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SESAR'S ATM TARGET CONCEPT: KEYS TO SUCCESS

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Introduction

There is often a right time to do things. In the 1570s, Martin Frobisher abandoned his efforts to find the Northwest Passage, but the attempt might well have been successful today. The nature of a problem and the technical tools available to tackle it can change dramatically over time. Is this the right time for radical changes to Air Traffic Management (ATM)? What will be the keys to success?

An earlier article in Navigation News (Jan/Feb 2007) examined the USA's Air Traffic Management (ATM) programme NGATS, now renamed 'NextGen'. There has recently been important progress in the European analogue to NextGen: SESAR. SESAR is the European ATM modernization programme, focused on 2020. Its first phase is the Definition Phase, which is co-funded by Eurocontrol and the European Commission (Trans European networks). The SESAR Consortium is carrying out the Definition Phase study. The Consortium has about 30 members (eg Air France, BAE Systems) and about 20 associated partners (eg Boeing, Dassault, and European ATM research centres).

A major 'SESAR Deliverable' was the 162-page 'ATM Target Concept', issued in late September 2007. This briefing paper illustrates some of the important features of the Concept, especially where its 'magic' might come from to deliver large improvements in performance, and tries to identify key issues in the path to successful implementation. The report's authors make it very clear that it is a vision not a plan, and certainly not a final blueprint of the future system.

SESAR Task and the Concept's Main Features

What are the goals for SESAR? There are four 'SESAR Performance Objectives' (and many other performance criteria):

- Designed for more capacity: +73% in 2020
  (compared to the 2005 situation)
  … and enabling 3 times in the longer term;
- Improved safety: 3 times for 2020
  … 10 times in the longer term;
- 10% less environmental impact/flight due
  to ATM;
- 50% less [direct] ATM cost/flight.

These are demanding goals. Presentationally, it would be better if the safety goal is first in the list: ATM is foremost about safety – in an imaginary world in which colliding aircraft suffered no damage whatsoever there would be little need for ATM.

The Target Concept is built on aircraft flying, with high precision, 4-dimensional (4D, ie position and time) Trajectories. The SESAR 2020 ingredients include:

- Business Trajectory at the System Core
- Trajectory Management Focus
- Collaborative Planning
- Integrated Airport Operations
- New Separation Modes
- System Wide Information Management (SWIM)
- Humans Central as Managers and Decision-makers
- Technology Enablers

Figure 1 expands on these headings, and the Executive Summary of the Concept document is a further expanded version. Here, ADS-B (Automatic Dependent Surveillance - Broadcast) is a core technology enabler – essentially through aircraft text messaging (Figure 2). ADS-B equipment has been extensively and successfully tested in operational environments, and is an example of a developed SESAR technological component.

The Concept includes a variety of technical and operational options. The SESAR Consortium notes that:

> "The ATM Target Concept is not about one size/one solution fits all; it offers different concept features which can be tailored to the specific local needs to meet the local performance objectives and their evolution in the life time of SESAR."

SESAR Safety Thinking

It takes some effort to get a mental grip of the SESAR Concept. One approach is to concentrate on the safety aspects of the proposed changes. Figure 3 is a schematic – highly simplified – of the *current* Air Traffic Control (ATC) Concept of Operations. It is largely self-explanatory, but there are some important features to note. First, controllers are important, as stressed by their involvement in planning, negotiation and the Safety Loop activities. Second, comparatively little is currently required from aircraft in terms of accurate navigation. Third, much of ATM presently relies on voice communication. Fourth, automated assistance focuses on warning systems: ground-based Short Term Conflict Alert (STCA), and air-based Traffic Collision Avoidance Systems (TCAS) – outside of the controller Safety Loop. STCA and TCAS both use what is essentially radar data to spot potential conflicts rather than information from aircraft or ground ATM systems.

The basic idea behind the SESAR Concept is to structure ATM around aircraft 'Trajectory Based Operations'. This is not a new idea, but its time seems to have arrived because of actual and potential system developments:

Accuracy/reliability of aircraft-achieved 4D trajectory

Accuracy/speed of passing information via data link

Huge improvements in surveillance capabilities

Automation and Decision Support Tool capabilities

Huge improvements in computer/equipment processing power and speed

What 'magic' do these offer when combined? Figure 4 sketches the safety thinking underpinning SESAR-like ideas – the starting point for the system design. Most of the linkages and boxes in Figure 4 are straightforward, but 'Position Integrity' and 'Reasonable Intent' need some additional explanation. (FMS stands for Flight Management Systems.)

'Precursor modes' here means that an accident has to start with something going wrong: given ATM's developed safety defences, there would then need to be other problems before a 'safety incident' turned into an accident. A Position Integrity risk could occur if an aircraft has a large undetectable altimetry error. A Reasonable Intent risk could occur if a pilot misunderstood a clearance, and descended to the wrong flight level; or if a controller issued a 'non-reasonable' clearance, perhaps because of high task demands to resolve an existing conflict.

Figure 5 shows some statistics – unofficial – on recent Airproxes (= ATM incidents reports). Controller and Pilot in the Figure indicate that the precursor was an immediate human error/misjudgement etc. The Airspace category focuses on incidents with airspace design and/or operational procedures that raise questions about ways of de-conflicting traffic features. 'Incorrect readback' means that the pilot incorrectly read back ATC instructions and that this was undetected by the controller. There are at most three 'Technical' incidents, ie where use/failure of equipment was involved. They were consequences of sudden cabin decompression, the misreading of a navigational chart, and the failure of flightdeck procedures to detect an incorrect setting on the flight computer.

The present systems incident/accident precursors are almost always from the right hand top box – failures of Reasonable Intent. So, for a markedly different ATM system to deliver safety, the system design – people, equipment, procedures – must prevent or mitigate misunderstandings, distractions, etc. The SESAR concept does this by ensuring that pilots and controllers possess the same picture of Intent, and that data transfer is the normal mode rather than voice communications.

Returning to Figure 4, important elements are marked in bold type. They generally represent the parts of the system changes that are most critical for SESAR to work with the high level of safety required. One equivalence is crucial: controller taskload ~ airspace capacity. The ATM system's throughput depends critically on the rate that controllers can process aircraft through their airspace sectors. Thus, for example, eliminating some voice communication tasks would – everything else being the same – free some of the controller's time, and hence enable a higher throughput.

Investment Case

Figure 1 is dramatically different from today's system. But commercial companies invest money in the expectation of getting benefits. An investment case for SESAR was first constructed by SDG (2005). The Concept paper also includes a financial section, which concludes with an outline cost benefit analysis (CBA). Airspace users gain financially in a variety of ways, eg reduced ATC charges, fuel saving on routes that are more direct. They have to pay for new avionics kit on their aircraft, which must also cover the costs of training aircrew to use the kit.

The Concept CBA is "'what-if' scenarios with only trend and rough order of magnitude results", and the Consortium suggests that they "should be considered conservative". In summary:

> "[CBA] has not provided conclusive evidence that the ATM Target Concept will be affordable or economically viable from an Airspace Users perspective. This will require further work."
>
> The best scenario examined assumes that *half* the cost effectiveness target is achieved (ie 25% less ATM cost/flight), because "there is incomplete evidence that the cost effectiveness target is going to be met". In this scenario, the benefits are larger than costs for scheduled airlines (a ratio of 1.7), but negative for business aviation and general aviation.
>
> Information about the SESAR impacts on the military airspace users is difficult to assess, and they are not included in the CBA. However, the current estimates are that the costs to European military users, almost all for investment in appropriate air platforms, would be €11.7 Billion. This is a significant amount of money even in defence terms – it is probably more than 5% of Europe's annual military spend.
>
> "[T]he investment in the ATM Target Concept should be seen as long-term and strategic in nature which would justify the need for public funding for implementation."

SDG(2005) and Brooker (2008) discuss benefits to society from SESAR. These assessments are complex, but the most important benefit contribution from a governmental viewpoint arise from passenger time-savings. There are more flights available and fewer delays. These gains generate worthwhile increases in Europe's Gross Domestic Product, so governments should be sympathetic to such investments.

But to get large amounts of public money requires *proof* to government decision-makers that the concept will deliver in practice *and* that there can be confidence in the estimates of costs and benefits. Governments have 'had their fingers burned' in the past, so they will want to see hard evidence. This presumably implies the need for convincing demonstrations of near full-scale operational SESAR systems.

SWIM

Figure 6, derived from an authoritative USA document, illustrates the nature and scope of SWIM. SWIM provides the infrastructure and services to deliver network-enabled information access to a multitude of ATM system users. It offers substantial system architecture benefits by reducing the number and types of interfaces and systems. Today's system has many 'evolved' technical sub-systems with custom-designed, developed, and managed connections. SESAR requires an infrastructure that is capable of flexible growth – and the cost of expanding today's variety of legacy sub-systems is daunting. SWIM must successfully integrate with a variety of legacy sub-systems over many years. SWIM is a rational solution to future modernization and development needs, in line with the kinds of decisions made by many major national and international corporations to create their own net-centric systems.

SWIM underlies everything: it is crucial to managing and sharing information effectively across ATM architecture. But SWIM is complex and very big. R&D expenditure into SWIM so far in Europe and the USA has been no more than tens of millions of Euro/dollars. The European implementation project will be large, certainly into the billions of Euros. From the Concept paper:

> "Ground network infrastructure, system interfaces and management required for the SWIM concept have so many unknowns that there is a high degree of uncertainty on the cost assessment specific to SWIM."

There are two special reasons why SWIM will not be cheap. First, because it is crucial to operational safety and efficiency, performance requirements and safety certification will be very demanding. Second, because of the need to have a secure ATM system against terrorist attack and to protect the military users of SWIM and SESAR generally, SWIM will need to meet the highest category of State and European-level security requirements.

Controllers' Tasks

Figure 3 shows the importance of the controller in today's system. Figure 1 indicates that the controller's task will change *dramatically* in a SESAR concept. Focusing on airspace capacity, these changes reduce controller taskload by some combination of:

- Automation for the routine controller task load supported by better methods of data input and improved data management;
- Automation support to conflict/interaction detection, situation monitoring and conflict resolution;
- Significant reduction in the need for controller tactical intervention:
    - Reduction of the number of potential conflicts using deconfliction methods;
    - Redistribution of the tactical intervention tasks to the pilots *when appropriate* through cooperative separation or self-separation.

All of these ideas have a long history of research and development work, alas not all of it completely successful. The most relevant large-scale R&D study into 4D-trajectory ATM was the PHARE (Programme for Harmonised ATM Research in

Eurocontrol) project which ran for a decade to 1999, and cost Europe about €90 Million [For background material, reports and presentations, see http://www.eurocontrol.int/phare/public/subsite_homepage/homepage.html]. PHARE demonstrated that 4D concepts, air-ground datalinking and controller tools worked well technically – all elements that have been further improved over the last decade. But PHARE did not prove that airspace capacity would increase as a consequence of these technological improvements. Possible reasons for this included insufficient training of controllers, lack of trust in the tools by controllers, and operational procedures and working methods not optimised to tools. PHARE was productive but unbalanced: it allocated insufficient attention and resources into controller taskload aspects.

However, the SESAR Concept devotes less than two pages to 'Humans and Automation', and most of the text lists the concerns that need to be tackled and general principles to be adopted rather than their solutions and implementations. Identifying high priority problems is not the same as finding answers to them and demonstrating that they work in the real world. Setting high-level principles for automation – with origins traceable to more than fifty years ago, and which are still not definitive (Sheridan, 2000) – is a starting point rather than a bankable assurance of practical automation designs. This is an intrinsically tough challenge – it is *not* some kind of self-serving psychobabble by Human Factors experts!

The key to SESAR success may well require an answer to the problem left open by PHARE. As noted by a French PHARE participant (Pavet, 2000): is the way forward to promote a "reinforcement of cognitive capability of controller" or is it to "deliver an automated system where controllers' role in scenario… becomes routine interlaced with exception management". Again, the key to success will be demonstrating a feasible automation path to the financial decision-makers. This is a crucial topic for decision-makers as staff costs are and are expected to continue to be a large proportion of direct ATM costs (Concept paper page 103 and related text).

Further Reading

The sources quoted are good starting points for further reading. There is an enormous amount of activity on NextGen and SESAR. A recent progress report on NextGen/SESAR R&D work is on the Eurocontrol Meetings website (http://www.eurocontrol.int/moc-faa-euro/public/standard_page/TIMS.html), the mid-2007 Workshop presentations are particularly interesting. One of the most important – and technically demanding – elements in NextGen/SESAR is Trajectory Prediction, particularly in the 'Courage' programme; again, key papers by technical experts are on the Eurocontrol website.

There are comparatively few publications so far on the safety issues raised by SESAR. The key problem is not that SESAR will be safe, but how to *prove* that all the transitional steps to the Concept will be safe. Note that some of these transitional steps will involve airspace containing mixed populations of aircraft, eg some with and some without the most developed 4D FMS. The radical system changes envisaged and the number of technical/operational options still available mean that these assessments would be much more complex than proving that new ATM sub-systems or limited-scope operational changes are safe (Brooker, 2007).

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Business Trajectory

- Aim to execute each flight as close as possible to the operator’s intention
- Changes to the Business Trajectory minimised
- Collaborative Decision Making (CDM)
- Business Trajectories are 4D and flown with much higher precision than today

Trajectory Management focus

- Airspace users fly preferred routeing without pre-defined routes
- Structured routes only if needed to enable the required capacity (eg congested TMAs)

Collaborative Planning

- Main stakeholders collaborate in a layered planning approach
- Collaborative planning matches capacity to demand, optimizes constrained resources

Integrated Airport operations

- Full integration of airport operations into the trajectory management processes
- Increased throughput and reduced environmental impact

New separation modes

- New separation modes use trajectory control and airborne separation systems
- Supported by controller and airborne tools

System Wide Information Management (SWIM)

- Integrates all ATM related data
- Supports CDM processes using efficient end-user applications

Humans central as managers and decision-makers

- Advanced level of automation support for the humans is required
- Nature of human roles and tasks necessarily change

Technology enablers

- Communication systems use integrated network services for all ATM sub-systems
- Data communication (rather than voice) is primary means
- Primary navigation system satellite based with a terrestrial fall back solution
- New surveillance systems, eg ADS-B, provide improved 4D-trajectory information

Figure 1. SESAR Components

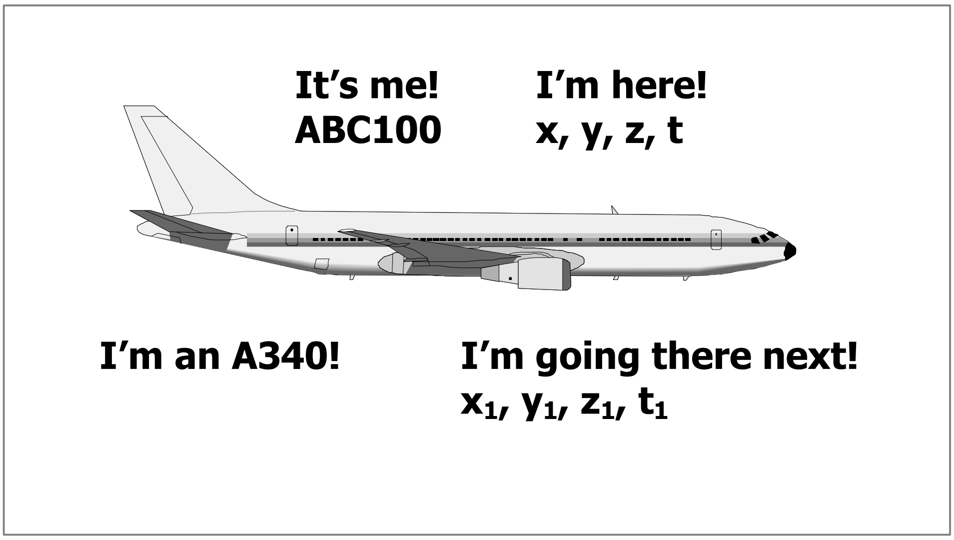

Figure 2. ADS-B – 'Aircraft Text Messaging'

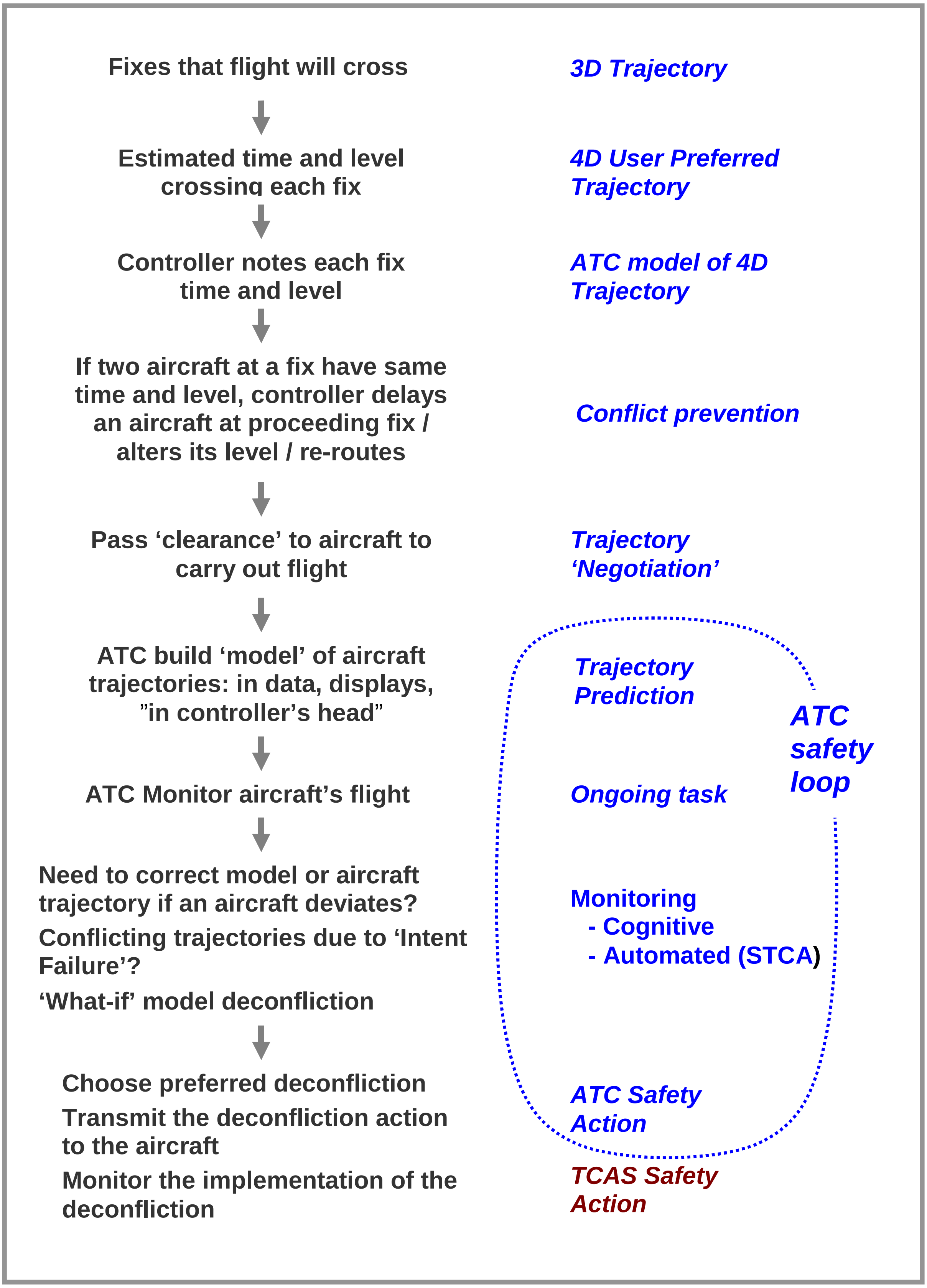

Figure 3. Schematic – highly simplified – of today’s Air Traffic Control (ATC) Concept

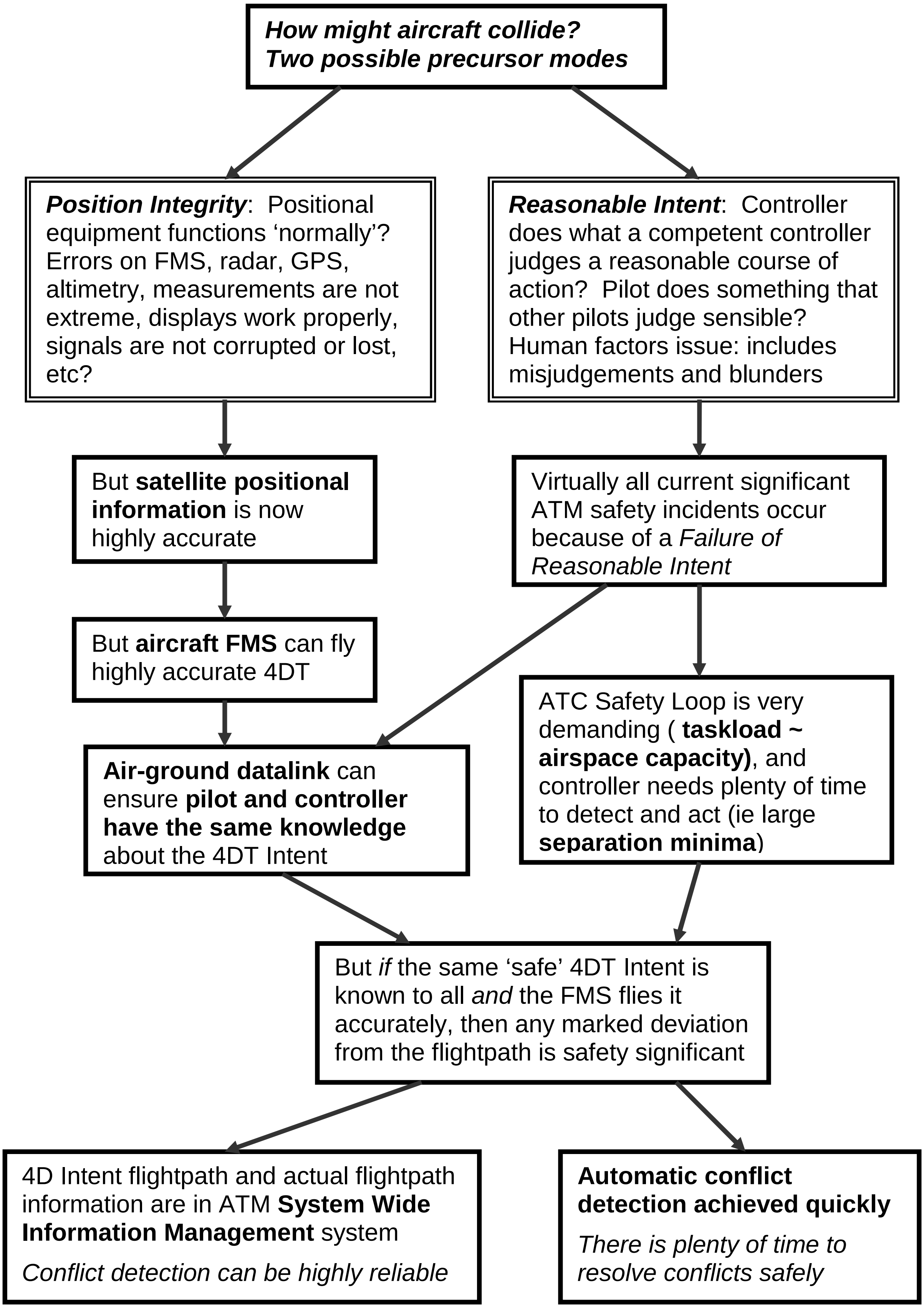

Figure 4. Sketch of safety thinking underlying SESAR-like Concepts
[4DT = Four Dimensional Trajectory]

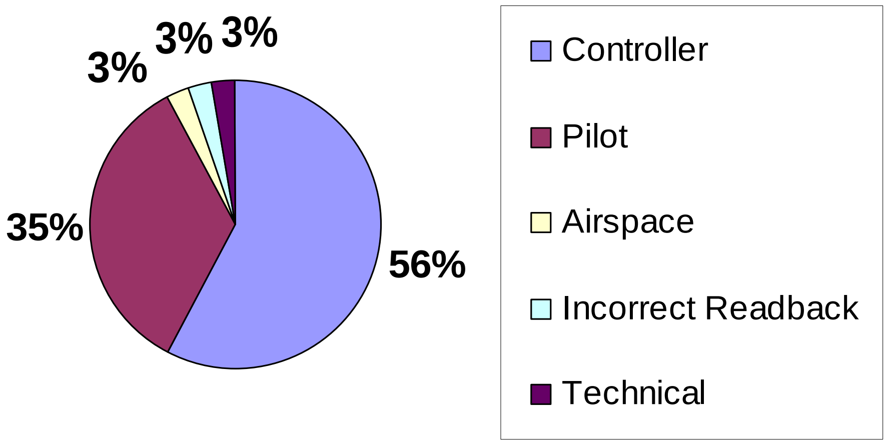

Figure 5. Airprox ‘Main Causes’

[Author’s analysis of a sample of 117 recent UK Airproxes (ATM incident reports) involving commercial flights. Eliminated from data set: Airproxes in ‘uncontrolled’ airspace (Class F/G), military zones, North Sea; military aircraft, parachutist, balloons, sighting reports. Data from Reports 11 to 16, http://www.airproxboard.org.uk/.]

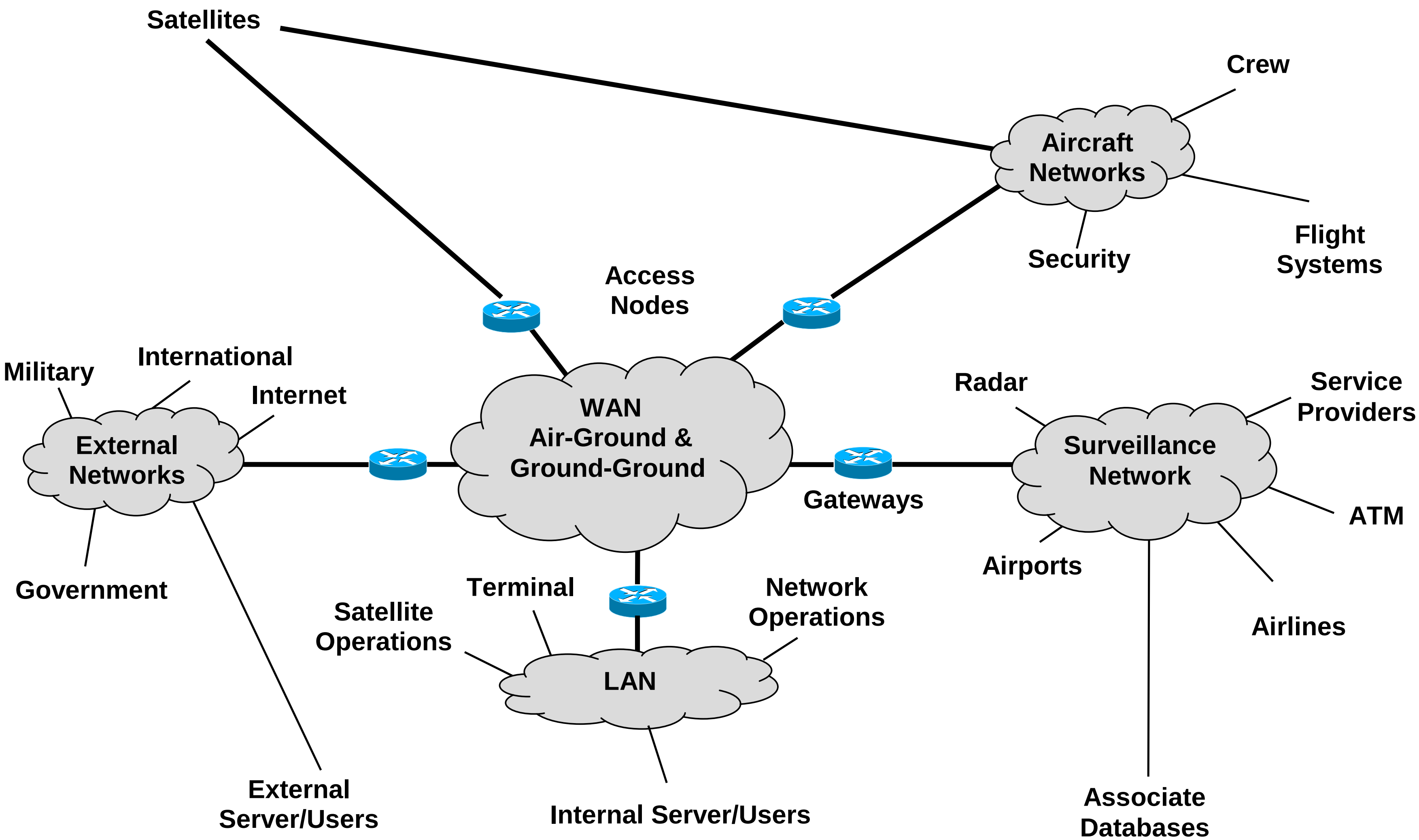

Figure 6. System Wide Information Management (SWIM) Schematic: adapted from Sayadian and Weill (2004)