (NRT)	100-103
	OSAKA	92-93	FUKUOKA	102-102
	NAGOYA	92-93	ADELAIDE	79-79
	MADRAS	127-128	NEW DELHI	123-124
	GUANGZHOU	106-110	CAIRO	88-89
	SHANGHAI	106-110	SAPPORO	92-93
	DENPASAR	99-100	CAIRNS (CNS)	76-76
	DARWIN (DRW)	90-90		

Europe	Airport	Price	Airport	Price
	ALGIERS(ALG)	93-95	MALAGA (AGP)	113-115
	AMSTERDAM (SPL)	95-97	MALTA (MLA)	100-102
	ATHENS (ATH)	100-102	MANCHESTER(MAN)	97-99
	BARCELONA (BCN)	101-103	MILAN (MXP)	102-104
	BERLIN (TXL)	107-109	MOSCOW (SVO)	110-115
	BIRMINGHAM(BHX)	108-111	MUNICH (MUC)	106-108
	BRUSSELS (BRU)	96-97	NICE (NCE)	101-103
	BUCHAREST (OTP)	113-115	OSLO (OSL)	104-106
	BUDAPEST (BUD)	114-116	PALMA (PMI)	106-108
	CASABLANCA(CMN)	109-110	PARIS (CDG)	98-100
	COPENHAGEN(CPH)	103-105	PARIS (ORY)	98-100
	DUBLIN (DUB)	109-111	PRAGUE (PRG)	103-108
	DUSSELDORF(DUS)	99-101	RIGA (RIX)	110-116
	FRANKFURT (FRA)	95-97	ROME (FCO)	102-104
	GENEVA (GVA)	103-105	SHANNON (SNN)	106-108
	GLASGOW (GLA)	104-106	SOFIA (SOF)	110-120
	HAMBURG (HAM)	102-104	ST.P'BURG (LED)	110-122
	HELSINKI (HEL)	106-108	STOCKHOLM (ARN)	105-107
	ISTANBUL (IST)	102-104	TEL AVIV (TLV)	108-113
	LARNACA (LCA)	108-109	TUNIS (TUN)	104-105
	LISBON (LIS)	100-101	VIENNA (VIE)	105-107
	LONDON (LGW)	93-96	VILNIUS (VNO)	112-118
	LONDON (LHR)	92-94	WARSAW (WAW)	110-115
	LUXEMBOURG(LUX)	99-101	ZURICH (ZRH)	106-108
	MADRID (MAD)	102-104		



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Middle East	Airport	Price	Airport	Price
	ABU DHABI (AUH)	91-93	DUBAI (DXB)	98-102
	AMMAN (AMM)	80-80	JEDDAH (JED)	81-104
	BAHRAIN (BAH)	91-92	KUWAIT (KWI)	90-94
	BEIRUT (BEY)	111-111	MUSCAT (MCT)	97-100
	DAMASCUS (DAM)	90-90	RIYADH (RHU)	91-93
	DOHA (DOH)	96-98	TEHRAN (THR)	96-99

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## ***APPENDIX 5.7***

### **CASE STUDY ANALYSIS OF COMMERCIALISED ANS PROVIDERS**



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## CASE STUDY ANALYSIS OF COMMERCIALISED ANS PROVIDERS

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*Sources: Numerous publications – as referenced hereunder.*

With reference to the discussion in **Section 5.4.1**, this appendix describes and further evaluates the commercialisation of ANS providers around the world, split into the following sections:

- Existing corporatised companies;
- Privatisation of the Canadian air navigation services;
- Public-Private Partnership (PPP) of the UK's National Air Traffic Services (NATS);
- Countries currently considering commercialisation.

### Existing corporatised companies

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**Section 5.4.1** refers to a recent ICAO study, which determined that 37 of 81 sampled nations have adopted an autonomous or corporatised public sector agency organisational structure. In addition, this research observes that Austria, Latvia, Moldova, the Slovak Republic and Ukraine have corporatised their providers, but they were not included in the ICAO study. The amalgamated findings, which are thought to be representative of the present situation, are listed and elaborated upon in some cases, thus:

- **Algeria;**
- **Australia:** Airservices Australia was one of the first providers to corporatise, in 1988. Its revenue is based mostly on user fees;
- **Austria:** Austro Control adopted autonomous status in 1994. 60% of its funding is from user charges. It is a founding member of CANSO;
- **Belgium:** Belgocontrol is a CANSO member;
- **Bolivia;**
- **Brazil;**
- **Brunei;**
- **Bulgaria;**
- **Czech Republic:** ANS CR is one of the original CANSO members;
- **Estonia:** Estonian Air Navigation Services is a member of CANSO;
- **Finland;**
- **Germany:** The German ATS provider, DFS, was corporatised in 1993. DFS, whose funding comes entirely from user fees, took the unprecedented step of reimbursing its airline customers in 2000 after posting a revenue surplus in 1999<sup>1454</sup>. In previous years, any over-recoveries have been offset against subsequent cuts in user charges. Privatisation is on DFS's agenda<sup>1455</sup>. DFS is a founding member of CANSO;
- **Greece;**
- **Grenada;**
- **Ireland:** The Irish Aviation Authority (IAA) was corporatised in 1994. It relies on user fees for 100% of its funding. The IAA is a founding member of CANSO;
- **Latvia:** LGS is one of the original CANSO members;
- **Maldives;**
- **Malta;**
- **Moldova:** MoldATSA is a CANSO member;
- **Morocco;**
- **Netherlands:** LVNL is a founding member of CANSO;

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<sup>1454</sup> 'DFS give profits back to airlines' – *Flight International*, 18 July 2000.

<sup>1455</sup> 'Flying Deutsche man' – *air traffic management*, July-August 1999.

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- **New Zealand:** Airways Corporation was established as a corporatised provider in 1987. It relies totally on user charges for funding. Airways Corporation initially reduced costs by stripping out layers of staff, but paying the remaining staff 2.5 times the national average, which may be compared with Germany's 1.4<sup>1456</sup>. When previously a government entity, the NZ Civil Aviation Division (CAD), it had evaluated the modernisation requirements of the ATC infrastructure over many years, but could not manage implementation of new systems. Within 6 months of being established, Airways Corporation had selected equipment, negotiated with suppliers, arranged finance and signed contracts<sup>1457</sup>. Correspondingly, Airways managed to turn the loss-making ANS provider into one that paid both company tax and a dividend to the government, based on reduced revenue from its main customer, Air New Zealand. Airways has linked with the ATM division of Lockheed Martin in a 10-year partnership that includes a bid for the UK NATS part-privatisation<sup>1458</sup>, although this bid was subsequently demoted to a reserve offer<sup>1459</sup>. International ventures indicate Airways' strategy for involvement in projects around the world. Airways Corporation is a founding member of CANSO;
- **Norway:** The NCAA is an associate member of CANSO;
- **Pakistan;**
- **Portugal:** NAV-EP was corporatised in 1992 and its funding is 100%-based on user fees. It is a founding member of CANSO;
- **Romania:** ROMATSA is one of the original CANSO members;
- **St. Vincent & Grenadines;**
- **Sao Tome & Principe;**
- **Singapore;**
- **Slovak Republic:** Its provider, ATS, is a member of CANSO;
- **South Africa:** ATNS was corporatised in 1993 using 100% user fee funding. ATNS is a founding member of CANSO;
- **Spain:** AENA is one of the original CANSO members;
- **Sri Lanka;**
- **Sweden:** LFV is an associate member of CANSO;
- **Switzerland:** The corporatised Swisscontrol is unique because shares are held by the government, main airports and airlines, in addition to various aviation employee and user groups<sup>1460</sup>. Swisscontrol is a founding member of CANSO;
- **Tanzania;**
- **Thailand:** AEROTHAI is a founding member of CANSO;
- **Tunisia;**
- **Uganda;**
- **Ukraine:** The country's ANS provider, UksATSE, is a founding member of CANSO;
- **United Kingdom:** The National Air Traffic Services (NATS) was corporatised in 1996, whereby its funding is 100%-based on user fees. NATS is presently undergoing a part-privatisation process, which is the subject of greater analysis hereunder. It is a founding member of CANSO;
- **Zimbabwe.**

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### Privatisation of the Canadian air navigation services

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The only example of direct migration from a government department to a fully privatised organisation is the transfer of the Canadian government's Department of Transport Air Navigation Service to the private sector as Nav Canada in 1996. Indeed, Nav Canada is the only example of a fully privatised national provider at present. It should be noted that the Canadian air transport safety regulator, Transport Canada, is a separate institution.

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<sup>1456</sup> 'Controlling the controllers' – *Aerospace International*, September 1998.

<sup>1457</sup> 'The benefits of commercialising ATC organisations' – Dr CJ Smith, *Coopers & Lybrand Europe Air Traffic Control '91 Conference*, Maastricht.

<sup>1458</sup> 'Buying into a privatised FAA' – *air traffic management*, July/August 2000.

<sup>1459</sup> 'UK Government shuns Lockheed bid for NATS' – *Air Transport Intelligence*, 22 February 2001

<sup>1460</sup> 'Re-engineering the provision of air navigation services' – *Integrating Global Air Traffic Management*. ICAO. 1998.



Nav Canada was formed as a trust to run the country's air navigation service as a private organisation because the previous government-run provider was unable to facilitate suitable funding and technologically intensive investments. Hence, the basic objective of Nav Canada's creation was to bring about management efficiency and meet investment demands, with the ability to raise required capital without any government support. Nav Canada is a non-share<sup>1461</sup> corporation, governed by four founding members and a board of directors. The four members are the government, the airlines, General Aviation and the unions. Any profits are invested in the business or recycled. The members each appoint a total of ten directors, who nominate four independent members, and the group as a whole designates a Chief Executive Officer.

The company obtains its financing from the public debt markets: Nav Canada initially arranged a credit line of \$1,850 million to purchase the air navigation service, with a purchase price of \$1,003 million. It is currently funded entirely through user fees. Nav Canada keeps a tight control on its costs: when it privatised, the company made 1,000 administrative support staff and 100 management employees redundant. Operational staff numbers remained the same. As a non-profitable organisation, Nav Canada must use any surplus due to favourable financial conditions to re-invest in the company, to minimise its debt or to return a portion of the charges to clients through fee reductions. Indeed, Nav Canada uses the greater availability of funds to invest in CNS/ATM systems: Chapter 4 and its associated appendices refer to Canada's spending and the new Canadian Automated Air Traffic System (CAATS). Thus, Nav Canada has greater ability to invest in new technology since it privatised: the firm invested ca.\$200 million in new systems in its first two years<sup>1462</sup>. However, it should be noted that Nav Canada has experienced operational mishaps that have prompted the regulator, Transport Canada, to demand installation of an automated conflict and alerting system for controllers<sup>1463</sup>. Other labour relation problems have been experienced with controllers<sup>1464</sup>, who have threatened potential strike action<sup>1465</sup>.

Now that it has been operating for five years, Nav Canada is in a position to realign user charges and adjust service levels to meet traffic patterns. The airlines are instigating this process because they maintain that fees have risen since privatisation: from September 1999, charges were lowered by 11% until end 2000 due to a surplus in the previous year<sup>1466</sup>. In early 2001, Nav Canada said that they'd extend the charge reductions until the end of 2001<sup>1467</sup>.

### Public-Private Partnership (PPP) of the UK's NATS

As mentioned in the evaluation of CNS/ATM that is conducted in Part 1 of this research, the UK is presently part-privatising its already-corporatised national ANS provider, National Air Traffic Services (NATS). Even though the process commenced in 1999<sup>1468</sup>, it has experienced potential setbacks<sup>1469</sup> and, indeed, the UK Parliament only granted approval for the Public-Private Partnership (PPP) in December 2000<sup>1470</sup>. The decision to privatise was the government's<sup>1471</sup>. The PPP process involves transferring ownership of NATS from the country's Civil Aviation Authority (CAA) to the UK Department of the Environment, Transport and the Regions (DETR).

<sup>1461</sup> Thus, there are no equity funding or shareholders. It is frequently referred to as a non-profit company, although a pedantic assessment of its status would reveal that it is allowed to make a surplus that is put back into the company as an investment.

<sup>1462</sup> 'Canadian airspace use levels to soar: Nav Canada' – *Air Transport Intelligence*, 16 April 1999

<sup>1463</sup> 'Canada's loss of separation crisis angers TSB' – *Air Transport Intelligence*, 6 October 2000.

<sup>1464</sup> 'Nav Canada provides \$107 million in customer savings and announces investment plans for 1999-2000' – *ATC Network*, 19 August 1999.

<sup>1465</sup> 'Northern exposure' – *Air Traffic Management*, May/June 1998.

<sup>1466</sup> 'A towering success' – *Air Transport World*, October 2000.

<sup>1467</sup> 'Nav Canada extends service charge reductions' – *Air Transport Intelligence*, 22 January 2001.

<sup>1468</sup> 'UK plans partial ATC sell-off' – *Flight International*, 24 November 1999.

<sup>1469</sup> 'Strategic withdrawal' – *air traffic management*, March-April 2000.

<sup>1470</sup> 'NATS gets go-ahead as AMS and Boeing mull fresh bids' – *Flight International*, 5 December 2000.

<sup>1471</sup> 'Pennies from heaven' – *Air Traffic Management*, November/December 1998.



The government will then sell 46% of its interest in NATS to its chosen strategic partner, the Airline Group, and a further 5% to NATS's employees. Hence, the government will retain a 49% 'golden' share in NATS<sup>1472</sup>.

NATS will become a holding company and will be restructured into a group of companies prior to the PPP. The licence for operating NATS facilities and services will contain the terms under which NATS is authorised to provide ATS<sup>1473</sup>, the services required to be provided by the licence holder and the economic conditions governing service provision. The Stakeholder Council's terms of reference will regulate the relationship between the private sector investor, namely the Airline Group, and the UK government upon implementation of the PPP. The Strategic Partnership Agreement (SPA) and the Articles of Association will cover issues such as corporate governance, partnership directors, management appointments, conduct of business, reserved matters, deadlock resolution, stakeholder Council, business plans, dividend policy and provision of financing for the NATS group. The transfer of infrastructure will include area, oceanic and terminal control centres; CNS, Flight Data Processing (FDP) and IT systems; simulation and research facilities; training facilities; and other assets. The separation from the CAA means that certain assets and systems will have to be segregated. The Airline Group will be obliged to complete some current commitments of NATS' corporate plan<sup>1474</sup>, which consists of its strategic, operating and long-term investment plans.

The current situation is that the Airline Group has been chosen as the government's preferred bidder in the process out of eight original applicants, which were recently short-listed to three, noting that many stakeholders were represented among the bidders<sup>1475</sup>. The three short-listed investing consortia were Nimbus (which included services company SERCo, ARINC, aerospace firm, EADS, and financier PPM Ventures), Novares (a co-operation between Lockheed Martin, New Zealand's Airways Corporation and Apex Partners) and the Airline Group (consisting of Airtours, Britannia Airways, British Airways, British Midland, easyJet, JMC, Monarch Airlines and Virgin Atlantic Airways with the Irish Aviation Authority). The Novares consortium was demoted to the status of a reserve offer in February 2001<sup>1476</sup>. A contract between the Airline Group and the UK government was signed towards the end of March 2001. It should be noted that the New Zealand government was forced by its opposition political party to assess Airways Corporation's bid for NATS over allegations of corrupt management<sup>1477</sup>. The provider was subsequently cleared of any wrongdoing<sup>1478</sup>, but this indicates how fierce the competition for an ANS provider can get. In addition, it should be added that many potential investors, including BAE Systems and Boeing<sup>1479</sup>, were, at some point, interested in acquiring a stake in NATS.

Assuming no further developments occur, the Airline Group will be responsible for managing NATS and raising capital investment necessary for system renewal and expansion. NATS says that it requires \$1.6 billion of investment this decade<sup>1480</sup>; this is one of the reasons for the part privatising the service<sup>1481</sup>. Other external reasons include defragmented European airspace and the EU Commission's Single Sky<sup>1482</sup>. As an autonomous agency, NATS has achieved the improved efficiencies and reduced cost base associated with corporatised entities. Under this guise, NATS has used the Private Finance Initiative (PFI) for some investment requirements. For instance, its New En-Route Centre (NERC) has been built, owned and managed by the

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<sup>1472</sup> 'UK first' – *Air Traffic Technology International* 2000.

<sup>1473</sup> Apart from air traffic control, ATS covers the supply of metrological information, emergency-related services and aeronautical information services. In addition, NATS will be obliged to advise the CAA and the UK government.

<sup>1474</sup> Such as the New En-Route Centre (NERC) and the New Scottish Centre (NSC).

<sup>1475</sup> The government wants as many stakeholders represented as possible.

<sup>1476</sup> 'UK Government shuns Lockheed bid for NATS' – *Air Transport Intelligence*, 22 February 2001.

<sup>1477</sup> 'NZ launches national audit into Airways' NATS bid' – *Air Transport Intelligence*, 30 May 2000.

<sup>1478</sup> 'NZ Govt clears Airways in controversy over NATS bid' – *Air Transport Intelligence*, 3 July 2000.

<sup>1479</sup> 'Boeing and BAE Systems eye NATS bid: Condit' – *Air Transport Intelligence*, 9 June 2000.

<sup>1480</sup> 'Airline Group to submit formal bid for NATS stake' – *Air Transport Intelligence*, 13 July 2000.

<sup>1481</sup> 'UK announces formal plans to privatise ATC' – *Air Transport Intelligence*, 27 July 1999.

<sup>1482</sup> 'A different service' – *Air Traffic Technology International* 2001.



private sector, but operated by NATS<sup>1483</sup>. However, PFI ventures are not a long-term, viable proposition due to diverse ownership and management situation, potentially leading to a defragmented organisation. Indeed, the NSC was supposed to be a Private Finance Initiative (PFI) project, but announcement of the part privatisation process led to NATS abandoning its PFI plans<sup>1484</sup>. In addition, it should be noted that the process is expected to raise \$800 million for the UK Exchequer. In contrast with the aforementioned Canadian multi-stakeholder privatisation process, the NATS PPP is the first opportunity for investors to acquire a stake in a major national ANS provider and control it. Correspondingly, noting that commercialisation of Pan-European operators should lead to greater harmonisation and reduced delays, the successful consortium in the NATS bid, the Airline Group, may have an added advantage with future (part) privatisation processes in other nations. New Zealand's Airways Corporation openly admits that this is the thinking behind its joint bid for NATS. Indeed, the UK government wishes NATS to outsource its knowledge to other markets<sup>1485</sup>. However, the UK Parliamentary Advisory Committee on Transport Safety (PACTS) has warned that the NATS PPP is an irrelevant solution to Europe's problems<sup>1486</sup>. In addition, PACTS has said that the PPP agreement should include clauses limiting NATS's investment in new ventures, to reduce the risk that a NERC-style fiasco should render the company bankrupt<sup>1487</sup>.

Once the PPP process is complete, the CAA will become the UK's aviation regulator: safety regulation will remain with the Safety Regulation Group (SRG); the Economic Regulation Group (ERG) will assume economic regulation of ATS<sup>1488</sup> and airports (see Section 5.5). The Secretary of State for the Environment, Transport and the Regions will continue to appoint the CAA's members. Thus, the PPP will separate NATS's operational and safety activities, although the CAA's SRG has always treated NATS as a separate entity. Indeed, the PPP will reinforce the distinction that they are separate, which should lead to greater public confidence. However, concerns about safety have been associated with the part privatisation process: thus, NATS has set up an independent advisory board, the Safety Review Committee, which is separate from the CAA's SRG, to review safety of management and operations within the organisation, in addition to making recommendations to NATS<sup>1489</sup>. Correspondingly, air traffic controllers have safety-related worries due to NATS's management being potentially more concerned with profits<sup>1490</sup> and with the prospect of performance-related bonuses for senior controllers. However, the Airline Group will operate NATS on a not-for-profit basis. The controllers are also concerned about the training of controllers during 2001 for NERC, with resultant extra delays and reduced standards. Indeed, the controllers are threatening industrial action. However, NATS expects that it will need to recruit 50% more controllers to meet increased demand in the years to come<sup>1491</sup>. The British Air Line Pilots Association (BALPA) is concerned that, in scouting for lucrative business abroad, NATS will lose focus on its core ATC responsibility in the UK<sup>1492</sup>. In addition, NATS employees have fears of cross-board cost cutting, including reductions in staff numbers<sup>1493</sup>, although the NATS chairman does not expect as many job cuts as experienced with the privatisation of other utilities<sup>1494</sup>. There is also unease about the new owner's commitment regarding non-remunerative activities with bodies such as Eurocontrol and ICAO<sup>1495</sup>, although such services may be included in the aforementioned obligations or, certainly, form part of the economic regulation process.

<sup>1483</sup> 'Autonomous air traffic services provision: a UK perspective' – *Integrating Global Air Traffic Management*, 1998.

<sup>1484</sup> 'NATS privatisation hits Scottish ATCC' – *Flight International*, 4 August 1999.

<sup>1485</sup> 'UK government rejects MPs' criticism of NATS privatisation proposals' – *Air Navigation International*, 10 July 2000

<sup>1486</sup> 'PACTS warns NATS PPP is an 'irrelevant solution'' – *ATC Market Report*, 20 July 2000.

<sup>1487</sup> 'UK cautions on ATC privatisation' – *Flight International*, 27 January 1999.

<sup>1488</sup> Section 5.5 analyses NATS' intention to adopt an RPI-X charging structure, which is a method of economic regulation to ensure that monopolies provide adequate services.

<sup>1489</sup> 'NATS sets up safety advisory group ahead of privatisation' – *Air Transport Intelligence*, 9 June 2000.

<sup>1490</sup> 'NATS public private partnership – the debate goes on' – *air traffic management*, May/June 2000

<sup>1491</sup> 'Busy year for NATS' – *Aerospace International*, March 2001.

<sup>1492</sup> 'Strategic withdrawal' – *air traffic management*, March-April 2000.

<sup>1493</sup> 'Controlling interest' – *Flight International*, 24 June 1998.

<sup>1494</sup> 'Free Flight' – *Flight International*, 14 July 1999.

<sup>1495</sup> 'UK first' – *Air Traffic Technology International* 2000.



### Countries currently considering commercialisation

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In addition to the aforementioned UK PPP, this section discusses the commercialisation plans of other nations, thus:

- Italy has set the end of 2001 as a target date for corporatising its provider, ENAV<sup>1496</sup>;
- The Netherlands' government is preparing legislation to privatise its provider, LVNL<sup>1497</sup>;
- In the US, commercialisation of the FAA was echoed in an executive order from the White House at the end of 2000, which directed the FAA to create a performance-based organisation to manage the operation of ANS<sup>1498</sup>. The Reason Public Policy Institute (RPPI) think tank has now produced a blueprint for the US Senate<sup>1499</sup>, which says that a stakeholder-controlled, not-for-profit corporation should take control of ANS provision from the FAA<sup>1500</sup>. It also suggests that current federal aviation user taxes' funding mechanism should be changed: the function of airport grants should be funded by a greatly reduced tax on airline tickets and cargo waybills; and ATC services should become the responsibility of the non-profit corporation, so that the services are self-funding through user fees.

In addition, it recommends that the FAA retain responsibility for economic and safety regulation: overall, the "new" FAA would be 47% funded by general revenues for safety-related services so that the government could still maintain primary oversight of safety.

As discussed in Part 1 of this research, the FAA has been unable to deliver many of its modernisation promises. Indeed, it is said that the FAA does not really know where its budget is spent. A commercial operation should enable greater modernisation through funding by long-term revenue bonds using a procurement process that is not as cumbersome as the present bureaucratic methods. As an interim measure, the FAA is becoming involved in cost sharing with other stakeholders for ATC projects<sup>1501</sup>. Furthermore, the FAA is now using cost-based accounting<sup>1502</sup>, which should aid the transition to a commercialised company.

Not surprisingly, airlines favour a government-funded entity that uses private sector management techniques, which are independent from the FAA<sup>1503</sup>. Unlike airlines, controllers do not want a commercialised organisation because they are concerned about job losses<sup>1504</sup>. In particular, the National Air Traffic Controllers Association (NATCA) does not believe that an institutional structure similar to Nav Canada's is applicable<sup>1505</sup>. Their position is that the problem lies with the lack of available runway space and not the ATC system itself<sup>1506</sup>.

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<sup>1496</sup> 'Italian Government sets date for ATC spin-off' – *Flight International*, 16 January 2001.

<sup>1497</sup> 'Dutch ATC wary over airline insolvency risk' – *Air Transport Intelligence*, 30 May 2000.

<sup>1498</sup> 'FAA to reform ATC unit' – *Air Transport World*, January 2001.

<sup>1499</sup> 'Another proposal to privatize ATC' – <http://avweb.com>, 26 February 2001.

<sup>1500</sup> 'User-funded airways corporation recommended for US ATC' – *Air Navigational International*, 2 October 2000.

<sup>1501</sup> 'FAA proposes cost-sharing guidelines for US ATC projects' – *Air Transport Intelligence*, 14 August 2000.

<sup>1502</sup> 'Buying into a privatised FAA' – *air traffic management*, July/August 2000.

<sup>1503</sup> 'Move ATC to government-sponsored corporation: Mullin' – *Air Transport Intelligence*, 16 November 2000.

<sup>1504</sup> 'A private concern' – *Airline Business*, January 2000.

<sup>1505</sup> 'NATCA slams report saying US ATC should follow Nav Canada' – *Air Transport Intelligence*, 22 February 2001.

<sup>1506</sup> '...while NATCA, industry respond to the proposal' – <http://avweb.com>, 26 February 2001



***APPENDIX 5.8***

**SAMPLE INTERNATIONAL  
CO-OPERATION AGREEMENT**



## **SAMPLE INTERNATIONAL CO-OPERATION AGREEMENT**

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*Source: Roberts FIR's Aeronautical Accord, 1978.*

This appendix lists the various articles that constitute the agreement between Guinea, Liberia and Sierra Leone relating to the establishment of its inter-state committee on the safety of air traffic and air navigation services, the Roberts FIR:

<b>Article I</b>	Name and location;
<b>Article II</b>	Organisation;
<b>Article III</b>	Rotation and tenure;
<b>Article IV</b>	Function of the Roberts FIR;
<b>Article V</b>	Functions of the Council of Ministers;
<b>Article VI</b>	Functions of the Technical Committee;
<b>Article VII</b>	Functions of the Secretariat;
<b>Article VIII</b>	Responsibilities of the member states;
<b>Article IX</b>	Sessions of the Council of Ministers;
<b>Article X</b>	Chairmanship and tenure of Office of the Council of Ministers;
<b>Article XI</b>	Sessions of the Technical Committee;
<b>Article XII</b>	Chairmanship and tenure of Office of the Technical Committee;
<b>Article XIII</b>	Financial structure;
<b>Article XIV</b>	Juridical status of the Roberts FIR;
<b>Article XV</b>	Property, funds and assets of the Robert FIR;
<b>Article XVI</b>	Financial facilities;
<b>Article XVII</b>	Tax exemptions;
<b>Article XVIII</b>	Facilities in respect of communications;
<b>Article XIX</b>	Diplomatic privileges and immunities for staff of the Roberts FIR;
<b>Article XX</b>	Settlement of dispute;
<b>Article XXI</b>	Relationship with other organisations;
<b>Article XXII</b>	En-route facilities;
<b>Article XXIII</b>	Search and rescue operations;
<b>Article XXIV</b>	Insurance of the Roberts FIR;
<b>Article XXV</b>	Aircraft accident inquiry procedures;
<b>Article XXVI</b>	Aircraft incidents and breaches of air traffic regulations;
<b>Article XXVII</b>	Users of Roberts FIR facilities route charges;
<b>Article XXVIII</b>	Accession;
<b>Article XXIX</b>	Amendments;
<b>Article XXX</b>	Termination of the 1975 agreement;
<b>Article XXXI</b>	Annexes;
<b>Article XXXII</b>	Registration;
<b>Article XXXIII</b>	Ratification.



## ***APPENDIX 5.9***

# **THE ICAO SARPs PROCESS**



## THE ICAO SARPs PROCESS

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**Sources: Numerous publications – as referenced hereunder.**

This appendix evaluates the ICAO SARPs process and states its relevance to this dissertation's framework strategy:

ICAO was formed in 1944, when it accepted the established US communications and navigation systems as the worldwide standard for air traffic control. One of ICAO's original goals was to standardise the world's aviation systems through the development and dissemination of suggested procedures for aviation regulatory agencies. Correspondingly, as mentioned throughout this research, ICAO develops Standards And Recommended Practices (SARPs) for CNS/ATM systems, which are classified as Annexes to the ICAO Chicago Convention: **Appendix 3.1** contains a list of the ICAO Annexes. It should be noted that the format and structure of Annexes and their amendment process were streamlined in 1997<sup>1507</sup>.

It should also be restated that additional SARPs have and continue to be created for the new generation of CNS/ATM systems. Annexes 2 and 11 to the Convention detail the rules of the air and Air Traffic Services<sup>1508</sup> (ATS) respectively, which are also covered in a 'Procedures for Air Navigation Services' (PANS) document. Even though all countries produce their own legislation based on Annex 2's rules, the adoption of SARPs by all ICAO Contracting countries, which is a prerequisite for joining ICAO, means that similar navigation aids (as described in **Chapter 2**) and the same procedures (as discussed in **Chapter 3**) are employed around the world. ICAO's Air Navigation Commission (ANC) has the responsibility for examining, co-ordinating and planning the international navigation standards and procedures. Therefore, it plays a pivotal rôle in ICAO's decision-making process. Its panels<sup>1509</sup>, whose members include representatives from industry, carry out a lot of the technical work. It should be noted that SARPs are continually reviewed and updated. Air Navigation Plans (ANPs) establish the necessary requirements for CNS/ATM facilities and services, which contracting states agree to implement.

This thesis consistently refers to the point that fragmentation of airspace and a diversity of national systems prevent optimum use of airspace. Correspondingly, it is possible to conclude that technologies and procedures are not totally harmonious. Thus, global adoption and implementation of SARPs would enable aircraft to fly around the world using similar CNS/ATM systems. It is for this reason that this framework suggests that the SARPs mechanism is sufficient as the basis for standardising the new generation of CNS/ATM technologies and procedures. However, it can be too general and somewhat lengthy in terms of time required<sup>1510</sup> to standardise systems. Accordingly, the SARPs process has not always chosen the most suitable equipment in the past: **Part 1** of this research demonstrates the benefits that are presently being obtained from FANS-1/A equipment, which is not SARPs compliant. But, ICAO may have recognised this fact: **Part 1** also portrays its current efforts to develop SARPs for both VHF DataLink (VDL) Modes 3 and 4. On a similar note, other components of the framework in this research have suggested that alternative technologies or procedures could be standardised under the auspices of a particular enabling system type: for instance, the aforementioned VDL could cover Modes 3 and 4. Indeed, this would facilitate a faster introduction of the ATN.

Therefore, this framework strategy recommends that all stakeholders aid the SARPs process wherever possible. For instance, this could occur through co-operation with Research & Development<sup>1511</sup> (R&D) or participation in technical standardisation trials. In addition, as

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<sup>1507</sup> 'Report on trial of a new abbreviated SARPs amendment process' – Proceedings from ICAO Assembly's 32<sup>nd</sup> Session, 1998.

<sup>1508</sup> Annex 11 pertains to the establishment of airspace and services necessary to promote safe, orderly and expeditious flow of air traffic.

<sup>1509</sup> Examples of the ANC's panels are the ADS Panel (ADSP), Aeronautical Mobile Communications Panel (AMCP), ATM operational Concept Panel (ATMCP), ATN Panel (ATNP), All Weather Operations Panel (GNSSP), Obstacle Clearance Panel (OCP), Review of the General Concept of Separation Panel (RGCSP), in addition to the SSR Improvements and Collision Avoidance Systems Panel (SICASP).

<sup>1510</sup> It takes 4 years for ICAO to develop SARPs.

<sup>1511</sup> R&D is very important because continued and increased efficiency of CNS/ATM systems depends on the development of new tools and procedures.



discussed in **Chapter 3**, designers of future ATM should adhere to internationally developed criteria. Given that, in many cases, the industry is still at a unique time for setting the architecture of future systems, all stakeholders should ensure that their solution has been appraised by the ICAO process as a potential enabling technology or procedure and that the answer remains a definitive one, so that the integration of CNS/ATM for that particular case can move further towards implementation. Another example of aiding the SARPs mechanism is that countries should ensure that their infrastructure details are current and improved where possible, noting that ICAO requires each of its contracting nations to produce Aeronautical Information Publications (AIP), which describe their CNS/ATM systems and any differences from the ICAO standard.

In turn, given that ICAO's only mandatory tool is the SARPs process, it should ensure that all SARPs are completed as soon as possible: **Chapter 4** indicates that the SARPs for the majority of presently-required CNS technologies will be developed by 2002<sup>1512</sup>. However, noting that there is still a lack in uniformity of ATM procedures due to differences and limitations in ATM capabilities around the world, SARPs for ATM are far from finished. An integrated, global ATM system will only be possible after SARPs have been developed, adhered to and comprehensively implemented by countries. Therefore, attaining the goal of an integrated, global ATM system also requires the aforementioned technical standardisation of CNS equipment. Accordingly, it is essential to ensure that adjacent systems and procedures are able to interface in such a way that boundaries are transparent to airspace users. Although this ideal system may always remain elusive, ICAO must develop SARPs for ATM. Its basis for ATM SARPs is an operational concept, which is intended to assist and guide airspace planners with ATM design in order to provide efficient and safe operations for all phases of flight, irrespective of where the aircraft is in geographic terms.

The concept gives countries and industry objectives for designing and implementing ATM with detail on how the new technologies should lead to a more effective ATM system. It is for this reason that the EU and the US have worked on their respective operational concepts. As discussed in **Chapter 3**, the concept aims to obtain consensus on the following objective issues: autonomy of flight, separation assurance, situational awareness, collision avoidance, optimisation of traffic flows and Required Total System Performance (RTSP). These concepts must be defined, in particular if responsibilities are to be transferred to the cockpit. When the issues are agreed, they will become part of the ATM operational concept, which will lead to SARPs. However, similar to the ATM SARPs, the concept has yet to be clearly defined and is nowhere near completion: ICAO Planning and Implementation Regional Groups (PIRG) are still assessing regional details and situations. When finished, the concept should give all stakeholders, including the PIRGs, a clearer objective for designing and implementing ATM systems than is presently available. The RTSP concept, in conjunction with its associated RCP, RNP and RSP concepts<sup>1513</sup>, will comprise the essential attributes of the CNS/ATM systems and should characterise operations in a given airspace, thereby providing the means to quantify and assure performance. Systems must have integrity so that they meet all accuracy, availability, continuity and reliability requirements. Because of its belief that benefits of new CNS/ATM systems will not be realised unless common international specifications are reached<sup>1514</sup> through the development of ATM SARPs, ICAO set up the Air Traffic Management operational Concept Panel (ATMCP) in 1998 to develop the necessary ATM SARPs<sup>1515</sup>. Accordingly, the Review of the General Concept of Separation Panel (RGCSP) completed its work on airspace planning methodology to support CNS/ATM infrastructure planning in 1996<sup>1516</sup>. Nonetheless, other inputs are required prior to the ATM operational concept being completed.

<sup>1512</sup> ICAO has developed SARPs for (HF & VHF) datalink, Inmarsat satellite communications, the ATN, GNSS, SSR Mode S, ADS and ADS-B.

<sup>1513</sup> The Required Communications Performance (RCP), Required Navigation Performance (RNP) and Required Surveillance Performance (RSP) concepts are described in Chapter 2.

<sup>1514</sup> 'ATM commonality crucial' – *Orient Aviation*, November 1999.

<sup>1515</sup> 'Airborne separation to feature on new ICAO panel agenda' – *air traffic management*, May-June 1999.

<sup>1516</sup> 'Overview of technical and operational activities related to CNS/ATM systems' – *Proceedings from ICAO Assembly's 32<sup>nd</sup> Session*, 1998.



## ***APPENDIX 6.1***

### **BASES AND STRUCTURES OF EN-ROUTE FORMULAE**



## BASES AND STRUCTURES OF EN-ROUTE FORMULAE

Sources: IATA Airport & en-route aviation charges manual (1999).

ICAO's Manual of airport & air navigation facility tariffs - Doc. 7100 (1998).

Region	Country	Basis			Formula structure		
		MTOW	Distance	No charge	Step	Continuous	Uniform
Africa	Algeria	X	X			X	
	Angola	X	X			X	
	Benin	X	X		X		
	Botswana	X	X			X	
	Burkina Faso	X	X		X		
	Burundi	X				X	
	Cameroon	X	X		X		
	Cape Verde	X	X		X		
	Central African Republic	X	X		X		
	Chad	X	X		X		
	Comoros	X	X		X		
	Congo, DR	X	X			X	
	Congo, PR	X	X		X		
	Cote d'Ivoire	X	X		X		
	Djibouti	X				X	
	Egypt	X					X
	Equatorial Guinea	X	X		X		
	Eritrea	X			X		
	Ethiopia	X	X			X	
	Gabon	X	X		X		
	Gambia			X			
	Ghana		X		X		
	Guinea Bissau			X			
	Guinea Conakry		X			X	
	Kenya	X			X		
	Lesotho			X			
	Liberia		X			X	
	Libyan Arab Jamahiriya	X				X	
	Madagascar	X	X		X		
	Malawi	X					X
	Mali	X	X		X		
	Mauritania	X	X		X		
	Mauritius	X	X			X	
	Morocco	X	X			X	
	Mozambique	X			X		
	Namibia			X			
	Niger	X	X		X		
	Nigeria	X	X			X	
	Rwanda	X			X		
	Senegal	X	X		X		
	Seychelles	X	X			X	
	Sierra Leone		X			X	
	Somalia						X
	South Africa	X	X			X	
	Sudan	X			X		
	Swaziland			X			
	Tanzania	X			X		
	Togo	X	X		X		
	Tunisia	X			X		
	Uganda	X					X
	Zambia	X	X		X		
	Zimbabwe	X	X			X	



Region	Country	Basis			Formula structure		
		MTOW	Distance	No charge	Step	Continuous	Uniform
Americas & Caribbean	Anguilla			X			
	Antigua		X			X	
	Argentina	X	X			X	
	Bahamas			X			
	Barbados		X			X	
	Belize		X			X	
	Bolivia	X	X			X	
	Brazil	X	X			X	
	British Virgin Islands			X			
	Canada	X	X			X	
	Cayman Islands			X			
	Chile		X			X	
	Colombia		X		X		
	Costa Rica		X				X
	Cuba	X					X
	Dominica		X	X			X
	Dominican Republic	X					X
	Ecuador	X	X				X
	El Salvador		X				X
	French Guyana				X		
	Greenland						X
	Grenada			X			X
	Guadeloupe			X			X
	Guatemala			X			X
	Guyana	X			X		
	Haiti	X					X
	Honduras			X			X
	Jamaica	X			X		
	Martinique			X			X
	Mexico	X	X				X
	Montserrat			X			X
	Netherlands Antilles	X	X				X
	Nicaragua			X			X
Panama	X	X		X			
Paraguay	X	X				X	
Peru	X	X		X			
Puerto Rico				X			
St Kitts & Nevis			X			X	
St. Lucia			X			X	
St. Maarten			X			X	
St Vincent & Grenadines			X			X	
Surinam						X	
Trinidad & Tobago			X			X	
Turks & Caicos				X			
Uruguay	X			X			
US Virgin Islands				X			
USA				X			
Venezuela	X	X		X			



Region	Country	Basis			Formula structure		
		MTOW	Distance	No charge	Step	Continuous	Uniform
Asia & Pacific	Afghanistan						X
	Australia	X	X			X	
	Bangladesh	X			X		
	Bhutan			X			
	Brunei			X			
	Cambodia, Kingdom of	X			X		
	China, PR		X			X	
	Cook Islands	X	X			X	
	Fiji	X	X			X	
	Guam			X			
	Hong Kong		X			X	
	India	X			X		
	Indonesia	X	X			X	
	Japan			X			
	Kazakhstan	X	X		X		
	Korea, Democratic PR of	X				X	
	Korea, Republic of	X					X
	Kyrgyzstan	X	X		X		
	Laos		X				X
	Malaysia	X	X		X		
	Maldives	X			X		
	Mongolia	X	X		X		
	Myanmar	X			X		
	Nepal	X			X		
	New Zealand	X	X			X	
	Pakistan	X			X		
	Papua New Guinea	X	X			X	
	Philippines						X
	Singapore			X			
	Solomon Islands	X	X			X	
	Sri Lanka	X			X		
	Taiwan, ROC						X
	Tajikistan	X	X		X		
Thailand	X			X			
Turkmenistan	X	X		X			
Uzbekistan	X	X			X		
Vietnam	X	X		X			
Western Samoa				X			



Region	Country	Basis			Formula structure		
		MTOW	Distance	No charge	Step	Continuous	Uniform
Europe	Albania						X
	Armenia	X	X			X	
	Austria	X	X			X	
	Azerbaijan	X	X			X	
	Belarus	X	X			X	
	Belgium	X	X			X	
	Bosnia and Herzegovina	X	X			X	
	Bulgaria	X	X			X	
	Croatia	X	X			X	
	Cyprus	X	X			X	
	Czech Republic	X	X			X	
	Denmark	X	X			X	
	Estonia	X	X			X	
	Finland	X	X			X	
	France	X	X			X	
	FYROM	X	X			X	
	Georgia	X	X			X	
	Germany	X	X			X	
	Greece	X	X			X	
	Hungary	X	X			X	
	Iceland						X
	Ireland	X	X			X	
	Italy	X	X			X	
	Latvia	X	X			X	
	Lithuania	X	X			X	
	Luxembourg	X	X			X	
	Malta	X	X			X	
	Moldova	X	X			X	
	Monaco	X	X			X	
	Netherlands	X	X			X	
	Norway	X	X			X	
	Poland	X	X			X	
	Portugal	X	X			X	
Romania	X	X			X		
Russian Federation	X	X		X			
Slovak Republic	X	X			X		
Slovenia	X	X			X		
Spain	X	X			X		
Sweden	X	X			X		
Switzerland	X	X			X		
Ukraine	X	X			X		
United Kingdom	X	X			X		
Yugoslavia	X	X			X		
Middle East	Bahrain	X			X		
	Iran	X	X			X	
	Iraq	X				X	
	Jordan	X				X	
	Kuwait						X
	Lebanon						X
	Oman	X			X		
	Saudia Arabia	X	X			X	
	Syria	X			X		
	Turkey	X	X			X	
	United Arab Emirates	X			X		
	Yemen, Republic of	X				X	



## ***APPENDIX 6.2***

### **EFFECT OF DIFFERENTIAL ON EN-ROUTE FORMULAE**



## EFFECT OF DIFFERENTIAL ON EN-ROUTE FORMULAE

Sources: IATA Airport & en-route aviation charges manual (1999).

ICAO's Manual of airport & air navigation facility tariffs - Doc. 7100 (1998).

Region	Country	Effect of landing in country on rate			Domestic differential		
		Lower	Higher	Not Specified	Lower	Higher	Not Specified
Africa	Algeria			X			X
	Angola			X			X
	Benin	X			X		
	Botswana	X			X		
	Burkina Faso	X			X		
	Burundi	X			X		
	Cameroon	X			X		
	Cape Verde			X			X
	Central African Republic	X			X		
	Chad	X			X		
	Comoros	X			X		
	Congo, DR			X			X
	Congo, PR	X			X		
	Cote d'Ivoire	X			X		
	Djibouti			X			X
	Egypt		X				X
	Equatorial Guinea	X			X		
	Eritrea			X			X
	Ethiopia			X		X	
	Gabon	X			X		
	Gambia						
	Ghana			X			X
	Guinea Bissau						
	Guinea Conakry			X			X
	Kenya			X			X
	Lesotho						
	Liberia			X			X
	Libyan Arab Jamahinya	X					X
	Madagascar	X				X	
	Malawi	X					X
	Mali	X				X	
	Mauritania	X				X	
	Mauritius			X			X
	Morocco			X			X
	Mozambique			X			X
	Namibia						
	Niger	X				X	
	Nigeria	X					
	Rwanda			X			X
	Senegal	X				X	
	Seychelles			X			X
	Sierra Leone			X			X
	Somalia			X			X
	South Africa			X			X
	Sudan			X			X
	Swaziland						
	Tanzania			X			X
Togo	X				X		
Tunisia	X						
Uganda			X			X	
Zambia			X			X	
Zimbabwe	X					X	



Region	Country	Effect of landing in country on rate			Domestic differential		
		Lower	Higher	Not Specified	Lower	Higher	Not Specified
Americas & Caribbean	Anguilla			X			X
	Antigua						
	Argentina	X			X		
	Bahamas						
	Barbados			X			X
	Belize			X			X
	Bolivia	X			X		
	Brazil	X			X		
	British Virgin Islands						
	Canada	X			X		
	Cayman Islands						
	Chile			X			X
	Colombia			X			X
	Costa Rica			X			X
	Cuba	X					X
	Dominica			X			X
	Dominican Republic			X			X
	Ecuador	X				X	
	El Salvador			X			X
	French Guyana						
	Greenland						
	Grenada			X			X
	Guadeloupe			X			X
	Guatemala			X			X
	Guyana		X				
	Haiti	X				X	
	Honduras			X			X
	Jamaica			X			X
	Martinique			X			X
	Mexico		X				X
	Montserrat			X			X
	Netherlands Antilles	X				X	
	Nicaragua			X			X
Panama	X				X		
Paraguay	X					X	
Peru	X					X	
Puerto Rico							
St. Kitts & Nevis			X			X	
St. Lucia			X			X	
St. Maarten			X			X	
St. Vincent & Grenadines			X			X	
Surinam	X					X	
Trinidad & Tobago			X			X	
Turks & Caicos							
Uruguay			X			X	
US Virgin Islands							
USA							
Venezuela	X				X		



Region	Country	Effect of landing in country on rate			Domestic differential		
		Lower	Higher	Not Specified	Lower	Higher	Not Specified
Asia & Pacific	Afghanistan	X					X
	Australia			X			X
	Bangladesh	X			X		
	Bhutan						
	Brunei						
	Cambodia, Kingdom of	X			X		
	China, PR	X					
	Cook Islands	X					X
	Fiji	X					X
	Guam						
	Hong Kong	X					
	India						
	Indonesia			X			X
	Japan						
	Kazakhstan	X			X		
	Korea, Democratic PR of			X			X
	Korea, Republic of		X				X
	Kyrgyzstan	X					X
	Laos			X			X
	Malaysia			X			X
	Maldives			X			X
	Mongolia	X				X	X
	Myanmar						
	Nepal				X		X
	New Zealand	X				X	
	Pakistan	X					
	Papua New Guinea				X		X
	Philippines		X				X
	Singapore						X
	Solomon Islands	X				X	
	Sri Lanka				X		X
	Taiwan, ROC				X		X
Tajikistan	X					X	
Thailand	X					X	
Turkmenistan	X					X	
Uzbekistan	X					X	
Vietnam			X			X	
Western Samoa						X	



Region	Country	Effect of landing in country on rate			Domestic differential		
		Lower	Higher	Not Specified	Lower	Higher	Not Specified
Europe	Albania			X			X
	Armenia	X					X
	Austria	X					X
	Azerbaijan	X					X
	Belarus	X					X
	Belgium	X					X
	Bosnia and Herzegovina				X		X
	Bulgaria	X					X
	Croatia	X					X
	Cyprus	X					X
	Czech Republic	X					X
	Denmark	X					X
	Estonia	X					X
	Finland	X					X
	France	X					X
	FYROM	X					X
	Georgia	X					X
	Germany	X					X
	Greece	X					X
	Hungary	X					X
	Iceland	X					X
	Ireland	X					X
	Italy	X					X
	Latvia	X					X
	Lithuania	X					X
	Luxembourg	X					X
	Malta	X					X
	Moldova	X					X
	Monaco	X					X
	Netherlands	X					X
	Norway	X					X
	Poland	X					X
Portugal	X					X	
Romania	X					X	
Russian Federation	X					X	
Slovak Republic	X					X	
Slovenia	X					X	
Spain	X					X	
Sweden	X					X	
Switzerland	X					X	
Ukraine	X					X	
United Kingdom	X					X	
Yugoslavia	X					X	

Region	Country	Effect of landing in country on rate			Domestic differential		
		Lower	Higher	Not Specified	Lower	Higher	Not Specified
Middle East	Bahrain	X				X	
	Iran	Y			X		
	Iraq			X			X
	Jordan			X			X
	Kuwait						
	Lebanon						
	Oman			X			X
	Saudia Arabia			X			X
	Syria	X					X
	Turkey	X					X
	United Arab Emirates	X					X
	Yemen, Republic of	X					X



## ***APPENDIX 6.3***

### **LIST OF COUNTRIES LEVYING THEIR OWN FEES**



## LIST OF COUNTRIES LEVYING THEIR OWN FEES

Source: IATA Airport & en-route aviation charges manual (1999).

<b>Africa</b>	Zambia Algeria Botswana Djibouti Egypt Eritrea Ethiopia Ghana Kenya Libyan Arab Jamahiriya Malawi Mauritius Morocco Mozambique Nigeria Rwanda Sudan Tunisia Zimbabwe	<b>Americas &amp; Caribbean</b>	Argentina Bolivia Brazil Canada Chile Cuba Dominican Republic Ecuador Guyana Greenland Haiti Mexico Panama Paraguay Peru Surinam Uruguay Venezuela
<b>Asia &amp; Pacific</b>	Australia Bangladesh Cambodia, Kingdom of China, PR Cook Islands Fiji Hong Kong India Indonesia Kazakhstan Korea, Democratic PR. of Korea, Republic of Kyrgyzstan Laos Malaysia Maldives Mongolia Myanmar Nepal New Zealand Pakistan Papua New Guinea Philippines Solomon Islands Sri Lanka Taiwan, ROC Thailand Vietnam	<b>Europe</b>	Estonia Finland Iceland Poland
		<b>Middle East</b>	Bahrain Iran Iraq Jordan Oman Saudia Arabia Syria United Arab Emirates Yemen, Republic of



## ***APPENDIX 6.4***

### **LIST OF COUNTRIES USING IATA TO BILL AND COLLECT FEES**



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**LIST OF COUNTRIES USING IATA TO BILL AND COLLECT FEES**


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Source: IATA Airport & en-route aviation charges manual (1999).

<b>Africa</b>	Angola Burundi Cape Verde Congo, DR ROBERTS FIR Seychelles Somalia South Africa Tanzania Uganda
<b>Americas &amp; Caribbean</b>	Colombia Jamaica Netherlands Antilles
<b>Asia &amp; Pacific</b>	Afghanistan Tajikistan Turkmenistan
<b>Europe</b>	Albania Armenia Azerbaijan Georgia Russian Federation
<b>Middle East</b>	<i>none</i>



## ***APPENDIX 6.5***

### **COUNTRIES' BILLING CURRENCIES**



## COUNTRIES' BILLING CURRENCIES

Sources: IATA Airport & en-route aviation charges manual (1999).

ICAO's Manual of airport & air navigation facility tariffs - Doc. 7100 (1998).

Region	Country	Currency	Region	Country	Currency
Africa	Algeria	DZD	Americas & Caribbean	Anguilla	n/a
	Angola	USD		Antigua	n/a
	Benin	FRF		Argentina	USD
	Botswana	BWP		Bahamas	n/a
	Burkina Faso	FRF		Barbados	n/a
	Burundi	USD		Belize	USD
	Cameroon	FRF		Bolivia	USD
	Cape Verde	USD		Brazil	USD
	Central African Republic	FRF		British Virgin Islands	n/a
	Chad	FRF		Canada	CAD
	Comoros	FRF		Cayman Islands	n/a
	Congo, DR	USD		Chile	USD
	Congo, PR	FRF		Colombia	USD
	Cote d'Ivoire	FRF		Costa Rica	USD
	Djibouti	DJF		Cuba	USD
	Egypt	USD		Dominica	n/a
	Equatorial Guinea	FRF		Dominican Republic	USD
	Eritrea	USD		Ecuador	USD
	Ethiopia	USD		El Salvador	USD
	Gabon	FRF		French Guyana	n/a
	Gambia	n/a		Greenland	GBP
	Ghana	USD		Grenada	n/a
	Guinea Bissau	n/a		Guadeloupe	n/a
	Guinea Conakry	USD		Guatemala	USD
	Kenya	USD		Guyana	USD
	Lesotho	n/a		Haiti	USD
	Liberia	USD		Honduras	USD
	Libyan Arab Jamahiriya	LYD		Jamaica	USD
	Madagascar	FRF		Martinique	n/a
	Malawi	USD		Mexico	MXN
	Mali	FRF		Montserrat	n/a
	Mauritania	FRF		Netherlands Antilles	ANG
	Mauritius	MUR		Nicaragua	USD
	Morocco	MAD		Panama	PAB
	Mozambique	USD		Paraguay	USD
	Namibia	n/a		Peru	USD
	Niger	FRF		Puerto Rico	n/a
	Nigeria	USD		St. Kitts & Newis	n/a
	Rwanda	USD		St. Lucia	n/a
	Senegal	FRF		St. Vincent & Grenadines	n/a
	Seychelles	USD		Surinam	USD
	Sierra Leone	USD		Trinidad & Tobago	USD
	Somalia	USD		Turks & Caicos	n/a
	South Africa	ZAR		Uruguay	USD
	Sudan	CHF		US Virgin Islands	n/a
	Swaziland	n/a		USA	n/a
	Tanzania	USD		Venezuela	USD
Togo	FRF				
Tunisia	EUR				
Uganda	USD				
Zambia	USD				
Zimbabwe	USD				



Region	Country	Currency
Asia & Pacific	Afghanistan	USD
	Australia	AUD
	Bangladesh	USD
	Bhutan	n/a
	Brunei	n/a
	Cambodia, Kingdom of	USD
	China, PR	USD
	Cook Islands	NZD
	Fiji	FJD
	Guam	n/a
	Hong Kong	HKD
	India	INR
	Indonesia	USD
	Japan	n/a
	Kazakhstan	USD
	Korea, Democratic PR of	USD
	Korea, Republic of	KRW
	Kyrgyzstan	USD
	Laos	USD
	Malaysia	MYR
	Maldives	USD
	Mongolia	USD
	Myanmar	USD
	Nepal	USD
	New Zealand	NZD
	Pakistan	USD
	Papua New Guinea	PGK
	Philippines	USD
	Singapore	n/a
	Solomon Islands	USD
	Sri Lanka	USD
	Taiwan, ROC	TWD
Tajikistan	USD	
Thailand	THB	
Turkmenistan	USD	
Uzbekistan	USD	
Vietnam	USD	
Western Samoa	n/a	

Region	Country	Currency
Europe	Albania	USD
	Armenia	USD
	Austria	EUR
	Azerbaijan	USD
	Belarus	USD
	Belgium	EUR
	Bosnia and Herzegovina	USD
	Bulgaria	EUR
	Croatia	HRK
	Cyprus	CYP
	Czech Republic	CZK
	Denmark	DKK
	Estonia	EEK
	Finland	FIM
	France	EUR
	FYROM	MKD
	Georgia	USD
	Germany	EUR
	Greece	GRD
	Hungary	HUF
	Iceland	GBP
	Ireland	EUR
	Italy	EUR
	Latvia	USD
	Lithuania	USD
	Luxembourg	EUR
	Malta	MTL
Moldova	USD	
Monaco	EUR	
Netherlands	EUR	
Norway	NOK	
Poland	USD	
Portugal	EUR	
Romania	EUR	
Russian Federation	USD	
Slovak Republic	SKK	
Slovenia	SIT	
Spain	EUR	
Sweden	SEK	
Switzerland	CHF	
Ukraine	USD	
United Kingdom	GBP	
Yugoslavia	USD	

Region	Country	Currency
Middle East	Bahrain	BHD
	Iran	USD
	Iraq	IQD
	Jordan	JOD
	Kuwait	n/a
	Lebanon	n/a
	Oman	USD
	Saudia Arabia	SAR
	Syria	SYP
	Turkey	EUR
	United Arab Emirates	USD
Yemen, Republic of	YER	

n/a ~ not applicable



***APPENDIX 6.6***

**\$ EXCHANGE RATES**



**\$ EXCHANGE RATES**Source: DataStream (30<sup>th</sup> June 1999).

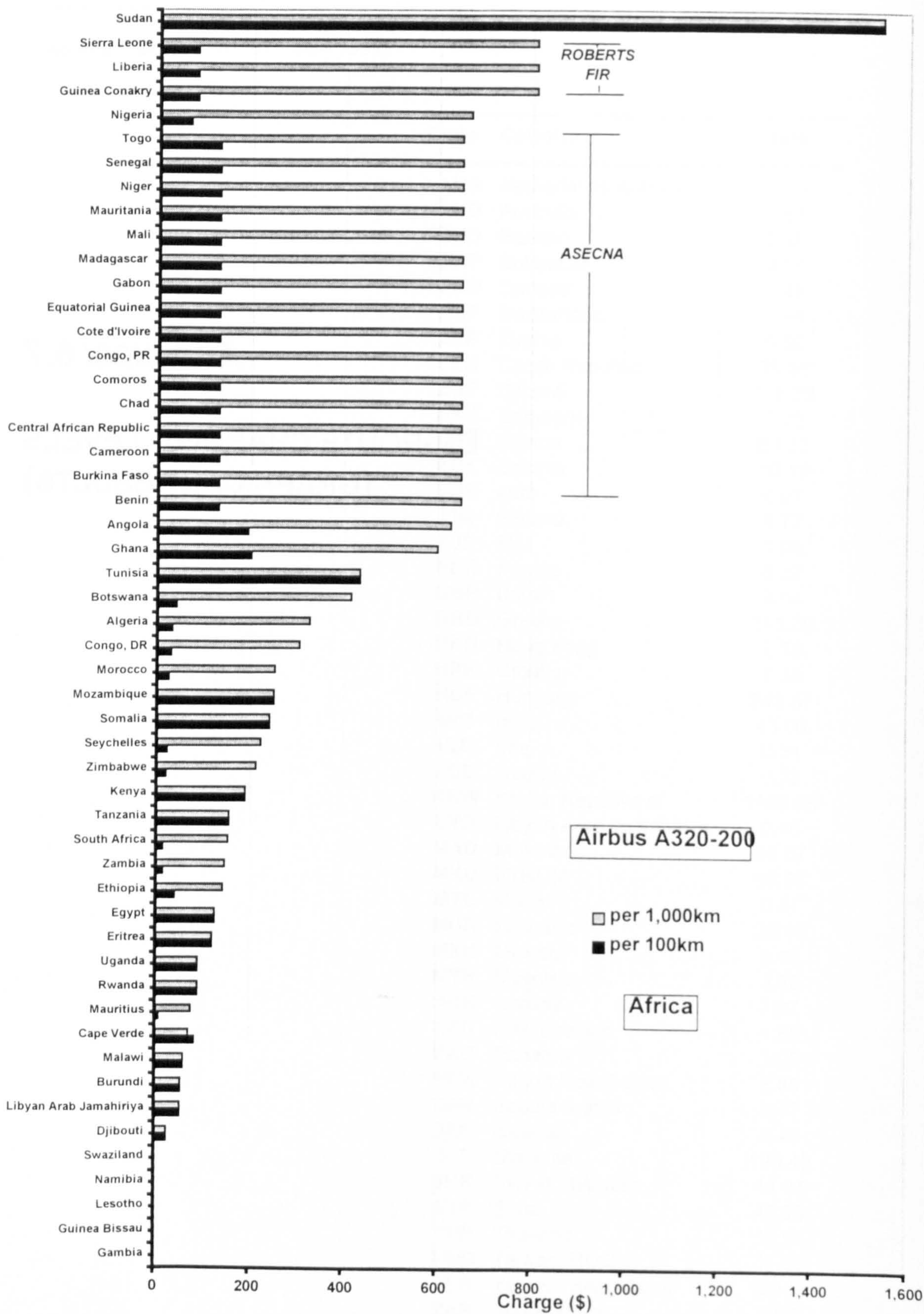
Code	Country	Rate
ANG	Netherlands Antilles	1.79
AUD	Australia	1.51
BHD	Bahrain	0.38
BWP	Botswana	4.66
CAD	Canada	1.48
CHF	Switzerland	1.56
CYP	Cyprus	0.56
CZK	Czech Republic	35.36
DJF	Djibouti	178.83
DKK	Denmark	7.22
DZD	Algeria	69.53
EEK	Estonia	15.19
EUR	euro	0.97
FIM	Finland	5.77
FJD	Fiji	1.98
FRF	France	6.37
GBP	Britain	0.64
GRD	Greece	315.00
HKD	Hong Kong	7.78
HRK	Croatia	7.38
HUF	Hungary	242.37
INR	India	43.06
IQD	Iraq	0.31
JOD	Jordan	0.72
KRW	Korea, Republic of	1160.65
LYD	Libyan Arab Jamahiriya	0.46
MAD	Morocco	10.07
MKD	FYROM	59.35
MTL	Malta	0.41
MUR	Mauritius	25.36
MXN	Mexico	9.45
MYR	Malaysia	3.82
NOK	Norway	7.87
NZD	New Zealand	1.88
PAB	Panama	1.00
PGK	Papua New Guinea	2.85
SAR	Saudia Arabia	3.77
SEK	Sweden	8.49
SIT	Slovenia	190.48
SKK	Slovak Republic	44.01
SYP	Syria	46.29
THB	Thailand	36.96
TWD	Taiwan, ROC	32.56
YER	Yemen, Republic of	150.54
ZAR	South Africa	6.08



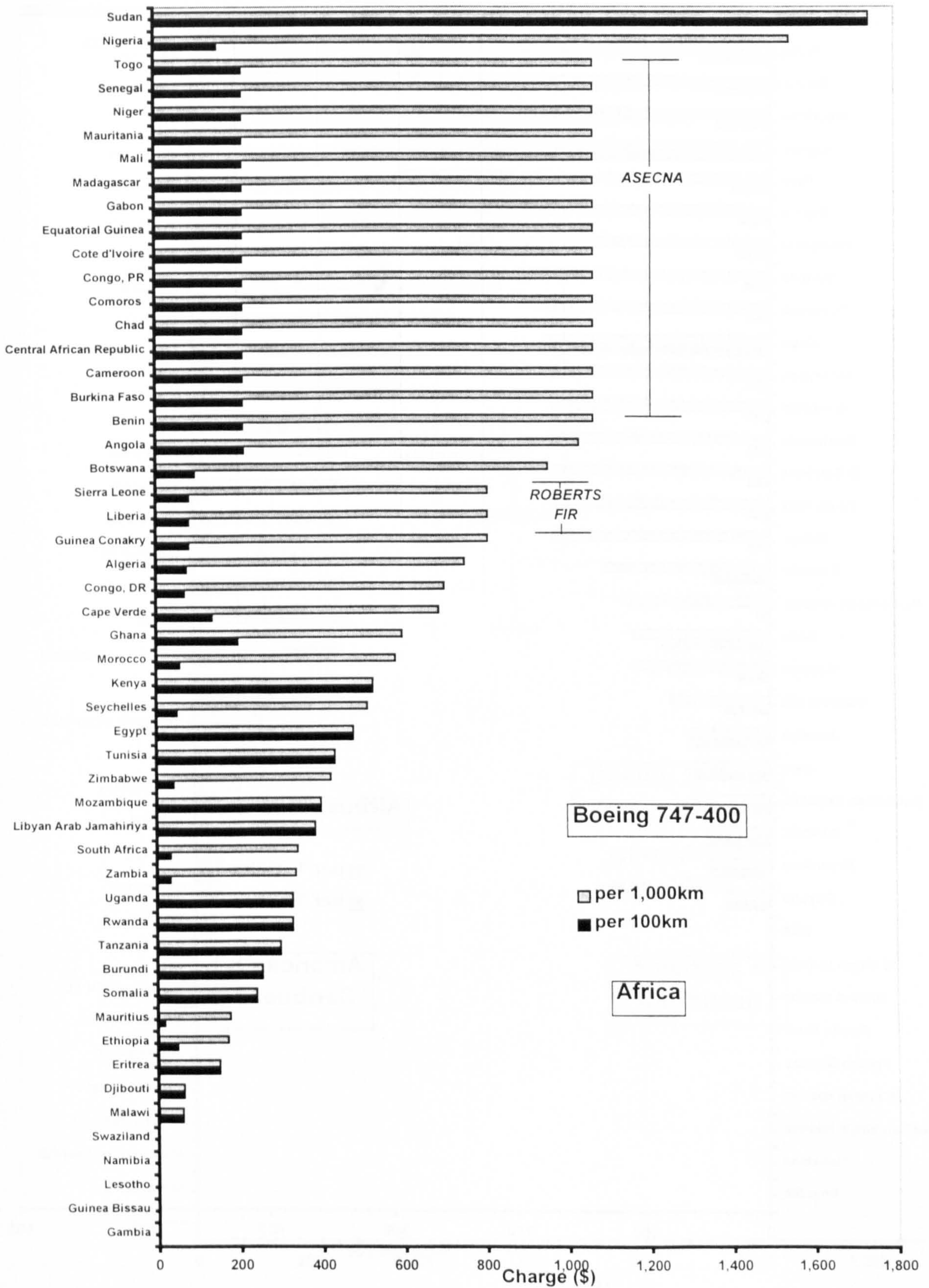
**APPENDIX 6.7**

**EN-ROUTE CHARGING LEVELS  
(GRAPHICAL RESULTS)**

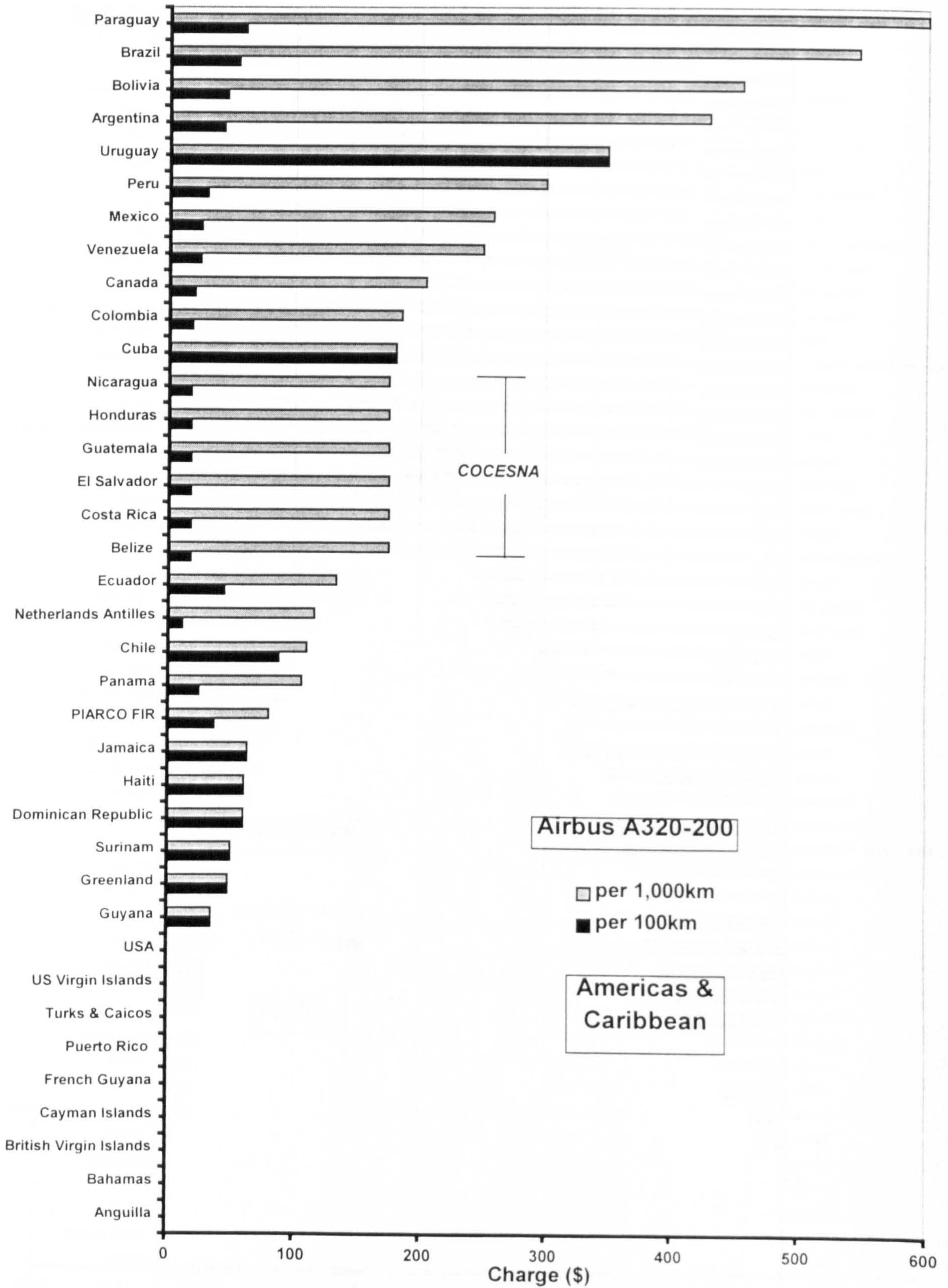




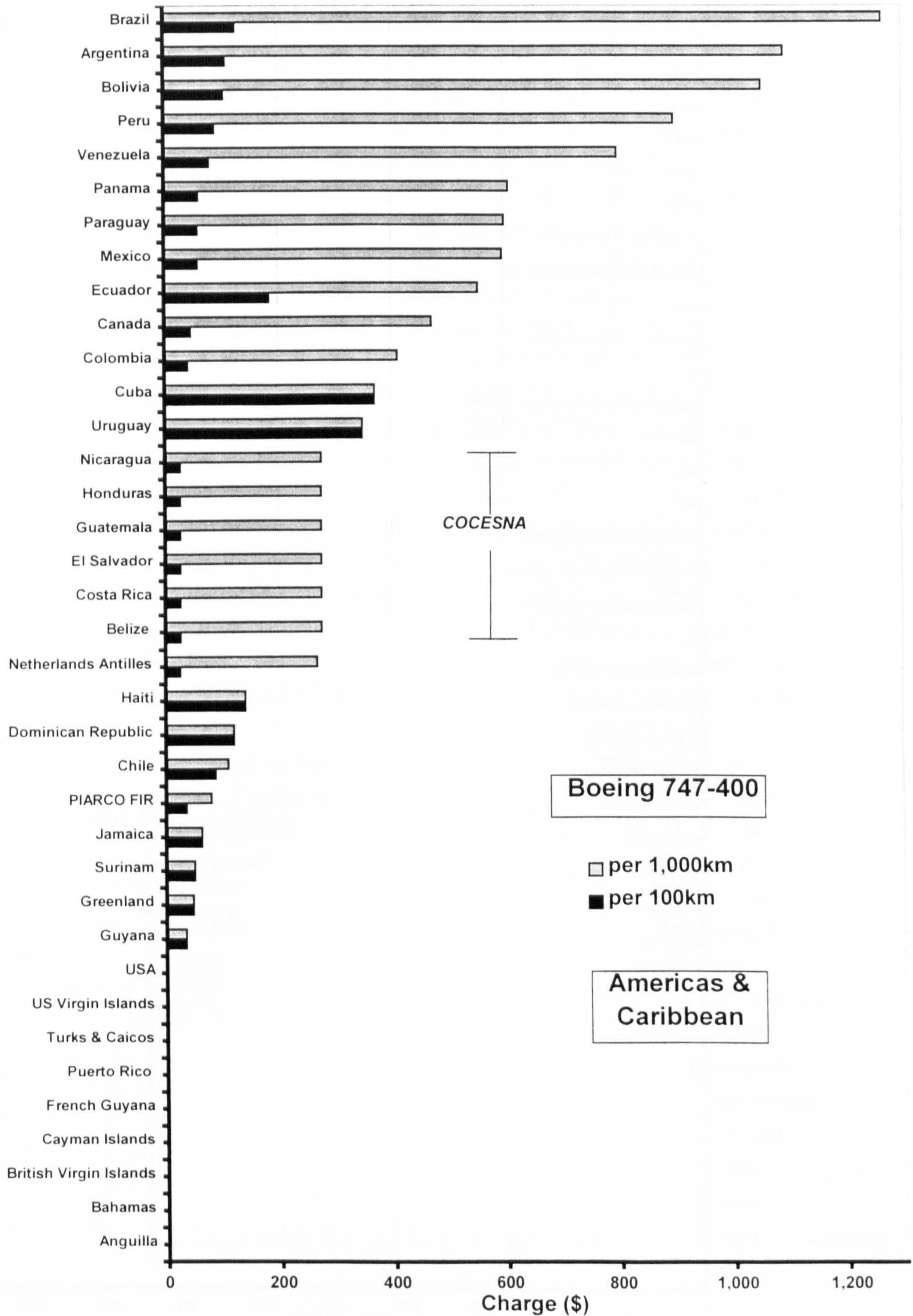




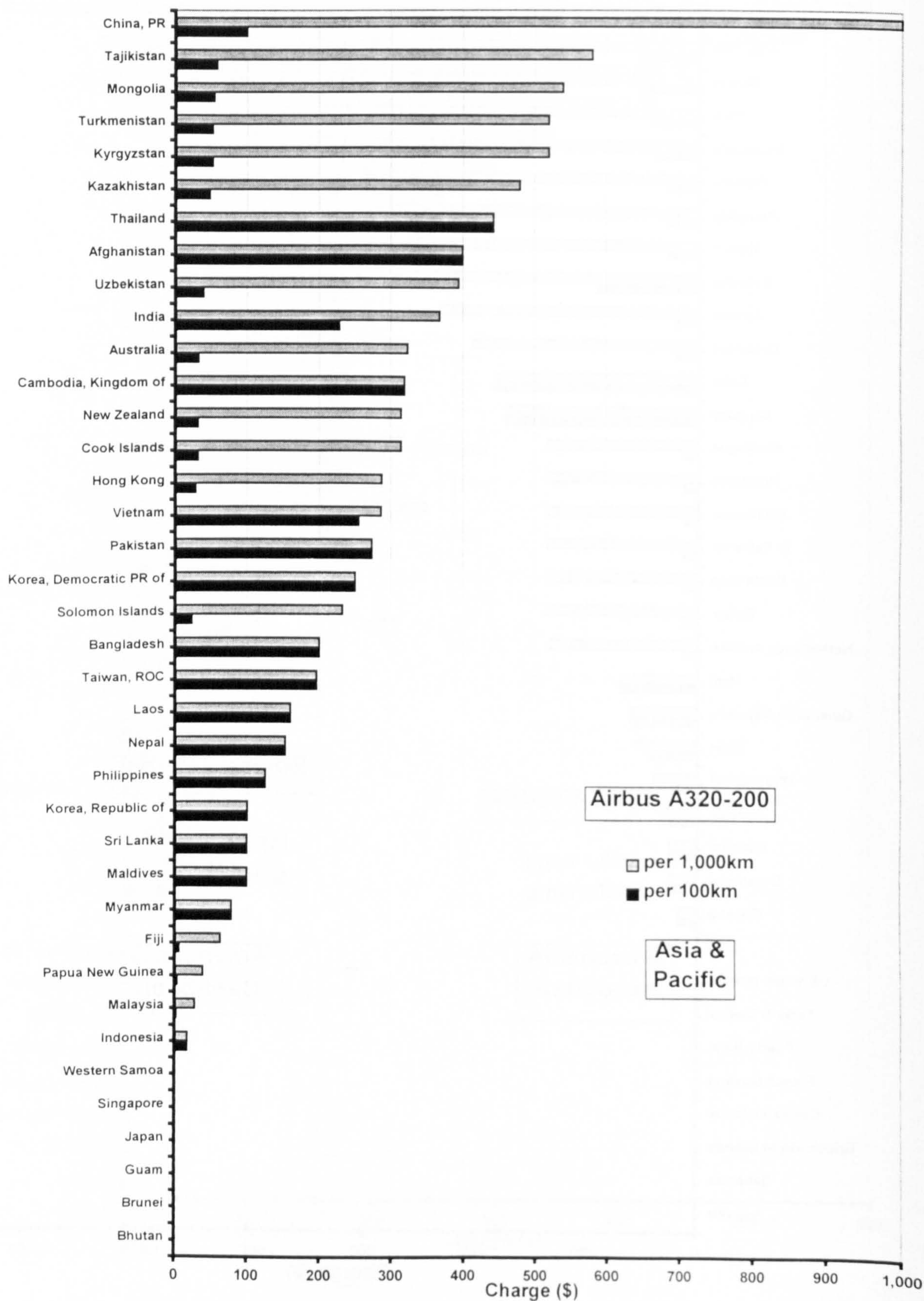




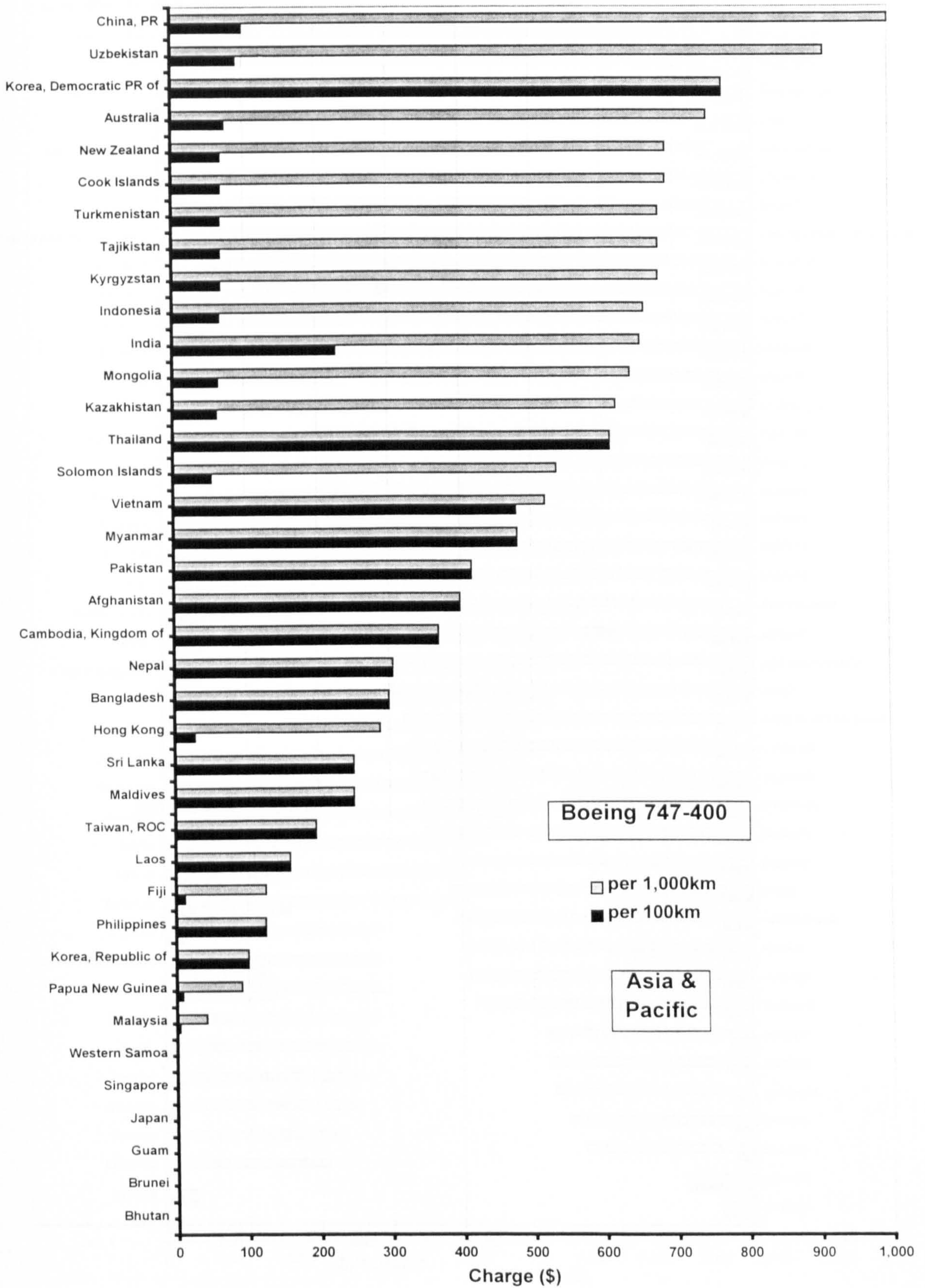




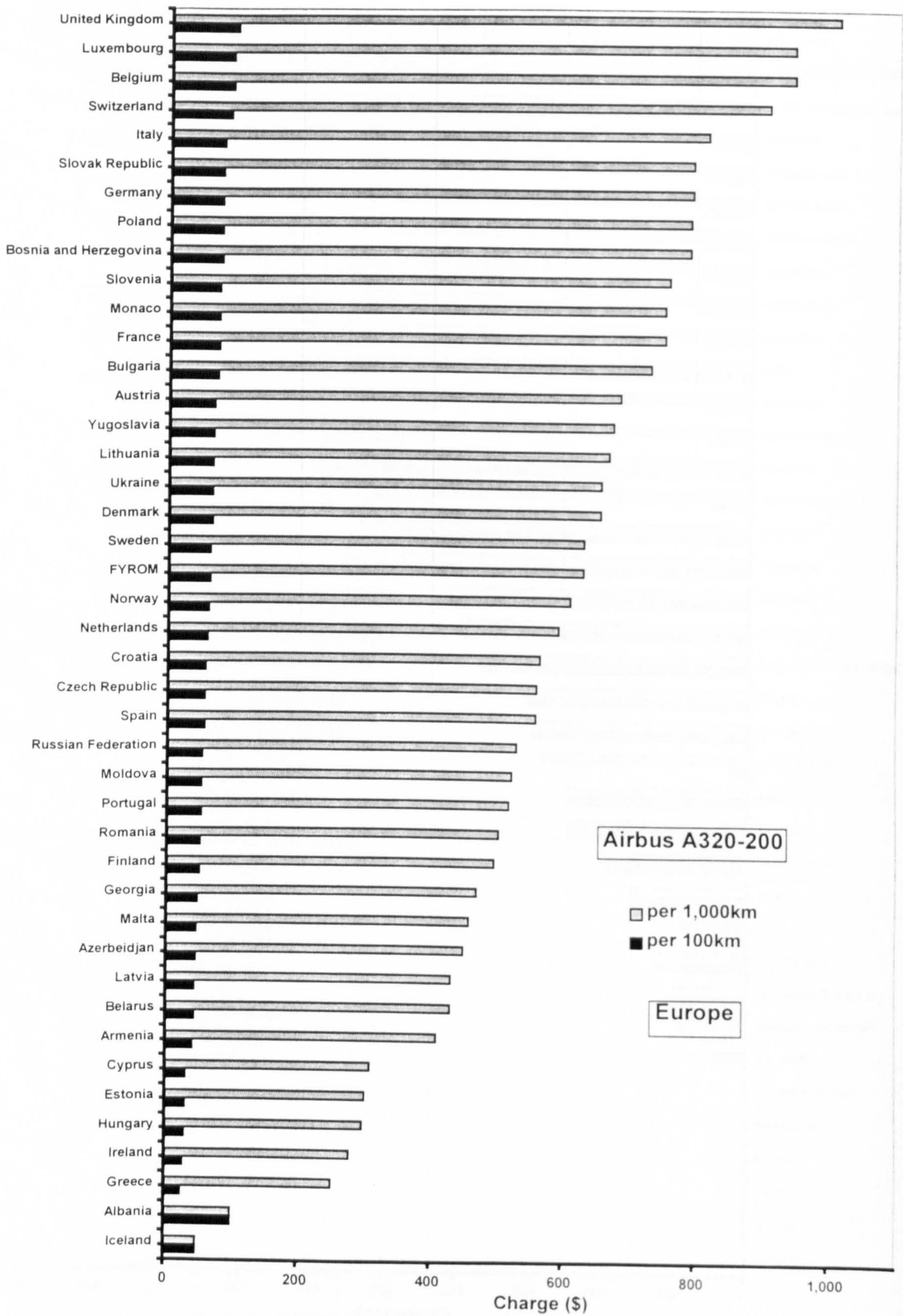




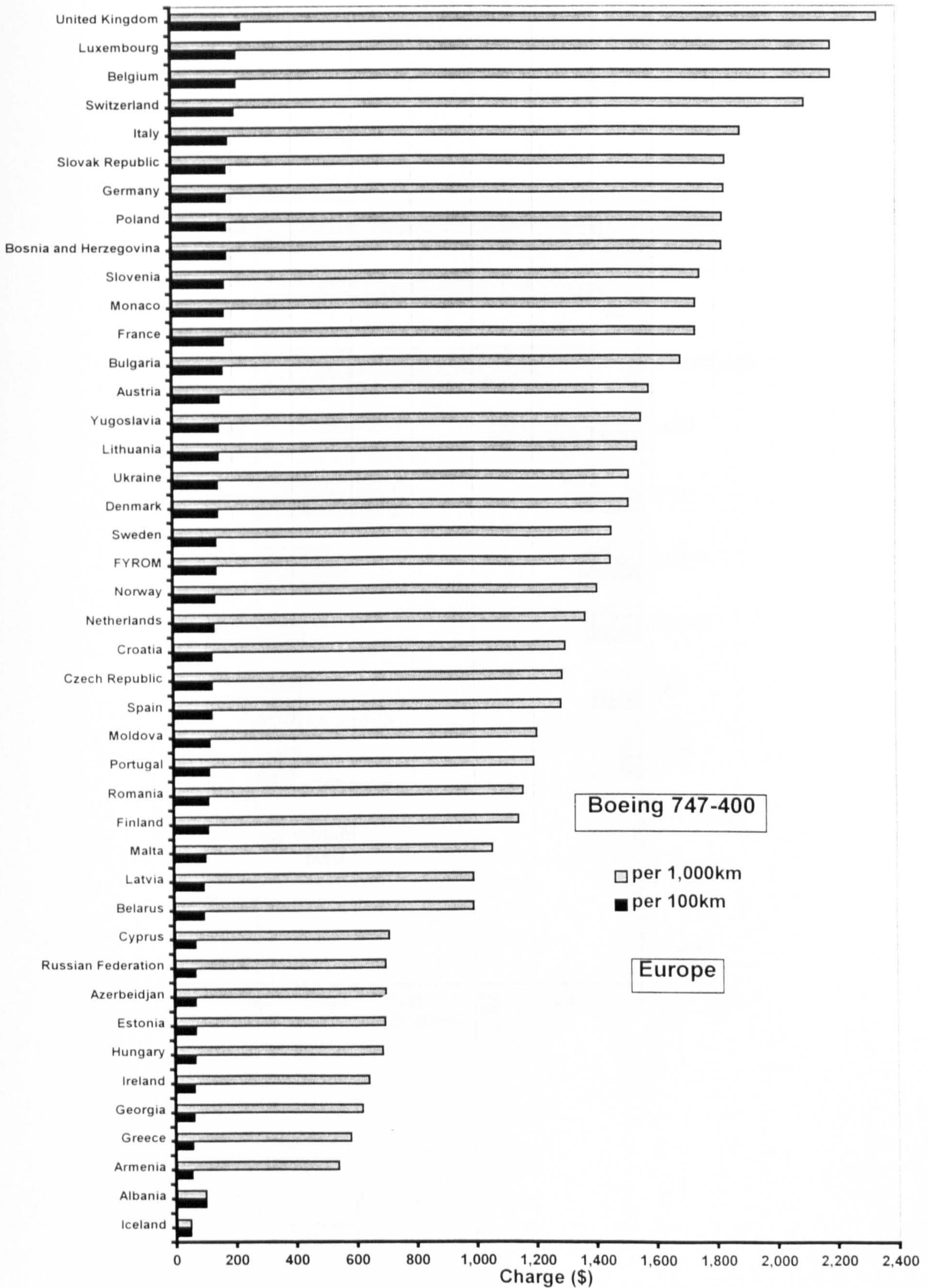




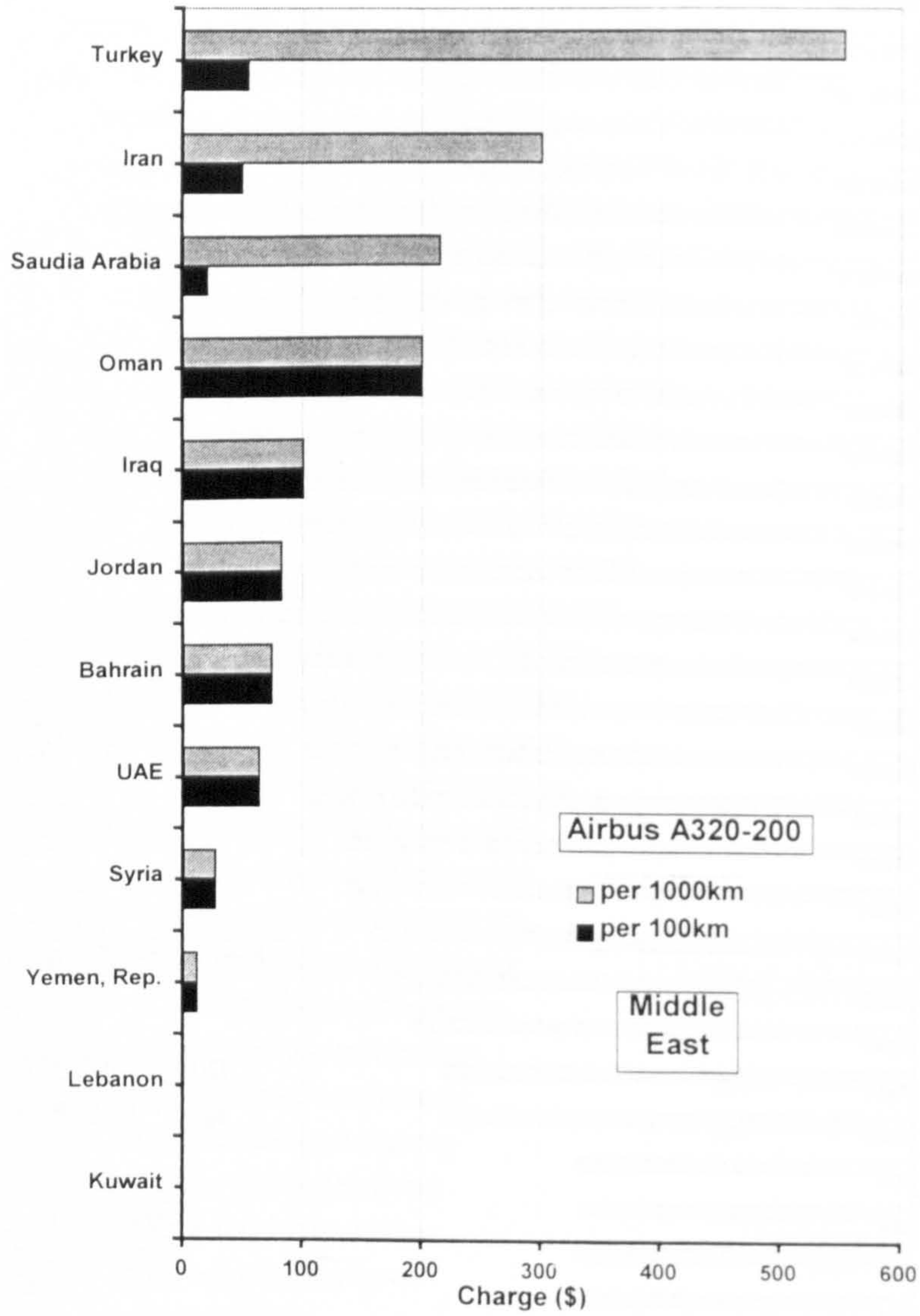




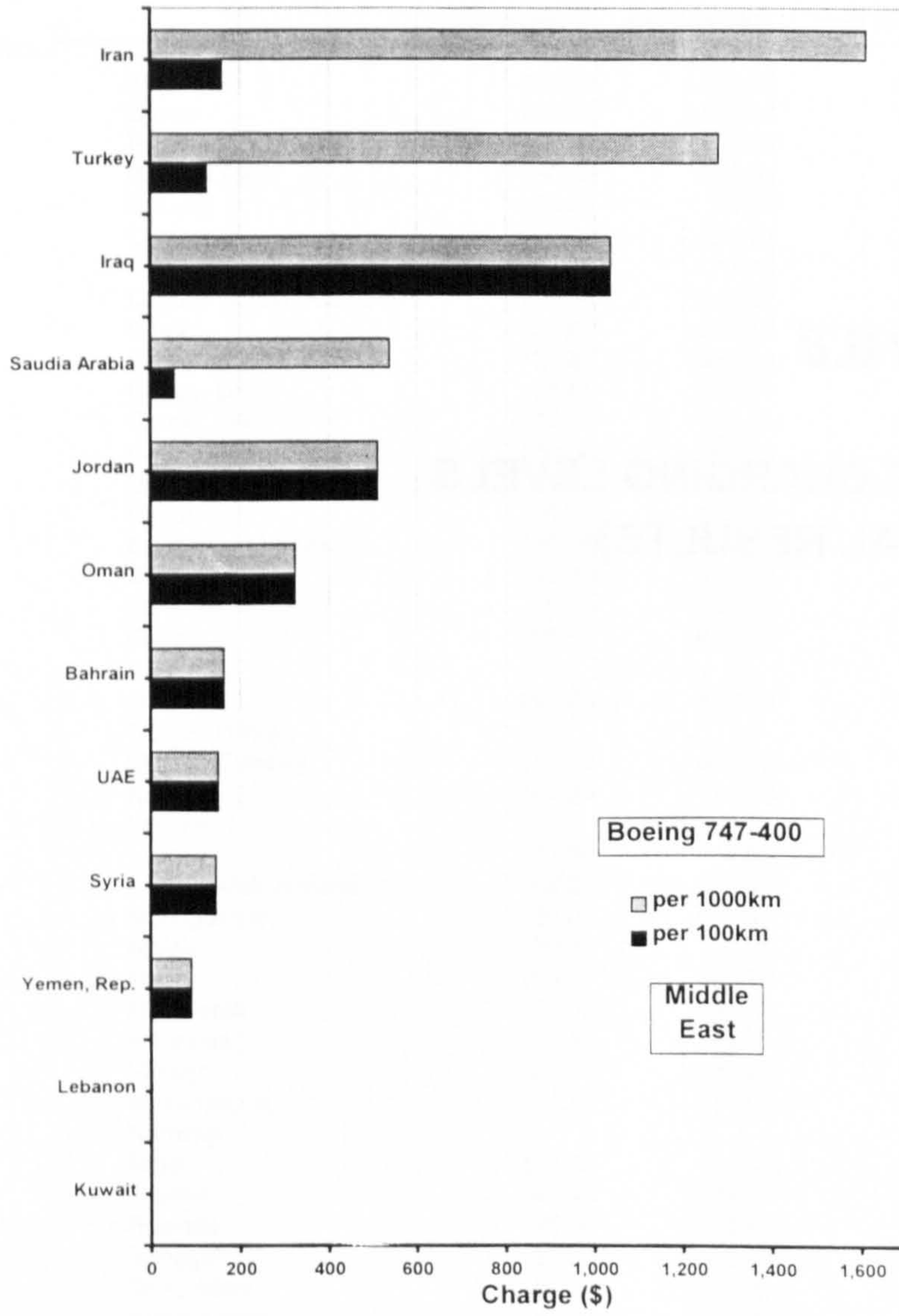














## ***APPENDIX 6.8***

### **EN-ROUTE CHARGING LEVELS (NUMERICAL RESULTS)**



## EN-ROUTE CHARGING LEVELS (CURRENCY: \$)

This appendix displays the results from the worldwide survey of en-route navigation fees that is conducted as part of the framework strategy.

Region	Country	A320-200 (\$)		B747-400 (\$)	
		per 100km	per 1,000km	per 100km	per 1,000km
Africa	Algeria	32.57	325.74	75.26	752.58
	Angola	193.00	628.37	215.44	1,032.32
	Benin	130.06	650.32	213.68	1,068.38
	Botswana	41.42	414.24	95.70	957.04
	Burkina Faso	130.06	650.32	213.68	1,068.38
	Burundi	55.00	55.00	255.00	255.00
	Cameroon	130.06	650.32	213.68	1,068.38
	Cape Verde	84.00	71.40	138.00	690.00
	Central African Republic	130.06	650.32	213.68	1,068.38
	Chad	130.06	650.32	213.68	1,068.38
	Comoros	130.06	650.32	213.68	1,068.38
	Congo, DR	30.41	304.14	70.27	702.67
	Congo, PR	130.06	650.32	213.68	1,068.38
	Cote d'Ivoire	130.06	650.32	213.68	1,068.38
	Djibouti	25.37	25.37	63.22	63.22
	Egypt	125.00	125.00	480.00	480.00
	Equatorial Guinea	130.06	650.32	213.68	1,068.38
	Eritrea	120.00	120.00	150.00	150.00
	Ethiopia	40.60	142.10	48.72	170.52
	Gabon	130.06	650.32	213.68	1,068.38
	Gambia	-	-	-	-
	Ghana	200.00	600.00	200.00	600.00
	Guinea Bissau	-	-	-	-
	Guinea Conakry	81.00	810.00	81.00	810.00
	Kenya	190.00	190.00	527.00	527.00
	Lesotho	-	-	-	-
	Liberia	81.00	810.00	81.00	810.00
	Libyan Arab Jamahiriya	54.03	54.03	385.05	385.05
	Madagascar	130.06	650.32	213.68	1,068.38
	Malawi	60.00	60.00	60.00	60.00
	Mali	130.06	650.32	213.68	1,068.38
	Mauritania	130.06	650.32	213.68	1,068.38
	Mauritius	7.65	76.47	17.67	176.68
	Morocco	25.21	252.09	58.24	582.43
	Mozambique	250.00	250.00	400.00	400.00
	Namibia	-	-	-	-
	Niger	130.06	650.32	213.68	1,068.38
	Nigeria	66.91	669.10	154.59	1,545.88
	Rwanda	90.00	90.00	330.00	330.00
	Senegal	130.06	650.32	213.68	1,068.38
	Seychelles	22.24	222.43	51.39	513.89
	Sierra Leone	81.00	810.00	81.00	810.00
	Somalia	241.00	241.00	241.00	241.00
	South Africa	15.26	152.60	34.25	342.52
	Sudan	1,545.91	1,545.91	1,739.15	1,739.15
	Swaziland	-	-	-	-
	Tanzania	155.00	155.00	300.00	300.00
Togo	130.06	650.32	213.68	1,068.38	
Tunisia	433.78	433.78	433.78	433.78	
Uganda	90.00	90.00	330.00	330.00	
Zambia	14.60	145.99	33.73	337.28	
Zimbabwe	21.20	211.98	42.40	423.97	



Region	Country	A320-200 (\$)		B747-400 (\$)	
		per 100km	per 1,000km	per 100km	per 1,000km
Americas & Caribbean	Anguilla	-	-	-	-
	Argentina	43.01	430.12	109.31	1,093.10
	Bahamas	-	-	-	-
	Belize	17.49	174.89	27.56	275.58
	Bolivia	45.59	455.89	105.33	1,053.27
	Brazil	54.74	547.45	126.48	1,264.81
	British Virgin Islands	-	-	-	-
	Canada	20.41	204.10	47.15	471.54
	Cayman Islands	-	-	-	-
	Chile	87.84	110.00	87.84	110.00
	Colombia	18.48	184.80	41.09	410.90
	Costa Rica	17.49	174.89	27.56	275.58
	Cuba	180.60	180.60	371.40	371.40
	Dominican Republic	60.00	60.00	120.00	120.00
	Ecuador	44.40	133.20	184.88	554.64
	El Salvador	17.49	174.89	27.56	275.58
	French Guyana	-	-	-	-
	Greenland	47.93	47.93	47.93	47.93
	Guatemala	17.49	174.89	27.56	275.58
	Guyana	35.00	35.00	35.00	35.00
	Haiti	60.56	60.56	139.92	139.92
	Honduras	17.49	174.89	27.56	275.58
	Jamaica	63.00	63.00	63.00	63.00
	Mexico	25.81	258.07	59.62	596.23
	Netherlands Antilles	11.58	115.78	26.75	267.50
	Nicaragua	17.49	174.89	27.56	275.58
	Panama	25.00	105.89	60.71	607.07
	Paraguay	60.00	600.00	60.00	600.00
	Peru	30.00	300.00	90.00	900.00
	PIARCO FIR	36.77	79.70	36.77	79.70
Puerto Rico	-	-	-	-	
Surinam	50.00	50.00	50.00	50.00	
Turks & Caicos	-	-	-	-	
Uruguay	349.00	349.00	349.00	349.00	
US Virgin Islands	-	-	-	-	
USA	-	-	-	-	
Venezuela	25.00	250.00	80.00	800.00	



Region	Country	A320-200 (\$)		B747-400 (\$)	
		per 100km	per 1,000km	per 100km	per 1,000km
Asia & Pacific	Afghanistan	400.00	400.00	400.00	400.00
	Australia	32.35	323.53	74.75	747.47
	Bangladesh	200.00	200.00	300.00	300.00
	Bhutan	-	-	-	-
	Brunei	-	-	-	-
	Cambodia, Kingdom of	319.00	319.00	370.00	370.00
	China, PR	100.00	1,000.00	100.00	1,000.00
	Cook Islands	31.43	314.32	68.99	689.86
	Fiji	6.29	62.92	12.58	125.84
	Guam	-	-	-	-
	Hong Kong	28.69	286.94	28.69	286.94
	India	227.67	367.80	227.67	653.88
	Indonesia	17.60	17.60	66.00	660.00
	Japan	-	-	-	-
	Kazakhstan	48.00	480.00	62.00	620.00
	Korea, Democratic PR of	250.00	250.00	768.75	768.75
	Korea, Republic of	100.40	100.40	100.40	100.40
	Kyrgyzstan	52.00	520.00	68.00	680.00
	Laos	160.00	160.00	160.00	160.00
	Malaysia	2.78	27.80	4.17	41.69
	Maldives	100.00	100.00	250.00	250.00
	Mongolia	54.00	540.00	64.00	640.00
	Myanmar	78.00	78.00	481.00	481.00
	Nepal	152.75	152.75	305.50	305.50
	New Zealand	31.43	314.32	68.99	689.86
	Pakistan	273.40	273.40	416.65	416.65
	Papua New Guinea	3.94	39.41	9.10	91.05
	Philippines	125.00	125.00	125.00	125.00
	Singapore	-	-	-	-
	Solomon Islands	23.23	232.26	53.66	536.61
	Sri Lanka	100.00	100.00	250.00	250.00
	Taiwan, ROC	196.32	196.32	196.32	196.32
Tajikistan	58.00	580.00	68.00	680.00	
Thailand	443.18	443.18	612.02	612.02	
Turkmenistan	52.00	520.00	68.00	680.00	
Uzbekistan	39.43	394.28	91.09	910.95	
Vietnam	255.00	286.00	480.00	520.00	
Western Samoa	-	-	-	-	



Region	Country	A320-200 (\$)		B747-400 (\$)	
		per 100km	per 1,000km	per 100km	per 1,000km
Europe	Albania	100.00	100.00	100.00	100.00
	Armenia	41.00	410.00	54.00	540.00
	Austria	68.63	686.28	158.56	1,585.56
	Azerbeidjan	45.00	450.00	70.00	700.00
	Belarus	43.08	430.78	99.53	995.27
	Belgium	94.55	945.48	218.44	2,184.42
	Bosnia and Herzegovina	79.02	790.15	182.55	1,825.55
	Bulgaria	73.19	731.89	169.09	1,690.93
	Croatia	56.55	565.51	130.65	1,306.54
	Cyprus	30.93	309.27	71.45	714.54
	Czech Republic	56.06	560.64	129.53	1,295.29
	Denmark	65.72	657.15	151.83	1,518.28
	Estonia	30.19	301.94	69.76	697.59
	Finland	49.66	496.60	114.73	1,147.34
	France	75.25	752.49	173.85	1,738.54
	FYROM	63.10	631.02	145.79	1,457.89
	Georgia	47.00	470.00	62.00	620.00
	Germany	79.33	793.33	183.29	1,832.88
	Greece	25.16	251.56	58.12	581.20
	Hungary	29.80	297.96	68.84	688.39
	Iceland	47.93	47.93	47.93	47.93
	Ireland	27.87	278.68	64.39	643.86
	Italy	81.61	816.07	188.54	1,885.42
	Latvia	43.13	431.27	99.64	996.39
	Lithuania	66.91	669.10	154.59	1,545.88
	Luxembourg	94.55	945.48	218.44	2,184.42
	Malta	45.84	458.40	105.91	1,059.08
	Moldova	52.31	523.12	120.86	1,208.60
	Monaco	75.25	752.49	173.85	1,738.54
	Netherlands	59.38	593.80	137.19	1,371.90
	Norway	61.12	611.21	141.21	1,412.13
	Poland	79.08	790.76	182.70	1,826.95
	Portugal	51.87	518.66	119.83	1,198.31
Romania	50.33	503.34	116.29	1,162.90	
Russian Federation	53.00	530.00	70.00	700.00	
Slovak Republic	79.44	794.45	183.55	1,835.48	
Slovenia	75.87	758.68	175.28	1,752.84	
Spain	55.90	559.00	129.15	1,291.49	
Sweden	63.20	632.05	146.03	1,460.27	
Switzerland	90.81	908.06	209.80	2,097.96	
Ukraine	65.78	657.79	151.97	1,519.74	
United Kingdom	101.20	1,011.98	233.81	2,338.05	
Yugoslavia	67.54	675.43	156.05	1,560.50	



Region	Country	A320-200 (\$)		B747-400 (\$)	
		per 100km	per 1,000km	per 100km	per 1,000km
Middle East	Bahrain	74.35	74.35	165.21	165.21
	Iran	50.00	300.44	160.37	1,603.70
	Iraq	100.57	100.57	1,035.71	1,035.71
	Jordan	82.85	82.85	510.77	510.77
	Kuwait	-	-	-	-
	Lebanon	-	-	-	-
	Oman	200.00	200.00	325.00	325.00
	Saudia Arabia	21.52	215.21	53.80	538.02
	Syria	27.41	27.41	146.33	146.33
	Turkey	55.27	552.71	127.70	1,276.98
	United Arab Emirates	64.00	64.00	151.00	151.00
	Yemen, Republic of	12.32	12.32	92.09	92.09

*n/a ~ not applicable*

**Note:** *these charges apply to international continental overflight en-route movements.*



## ***APPENDIX 6.9***

### **IMPLEMENTATION DATES OF EFFECTIVE RATES**



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**IMPLEMENTATION DATES OF EFFECTIVE RATES**


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Sources: IATA Airport & en-route aviation charges manual (1999).

ICAO's Manual of airport & air navigation facility tariffs - Doc. 7100 (1998).

<b>Africa</b>	Algeria	01-Jan-97	<b>Americas &amp; Caribbean</b>	Anguilla	n/a
	Angola	01-Jan-95		Antigua	01-Jul-99
	Benin	01-Jan-99		Argentina	22-Jun-98
	Botswana	15-Jul-99		Bahamas	n/a
	Burkina Faso	01-Jan-99		Barbados	01-Jul-99
	Burundi	01-Mar-89		Belize	01-Jul-95
	Cameroon	01-Jan-99		Bolivia	01-Jan-99
	Cape Verde	01-Apr-95		Brazil	01-Jan-96
	Central African Republic	01-Jan-99		British Virgin Islands	n/a
	Chad	01-Jan-99		Canada	01-Mar-98
	Comoros	01-Jan-99		Cayman Islands	n/a
	Congo, PR	01-Jan-99		Chile	01-Jan-88
	Congo, DR	01-Dec-91		Colombia	01-Jan-99
	Cote d'Ivoire	01-Jan-99		Costa Rica	01-Jul-95
	Djibouti	23-May-96		Cuba	01-Jan-99
	Egypt	17-Aug-91		Dominica	01-Jul-99
	Equatorial Guinea	01-Jan-99		Dominican Republic	23-Apr-96
	Eritrea	17-Oct-92		Ecuador	01-Jul-94
	Ethiopia	15-Nov-92		El Salvador	01-Jul-95
	Gabon	01-Jan-99		French Guyana	n/a
	Gambia	n/a		Greenland	01-Jan-99
	Ghana	01-Aug-95		Grenada	01-Jul-99
	Guinea Bissau	n/a		Guadeloupe	01-Jul-99
	Guinea Conakry	01-Jan-98		Guyana	15-Feb-84
	Kenya	01-Jul-98		Guatemala	01-Jul-95
	Lesotho	n/a		Haiti	01-Dec-97
	Liberia	01-Jan-98		Honduras	01-Jul-95
	Libyan Arab Jamahiriya	15-Jul-89		Jamaica	01-Jan-89
	Madagascar	01-Jan-99		Martinique	01-Jul-99
	Malawi	01-Nov-93		Mexico	01-Dec-95
	Mali	01-Jan-99		Montserrat	01-Jul-99
	Mauritania	01-Jan-99		Netherlands Antilles	01-Feb-99
	Mauritius	12-Apr-99		Nicaragua	01-Jul-95
	Morocco	01-Apr-97		Panama	01-Jul-98
Mozambique	01-Jun-98	Paraguay	02-Feb-95		
Namibia	n/a	Peru	01-Sep-95		
Niger	01-Jan-99	Puerto Rico	n/a		
Nigeria	01-Jan-90	St. Kitts & Nevis	01-Jul-99		
Reunion	n/a	St. Lucia	01-Jul-99		
Rwanda	01-Sep-94	St. Maarten	01-Jul-99		
Senegal	01-Jan-99	St. Vincent & Grenadines	01-Jul-99		
Seychelles	01-Feb-95	Surinam	01-Jan-94		
Sierra Leone	01-Jan-98	Trinidad & Tobago	01-Jul-99		
Somalia	31-Aug-86	Turks & Caicos	n/a		
South Africa	01-May-99	Uruguay	01-Aug-93		
Sudan	30-Nov-97	US Virgin Islands	n/a		
Swaziland	n/a	USA	n/a		
Tanzania	08-Dec-94	Venezuela	01-Jan-90		
Togo	01-Jan-99				
Tunisia	01-Apr-95				
Uganda	12-Nov-92				
Zambia	01-Apr-87				
Zimbabwe	22-May-97				



Asia & Pacific	Afghanistan	20-Jan-92
	Australia	01-Jul-96
	Bangladesh	01-Apr-91
	Bhutan	01-Jan-97
	Brunei	n/a
	Bulgaria	01-Jan-99
	Cambodia, Kingdom of	01-Jan-94
	China, PR	01-Oct-95
	Cook Islands	01-Oct-95
	Fiji	01-Jan-97
	Guam	n/a
	Hong Kong	01-Jul-90
	India	01-Feb-99
	Indonesia	01-Apr-92
	Japan	n/a
	Kazakhstan	01-Apr-97
	Korea, Democratic PR of	30-Sep-98
	Korea, Republic of	01-Mar-98
	Kyrgyzstan	01-Nov-96
	Laos	01-Apr-89
	Malaysia	06-Sep-86
	Maldives	07-Jan-93
	Mongolia	01-Oct-98
	Myanmar	01-Dec-98
	Nepal	05-Feb-96
	New Caledonia	n/a
	New Zealand	01-Oct-95
	Pakistan	01-Jul-90
	Papua New Guinea	01-Jul-93
	Philippines	01-Nov-94
	Singapore	n/a
	Solomon Islands	01-Jan-97
Sri Lanka	01-Apr-90	
Taiwan, ROC	01-Jan-96	
Tajikistan	01-Feb-98	
Thailand	01-May-98	
Tonga	n/a	
Turkmenistan	01-Nov-95	
Uzbekistan	01-Jan-99	
Vietnam	01-May-95	
Western Samoa	n/a	

Europe	Albania	19-Oct-90
	Armenia	01-Feb-94
	Austria	01-Jan-99
	Azerbaijan	01-Jan-96
	Belarus	01-Jan-99
	Belgium	01-Jan-99
	Bosnia and Herzegovina	06-Apr-98
	Croatia	01-Jan-99
	Cyprus	01-Jan-99
	Czech Republic	01-Jan-99
	Denmark	01-Jan-99
	Estonia	01-May-99
	Finland	01-Jan-99
	France	01-Jan-99
	FYROM	01-Jan-99
	Georgia	01-Jan-99
	Germany	01-Jan-99
	Greece	01-Jan-99
	Hungary	01-Jan-99
	Iceland	01-Jan-99
	Ireland	01-Jan-99
	Italy	01-Jan-99
	Latvia	01-Jan-99
	Lithuania	01-Jun-95
	Luxembourg	01-Jan-99
	Malta	01-Jan-99
	Moldova	01-Aug-98
	Monaco	01-Jan-99
Netherlands	01-Jan-99	
Norway	01-Jan-99	
Poland	01-Apr-98	
Portugal	01-Jan-99	
Romania	01-Jan-99	
Russian Federation	01-Apr-97	
Slovak Republic	01-Jan-99	
Slovenia	01-Jan-99	
Spain	01-Jan-99	
Sweden	01-Jan-99	
Switzerland	01-Jan-99	
Ukraine	01-Jan-99	
United Kingdom	01-Jan-99	
Yugoslavia	14-Nov-92	



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<b>Middle East</b>	Bahrain	01-Nov-86
	Iran	01-Oct-98
	Iraq	26-Mar-84
	Jordan	16-Nov-98
	Kuwait	n/a
	Lebanon	n/a
	Oman	01-Apr-96
	Saudia Arabia	12-Jan-89
	Syria	01-Jul-88
	Turkey	01-Aug-99
	United Arab Emirates	23-Jul-92
	Yemen, Republic of	22-Nov-84

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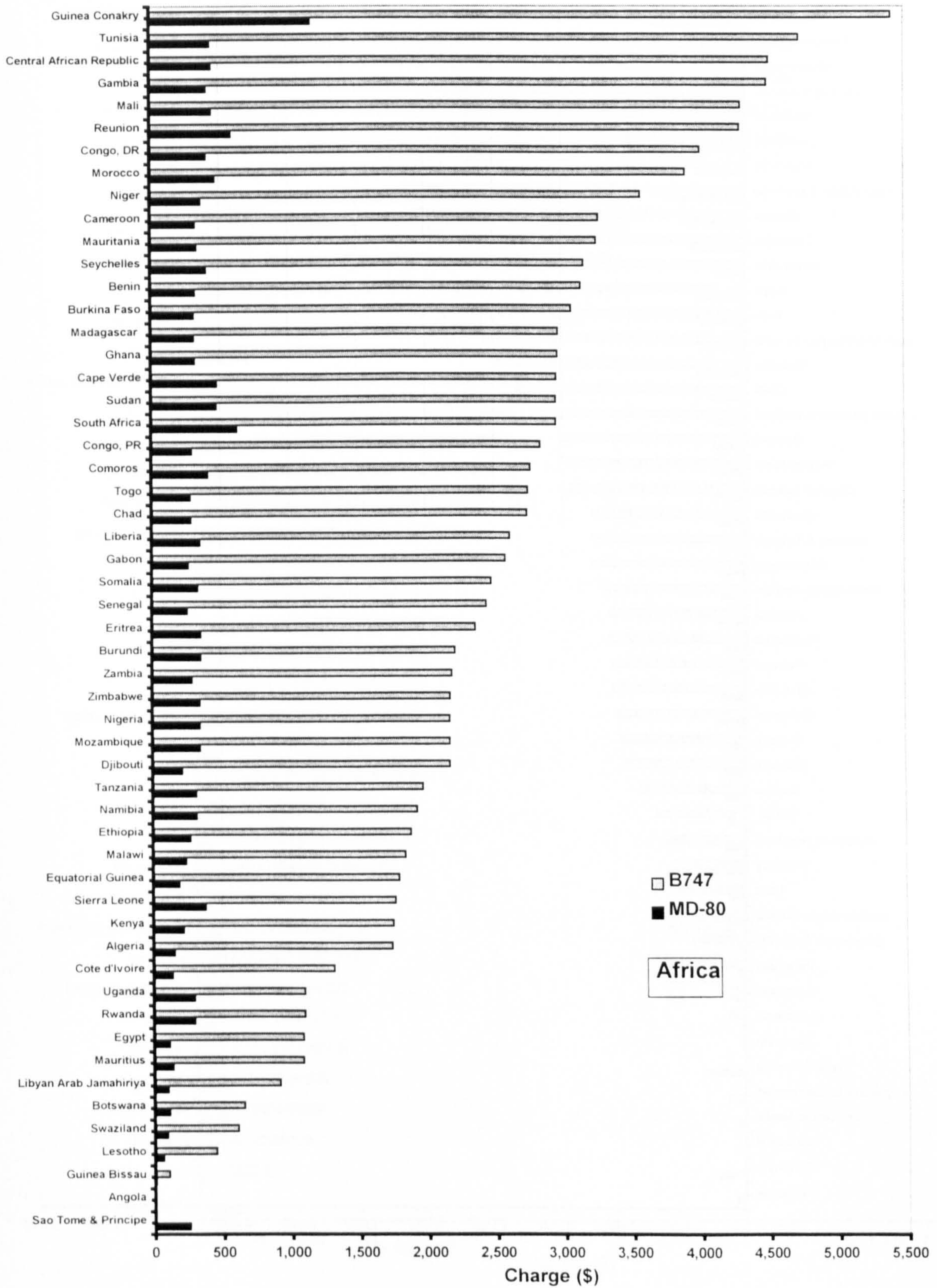
*n/a ~ not applicable*



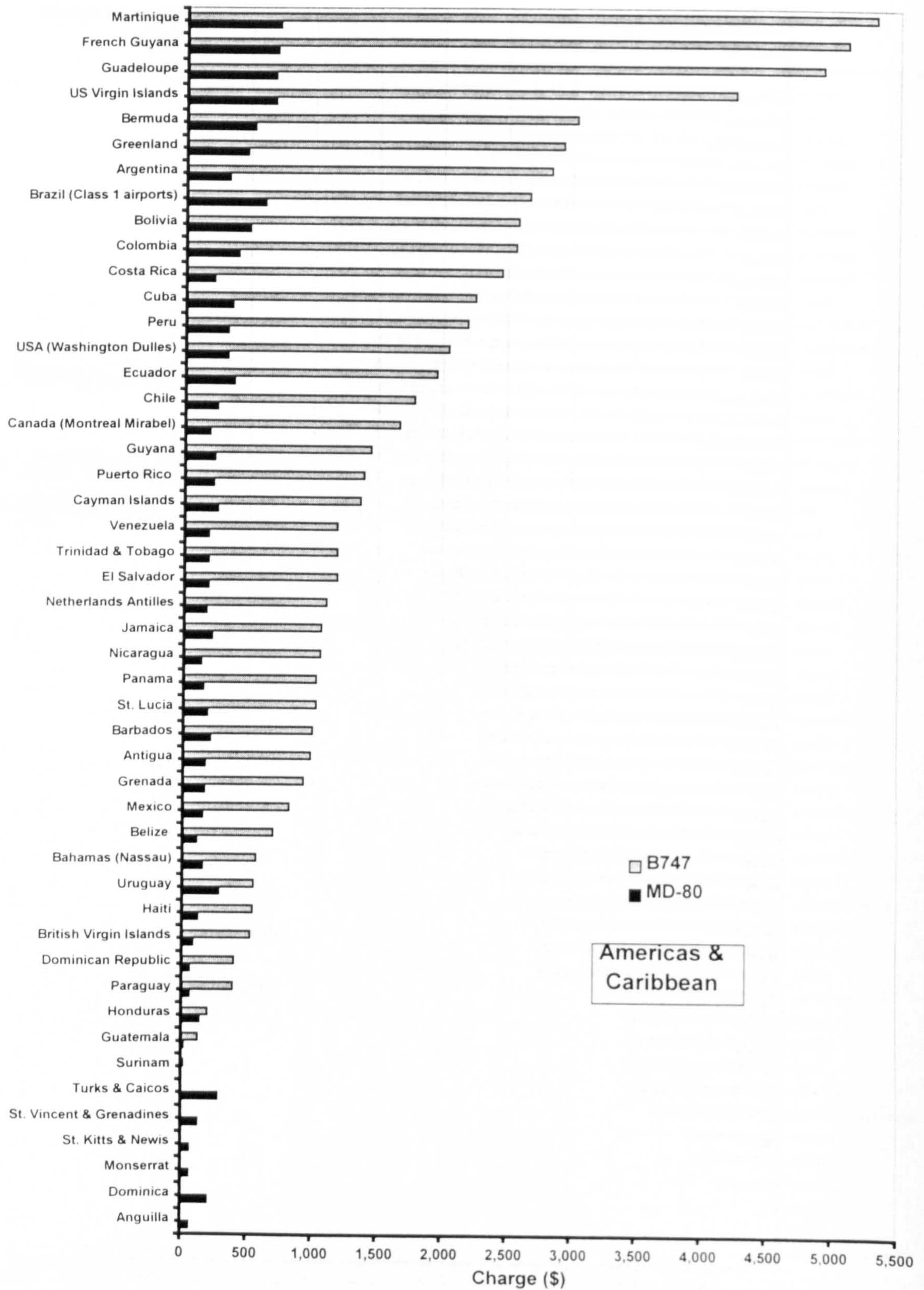
## ***APPENDIX 6.10***

### **LANDING FEE LEVELS (GRAPHICAL RESULTS)**

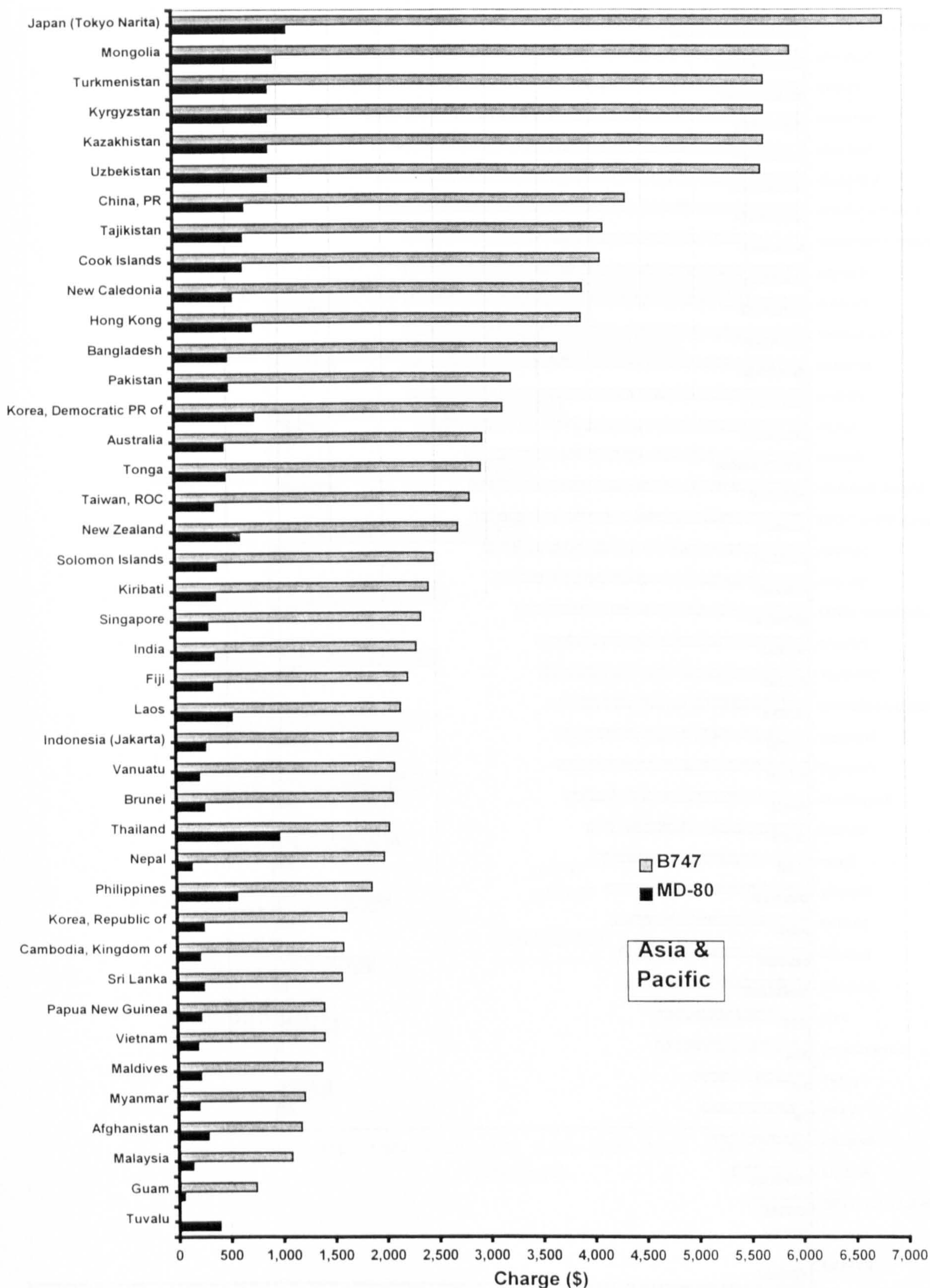




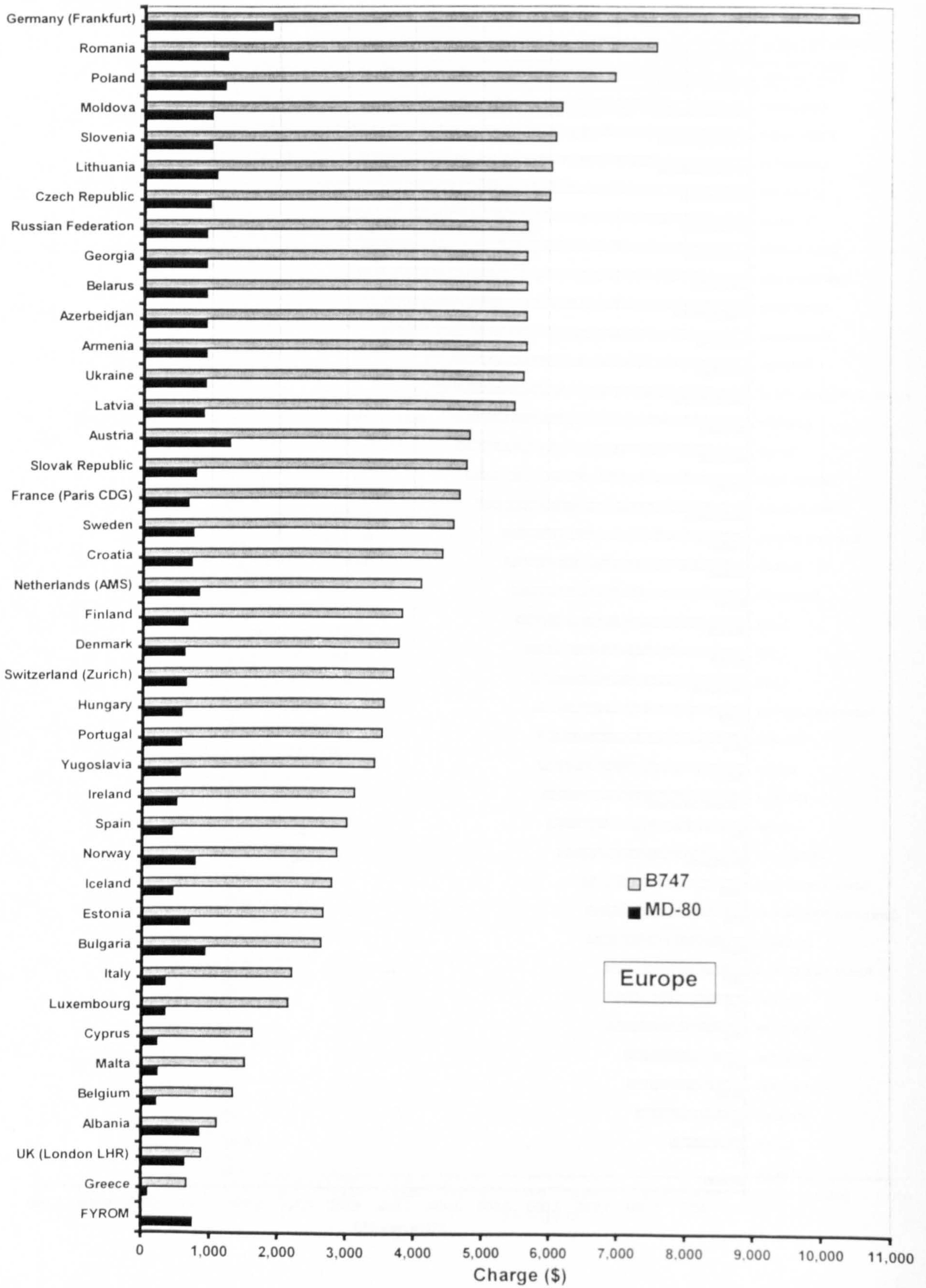




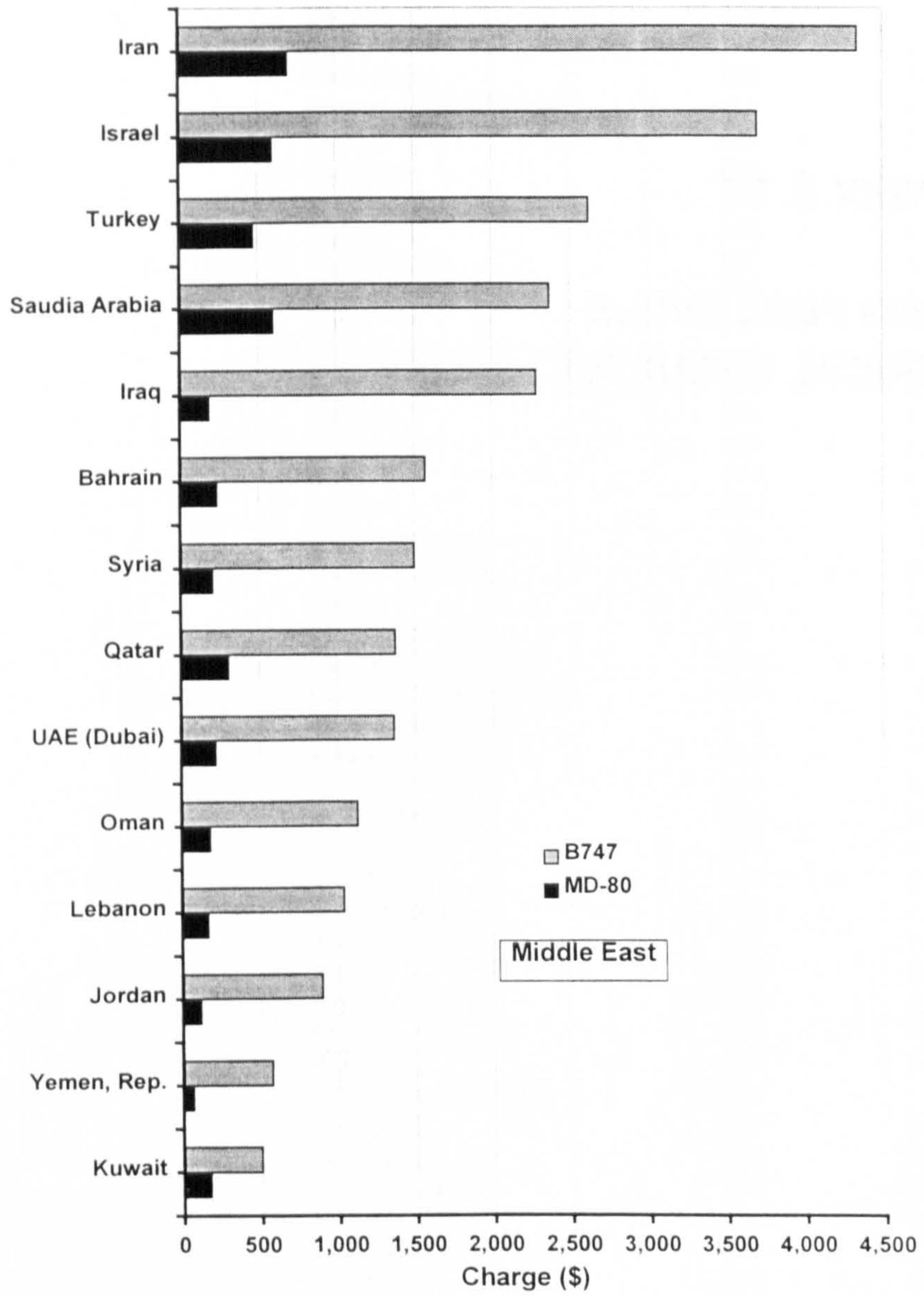














## **APPENDIX 6.11**

### **LANDING FEE LEVELS (NUMERICAL RESULTS)**



## LANDING FEE LEVELS (CURRENCY: \$)

This appendix displays the results from the worldwide survey of landing fees that is conducted as part of the framework strategy.

Region	Country (Airport)	MD-80 (\$)	B747 (\$)
Africa	Algeria	156	1,743
	Angola	1	1
	Benin	327	3,145
	Botswana	110	653
	Burkina Faso	317	3,074
	Burundi	356	2,210
	Cameroon	330	3,276
	Cape Verde	480	2,963
	Central African Republic	450	4,518
	Chad	287	2,746
	Comoros	414	2,771
	Congo, DR	408	4,016
	Congo, PR	296	2,846
	Cote d'Ivoire	137	1,315
	Djibouti	219	2,170
	Egypt	115	1,088
	Equatorial Guinea	191	1,794
	Eritrea	355	2,363
	Ethiopia	276	1,882
	Gabon	268	2,584
	Gambia	414	4,503
	Ghana	322	2,972
	Guinea Bissau	10	103
	Guinea Conakry	1,173	5,411
	Kenya	223	1,750
	Lesotho	64	449
	Liberia	354	2,619
	Libyan Arab Jamahiriya	100	915
	Madagascar	314	2,978
	Malawi	243	1,842
	Mali	449	4,311
	Mauritania	338	3,258
	Mauritius	137	1,086
	Morocco	473	3,909
	Mozambique	349	2,170
	Namibia	323	1,928
	Niger	370	3,581
	Nigeria	349	2,170
	Reunion	595	4,306
	Rwanda	300	1,100
	Sao Tome & Principe	254	
	Senegal	257	2,444
	Seychelles	405	3,165
	Sierra Leone	383	1,770
	Somalia	335	2,480
	South Africa	626	2,959
	Sudan	476	2,960
Swaziland	94	606	
Tanzania	318	1,973	
Togo	284	2,753	
Tunisia	441	4,739	
Uganda	300	1,100	
Zambia	293	2,189	
Zimbabwe	350	2,174	



Region	Country (Airport)	MD-80 (\$)		B747 (\$)	
<b>Americas &amp; Caribbean</b>	Anguilla	66		n/a	
	Antigua	174	1	984	1
	Argentina	335	2	2,837	2
	Bahamas (Nassau)	159		568	
	Barbados	210		997	
	Belize	112		696	
	Bermuda	527	2	3,032	2
	Bolivia	493		2,581	
	Brazil (Class 1 airports)	614	2	2,670	2
	British Virgin Islands	87		525	
	Canada (Montreal Mirabel)	193		1,665	
	Cayman Islands	257	2	1,362	2
	Chile	251		1,780	
	Colombia	407		2,565	
	Costa Rica	222	2	2,454	2
	Cuba	362		2,249	
	Dominica	207		n/a	
	Dominican Republic	65		403	
	Ecuador	382		1,955	
	El Salvador	191		1,184	
	French Guyana	702	2	5,107	2
	Greenland	475		2,930	
	Grenada	169		931	
	Guadeloupe	687	2	4,921	2
	Guatemala	21		126	
	Guyana	232		1,444	
	Haiti	122	2	544	2
	Honduras	140		200	
	Jamaica	217	2,5	1,064	2,5
	Martinique	723	2	5,319	2
	Mexico	158	2	821	2
	Montserrat	65		n/a	
	Netherlands Antilles	177		1,102	
	Nicaragua	137		1,056	
Panama	156		1,026		
Paraguay	64		395		
Peru	327		2,190		
Puerto Rico	224		1,392		
St. Kitts & Newis	66		n/a		
St. Lucia	187		1,025		
St. Vincent & Grenadines	130		n/a		
Surinam	5		17		
Trinidad & Tobago	191		1,184		
Turks & Caicos	280		n/a		
Uruguay	286		550		
US Virgin Islands	685		4,254		
USA (Washington Dulles)	329		2,045		
Venezuela	191		1,184		



Region	Country (Airport)	MD-80 (\$)		B747 (\$)	
Asia & Pacific	Afghanistan	286		1,176	
	Australia	477	1,2	2,965	1,2
	Bangladesh	516	1	3,693	1
	Brunei	273		2,088	
	Cambodia, Kingdom of	221		1,597	
	China, PR	680		4,343	
	Cook Islands	660		4,104	
	Fiji	359		2,233	
	Guam	54		740	
	Hong Kong	756		3,917	
	India	377	2	2,315	2
	Indonesia (Jakarta)	286		2,134	
	Japan (Tokyo Narita)	1,096		6,811	
	Kazakhstan	912	1,2	5,668	1,2
	Kiribati	393		2,441	
	Korea, Democratic PR of	770	1	3,158	1
	Korea, Republic of	262		1,628	
	Kyrgyzstan	912	1,2	5,668	1,2
	Laos	544	2	2,163	2
	Malaysia	135		1,085	
	Maldives	222		1,381	
	Mongolia	960		5,925	
	Myanmar	203		1,215	
	Nepal	148		1,997	
	New Caledonia	565	2	3,929	2
	New Zealand	625	2	2,727	2
	Pakistan	522		3,244	
	Papua New Guinea	226	1,2	1,406	1,2
	Philippines	584	2	1,874	2
	Singapore	317		2,366	
	Solomon Islands	400		2,487	
	Sri Lanka	254		1,578	
	Taiwan, ROC	381		2,841	
Tajikistan	665	1	4,129	1	
Thailand	988		2,045		
Tonga	490		2,948		
Turkmenistan	912	1,2	5,668	1,2	
Tuvalu	393				
Uzbekistan	908	1	5,643		
Vanuatu	225		2,101		
Vietnam	195		1,405		



Region	Country (Airport)	MD-80 (\$)		B747 (\$)	
Europe	Albania	850		1,100	
	Armenia	912	1.2	5,668	1.2
	Austria	1,261	2	4,822	2
	Azerbaijan	912	1.2	5,668	1.2
	Belarus	912	1.2	5,668	1.2
	Belgium	216		1,341	
	Bulgaria	918		2,628	
	Croatia	711		4,420	
	Cyprus	229		1,619	
	Czech Republic	965	2	5,997	2
	Denmark	613	2	3,771	2
	Estonia	694		2,655	
	Finland	649	2	3,820	2
	France (Paris CDG)	658	2	4,674	2
	FYROM	748	2	n/a	
	Georgia	912	1.2	5,668	1.2
	Germany (Frankfurt)	1,878	4	10,514	4
	Greece	96		664	
	Hungary	572		3,551	
	Iceland	448		2,782	
	Ireland	502	2	3,117	2
	Italy	341	2	2,197	2
	Latvia	883		5,485	
	Lithuania	1,060	1.2	6,022	1.2
	Luxembourg	345		2,144	
	Malta	232		1,514	
	Moldova	993	1.2	6,174	1.2
	Netherlands (Amsterdam)	820	2	4,104	2
	Norway	773		2,860	
	Poland	1,181	2	6,961	2
	Portugal	567	2	3,522	2
	Romania	1,214	2	7,571	2
Russian Federation	912	1.2	5,668	1.2	
Slovak Republic	768	2	4,775	2	
Slovenia	980		6,088		
Spain	436		3,006		
Sweden	735	2	4,582	2	
Switzerland (Zurich)	634	2	3,694	2	
Ukraine	905	2	5,623	2	
United Kingdom (London LHR)	632	2	881	2	
Yugoslavia	553		3,414		



Region	Country (Airport)	MD-80 (\$)	B747 (\$)
Middle East	Bahrain	236	1,574
	Iran	699	4,341
	Iraq	187	2,287
	Israel	596	3,705
	Jordan	117	900
	Kuwait	176	501
	Lebanon	167	1,039
	Oman	182	1,129
	Qatar	302	1,374
	Saudia Arabia	603	2,372
	Syria	206	1,500
	Turkey	473	2,625
	United Arab Emirates (Dubai)	220	1,365
Yemen, Republic of	66	573	

## Notes.

- 1 - includes security charge
- 2 - includes separate approach and aerodrome control charge.
- 3 - includes charge for use of transfer vehicle.
- 4 - includes airport infrastructure use charge.
- 5 - includes separate communications charge
- n/a - not applicable



## **APPENDIX 7.1**

### **US FAA AVIATION SYSTEM INDICATORS**



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## US FAA AVIATION SYSTEM INDICATORS

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*Source: FAA & US DoT – Aviation System Indicators (1998 Annual Report).*

The FAA Aviation System Indicators are classified as:

### Accident Indicators

- Large air carrier accident rates;
- Commuter air carrier accident rates;
- Air taxi accident rates;
- General aviation accident rates;
- Rotorcraft accident rates;
- Midair collision accident rates.

### Efficiency Measures

- Facility/service reliability;
- Facility/service operational availability;
- Delay rates;
- Delays due to volume rates.

### Compliance Measures

- Aircraft certification system evaluation programme;
- Stage 3 aircraft ratio;
- Airport certification indicator rates.

### Inspector Activity Measures

- National inspector activity rates.

### Incident Indicators

- Large air carrier aircraft incident rates;
- Commuter air carrier aircraft incident rates;
- Air taxi aircraft incident rates;
- General aviation aircraft incident rates;
- Rotorcraft aircraft incident rates;
- Number of midair collisions.
- Air carrier near midair collision rates;
- Pilot deviation rates;
- Operational error rates.
- Runway incursion rates;
- Number of vehicle/pedestrian deviations.

### Note.

*Rates are simple numerical averages or are calculated per flight hour and per departure.*



## ***APPENDIX 7.2***

### **US FAA AVIATION ENVIRONMENTAL INDICATORS**



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## US FAA AVIATION ENVIRONMENTAL INDICATORS

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*Source: FAA & US DoT – Aviation System Indicators (1998 Annual Report).*

The FAA Aviation Environmental Indicators are:

- Forecast of annual gross domestic product (GDP) and growth rate;
- Forecast of annual enplanements and growth rate;
- Total facility activity;
- Forecast of annual IFR aircraft handled at en-route centres and growth rate;
- Forecast of general aviation aircraft flight hours;
- Number of certificated airports;
- Number of certificated airmen;
- Number of certificated holders;
- Number of registered aircraft;
- Total system flight hours (broken down into large air carriers, commuters, air taxis and general aviation);
- Number of production approval holders;
- Operating profit or loss for all Form 41 reporting carriers.



## **APPENDIX 7.3**

### **US FAA INTERNATIONAL AVIATION SAFETY ASSESSMENT RESULTS**







## **APPENDIX 7.4**

### **IFALPA DEFICIENCY SHEET LAYOUT**



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## IFALPA DEFICIENCY SHEET LAYOUT

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**Source: International Federation of Airline Pilot Associations (IFALPA).**

- |                                  |   |
|----------------------------------|---|
| <b>Airports (AGA)</b>            | <ul style="list-style-type: none"> <li>(1) Runways</li> <li>(2) Approach Lighting</li> <li>(3) VASIs</li> <li>(4) Runway Lighting</li> <li>(5) Taxways</li> <li>(6) Parking Areas</li> <li>(7) Markings</li> <li>(8) Fire &amp; Safety Equipment/Personnel Standards</li> <li>(9) Primary Power Supply</li> <li>(10) Standby Power Supply</li> <li>(11) Snow Removal</li> </ul> |
| <b>Charts (RAC)</b>              | <ul style="list-style-type: none"> <li>(1) Air Traffic Clearance</li> <li>(2) Air Traffic Services</li> <li>(3) Arrival and Departure Procedures (SIDs and STARs)</li> </ul>  |
| <b>Search &amp; Rescue (SAR)</b> | <ul style="list-style-type: none"> <li>(1) SAR Facilities</li> </ul>  |
| <b>Communications (COM)</b>      | <ul style="list-style-type: none"> <li>(1) VHF Tower</li> <li>(2) VHF Approach</li> <li>(3) VHF</li> <li>(4) HF</li> <li>(5) SELCAL</li> <li>(6) ATIS (COM Aspects)</li> <li>(7) AIS</li> <li>(8) VOLMET</li> </ul>   |
| <b>Navigation (NAVAIDS)</b>      | <ul style="list-style-type: none"> <li>(1) ILS</li> <li>(2) VOR</li> <li>(3) DME</li> <li>(4) Radar (Primary and Secondary)</li> <li>(5) NDB and LOC</li> <li>(6) Other Aids</li> </ul>   |
| <b>Meteorology (MET)</b>         | <ul style="list-style-type: none"> <li>(1) Forecasts</li> <li>(2) Briefing</li> <li>(3) Observations</li> <li>(4) SIGMET</li> <li>(5) ATIS (Content)</li> <li>(6) VOLMET (Content)</li> </ul>   |



## **APPENDIX 7.5**

### **IFALPA INSTALLATION PRIORITIES**



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## IFALPA INSTALLATION PRIORITIES

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**Source: International Federation of Airline Pilot Associations (IFALPA).**

### Airports (AGA)

- a) **MARKINGS**  
**First Priority.** Runway threshold, runway centre line, taxiway centre line, touchdown zone, apron guide lines, side stripe (when runway width is 150 feet including shoulders).  
**Second Priority.** Runway designator, side stripe (when runway width is 200 feet including shoulders).
- b) **LIGHTING**  
**First Priority.** Aerodrome beacon, obstruction lights, runway, taxiway, threshold, VASIS.  
**Second Priority.** Simply approach, precision approach, strobe, secondary power supply.
- c) **SAFETY EQUIPMENT, ETC.**  
**First Priority.** Major fire fighting vehicles, mobile rescue vehicles, launches or amphibious vehicles (aerodrome adjacent to water or swamps).  
**Second Priority.** First aid at aerodromes.

### Charts (RAC)

#### AIR TRAFFIC CONTROL

- First Priority.** Aerodrome, approach
- Second Priority.** Surface movement, ATS.

### Search & Rescue (SAR)

- First Priority.** Crash position indicators for low visibility conditions.

### Communications (COM)

- First Priority.** Aerodrome VHF, approach VHF.
- Second Priority.** Surface movement VHF.

### Navigation (NAVAIDS)

- a) **AERODROME NAVIGATIONAL FACILITIES**  
**First Priority.** VOR/DME, ILS and associated locators.  
**Second Priority.** NDBs, precision approach radar
- b) **EN ROUTE NAVIGATIONAL FACILITIES**  
**First Priority.** VOR/DME (R-NAV update).  
**Second Priority.** NDBs (High powered)  
**Third Priority.** Surveillance Radar, area coverage system.

### Meteorology (MET)

- First Priority.** ATIS on discrete VHF frequency.
- Second Priority.** VOLMET broadcast on HF (preferable compatible SSB/DBS).
- Third Priority.** Closed circuit TV



## **APPENDIX 7.6**

### **PRC'S SUGGESTED KEY PERFORMANCE INDICATORS (KPIs)**



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## PRC'S SUGGESTED KEY PERFORMANCE INDICATORS (KPIs)

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**Source: Eurocontrol's Performance Review Commission (PRC).**

The following are the PRC key performance indicators (KPIs), grouped by key performance area (KPA):

### Safety

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□ **Conformance of air transport to specified safety targets =**

- ▶ *total number of accidents;*
- ▶ *total number of serious incidents;*
- ▶ *total number of other incidents;*
- ▶ *aircraft operators' perception of ATM safety;*
- ▶ *ATS providers' perception of ATM safety.*

### Delay

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□ **Departure delay =**

- ▶ *total minutes of departure delay / total number of flights;*
- ▶ *total number of delayed flights / total number of flights;*
- ▶ *total minutes of departure delay / number of delayed flights.*

□ **Flight delay =**

- ▶ *total minutes of gate-to-gate delay / total number of flights.*

□ **Terminal control area (TMA) delay =**

- ▶ *total minutes of TMA delay / total number of flights.*

□ **Arrival delay =**

- ▶ *total minutes of arrival delay / total number of flights.*

□ **Causes of delay =**

- ▶ *proportion of total delay arising from each identified cause.*

□ **Relationship between delay, traffic volume and capacity =**

- ▶ *weekly minutes of ATFM delay by volume of traffic.*

□ **Capacity management =**

- ▶ *capacity index;*
- ▶ *actual capacity variation / target capacity variation;*
- ▶ *actual capacity variation / actual traffic variation*



### **Cost effectiveness**

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- Unit cost of ATM services =**
  - *total cost per movement;*
  - *total cost per kilometre flown.*
  
- Productivity measures =**
  - *number of movements / number of controllers employed.*
  - *total flight hours handled / total hours worked by controllers;*
  - *value of fixed assets / number of movements;*
  - *value of fixed assets / total kilometres flown.*
  - *sector capacity used / declared sector capacity*
  
- Cost transparency (no KPI(s) yet).**
  
- Investment plans (no KPI(s) yet).**

### **Predictability**

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- Anticipated delay =**
  - *difference between scheduled and optimum gate-to-gate time*
  
- Variability in arrival delay =**
  - *standard deviation of arrival delay.*
  - *standard deviation of each delay component.*
  - *causes of delay in each delay component*
  
- Taxi time variability =**
  - *taxi-in variation time;*
  - *taxi-out variation time*

### **Access**

---

- Availability of airspace =**
  - *number of aircraft operator preferred routes accepted / flight plans submitted*
  
- Availability of airport capacity =**
  - *aircraft movements at peak hours / declared capacity.*
  - *declared capacity / unconstrained runway capacity*
  - *peak hour demand realised / scheduled peak hour capacity*
  
- Causes of preferred routes being unavailable (no KPI(s) yet)**
  
- Availability of airspace for military purposes =**
  - *% of time a given restricted airspace is not available for planned mission*
  - *% of time a given restricted airspace is reserved and not used*



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**Flexibility**


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- Freedom to change departure time or planned route at short notice =
  - ▶ *number of regulated flights / number of actual flights.*
- Freedom to exchange slots =
  - ▶ *number of slots exchanged / number of slot exchange requests.*
- Freedom to identify re-routes *{no KPI(s) yet}*.
- Freedom to alter route or speed during flight *{no KPI(s) yet}*.

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**Flight efficiency**


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- Efficiency of the route structure =
  - ▶ *1 - (preferred route length - optimal route length) / optimal route length.*
- Efficiency of the actual route flown =
  - ▶ *1 - (actual route length - planned route length) / planned route length.*

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**Availability**


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- Time lost due to any component of the ATM system being unavailable =
  - ▶ *total time affected by any form of industrial action;*
  - ▶ *minutes of unplanned downtime of all critical systems.*
- Disruption caused by unavailability =
  - ▶ *number of flights delayed, re-routed, cancelled or diverted as a result of industrial action / number of planned flights;*
  - ▶ *number of flights delayed, re-routed, cancelled or diverted as a result of downtime of all critical systems / number of planned flights.*

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**Environment**


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- Effects of emissions =
  - ▶ *estimated fuel consumption / optimum fuel consumption;*
  - ▶ *taxi time / optimum taxi time.*

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**Equity**


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- Equity of treatment of all airspace users within and between all classes of user =
    - ▶ *% of aircraft operators by class who consider that equity is being achieved*
-



## **APPENDIX 7.7**

### **PRC TOTAL COSTS OF EN-ROUTE SERVICES**



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**PRC TOTAL COSTS OF EN-ROUTE SERVICES (CURRENCY: \$'000)**


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*Source: First Performance Review Report (1998 data), Eurocontrol's PRC, 1999.*

	National costs	Eurocontrol costs		Total costs
		General	Maastricht	
France	736,376	51,746	-	788,122
United Kingdom	601,637	34,913	-	636,550
Germany	501,117	50,492	31,059	582,667
Italy	373,460	28,733	-	402,193
Spain (Continental)	246,492	17,259	-	263,751
Turkey	142,138	5,766	-	147,904
Austria	129,909	8,385	-	138,294
Belgium - Luxembourg	80,308	8,553	28,100	116,962
Sweden	99,997	6,514	-	106,510
Netherlands	65,959	6,647	14,790	87,396
Switzerland	79,375	7,456	-	86,831
Bulgaria	74,759	1,637	-	76,396
Greece	68,257	3,946	-	72,203
Portugal	65,467	3,257	-	68,724
Romania	58,319	3,035	-	61,354
Denmark	56,970	3,936	-	60,906
Spain (Canarias)	54,458	3,535	-	57,993
Norway	52,244	3,551	-	55,795
Ireland	50,839	2,981	-	53,820
Hungary	36,404	1,761	-	38,166
Czech Republic	22,024	1,529	-	23,553
Cyprus	19,812	948	-	20,760
Slovak Republic	18,402	876	-	19,277
Croatia	7,945	511	-	8,456
Slovenia	6,841	522	-	7,363
Malta	6,682	391	-	7,073
<b>Total</b>	<b>3,656,192</b>	<b>258,878</b>	<b>73,949</b>	<b>3,989,019</b>



## **APPENDIX 7.8**

### **PRC NATIONAL COST BREAKDOWN BY TYPE OF EXPENDITURE**



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**PRC NATIONAL COST BREAKDOWN BY EXPENDITURE TYPE (CURRENCY: \$'000)**


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*Source: First Performance Review Report (1998 data), Eurocontrol's PRC, 1999.*

	Staff costs	Operating costs	Depreciation costs	Interest costs	Other costs
Austria	81,303	13,354	12,909	4,854	2,144
Belgium - Luxembourg	57,995	7,641	11,027	5,637	24
Bulgaria	33,516	23,083	5,828	4,184	-
Croatia	3,477	1,571	1,897	1,001	-
Cyprus	7,969	7,493	2,448	1,901	-
Czech Republic	7,766	2,209	3,922	3,181	4,667
Denmark	31,593	15,648	5,096	2,157	-
France	403,954	110,056	146,949	32,986	28,920
Germany	285,909	98,104	79,614	27,086	-
Greece	50,236	6,115	6,182	5,578	-
Hungary	12,934	14,833	3,750	4,887	-
Ireland	22,474	20,903	5,423	2,039	-
Italy	177,465	156,444	32,936	5,214	-
Malta	4,427	829	1,123	580	-
Netherlands	32,776	8,396	9,721	4,026	10,061
Norway	27,866	11,430	8,845	7,471	-
Portugal	46,176	8,268	6,447	4,575	-
Romania	25,800	18,210	10,508	10,311	217
Slovak Republic	7,454	4,197	6,720	32	-
Slovenia	2,091	1,312	2,474	949	533
Spain (Canarias)	28,017	10,455	11,155	4,063	-
Spain (Continental)	135,715	45,032	50,220	17,078	-
Sweden	61,402	27,765	4,344	4,182	4,115
Switzerland	45,624	19,097	11,113	3,540	-
Turkey	36,982	41,709	45,347	26,965	-
United Kingdom	253,998	244,374	64,575	79,410	-
<b>Total</b>	<b>1,884,920</b>	<b>918,536</b>	<b>550,572</b>	<b>263,889</b>	<b>50,681</b>

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## ***APPENDIX 7.9***

### **PRC UNIT COST RESULTS**



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**PRC UNIT COST RESULTS (CURRENCY: \$)**


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*Source: First Performance Review Report (1998 data), Eurocontrol's PRC, 1999.*

	<b>Cost per flight</b>	<b>Cost per Kilometre</b>
Austria	151	0.81
Belgium - Luxembourg	124	0.83
Bulgaria	230	0.81
Croatia	64	0.41
Cyprus	110	0.36
Czech Republic	87	0.41
Denmark	99	0.56
France	313	0.69
Germany	224	0.73
Greece	184	0.35
Hungary	87	0.35
Ireland	124	0.43
Italy	317	0.75
Malta	142	0.54
Netherlands	94	0.58
Norway	121	0.50
Portugal	237	0.55
Romania	263	0.58
Slovak Republic	128	0.77
Slovenia	49	0.61
Spain (Canarias)	236	0.68
Spain (Continental)	237	0.54
Sweden	167	0.52
Switzerland	84	0.75
Turkey	321	0.61
United Kingdom	345	1.10

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## ***APPENDIX 7.10***

### **PRC STAFF PRODUCTIVITY RESULTS**



## PRC STAFF PRODUCTIVITY RESULTS

Source: First Performance Review Report (1998 data), Eurocontrol's PRC, 1999.

	Km (million) per controller	Flights ('000) per controller
Austria	1.45	7.75
Belgium - Luxembourg	n/a	n/a
Bulgaria	0.20	0.71
Croatia	n/a	n/a
Cyprus	n/a	n/a
Czech Republic	0.53	2.55
Denmark	0.58	3.27
France	n/a	n/a
Germany	0.72	2.36
Greece	n/a	n/a
Hungary	1.04	4.19
Ireland	0.55	1.92
Italy	n/a	n/a
Malta	n/a	n/a
Netherlands	n/a	n/a
Norway	n/a	n/a
Portugal	1.58	3.63
Romania	0.29	0.64
Slovak Republic	0.37	2.25
Slovenia	0.19	2.31
Spain (Canarias)	n/a	n/a
Spain (Continental)	n/a	n/a
Sweden	0.46	1.43
Switzerland	0.40	3.56
Turkey	0.83	1.58
United Kingdom	n/a	n/a



## ***APPENDIX 7.11***

### **ICAO EN-ROUTE FINANCIAL AND TRAFFIC DATA**



## ICAO EN-ROUTE FINANCIAL AND TRAFFIC DATA (CURRENCY: \$'000)

Source: ICAO Digest of Statistics (Airports & route facilities' 1997 financial & traffic data).

		En-route revenues	Total	En-route expenses Ops. & Main.	Admin.	Total flights
Africa	Mauritius	1,234	2,319	2,319	n/a	14,682
	Seychelles	3,953	1,404	858	243	32,588
		En-route revenues	Total	En-route expenses Ops. & Main.	Admin.	Total flights
Americas & Caribbean	Argentina	25,354	98,482	60,451	27,123	210,844
	Canada	526,862	517,765	396,690	n/a	n/a
	COCESNA	12,718	9,565	5,740	2,668	75,985
	Ecuador	24,428	n/a	n/a	n/a	69,618
	Mexico	111,562	111,562	64,890	9,164	1,250,063
	Paraguay	15,718	14,739	11,892	1,617	37,876
		En-route revenues	Total	En-route expenses Ops. & Main.	Admin.	Total flights
Asia & Pacific	Bangladesh	26,854	13,780	2,697	7,786	62,701
	Fiji	6,343	5,383	4,362	502	100,840
	Sri Lanka	1,213	662	544	86	42,673
	Thailand	60,036	66,214	40,005	20,337	281,383
		En-route revenues	Total	En-route expenses Ops. & Main.	Admin.	Total flights
Europe	Austria	131,825	115,159	n/a	n/a	662,868
	Czech Republic	22,056	22,828	9,762	2,344	209,024
	FYROM	8,365	6,655	3,165	182	89,793
	Georgia	4,891	2,248	1,819	342	38,119
	Germany	587,502	550,852	98,752	339,165	1,985,918
	Italy	382,304	348,049	56,117	27,706	906,928
	Lithuania	8,728	8,008	3,139	1,323	58,679
	Malta	7,555	7,018	n/a	n/a	38,740
	Slovak Republic	19,005	18,146	10,133	4,569	116,754
	Spain	310,685	319,792	n/a	n/a	1,184,651
	Sweden	97,988	106,863	80,725	11,063	557,496
United Kingdom	643,063	628,860	n/a	n/a	1,596,289	
		En-route revenues	Total	En-route expenses Ops. & Main.	Admin.	Total flights
Middle East	Turkey	136,708	29,921	22,741	1,290	n/a

n/a ~ not available



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## REFERENCES

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The following industry periodicals, Internet sites or published books, papers and reports are referred to in this dissertation<sup>1517</sup>:

### Industry periodicals

Many articles, whose details are given as footnotes in the main text, are sourced from:

- Aerogram;
- Aeronautical Satellite News;
- Aerospace International;
- Air Navigation International;
- air traffic management;
- Air Transport Action Group News;
- Air Transport Intelligence;
- Air Transport World;
- Airbus FAST;
- Aircraft Engineering and Aerospace Technology;
- Aircraft Technology Engineering & Maintenance;
- Airline Business;
- Airports International;
- ATC e-zine;
- ATC Market Report;
- ATC Network;
- Aviation Week & Space Technology;
- Boeing Airliner;
- CANSO news;
- Civil Aviation Training;
- CNS Outlook;
- Commuter World;
- era regional report;
- Flight International;
- Global Airspace;
- IATA FANS FACTS;
- ICAO Bulletin;
- ICAO Journal;
- inflight;

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<sup>1517</sup> In addition, it should be noted that a multitude of CNS/ATM product brochures were sourced for the purpose of this thesis.

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- Interavia;
- Jane's Airport Review;
- Journal of ATC;
- Navigation News;
- Orient Aviation;
- Regional Airline World;
- Satnav news;
- Via Inmarsat.

### Internet sites

The following Internet sites were referred to, among others, during the course of this research:

- <http://ffp1.faa.gov>
- <http://mx.iki.rssi.ru/sfcsic/english.html>
- <http://www.aci-europe.org>
- <http://www.aea.be>
- <http://www.airbus.com>
- <http://www.airfax2000.com>
- <http://www.airsysatm.thomson-csf.com>
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- <http://www.asy.faa.gov>
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- <http://www.icao.org>
- <http://www.ifatca.org>
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- <http://www.smithsind-aerospace.com>
- <http://www.srg.caa.co.uk>
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- A forum for action. *Integrating Global Air Traffic Management*, ISC & ICAO, 1998.
- A gate-to-gate, seamless European Air Traffic Management System for the Years 2000+. *International Airport Review*, Winter 1999.
- A Guide to CNS/ATM*, Philip Butterworth-Hayes, February 1999.
- A guide to CNS/ATM: equipment, programmes & markets.* Jane's Information Group, February 1999.
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