CRANFIELD UNIVERSITY

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REVIEW AND IMPROVE THE MANUFACTURING ENGINEERING NEW PRODUCT INTRODUCTION PROCESS – AIRBUS UK

SCHOOL OF INDUSTRIAL AND MANUFACTURING SCIENCE

MRes THESIS

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ABSTRACT

This research has developed an organisational improvement methodology for the Manufacturing Engineering (ME) New Product Introduction (NPI) process at Airbus UK. The methodology is focused on improving the management of Concurrent Engineering (CE) and team/stakeholder effectiveness through improved involvement, communication, and coordination.

In the context of Airbus UK's ME NPI process the objectives were: to examine the current process, including the monitors and controls, deployed by the ME development team to design, implement and support NPI; to map/model the ME NPI process and hence, conduct a comparative analysis with best industrial practice; and to evaluate the pragmatic options open to ME and recommend appropriate business improvements/solutions.

The research showed that effective CE teams provide the main vehicle for improving product development performance, by increasing integration through improved involvement, communication, and coordination. A literature study of 'best practices' identified the major causes of 'waste' within NPI as, poor communication and poor programme management. The research also showed that process modelling not only achieves a better understanding of the processes but also serves as a tool to contribute towards the assessment of CE teams using process based analysis. It was also found that process modelling improves process management within NPI. Process modelling and analysis is applied to the ME NPI process in order that a structured and pragmatic improvement methodology can be developed.

The presentation of the CE organisational improvement methodology developed by this research provides Airbus UK with a less prescriptive approach to improving their business within the ME function and area of NPI. The application of the methodology is, unfortunately, outside the time limitations of this research. However, it is widely purported by ME NPI process stakeholders, and literature, that the most significant improvements to the current process can be realised through the improvement of 'softer' organisational issues.

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GLOSSARY OF TERMS

ACE	Airbus Concurrent Engineering
AMOS	Advanced Material Order Schedule
ASO	Assembly Stage Operations
BPB	Build Philosophy Brochure
CAA	Civil Aviation Authority
CE	Concurrent Engineering
CNPD	Concurrent New Product Development
COS	Condition of Supply
DAP	Design As Planned
DMU	Digital Mock-Up
DTI	Department of Trade and Industry
ENGs	Visual Aids (Production)
EQNs	Engineering Query Notes
HSE	Health, Safety & Environment
ICYs	Components which can be fitted to more than one aircraft (Interchangeability)
IDA	Institute for Defence and Analysis
IDEF0	Integrated Definition for Functional Modelling
IPPT	Integrated Product/Process Teams
IPT	Integrated Project Teams
KCs	Key Characteristics
LAI	Lean Aerospace Initiative
LE	Leading Edge
LOFT	Component Outline Template
ME	Manufacturing Engineering
MEM	Manufacturing Engineering Manager
MES	Manufacturing Engineering Specialist
MSE	Manufacturing System Engineer
NPD	New Product Development
NPI	New Product Introduction
PBoM	Preliminary Bill of Materials
PEGS	Production Engineering Group System (Software)
PIMS	Project Management Process
QFD	Quality Function Deployment
SE	Sequential Engineering
TDF	Tool Definition Form
TE	Trailing Edge

1 Introduction

1.1 Background

This chapter explains the background to the research area, the sponsoring company, the research problem, the research aim, objectives and deliverables. It also outlines the need for improvement and the industrial significance of the research.

1.1.1 New Product Introduction/Development

The development of new products continues to be a critical business activity to all companies. More than ever, existing products can be expected over the course of time to either be replaced by new and improved products, or deteriorate to a position where profits are non-existent. Without a doubt, the survival and long-term stability of manufacturing companies is tied in with their ability to provide existing and new customers with an ongoing stream of new products. At the same time, product life cycles are becoming shorter, leading companies to reduce the time to bring new products to the marketplace. Being early can provide a significant competitive advantage, not least within the commercial aircraft industry, making the management and organisation of New Product Introduction (NPI) an important area of research and enquiry.

According Wheelwright and Clark (1992) effective NPI processes are an essential element in maintaining competitive advantage for business. Hague and Moore (2004) concur; Survival in today's globally competitive marketplace is becoming increasingly dependent on effective management and control of innovation through the introduction of new products. Within many organisations, academic literature, and this thesis, the terms New Product Introduction and New Product Development are used synonymously. Both terms are used to refer to the process by which new products are developed in companies. It is also worth noting that some organisations refer to the activity of product design and development under the titles of R&D and Innovation. The authors Cooper and Kleinschmidt (1986) describe a generic set of tasks involved in the activity of New Product Development (NPD) as follows:

- initial screening
- preliminary market assessment
- preliminary technical assessment
- detailed market study/market research
- business/financial analysis
- product development
- in-house product testing
- customer tests of product
- test market/trial sell
- trial production
- precommercialisation business analysis

- production start-up
- market launch

The extent to which these tasks take place, how they are organised, and the way in which they are managed varies between companies. However, this thesis is concerned not with the entire New Product Development process but with the manufacturing engineering (ME) tasks associated with the introduction of new products. In many organisations the role of the manufacturing engineering function within NPI includes; establishing a manufacturing strategy, manufacturing process and resource planning, and of course production. The research is focused within, and sponsored by, AIRBUS UK - commercial aircraft manufacturers.

1.1.2 The Commercial Aircraft Industry

The commercial aircraft industry has undergone extensive growth worldwide over the last twenty years, encouraged by increased governmental deregulation of the airlines. Economic growth is said to be the major contributor to air travel demand (Boeing Aircraft Corp. 2004) with increased competition leading to more airline entrants, lower fares, and improved networks. The market potential for the next twenty years is forecast as being 34700 aircraft worth $20 trillion US dollars in 2003.

The market structure of the commercial aircraft industry in the 100 to 500+ seat sectors are essentially Boeing Aircraft Corporation and Airbus. Airbus is a relatively new organisation with the entry into service of its first aircraft, the A300, in 1972. Since this time they have increased their product portfolio to include the current 'families' of aircraft. At present Airbus have more than 3500 airliners in service. The global commercial aircraft market is split relatively equally between Boeing and Airbus. Currently Boeing benefits from a monopoly in the large aircraft sector with the 747 or 'Jumbo Jet'. This market distortion is set to change with the scheduled delivery of the Airbus A380 family of aircraft into service by 2006. The new 555-seat A380 aircraft is the worlds largest commercial aircraft.

In the last 20 years the commercial aircraft industry have increase their corporate focus fuelled by increasing production costs and the immense cost attributed to the development and introduction new products. The design and development of the Airbus A380, for example, was estimated in 2000 to cost in excess of $12 billion (Boeing Aircraft Corp, 2002). Both organisations have adopted a distributed manufacturing and supply strategy. Airbus with an annual turnover in 2004 of €20 Billion has 13 major manufacturing sites and 1500 suppliers in 30 countries (Airbus 2004). Boeing Commercial Airplanes with an annual turnover of $22 Billion in 2004 with six major manufacturing sites in America and a network of over 3000 suppliers world wide.

In summary, the commercial aircraft manufacturing industry operates in a complex economic environment and must respond by making continuous improvements to all aspects of product quality, cost, and time to delivery to ensure effective use of resources.

Within this business the characteristics of the product are an important differentiator also the process employed for bringing new products to the market – hence the NPI process is a vitally important area for continuous improvement. Improving the management and effectiveness of the new product introduction (NPI) process is widely considered a means of achieving one form of 'best practice' within many companies and academic literature alike. This is certainly the case for the commercial aircraft industry. Where reducing the 'time to market' of an aircraft provides significant competitive advantage. In recent years design and development of the Airbus A380 was estimated to cost in excess of $12 billion. The company cannot begin to recoup any of the monies invested until the first aircraft is delivered to the customer. It is currently estimated the time from project launch to delivery of the first A380 aircraft will take 5 years. In a highly competitive industry such as the commercial aircraft industry reducing the NPI process time, and consequently cost, is of utmost importance.

1.2 Problem Statement

There is a need for manufacturing companies such as Airbus to improve their ability to get new products to the marketplace quickly and efficiently. One way of achieving this is by adopting Concurrent Engineering (CE) and team-based product development practices. Airbus UK currently utilises integrated work teams and functional teams within their NPI process. Airbus UK has successfully employed CE practices on more than one project. ACE, Airbus Concurrent Engineering, was first launched in 1995 and has successfully been applied on; A340-500/600 and A380 projects.

At present the company do not have a formalised ME NPI process model. The lack of such a model leads to uncertainty and confusion between project team members and leaders alike. The construction of an ME NPI process document reduces the risk of uncertainty and eliminates confusion by providing a means of communicating the process between ME NPI stakeholders. Having a formalised and documented ME NPI process model will enhance the effectiveness of managing the future process whilst providing the potential for improving the current process inline with current best industrial practices.

The focus on CE within literature has primarily been via technology although, more recently, there is recognition that it is really human factors that are important. There is also significant evidence that organisations require help to improve their CE effectiveness.

Organisations such as Airbus need tools and methodologies which disseminate CE knowledge and support the improvement of CE effectiveness. The thesis will focus on the managerial and organisational issues of improving the ME NPI process effectiveness.

1.3 Research Aim

The aim of this research is to:

- Review and improve the Manufacturing Engineering (ME) New Product Introduction (NPI) Process with Airbus UK.

1.4 Research Objectives

The objectives of the research are to:

- Examine the current process, including the monitors and controls, deployed by the ME development team to design, implement and support New Product Introduction.
- Map/model the Manufacturing Engineering NPI process and hence conduct a comparative analysis with best industrial practice.
- Evaluate the pragmatic options available to the ME function and recommend appropriate business improvements/solutions.

The third objective was the driver for this research programme. An important outcome of the research was to recommend pragmatic improvements to the ME NPI process within Airbus UK. In order for this to be achieved the current process was required to be formalised and documented. Practical improvements to the current process are to be seen through the provision of a structured methodology focused on reviewing and improving the ME NPI process.

These three objectives are ambitious within the time constraints of a Master of Research thesis programme. In addition, it was felt that confidence in the research findings, embodied in an improvement methodology, could be increased by application and evaluation against short term objectives within Airbus UK and other industrial test sites.

There are a number of assumptions underlying the research objectives. The first is that Airbus UK and other companies that apply the pragmatic improvements will have already recognised the need to improve their CE effectiveness but will be unsure of how to do so. They will also have recognised that multifunctional product development teams are an important part of the improvement process but will have little detailed knowledge of effective CE teamworking and best industrial practices within NPI.

The novelty of this research is the exploration and creation of a pragmatic improvement methodology based on current best industrial practices and recommendations of NPI project team members and leaders (stakeholders) within ME at Airbus UK. The data collection activities during this research showed that although there is a good understanding of best industrial practices within NPI, there is very little knowledge or research about how to practically achieve the purported best practices. The research will therefore explore how to re-design the current ME NPI process to maximise CE organisational effectiveness through the provision of a pragmatic and structured methodology.

1.5 Deliverables

1. An 'As-Is' map/model of the existing ME NPI process at Airbus UK's Broughton facility.
2. A structured and pragmatic methodology to aid the review and improvement of the ME NPI process at Airbus UK.
3. Recommendations for business improvements.

1.6 The Need for Improvement

Managers with responsibility for introducing new products with the manufacturing engineering function, or any other task or phases within NPI, are under increasing pressure to improve the performance of the process. The nature of improvement sought differs between organisations. The most common and widely cited improvement objectives are presented below:

- Reduction in costs
- Reduction in cycle time
- Increased market share
- Increased product quality

Any improvements proposed to the current ME NPI process within Airbus UK should be directly or indirectly attributed to at least one of the objectives outlined above.

1.7 Industrial Significance of Research

The aerospace industry is one of the key strengths of the UK economy. According to the Department of Trade and Industry's DTI recent report (June 2004), the UK aerospace industry is forecast to grow by at least 25 percent in real terms over the next 20 years; to £250 billion a year. The Aerospace industry contributes around £5.5 billion value added to the economy, with a turnover of over £17bn in 2003. It has over 120,000 skilled employees in direct employment, and supports a further 130,000 indirectly. As a result there are many government and private organisations actively perusing research within this sector.

In May 2002, Patricia Hewitt, the UK Secretary of State for Trade and Industry set up the Aerospace Innovation and Growth Team (AeIGT). The team was set up in order to map out a 20-year vision for the future of the UK aerospace industry. Over 140 senior people from industry, Government departments, trade unions, universities and research bodies have been involved. There primary aim was to draw on the knowledge and expertise of all major industry stakeholders, to look at how the UK can best respond to international competition and secure the long-term future of the UK Aerospace Industry.

The UK LAI is a consortium consisting of the Universities of Bath, Cranfield, Nottingham, and Warwick and some 40 participating company members of the Society of British Aerospace Companies (SBAC). The initiative has joint funding by participating SBAC members and IMI Aerospace (Link) Sector, Engineering and Physical Sciences Research Council.

The research presented in this thesis contributes to a growing body of knowledge focused specifically on the aircraft industry. If aircraft manufacture is to remain in the UK, and not be outsourced to more cost effective economies, then there must be significant research and development into key business areas such as NPI.

2 Literature Review

The literature review has been divided into three key areas; product innovation, major studies/projects focused on NPD success/failure factors, and product development process models. The purpose of this chapter is to gain an understanding of the research top area.

2.1 *Product Innovation*

According to Bright (1964) technological innovation can be described as; *"A unique chronological process involving science, technology, economics, entrepreneurship and management in a medium that translates scientific knowledge into the physical realities that are changing society"*. The possibilities of tomorrow's organisational advancements are set by the technologies available today. Cardwell (1994) states that; *"technological innovations and their related socio-economic and political implications have totally dominated and shaped our world since the industrial revolution"*. It is worth considering that some companies organise the activity of product design and development under the titles of R&D and innovation. The author; Hughes (1985), states that the start of industrial R&D is generally dated from 1897, by Thomas Edison, with the establishment of Menlo Park Labs.

2.1.1 Lessons from America's Best-Run Companies

In successful US companies the authors; Peters & Waterman (1982) identified attributes of innovative companies which can equally be applied to product innovation. The authors work is summarised and presented in the table below. (see Table 1).

People	Autonomy and entrepreneurship Foster innovators and leaders in the company A bias for action, for getting on with it Productivity through people Respect for the individual
Attitude	Value driven Hands on Leadership and management support
Organisation	Simple form Lean Staff Simultaneous loose/tight properties Centralised and decentralised
Market	Stay close to customer 'Stick to the knitting' Stay close to businesses you know

Table 1: Attributes of Innovative US Companies

The authors discuss a 'loose/tight' organisational concept; where there has to be enough 'freedom' to allow creativity, and the exchange of ideas to flow, yet sufficient 'control' to meet financial and lead time targets. This concept is one of the most difficult balances to achieve within the management of innovation and consequently NPI.

2.2 *Major Studies/Projects focused on NPD Success/Failure Factors*

This section identifies some of the most significant literature focused on the identification of factors relating to NPD success and failures within industry.

2.2.1 New Product Failure Rates

Most new products fail according to Booz, Allen and Hamilton (1982), the authors estimated that 58 ideas were needed for one new product. Crawford (1979) produced a summary of research into new product success / failure (see Table 2). The author states that; *"Most past studies on new product failure rates are unreliable and they put the failure rate at too high a level."*

Research Study (Source)	Percent Failed
Booz Allen Hamilton	37% (consumer)
	38% (industrial)
Buzzell	27% (food)
Cochran/NICB	30% (mixed)
Gallagher	41% (mixed)
Graf/Nielsen	42% (food)
Hopkins and Bailey/CB	40% (consumer)
	20% (industrial)
Mansfield and Wagner	26% (industrial)

Table 2: New Product Failure Rates, (Source: Crawford, 1979)

Around 25% of Industrial new products and 30/35% of consumer products failed to meet the expectations of their developers. Innovation is risky and so some projects must fail – unless companies choose very marginal and incremental improvements, for example; low risk but low reward; in the long term this will mean demise for the organisation involved. Others say success/failure go in cycles; for success companies must have failures. In an industry such as the aerospace industry the cost of a new product failure will have significant effects on the business as a whole.

2.2.2 Successful and Unsuccessful Technological Innovations

Project SAPPHO was initiated in 1972 by the Science Policy Research Unit (SPRU) of the University of Sussex. This was the first study to systematically compare successful and unsuccessful innovations from the same market. The study compared 43 "paired" commercially successful and unsuccessful technological innovations. The study revealed 41 variables that were statistically significant in the outcome of projects. Hence the variables revealed 41 differences between success and failure. Project SAPPHO is seen as a landmark in the study of innovation and so is widely quoted in literature.

According to Rothwell *et al* (1974) successful companies have:

- A much better understanding of user needs
- Paid more attention to marketing and publicity
- Performed their development work more efficiently than the failures – but not necessarily more quickly
- Made more use of outside technology and scientific advice – in the specific area concerned
- Had responsible individuals in more senior positions with greater authority than their counterparts

2.2.3 Research Review of New Product Successes and Failures

Cooper (1979) reported the results of *Project NewProd* which contrasted New Product successes with failure by reviewing previous research. The author developed 77 variables that influence new product outcomes. The respondents (103) characterised each venture on the 77 variables. There were 11 factors that differentiated between New Product success and failure. Copper's results are different from other studies as they are focused towards the product/market characteristics with little emphasis on management, communication, and people. The authors key findings are summarised below (see Table 3). Later research by Cooper (1985) and Cooper (1990) expanded on the results obtained through the Project NewProd survey.

Success Factors	Success Barriers	The Facilitators
Introducing a unique and superior product	High priced product relative to competition	A good 'product/company fit' with respect to managerial and marketing resources
Market Knowledge and marketing efficiency	Being in a dynamic market	Strong marketing communication & launch effort
Technical/Production synergy and proficiency	Entering a highly competitive market	Being in a large, growing, high need market
Avoiding products new to the firm		
Market derived idea		

Table 3: New product success factors, barriers, and facilitators

2.2.4 Japanese and British Companies Compared

The authors Edgett *et al* (1992) conducted a study of 86 British and 116 Japanese companies operating in the UK (see Table 4). The companies selected specialised in manufacturing industrial and consumer products. The research findings cast doubt over the commonly held belief that Japanese companies are more successful with their new products than British companies. The most common reasons for failure of a product, cited by both British and Japanese companies, are deemed to be controllable within the company. Hence, a more formalised approach to product development could eliminate many of the initial reasons given for a products failure.

British Companies	Japanese Companies
Over enthusiastic about their new products which consequently tends to reduce the applied care to the development process.	Marginally higher rate of successful product launches
	Placed more emphasis on meeting customer needs with good quality, competitively priced, reliable products

Table 4: Contributing factors to success and failure in British and Japanese companies

2.3 *Product Development Process Models*

This section aims to identify the way in which academic literature classifies existing product development process models. The advantages and disadvantages are also discussed.

2.3.1 Phased Project Planning (PPP)

It is widely accepted that NASA developed the first generation scheme for product development. According to Cooper (1994) the scheme was named Phased Project Planning (PPP) by NASA in the 1960s. PPP, commonly known as Phase Review Process, provided the basis for the first generation of stage-gate systems. The systematic process broke development into discrete phases with review points (or gates) at the end of each phase. The process was primarily a measurement and control methodology as a project could not move to the next phase until all tasks in the current phase were complete. Development funding was also linked to the completion of the previous phase. Literature has given mixed reviews of the PPP process. Cooper (1994) reported that, although it brought discipline and reduced technical risks (though not business risks) it was cumbersome, slow, too narrow and too functional. Smith and Reinertsen (1992) suggest that when speed is important, market risk becomes more critical. The result of which means that a monumental PPP-type system is no longer a clear choice. The authors report that under such circumstances adaptation and balance are needed in the project management system, and that balance shifts toward empowering the people and away from depending on formal control systems.

2.3.2 The Stage-Gate Process

The Stage Gate Process is described by Cooper (1990) as a conceptual and organisational model for moving a new product from idea to launch (see Figure 1).

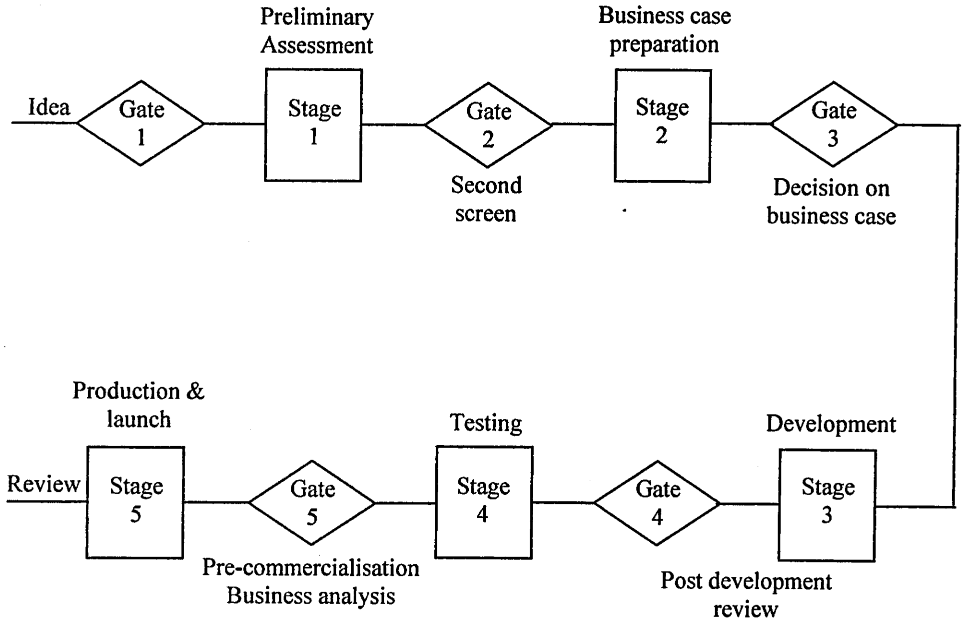

Figure 1: Stage Gate System (Source: Cooper, 1990)

Many companies have adopted the stage gate system which has provided them with "a road map from idea to launch consisting of discrete stages, each stage preceded by a Go/Kill decision point or gate" Cooper (1994). The process model was developed as a means of managing the new product process to improve effectiveness and efficiency. The belief is that dividing the whole process into smaller, more manageable, subsets can improve the quality of the final product. Preceding each subset, or stage, conformance checks, or gates, are applied. According to Cooper (1990) stage gate systems usually involve four to seven stages and gates, depending on the organisation and the nature of the development activity. Prior to entering each stage in the process there is a gate. Each gate controls the development process. Each gate requires a set of deliverables and exit criteria. Project managers must provide the required deliverables at each gate. The exit criteria for each gate are typically decisions based on answers to predefined questions. The decisions are typically in the form of Go/Kill/Hold/Recycle. The deliverables and exit criteria will vary for each gate. Each gate will have a checklist that project teams must complete in order for the process to progress to the next stage. The responsibility for each gate is held by senior managers or 'gate keepers'. The idea for having senior management as gate keepers is to build involvement and commitment at the highest organisational level. A project team will usually consist of cross-functional/multi-disciplinary team members. The deliverables for each gate must be recognised and understood by project team leaders.

The authors Cooper and Kleinschmidt (1993) suggest that application of such a stage gate system can achieve "impressive" results. The major benefits cited by respondents to a research study presented, by Cooper (1994), are shown in Table 5. However, the same study also identified some weaknesses with the stage gate systems. The original stage gate system has been developed and renamed as the third generation process by Cooper (1994).

Improvements	Weaknesses
Much better cross functional teamwork	Project must wait at each gate until all tasks have been completed
Less recycling and rework	Overlapping of stages is not possible
Higher new product success rates	Project must go through all stages and gates
Better launch	Does not lead to project priority and focus
Earlier detection of failures	Some new product processes are spelled out in far too much detail
Shorter cycle time	Some new product processes tend to be bureaucratic

Table 5: Stage gate new product processes; improvements and weaknesses

2.3.3 Concurrent Engineering

Concurrent Engineering is a design approach in which the development of the products and their related manufacturing and support processes are performed in parallel. According to Bicheno (2003) concurrent engineering is an established 'Lean Technique'. It is based on the concept that product design, process design and design for manufacturability must be integrated into one step. In the past, these activities were typically performed sequentially by experts within different functions, thereby resulting in what Womack and Jones (1990) refer to as batch and queue processing (see Figure 2).

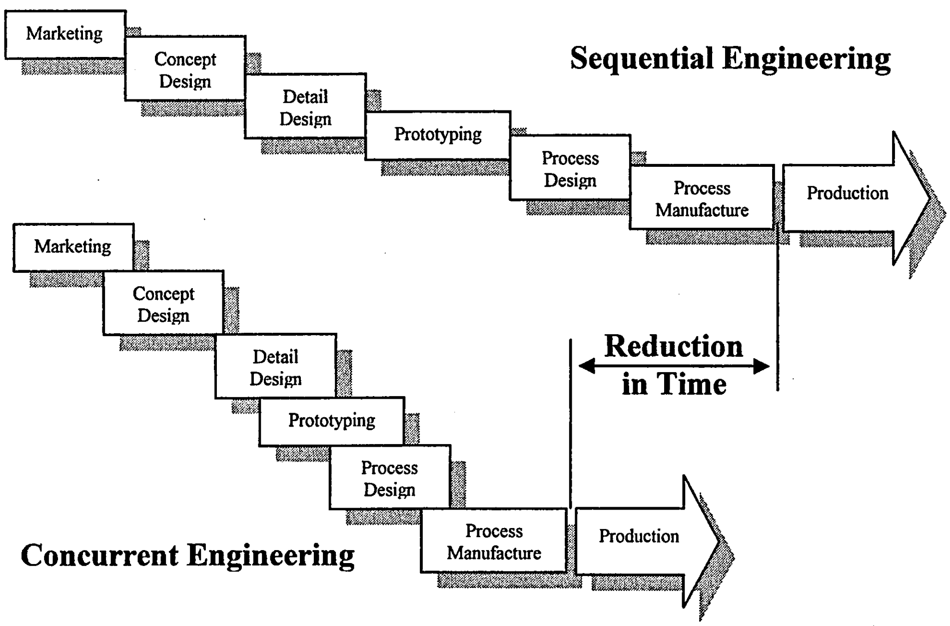

Figure 2: Concurrent and Sequential Engineering (Source: Yazdani and Holmes, 1999)

Within academic literature CE is also commonly described as Simultaneous Engineering (SE), Integrated Product/Process Development (IPPD), and Concurrent New Product Development (CNPD). There are many definitions of CE presented in academic literature. The earliest and possibly most widely quoted is presented below:

".....a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements." (Winner *et al,* 1988)

In 1988 the Institute for Defence and Analysis (IDA) formed a study team to investigate CE and its possible application to weapons system acquisition (see Winner *et al,* 1998). A report of the IDA investigation, describing CE terms of success stories, was presented to the Department of Defence (US) in December 1988. It included case studies of companies that simultaneously improved quality, decreased cost, and reduced development time through the application of CE. The main results of the investigation are presented below in Table 6.

Institute for Defence and Analysis (IDA) Survey	
Concurrent Engineering and Cost	
Development cost	Reduced by upto 30%
Inventory	Reduced by upto 65%
Manufacturing cost	Reduced by upto 42%
Concurrent Engineering and Time to Market	
Development time	Reduced by upto 60%
Prototype build	Reduced by upto 75%
Concurrent Engineering and Quality	
Inspectors	Reduced by upto 60%
Service life	Increased by upto 100%
Early yields	Increased by upto 100%
Defects	Reduced by upto 30%
Scrap & rework	Reduced by upto 75%
Engineering changes	Reduced by upto 93%

Table 6: (IDA) Concurrent Engineering Successes

Concurrent engineering provides many benefits to manufacturing organisations. Conceptually, CE should reduce time to market, improve quality, and reduce costs. However, quantifying the benefits of CE has proven a difficult task.

The authors Riedel and Pawar (1991) consider the benefits of simultaneous engineering over more traditional sequential approaches to product development. Their findings are based on two case studies. Only one of the firms has applied a CE approach the other a sequential approach. The case studies are analysed in terms of five competitive priorities, quality, delivery, cost, flexibility, and innovation, identified by manufacturing strategy literature (see Table 7).

Competitive Priorities	Concurrent Engineering
Quality	Fewer modifications required during the transfer of the design to production. Fewer modifications required to adjust the design for manufacture during production.
Delivery	Depends on responsiveness of the production system and its management and is not directly influenced by design strategy.
Cost	Design / manufacturing synergy produce a better and simpler product which is easier to manufacture, hence; cheaper to produce.
Flexibility	More suited to low or fluctuating product volumes. The production process can be 'tuned' during design to cope with volume changes.
Innovation	Enables new products to be introduced quickly.

Table 7: Concurrent Engineering and Competitive Priorities

The authors Ainscough and Yazdani (2000) conducted a survey of 142 British companies across different industry sectors. They found that there was a non-uniform spread on the usage of CE across the industry sectors (see Table 8). The survey also identified that; although 100% of the aerospace companies use a formal process for NPI only 68% used multifunctional teams.

Industry Sector	% Claiming to use CE
Power Generation	100
Petrochemical	91
Aerospace	75
Medical	67
Electrical	67
Military	65
Machinery	46
Automobile	40
White Goods	40
Transportation	33

Table 8: Take up of CE in British Industry (Source: Ainscough and Yazdani, 2000)

3 Development of Research Aim and Method

The purpose of this chapter is to describe the research methodology, data collection and analysis methods chosen, explain why they were chosen, how they were used, and discuss the benefits and limitations of the approaches selected.

3.1 Research Aim

The aim of this research is to review and improve the Manufacturing Engineering (ME) New Product Introduction (NPI) Process with Airbus UK.

3.2 Research Methodology

The research process can be separated into three distinct stages, as shown in Table 9. The initial stage of the research involved data gathering to understand the New Product Development process and historical issues concerned with innovation and NPD success and failure. This was an exploratory activity resulting in theory building. The results of this activity are presented in the Literature Review section of this thesis. The second stage of the research involved data gathering within Airbus UK in order to define the current process including inhibitors to the effective management of the ME NPI process. The results of this activity are presented in Chapters Five and Six. The third stage involved data gathering to understand what constitutes best industrial practices within NPI. A number of key theories were identified and selected. The results of this activity are presented in Chapter Seven. The selected theories or solutions were then used to develop a structured ME NPI improvement methodology. The methodology is explained in Chapter Eight – Organisational Improvement Methodology.

Research Stage	Nature of Data	Methods	Data Sources
1. Theory building – Root Cause Analysis	Qualitative & Quantitative	Literature Review	On-line search Thesis Search Innovation Books Innovation Journals Product Development Books Product Development Journals Concurrent Engineering Books Concurrent Engineering Journals Business Journals Engineering journals
2. Theory building – Development of Proposed Improvements & Conceptual Solution	Qualitative	Focus Group, Discussion & Observation	Airbus UK, ME NPI Project Team Members & Leaders Academic Staff
3. Theory building - Refined Solution	Qualitative	Literature Review	On-line search Thesis Search Concurrent Engineering Books Concurrent Engineering Journals Best Practice Books Best Practice Journals Multifunctional/Collocated Team Journals

Table 9: Research Methods and Data Sources

Initially the final stage of the research involved an extensive survey of current literature. Cranfield University's library service gave access to a range of databases encompassing literature primarily from Europe and North America.

The research undertaken began with a thorough search of five databases; Business Source Premier (EBSCO), Compendex (Ei Village II), Emerald, SwetsWise, and Google Scholar.

The search was initially conducted into areas of:

- *(New) Product Introduction/Design/Development*
- *Concurrent Engineering* which may also be called:
  - Simultaneous Engineering
  - Integrated Design and Development
  - Integrated Product/Process Development
  - Life Cycle Engineering
  - Integrated Product Teams

This was combined with a search of literature on:

- Success and Failure
- Manufacturing/Design Interface
- Process Modelling/Analysis
- Best Practices

Literature was also sought on:

- Lean New Product Introduction
- Continuous Improvement

As the use of teams is fundamental to Concurrent Engineering philosophy, the following terms were used to find relevant literature:

- (New) Product Teams
- Product Development Teams
- Multifunctional/Crossfunctional/Multidisciplinary Teams
- Teams/Teamwork/Teamworking

In order to conduct the research rigorously and systematically literature was also found on Research Methods:

- Data Collection and Analysis
- Focus Groups

As well as regularly searching the library databases a 'snowball' approach was used by reading references quoted in previously identified articles.

Benefits of a literature based survey are that the data is in a permanent form and can be subject to re-analysis and organisation. It is also a low cost method of obtaining information on a wide range of topics. The advent of literature available in an electronic format provides a means of organising and grouping by topic areas. The main disadvantage is that the literature available may be limited or partial and in some circumstances may not be written for the purpose of academic research.

During the initial stage of this research a spreadsheet was created and hyperlinked to over 100 electronic copies of literature. Conditional formatting was used to group and locate specific papers by primary, secondary and tertiary topic areas. This enabled literature to be organised in a way that provided quick, easy, access to specific topic areas.

Initially the literature was used to form a general understanding of the research topic. From the second stage of the research the current process was documented. This assisted in defining the research problem. The literature review was complemented by data from different sources and other methods of data collection.

3.3 Observation and Discussion

During the course of the research process, numerous visits were made to Airbus UK's, Broughton site. During these visits casual discussions took place with NPI experts from the ME function. The impromptu process meant that issues of most concern were raised and explored without using structured or semi-structured interview techniques. Significant points arising from the discussions were recorded in a notebook as site visit reports.

This informal data collection and analysis process has played a significant part in generating ideas whilst validating thought processes and potential solutions to the research problem. They were used as a supplementary technique to collect data and to corroborate the message obtained from other data sources. Due to the largely unstructured nature of the observations and discussions the main disadvantage is the potential for researcher bias. There is a danger of selecting and remembering information that supports the researcher's point of view. There is also the danger of being blinded by the 'Kudos' of ones own ideas.

3.4 Focus Groups

The literature review, unstructured observations, and discussions were complimented by using focus groups to better understand the research problem and to gather data relating to the current process. Originally, focus groups emerged as a research method to meet the need of the researcher to take a less dictatorial and dominating role than is usually the case with standard interview techniques. The technique was developed by social scientists who felt that the respondent should be given more freedom to comment on what they perceived to be important.

Focus groups are recognised as providing a number of advantages over standard interviewing and questionnaire techniques. They provide a more relaxed or natural setting for participants and the group setting is viewed as more stimulating. From the perspective of the researcher they provide a rich source of data, from a manageable sample size, whilst being less time consuming to administer than interviews. Focus groups provide the researcher with the opportunity to understand the participants' viewpoints and problems whilst it also allows unanticipated issues to be explored.

Focus groups are also recognised as having their disadvantages. The groups can be difficult to assemble; participants may have to give up several hours of their time they may also have to travel to attend the session. The group formation tends to suffer from 'volunteer bias', where a certain type of personality attends in higher numbers. Due to the extra freedom afforded, the researcher has less control over the direction of the discussion which emphasises the need for good facilitation skills. There are dangers that the group is dominated by the most talkative members or that participants influence each other by their interaction. Consequentially, weaker members of the group may be coerced into modifying or possibly reversing their opinion on an issue.

3.5 Application of Focus Group Method

The three hour focus group meetings have been held on two occasions during the completion of this research. Both focus group meetings were conducted with participants from ME NPI project teams. Project team leaders and members alike brought a wide range of knowledge and experience to the meetings.

The focus group method was chosen to meet specific requirements:

1. To act as a data collection exercise in order that the documentation of the current ME NPI process, at Airbus UK, can begin.
2. To determine current process efficiency inhibitors.
3. To benefit practitioners/participants by enabling them to share ideas and experiences.

The agenda for each meeting began with an introductory exercise. During the meeting only two or three questions can be asked. This gives participants time to explore and discuss the issues raised. Open-ended questions were used so that participants can determine the direction of their response. The questions were designed by the researcher to evoke group discussion. Less directive questions such as 'What' and 'How' were used in preference to 'Why' questions. During the first focus group meeting a short presentation was given to set the context of the questions (see Appendix 1). The presentation is based on design definition models described by the authors; Yazdani and Holmes (1999).

The questions from the focus group meetings are presented below:

1. What are the main activities within the ME NPI process?
2. Are there presidencies with the main ME NPI process – if so what are they?
3. What are the inputs and outputs for each activity?
1. Who and what is required for each activity to be completed?
2. What are the main inhibitors to an effective ME NPI process at AIRBUS UK?

The participants generate ideas and answers in response to the questions presented. 'Post-It' notes are used by participants for writing a single idea on. All the ideas are gathered before they are presented to the group. This procedure gives each idea equal value until a decision is made and prevents the first idea being seized upon. The participants were then asked to group their ideas into families on a flipchart.

The focus group method was used in this research in three ways:

1. To provide data for initial documentation of the 'As-Is' ME NPI process model.
2. To help clarify the research problem – based on the experience of ME NPI team members and leaders.
3. To test theories and potential solutions against practitioners experience and knowledge.

4 Execution of Method

The purpose of this chapter is to describe the root cause analysis, development of proposed solution, conceptual solution and the refined solution as a summary of the research method applied.

4.1 Root Cause Analysis

The research presented in this thesis began with observations and discussions also focus group sessions organised with ME NPI process team members, leaders, and senior management. During the research process, visits were made to Airbus UK's, Broughton site. During the casual discussions and focus group meetings that took place the primary inhibitor to CE effectiveness and consequently the ME NPI process were identified and discussed.

The vast majority of the ME NPI process stakeholders clearly identified poor communication and integration of CE teams as being a problem. As a result of this, poor ME NPI process management was also identified as hampering an effective ME NPI process and consequently CE effectiveness.

The lack of true manufacturing engineering process understanding and cross functional process understanding combined with ineffective team communication and coordination are cited as significant inhibitors to ACE effectiveness at Airbus UK.

4.2 Development of Proposed Improvements

In order to evaluate the pragmatic options available to ME and recommend appropriate business improvements, the current ME NPI process was modelled. The technique adopted for modelling the current process was the IDEF0 functional modelling technique. A sizeable amount of literature identify IDEF0 as an appropriate tool for modelling manufacturing systems also NPI processes (see Fleisher and Liker, 1997; Haque and Pawar, 2001; Harrington, 1984; Ang *et al*, 1994).

The completed IDEF0 model (ME NPI process model) provides a rich, easy to interpret, method of communicating the current process whilst maintaining significant process detail (see Appendix 3). It is this detail that enables the identification of major ME NPI activities and stakeholders. Identification of the activities and stakeholders provides the potential for recommending appropriate improvements.

Current literature identifies the IDEF0 modelling technique as a method of improving process management (Haque and Pawar, 2001). Without a clearly defined and documented process model, it will always present a challenge to senior process managers.

4.3 Conceptual Solution

A thorough search of literature was used to identify a conceptual solution for the ME NPI process at Airbus UK based on best industrial practices. There is a large amount of literature dedicated to the improvement of teams within CE practices. Literature was identified that linked process modelling, process management, and CE team effectiveness.

The authors Haque and Pawar (2001) present a model (see Figure 9, page 40) that depicts the relationship between NPI process understanding, modelling and analysis, and effective CE teams. The model describes how CE integration is achieved through effective teams and process understanding. The authors also describe how the application of process modelling fits in with improved integration.

Research carried out through the Lean Aerospace Initiative (LAI) into the application of lean principles in NPI corroborated the opinions of the ME stakeholders at Airbus UK. The authors Parry and Turner (2003) presented the results of research carried out by the LAI and an NPI Working Party consisting of eleven representatives from seven aerospace companies. The authors state that 'value' within the NPI process can be expressed in a qualitative manner and so can; waste, cause, counter measure, and customer effected. The primary effect of NPI 'waste' was identified as 'sub-optimal design'. The primary and secondary 'causes' of NPI 'waste' were identified as poor communication and poor programme management. The 'counter measure' recommended to combat the 'causes' of 'waste' was Integrated Project Teams (IPTs). Finally, the authors identified that the 'internal customer' is most affected. It is clear that, if Airbus UK can improve the integration of their ME NPI teams then by doing so will increase the effectiveness of CE and consequently the ME NPI process.

4.4 Refined Solution

The concurrent engineering approach employed at Airbus (ACE) requires effective information flow between those involved to allow the smooth working of the process. The work presented in this thesis is focused on an investigation of current practices.

Development of an organisational improvement methodology and matrices provides Airbus UK with a structured and pragmatic methodology to aid the review and improvement of the ME NPI process. The focus of the methodology is to improve the current ME NPI process through better CE team/stakeholder effectiveness via increased and improved involvement, communication, and coordination. The significance of good communication and coordination for successful NPD is recurrent within literature (Lawrence and Lorsch, 1967; Barclay 1992).

The organisational improvement methodology and matrices presented are adapted from; Fleischer and Liker (1997). 'Concurrent Engineering Effectiveness – Integrating Product Development Across Organisations'. The 'As-Is' ME NPI process model is used to develop the generic organisational methodology to that of one specific to the process of

NPI within the ME function at AIRBUS UK. The improvement methodology has seven stages. Stage 1 determines the team/stakeholder task responsibilities. Stage 2 determines the core design technology need by team/stakeholder. Stage 3 determines the team/stakeholder communication patterns. Stage 4 determines the coordination needs of teams/stakeholders. Stage 5 determines the coordination mechanism required by teams/stakeholders. Stage 6 designs the project management approach to be adopted. Stage 7 concludes the methodology with considerations to the effects on the organisation culture. The each stages of the methodology should be applied initially to determine the 'As-Is' or current process then each stage should be applied a second time to determine the 'To-Be' or improved process. Due to the time constraints of this Master of Research thesis the application of the methodology has not been possible.

5 Modelling and Analysis

The first objective of the research presented is to map/model the 'As-Is' ME NPI process currently employed within Airbus UK. This section will focus on how process modelling and analysis using 'light weight' technology supported by focus group discussions can improve process management, process measurement and process improvement within the new product development process.

5.1 *Process Management in CE*

The authors Haque and Pawar (2001) present a definition of process management specifically in the context of developments relating to the management of concurrent new product development processes and approaches used to model and analyse them. Thus, in this context the authors state that process management can most appropriately be defined as:

" *...defining, analysing, documenting, controlling, and improving the business process to make them effective, efficient, and adaptable so that customers (external and internal) expectations are exceeded and waste within the process is eliminated*" (Black and Decker, 1994)

The authors also state that the effectiveness of process management is reflected in the following four beliefs. Each of the beliefs presented by the authors is considered in the context of the concurrent new product development process and organisational structure at Airbus UK. This is done in an attempt to identify the effectiveness of the current ME NPI process management at Airbus UK.

1. *"Organisations may be structured vertically, but most value added work takes place horizontally."*
2. *"All work processes should be made up of definable, repeatable and predictable activities."*
3. *"If a work process can't be measured, it can't be managed – or (knowingly) improved."*
4. *"Effective work processes depend on involved, empowered employees, and a coaching, facilitating, supportive management, working in teams, using basic principles of behaviour, and the core values."*

Process management, when used effectively, has positive effects on organisational dynamics including the relationships between the manager/supervisor and employee also peer-to-peer relationships. Comparing the beliefs of Haque and Pawar (2001) to the current situation at Airbus UK it is clear that improvements can be made to the effectiveness of the current ME NPI process management. The tasks and responsibilities of the NPI process within ME at Airbus UK are performed using teams. There are many project teams involved in the process however, some are not collocated. Although the organisational structure at Airbus UK is project based, and not structured vertically, the absence of a current ME NPI process model inhibits effective process management, process measurement, and process improvement. If the current process is to be improved then it must first be mapped or modelled. In conclusion, the authors state that; one of the main elements of process management is mapping or modelling of the process and analysis of the process.

5.2 Process Modelling in CE

Haque and Pawar (2001) identify several methods and techniques for applying process modelling to the Concurrent New Product Development process (CNPD):

- IDEF family, particularly;
  - IDEF0 for activity modelling (USAF, 1981)
  - IDEF3 (Mayer *et al.*, 1992)
- Petri Nets (Peterson, 1977) for state transition diagrams, which enable representation of interactions between multiple actors in a process.
- Role Activity Diagrams (Holt *et al.*, 1983; Holt, 1988) a derivative of Petri Nets.
- Role Interaction Nets (Singh and Rein, 1992) also a derivative of Petri Nets.

Analysis carried out by Haque and Pawar (1998) has revealed that industrial application of process modelling has been predominantly for documenting purposes and these models are rarely used for analysis of organisational issues in CNPD. The modelling technique applied to the ME NPI process at Airbus UK is used to provide improvements to the current process and not simply as a method of documenting the current process. However, there are still significant benefits to Airbus UK from using the documented ME NPI process as a means of communicating the process between individuals and teams involved.

5.3 IDEF0 Modelling Technique

In order to model the current ME NPI process at Airbus UK the IDEF0 modelling technique was applied. The IDEF0 structure represents a system as a network of inter-connecting activities. It allows one to look at the flow of both physical and intellectual objects. The IDEF0 structure is well suited for this purpose and has been used in a similar manner to produce models of many manufacturing enterprises and NPI processes (Fleisher and Liker, 1997; Haque and Pawar, 2001; Harrington, 1984; Ang *et al*, 1994).

In the United States the IDEF0 modelling technique (Integrated Definition for Functional Modelling IDEF0) is a Federal Information Processing Standard (FIPS). The standard is based on the Air Force Wright Aeronautical Laboratories Integrated Computer – Aided Manufacture (ICAM) Architecture, Part II, Volume IV – Functional Modelling Manual (IDEF0). This means that the IDEF0 methodology will be the standard methodology to use in US industry when documenting, e.g., manufacturing systems.

The hierarchical structure of IDEF0 means that each page of the model contains a relatively small amount of information. This is particularly useful when documenting and improving a complex processes such as the ME NPI process at Airbus UK. This is in stark contrast to more common, and simpler to use, techniques such as flow charts. Flow charts can have many different activities on a single page, whereas the IDEF0 methodology restricts the number of activities to six per page. Another feature that enables IDEF0 to communicate complex process is that the methodology only contains two elements – boxes and arrows see Figure 3 .

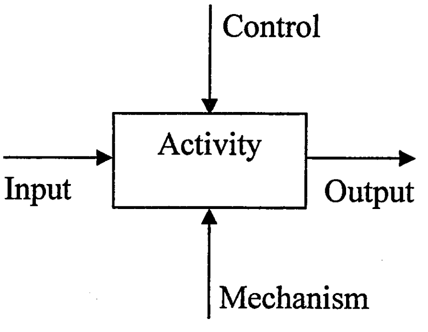

Figure 3: Elements of IDEF0 Methodology

The arrows represent the inputs, outputs, controls, and mechanisms of the activities presented. The inputs are transformed through the performance of the activity using, although not consuming, mechanisms or resources such as people or equipment to produce outputs. Generally the operation of the activity will be moderated by controls such as procedures and documentation.

6 New Product Introduction at AIRBUS

This chapter will introduce the current process employed for introducing new products within Airbus UK, the inhibitors to a more effective process, and how process management can be improved through modelling the current ME NPI process.

6.1 *AIRBUS Concurrent Engineering (ACE)*

A holistic view of the NPI process at Airbus UK formed the basis for discussion within the focus group as a result of the initial presentation (see Appendix 1).

The current NPI process at Airbus UK is based on CE practices (see Figure 4). According to Haque (2003) concurrent engineering is gradually becoming the norm for developing and introducing new products into the market place. The perceived benefits of concurrent engineering at Airbus are shown in Table 10.

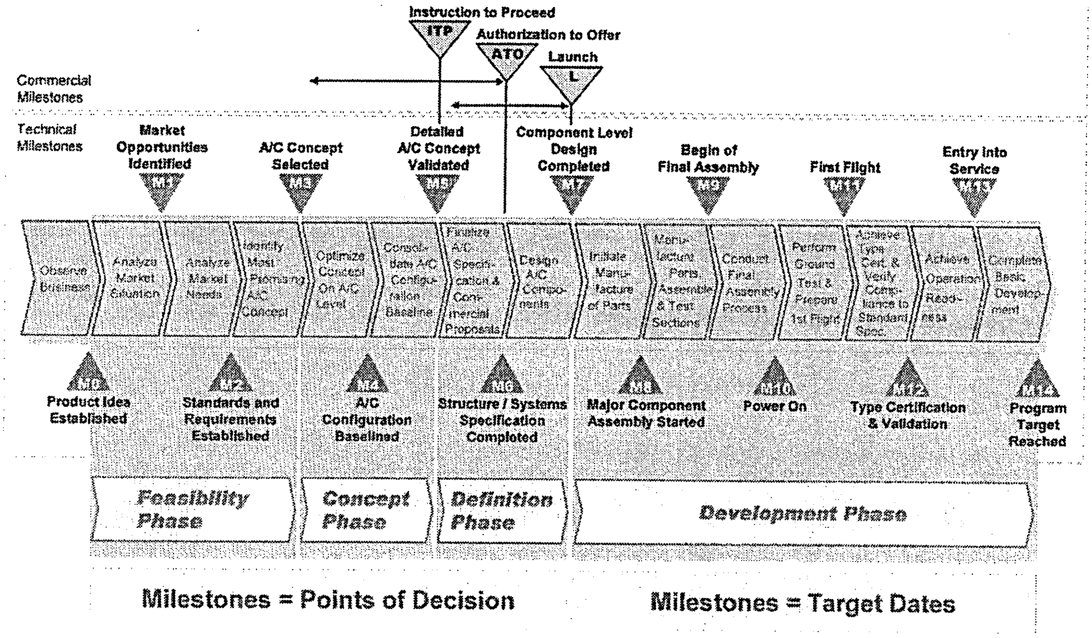

Figure 4: Concurrent Product Development at Airbus (Source: Airbus Industrie Procedure AP2054, 2001)

Airbus Concurrent Engineering (ACE) was launched in 1995 and has successfully been applied on A340-500/600 and A380 aircraft projects (ACE presentation see Appendix 2).

The Airbus ACE mission statement is:

- Providing Airbus with a competitive advantage by establishing integrated and efficient processes, methods and tools along the whole product life cycle.

The scope of Airbus ACE is defined as:

- Integrate data and information related to the Airbus development process in the trans-national ACMT Organisation. Major focus on the A380, A3456 and A400M.

Airbus have an NPD process based on the 'stage gate' process and purport benefits due to the application of concurrent engineering practices in three key areas, improved quality, reduced effort, and reduced development time. During the application of ACE on the A340-600 aircraft programme, only one concession was reported with no rework required. This is in contrast to the A340 where 500 concessions were reported resulting in approximately four months rework. At Airbus France the reduction in effort due to CE has seen savings of; €50million on the A340-600 programme with the workload halved due to numerical control programming. At Airbus Germany; €8 million savings were seen through the optimisation of hanger construction and tool optimisation. Development cycle times are purported to have been reduced by 30% on the A340-500/600 aircraft programmes (for more information on the ACE presentation see Appendix 2).

The application of ACE is said to have three major impacts on the business. Firstly, the replacement of sequential processes with parallel or concurrent sub-process has significant effects on reduced lead-time. Secondly, the standardisation of the product development process improves the efficiency of repetitive tasks. And thirdly, sub-processes are integrated through dedicated cross-functional teams resulting in improved communication. Benefits to the business and customer are reported through improved competitiveness.

Increased customer focus:	Reduced lead-time to accommodate late customer requirements for new, derivative and customised aircraft
	Improved dispatch reliability
	Achieved rapid aircraft maturity (minimal adjustment, high quality of assemblies for system installation)
	Improved customer driven maintainability
Improved Quality:	Improved quality of definition dossiers
	Reduced adjustment (fine tuning) - with higher quality of assemblies
	Improved consistency between aircraft and tooling
	Enabled easy transfers between design and definition
Reduced Effort:	Optimised processes by standardisation of repetitive tasks
	Elimination of physical mock-ups Facilitated access to the design or definition data
	Validation of factory flows through digital simulations
Time Reduction:	Decreased time for creation of Definition Dossiers
	Reduced lead time for tooling development
	Improved reactivity to unforeseen events

Table 10: Perceived benefits of concurrent engineering at Airbus (Source: Airbus, 2004)

6.2 ME NPI Effectiveness Inhibitors

As a result of the focus group observations and discussions with key Airbus UK personnel the main inhibitors to effective concurrent engineering within the manufacturing engineering function were identified. The primary inhibitors are; poor communication and integration, both internally and between functions, and consequently poor process management.

In general, the main problem is described as integration, both internally (manufacturing engineering project teams) and between the design and manufacturing functions. Communication and coordination both vertically and horizontally across functions is described as requiring improvement in order to improve NPI process integration and consequently concurrent engineering integration.

The lack of true manufacturing engineering process understanding and cross functional process understanding combined with ineffective team communication and coordination are cited as significant inhibitors to ACE effectiveness at Airbus UK.

Process understanding can be improved and consequently process management, through a structured approach to process modelling. Hence, the creation of an 'As-Is' manufacturing engineering new product introduction (ME NPI) process model. Further analysis is also required to improve organisational issues such as; communication and coordination of teams within the ME NPI process.

6.3 'As-Is' ME NPI Process Model

A literature review carried out by Haque (1999) revealed that despite considerable recent advances in the development of process modelling methods and software their application as tools to improve the management and organisational aspects (such as communication and collaboration between team members) of concurrent new product development process remains inadequate; Haque and Pawar (2001).

As a result of the focus groups unstructured observations and discussions the functional structure, data requirements, and data creation activities within the ME NPI process at Airbus UK were identified and documented using the IDEF0 methodology (see Appendix 3). Focus groups enabled the initial creation and documentation of the ME NPI process whilst informal discussions, with key Airbus UK personnel, provided the level of model decomposition required.

The intention of the 'As-Is' model is to provide a qualitative methodology of the current ME NPI process. Having a formalised and documented process model will improve CE integration, through improved process understanding and communication, whilst enhancing the effectiveness of managing the process. The model will also enable appropriate improvements to the current process.

The purpose, viewpoint, and context describe the limits, surroundings, and end criteria of the Airbus UK, IDEF0 model. They are characterised by the fact that they are all established before the modelling starts and that they are attached to the final model.

Purpose: To provide Airbus UK with a qualitative methodology of the current ME NPI process and so enabling process understanding and communication whilst increasing process management efficiency.

Viewpoint: Research Engineer

Context: The model should assist the researcher in understanding the current ME NPI process in order that improvements can be made inline with Airbus ME NPI process expert opinion and best industrial practices.

Detail level of enclosed IDEF0 diagrams: A-0, A0, A1, A2, A21, A24, A25.

7 Best Practice and Effective NPI Teams

This chapter will describe how process management and integration of the ME NPI process is improved through effective teams and best industrial practices.

7.1 Best Practice in Context

Clark and Fujimoto (1991) state that multifunctional teams are recognised as one of the most efficient and effective ways to improve communication and speed up the product development process. According to Griffin (1997) the Product Development and Management Association's (PDMA) 1995 survey found that multi-disciplinary teams were used for 64% of all projects. As the number of companies adopting concurrent engineering practices increases then so does the use of multi-disciplinary, cross functional teams. Cooper and Kleinschmidt (1993) report that cross functional, multi-discipline team is seen as an important mechanism for achieving integration. The authors Haque and Pawar (2001) suggest that the ever elusive concurrent new product development integration is achieved through effective teams and process understanding and describe how the application of process modelling and analysis fits in. The basis for best practices and effective teams within new product development is based on the following literature review.

7.1.1 Product Development: Past research, present findings, and future directions

The authors Brown & Eisenhardt (1995) purported evidence that senior management support and control, internal and external team communication, and cross-functional team composition all have positive effects on NPD process performance.

7.1.2 Best Manufacturing Practices Program

The findings from the Best Manufacturing Practices Program were reported by Stevenson *et al* (1994). The BMP program began in 1985 by the Department of the US Navy. The report was concerned with the practices used in manufacturing by 31 US Navy contractors. Included in the results was the recognition of value attributed to concurrent engineering and teamworking, the extent to which sophisticated design tools are utilised, also the lack of attention to design policy and NPD organisation.

7.1.3 Product Innovation in the Computer Industry

The authors Eisenhadrt & Tabrizi (1995) identified that "organizations using an experiential strategy of multiple design iterations, extensive testing, frequent project milestones, a powerful project leader, and a multifunctional team" accelerated product development. Whereas, organisations applying "the compression strategy of supplier involvement, use of computer-aided design, and overlapping development steps describes fast pace only for mature industry segments".

7.1.4 Fast Product Developers

The authors Zirger & Hartley (1996) proved that fast product developers had teams that were cross functional, dedicated, included fast time to market as a development goal, and overlapped development activities more than slow product developers.

7.2 Lean New Product Introduction

The aim of the following section is to present recent 'best practices' identified through literature. The research literature outlined is focused on the aircraft manufacturing industry and improvements to NPI.

7.2.1 UK LAI

The UK Lean Aerospace Initiative (LAI) is a group consisting of the University of Bath, Cranfield University, the University of Nottingham, and the University of Warwick with 40 participating company members of the Society of British Aerospace Companies (SBAC). The initiative has joint funding by participating SBAC members and IMI Aerospace (Link) Sector, Engineering and Physical Sciences Research Council.

In September 1999 the UK LAI began research and development activities into Lean Product Introduction. The programme was led by academics at Warwick Manufacturing Group, University of Warwick.

7.2.2 LAI and Lean Product Introduction

The LAI research was focused on the application and extension of Lean Production concepts to the concept of Lean Product Development (see: Womack, Jones, Roos, 1990). The authors discussed Lean Product Development in terms of a number of techniques. The techniques were:

- *a strong project leader with total control over functional resources,*
- *teamwork,*
- *early and controlled communication, and*
- *simultaneous development.*

The author Haque (2001) states that many companies in the West have taken up these techniques, particularly Simultaneous Development or Concurrent Engineering (CE). The author also identifies a recent survey carried out by Ainscough and Yazdani (1999) where 6 of the 9 aerospace companies they surveyed for NPD best practice claimed to use CE in one way or the other.

The Lean Product Introduction research is based on the comprehensive lean philosophy developed by Womack and Jones (1997) following the book '*The Machine that Changed the World*'. The philosophy is based on five principles. Brief definitions of these principles are as follows:

- Specify Value - define value precisely from the perspective of the end customer in terms of a specific product with specific capabilities offered at a specific price and time.
- Identify the Value Stream - identify the entire value stream for each product or product family and eliminate waste.

- Make the Value Flow - make the remaining value creating steps flow.
- Let the Customer Pull the Process - design and provide what the customer wants only when the customer wants it.
- Pursue Perfection - strive for perfection by continually removing successive layers of waste as they are uncovered.

Haque (2001) summarises his introduction to Lean Product Development by stating that; a lean system is achieved by eliminating *waste* and unnecessary actions, and linking all steps that create *value* in a continuous sequence. The author also states however, that even this new book was heavily biased towards manufacturing environments, as is illustrated in the examples they use. Consequently the five principles have only been applied specifically to manufacturing. Explicit application of the five lean principles to product development has been lacking, both in industry and academic research. The author presents a table comparing and contrasting the concurrent engineering philosophy and the lean philosophy (see Table 11).

Concurrent Engineering Philosophy	Lean Philosophy
CE lacks an enterprise wide common strategic theme or statement for implementation. It is naturally geared towards improving the NPD process and thus promotes specialised tools such as the Design For 'x' tools, QFD etc.	Lean is by definition an Enterprise initiative with a common format for all business processes with the single strategic goal of eliminating waste and improving the flow of value.
Lacks a life-cycle approach - i.e., does not answer the question: where do I start and how do I sustain the movement? The focus is on the 'what to do' and not the 'how to'.	Provides a life cycle approach with both the 'what' and 'how to', starting and ending with the customer ('pull the value'), with a continuous drive for waste elimination.
Liable to different interpretations and definitions	Easy to understand with only two themes- VALUE & WASTE
Does not at the outset classify and contextualise waste. Waste elimination is a by-product of CE activities.	Wastes identified, classified and contextualised within given value streams, and then eliminated.
Promotes customer focus and improvement of information flow, but does not explicitly define a systematic approach.	Explicitly promotes (a) the creation of Value Stream Maps based on customer demands, (b) flow is only truly possible after elimination of waste, and (c) that the value creating process be pulled at a customer-defined rate.
Does not explicitly define the concept of producing information at a rate dictated by downstream functions.	Promotes the concept of Takt Time, Single Piece Flow and the Pacemaker Process.

Table 11: Comparison of CE and Lean (Source: Haque, 2001)

7.2.3 LAI and NPI Value

The authors Parry and Turner (2003) specify value in the context of Lean Product Introduction based on research in the form of academic papers and the NPI Working Party. The NPI Working Party consisted of eleven representatives from seven Aerospace companies. The working party were asked to define NPI value. The results of which are presented below. Each of the 'values' defined by the Working Party was expanded to include definitions of the following:

- the resultant *waste*(s) if the value is not exploited correctly
- the *cause*(s) for not exploiting the value correctly
- the *counter measure*(s) that can be implemented to change the potential waste to added value
- the *customer*(s) effected by enhancing the value listed
    - internal customer – includes all other departments as well as other members of the IPT
    - direct customer – first point of delivery of parts
    - carrier – airline
    - passenger
    - flight crew – to include maintenance/pilots/cabin crew

A tally of each occurrence of waste, cause, counter measure, and customer effected was charted. The results of which are detailed in the following sections; NPI Value, NPI Waste, NPI Cause, NPI Counter measure, and NPI Cumulative customer effected:

7.2.4 NPI Value

Parry and Turner (2003) state the following were all considered areas that can enhance value within NPI:

- Accurate data
- Achieving customer requirements
- Agreement of all stakeholders
- Communication
- Core competency
- Defined processes/gates
- Development cost
- Efficient Key Performance Indicators
- Flexible design (scaleable/reuse)
- Functionality
- Information technology
- Innovation
- Integrated Product Teams
- Intellectual Property Rights
- Knowledge and experience
- Leadership
- Maintainability
- Maintaining delivery times
- Manufacturing capability
- Patents
- Percent complete
- Product cost
- Product portfolio
- Programme management
- Quality
- Reliability
- Risk reduction and mitigation

7.2.5 NPI Waste

The authors suggest if value is not fully addressed, then the most likely waste generated will be a suboptimal design (see Figure 5).

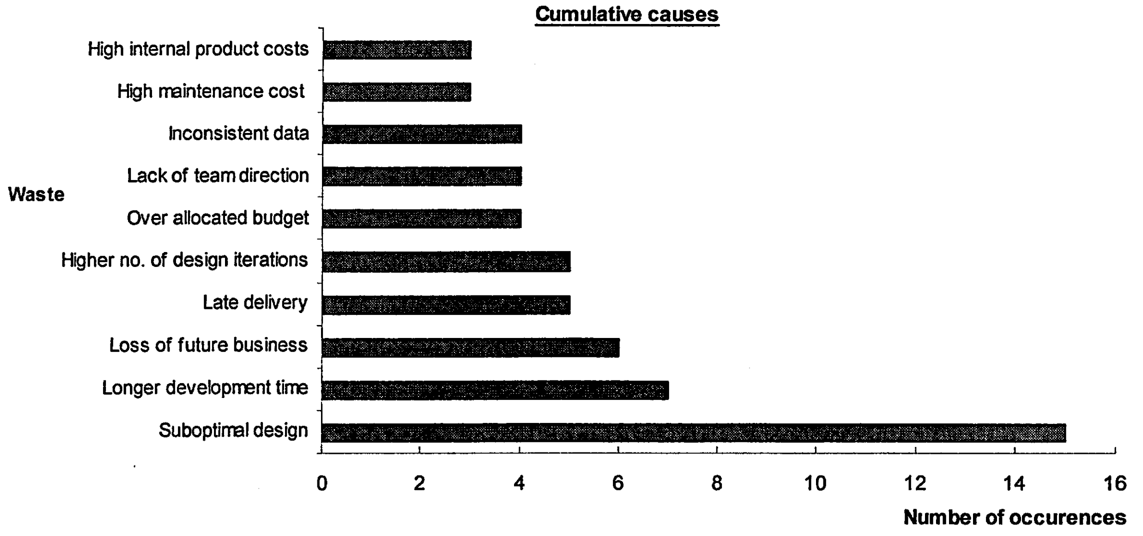

Figure 5: NPI Waste (Source: Parry and Turner, 2003)

7.2.6 NPI Cause

The most common causes for not enhancing value of a project as described by the authors include poor programme management and poor communication (see Figure 6).

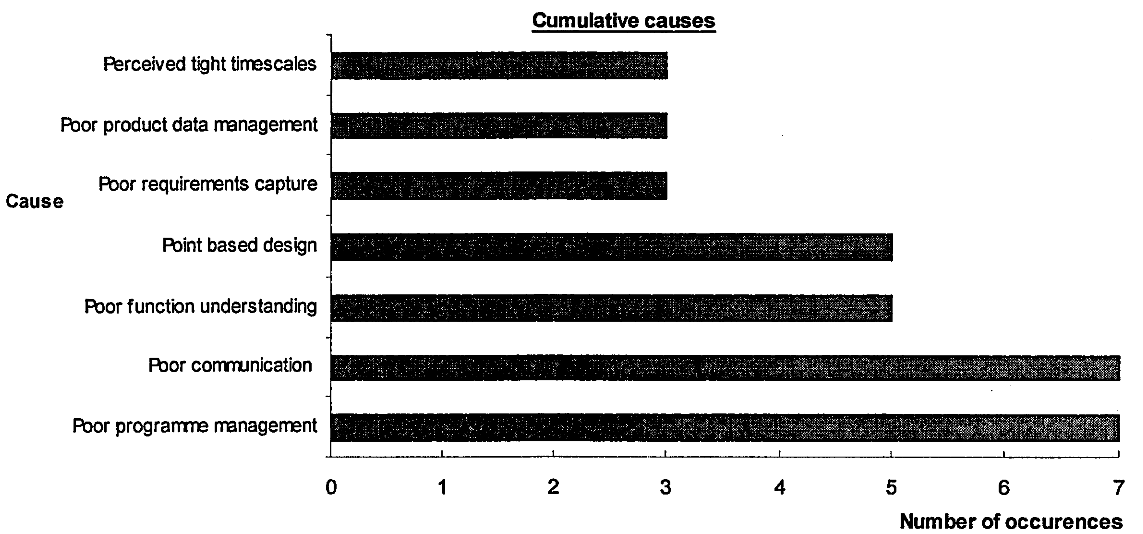

Figure 6: NPI Cause (Source: Parry and Turner, 2003)

7.2.7 NPI Counter measure

The authors state that Integrated Product Teams appear to be the most productive method to eliminate waste and enhance the value of the project (see Figure 7).

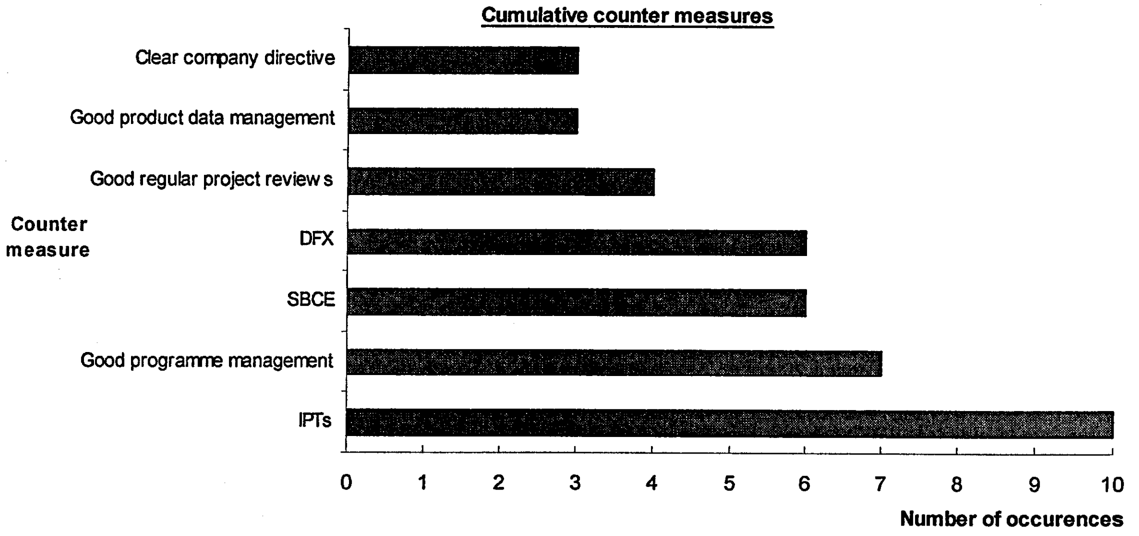

Figure 7: NPI Counter measure (Source: Parry and Turner, 2003)

7.2.8 NPI Cumulative customer effected

If the value of a project is not understood then, the authors purport, the internal 'customer' will be most effected (i.e. other department) (see Figure 8).

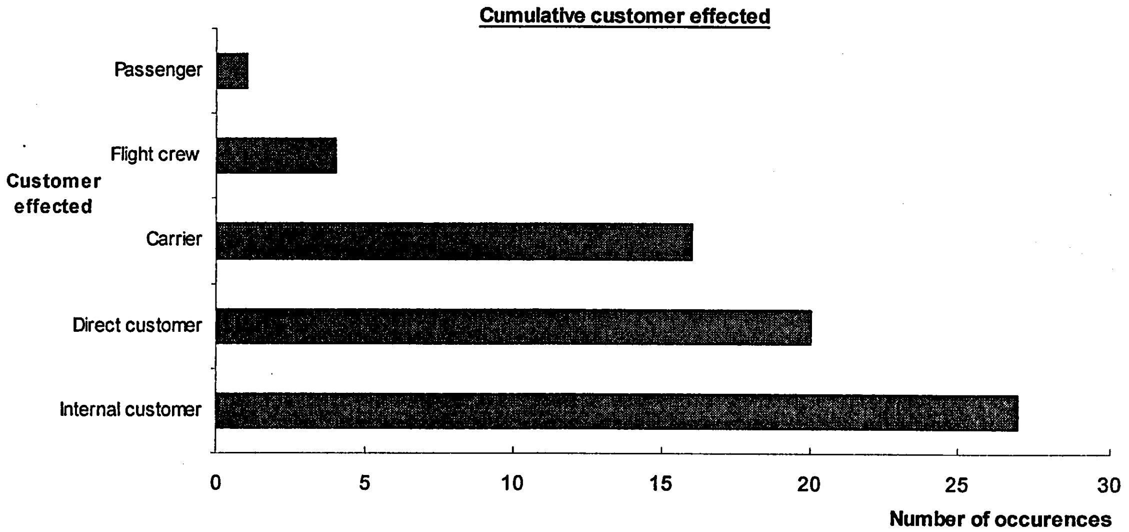

Figure 8: NPI Customer effected (Source: Parry and Turner, 2003)

The authors conclude that; further discussions within the group confirmed that the most common method of enhancing value and eliminating waste is through the use of Integrated Project Teams (IPTs) and concurrent engineering. The authors also suggest that by using CE and IPTs, the time of the process can greatly be reduced. Also, that the quality of information is improved as the key members of the NPI process are all included in the IPT.

It is the improvement of these teams that is the key to improving the ME NPI process at Airbus UK. The most effective method of eliminating waste in the current ME NPI process at Airbus UK, as defined by NPI process leaders and members, is the improvement of team integration and communication. Poor communication and integration, both internally and between functions, and consequently poor process management are cited as major inhibitors to an effective ME NPI process.

The main problem is described as integration, both internally (manufacturing engineering project teams) and between the design and manufacturing functions (both constitute internal customers). Communication and coordination both vertically and horizontally across functions is described as requiring improvement in order to improve the effectiveness of the current ME NPI process.

7.3 Effective Teams, Process Understanding, Modelling and Analysis

The authors Haque and Pawar (2001) produced a model to depict the relationship between NPI process understanding, modelling and analysis, and effective CE teams. Figure 9, illustrates how the ever-illusive CNPD integration is achieved through effective teams and process understanding and how the application of process modelling and analysis fits in. Process modelling and analysis is proposed, by the authors, as a way not only to achieve a better understanding of the processes but also to serve as a tool to contribute towards effective CE teams. The authors' state that this is achieved through the continuous assessment of teams using process based analysis.

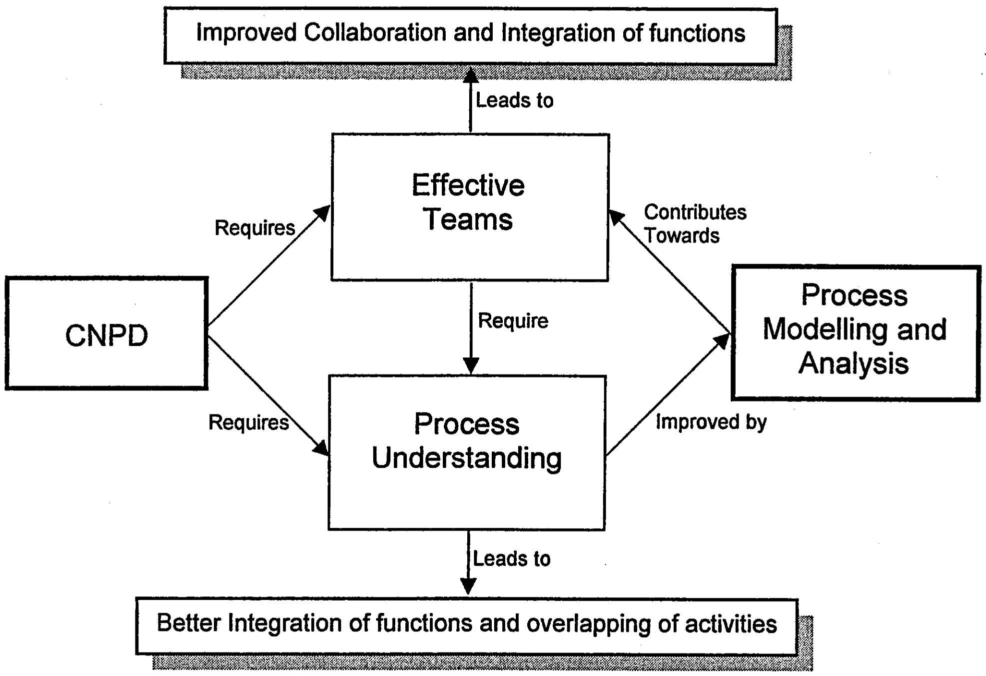

Figure 9: Relationship between CNPD, process modelling and analysis, and teams (Source: Haque and Pawar, 2001)

In the case of the research presented, the authors' model is clearly relevant in the context of Airbus Concurrent Engineering (ACE). Process modelling and analysis has been applied to the ME NPI process at Airbus UK. Process modelling and analysis was employed using IDEF0 functional modelling methods to document and communicate the 'As-Is' ME NPI process. The benefits, as purported by the authors', are improved process understanding, better integration of functions, and overlapping of activities. It is clear from this research that the ME NPI process understanding has been improved. The model also describes how process modelling and analysis contributes to effective teams. For the research presented process modelling and analysis has also been used to enable the creation of an organisational improvement methodology. The methodology is focused on improving the effectiveness of ME NPI teams at Airbus UK.

8 Organisational Improvement Methodology

The importance of good communication and co-ordination for successful NPD is a recurrent theme within literature (Lawrence and Lorsch, 1967; Barclay 1992). The concurrent engineering approach employed at Airbus (ACE) requires effective information flow between those involved to allow the smooth working of the process. Haque and Pawar (2001) argue that traditional changes in human resource management via the introduction of multifunctional/collocated teams required by concurrent new product development (CNPD) can be complemented by the introduction of process management, focused on the modelling and analysis of the 'softer' organisational issues.

The research presented in this thesis uses process management improvements enabled by modelling and analysis of the 'As-Is' ME NPI process. Also, focus group discussions and 'best practice' literature to develop an organisational improvement methodology which is focused on improving 'softer' organisational issues within Airbus UK's ME NPI process.

The organisational improvement methodology and matrices presented are adapted from; Fleischer, M. and Liker, J.K. (1997). 'Concurrent Engineering Effectiveness – Integrating Product Development Across Organisations'. The methodology and matrices have been developed to contain the major activities and teams/stakeholders within the ME NPI process at Airbus UK rather than the generic stages of an entire NPD process detailed by the authors. The 'As-Is' ME NPI process model was analysed and used to create the methodology and matrices specific to the ME NPI process at Airbus UK.

The entire analysis of the 'As-Is' situation should be performed before the methodology is repeated to determine the 'To-Be' or improved process. The methodology is aimed at improving the current ME NPI process through better CE team/stakeholder effectiveness via increased and improved involvement, communication, and coordination.

8.1 Determine 'As-Is' and 'To-Be' Task Responsibilities

Due to the time constraints imposed on this MRes thesis the methodology has not been applied in order to improve the current ME NPI process at Airbus UK. The Matrices presented have been populated only to serve as an example of how they should be applied to the current process.

8.1.1 Determine Task Responsibilities

The purpose here is to identify how different ME NPI process teams/stakeholders are involved in the main activities described in the 'As-Is' ME NPI process model. The main activities are documented but it is important to determine 'who' is involved with the execution of each activity. Knowing 'who' does 'what' will assist in the next stages of the methodology.

The authors have identified four different types of involvement which the matrix is based on. The four types of involvement are described below:

1. *Responsibility.* The group/individual has major responsibility for the conduct of that activity. They may delegate some of the tasks to others or actually do it themselves – in either case, they are responsible.
2. *Approval.* The group/individual has authority to approve or not approve key decisions in the activity. They are decision makers.
3. *Support.* The group provides important support for this activity. This support might be in the form of providing information, providing resources, or performing specific delegated tasks that are part of the activity.
4. *Informed.* The group/individual is informed about the progress or outcomes of the activity.

The task here is to identify how different groups/individuals are involved in key activities. The ME NPI Involvement Matrix has been developed as a tool to aid this.

8.1.2 ME NPI Involvement Matrix

The ME NPI Involvement Matrix (see Figure 10) classifies the involvement and responsibilities of teams/individuals for different activities with the ME NPI process at Airbus UK. The 'As-Is' or current situation is documented above the dotted line while the 'To-Be' or future situation is documented below the line.

After stating 'who' is responsible for 'what' activity, a preliminary assessment of strengths and weaknesses are recommended. For example, are the right people being informed? Are the right people with the most knowledge of the product sufficiently involved in decisions about the product? Who is making the decisions and who is informed? Is this appropriate or should others be involved in making decisions up front?

Phase	As-Is (Top) / To-Be (Bottom)	Commercial Estimating	ME Manager (MEM)	ME Chief Engineer	ME Project Engineers	ME Jig & Tooling Engineers	ME Systems Engineers (MSE)	Process Planning Engineers	Interchangeability Engineers (ICY)	Reprographics Team	Design Configuration Team	Component Design Build Team	Operations Team	ME Support Team
Establish Manufacturing Strategy (PROJECT	Establish Manufacturing Systems Technology			A	R	R								
	Create Build Sequence			A	R	S								
	Establish Key Interfaces – KC's & Tooling Strategy			A	R	R								
	Create Build Philosophy Brochure			A	R	S								
Produce Manufacturing Planning (PROCESS PLANNING PHASE)	Create Build Index / Text Network	S		A	R	I							I	
	Define Tooling Requirements					S		R						
	Create Supporting Documents		A				R	R	R	S				
	Create DAP Structure & Manufacturing Sequence				R						I			
	Establish & Agree Drawing Requirements				R			S				R		
	Create Assembly Process Plans							R					S	
	Build First Article													R

Key:
A = Approval
I = Informed
R = Responsible
S = Support

Figure 10: ME NPI Involvement Matrix

The interpretation of the matrix shown in Figure 10 is straightforward. From the example shown, it is clear that the ME Manager has authority for the activity 'Create Supporting Documents'. After that they are no longer part of the process. In contrast, ME Jig and Tooling Engineers are responsible for certain activities whilst only supporting and being informed of others. It is advised, by the authors, to fill in a comments form. An example is presented in Figure 11.

ME NPI Involvement Comments Form
1. List any cases in which people who should be involved are currently not in the loop (consider blank cells in ME NPI Involvement Matrix).
Project Management should be involved in the tooling phase although are not currently.
Manufacturing Engineers should have input earlier in the process
Tooling Engineers should support installation of tooling and equipment
Test Engineers has no direct involvement in the process
2. Consider obvious cases where stakeholders do not have the level of involvement warranted by their expertise.
Project Managers do not have enough responsibility
Manufacturing Engineers should have a stronger role in the final design
Design Engineers should have more responsibility for production launch

Figure 11: ME NPI Involvement Comments Form

The ME NPI Involvement Matrix should be coupled with a more detailed account of the entries in each cell. Notes should be kept with more details of entries. For example, an entry such as 'support' will become much less meaningful as time passes by. The preferred method recommended by the authors is to record minutes of meetings with notes included in the minutes as an appendix.

As a consequence of the analysis of the 'As-Is' or current situation the 'To-Be' or improved process can be documented. The 'To-Be' process is documented below the dotted line on the same matrix. The easiest way, reported by the authors, to fill out the 'To-Be' responsibilities is to start with the existing responsibilities. A decision on how the responsibilities should be changed is based on the 'As-Is' assessment, the benchmarking, and the design principles employed. It is important to note that these are only 'first cut' decisions and may change when downstream applications are considered.

8.2 Determine Core Design Technology Needs

The aim here is to determine which teams/stakeholders need access to core technologies. By core technologies the authors mean; basic design technologies needed by teams/stakeholders to do their work, such as a CAD system for a designer. The documented work process ('As-Is' ME NPI process model) should aid directly in selecting technologies.

Part of the generic worksheet example presented by the authors is shown below (see Figure 12). In the context of the ME NPI process at Airbus UK, function will be replaced by team/stakeholder. Although there are cross functional teams involved there are also various teams and individuals (e.g., ME Chief Engineer, ME Jig and Tooling Engineers, Process Planning Engineers) within the manufacturing engineering function. Hence, the terms team/stakeholder are used to identify those involved in the process at Airbus UK.

Function	Technology Description	Comments
Project Management	PC with word processing, spreadsheet, database, project management software; LAN with fileserver, internet e-mail and internet access.	
Design Engineering	CAD workstation + PC. Workstation includes 3D CAD with solid modelling capability, STEP translation capability, engineering analysis modules + ability to exchange data with the PC which contains design of experiments software. PC includes word processing, spreadsheet, project management software. QFD software available on selected systems. LAN with fileserver, internet e-mail and internet access.	Not all design engineers will use CAD though all should at least learn how to access files and read them on the screen.
Tool Engineers	CAD workstation – includes 3D CAD with solid modelling capability and STEP translation capability. LAN with fileserver and internet e-mail.	Tool design will be done on CAD.
Tool Production	CNC equipment to cut tools programmed from CAM system; CAM can use CAD files accessed over LAN with fileserver and internet e-mail.	
Manufacturing Engineering	PC with CAD, word processing and spreadsheet; LAN with fileserver and internet e-mail.	

Figure 12: Core Technology Description Worksheet (Source: Fleischer and Liker, 1997)

8.3 Determine 'As-Is' and 'To-Be' Communication Patterns

The initial purpose here is to document the current communication patterns between teams/stakeholders within the ME NPI process. The teams/stakeholders are the same as those documented in the ME NPI involvement analysis. The focus is on communication between process teams/stakeholders. Strengths and weakness with the 'As-Is' situation should be identified so that a 'To-Be' or improved model can be proposed.

8.3.1 Determine Communication Patterns

The authors state the primary questions that are traditionally defined about communication are who, what, how, how often, and to what purpose? In this case the 'who' is defined as the ME NPI process teams/stakeholders. The 'what' are the process activities (e.g., Establish manufacturing systems technology, Create build sequence, etc.)

that the teams/stakeholders perform. The 'how' are the mechanisms used for communication. With this section the focus is 'patterns' of communication. Patterns of communication include issues related to who, how, and how often. Other communication questions will be addresses in section 8.5; Determine Coordination Needs.

According to the authors, communication patterns have three critical dimensions: direction, synchronicity, and frequency. The authors also describe each of the critical dimensions as follows:

- *Direction.* Direction can be communication flowing in one direction only; from party A to party B, or B to A; or flowing in both directions.
- *Synchronicity.* Synchronous communication is almost immediate, two-way 'give and take' across parties. Asynchronous is when a significant lag exists from the time a communication is sent until a response is received (e.g., ME Project Engineers send Build Sequence documents to the ME Chief Engineer for approval. If approval is given it could possibly be several days later).
- *Frequency.* There may be frequent communication between stakeholders, or there may be very little.

The amount of communication and type that is necessary depends on the activities that are required to be coordinated between teams/stakeholders. If more than one team is involved in an activity they will need to communicate. If it is a complex activity that requires intense joint problem solving (e.g., Create Supporting Documents) then two-way synchronous communication is recommended by the authors. Similarly, if one team/stakeholder can do the job them self and they only need to keep others informed, one-way communication or low frequency is recommended.

8.3.2 ME NPI Communication Matrix

ME NPI Communication Matrix (see Figure 13) is used for analysing communication patterns between teams/stakeholders within the ME NPI process at Airbus UK. The 'As-Is' or current situation is documented above the dotted line while the 'To-Be' or improved model is to be documented below the line.

As with the ME NPI Involvement Matrix an assessment of the strengths and weaknesses of the current state of communication should be made. This should be done prior to the completion of 'As-Is' ME NPI Communication Matrix.

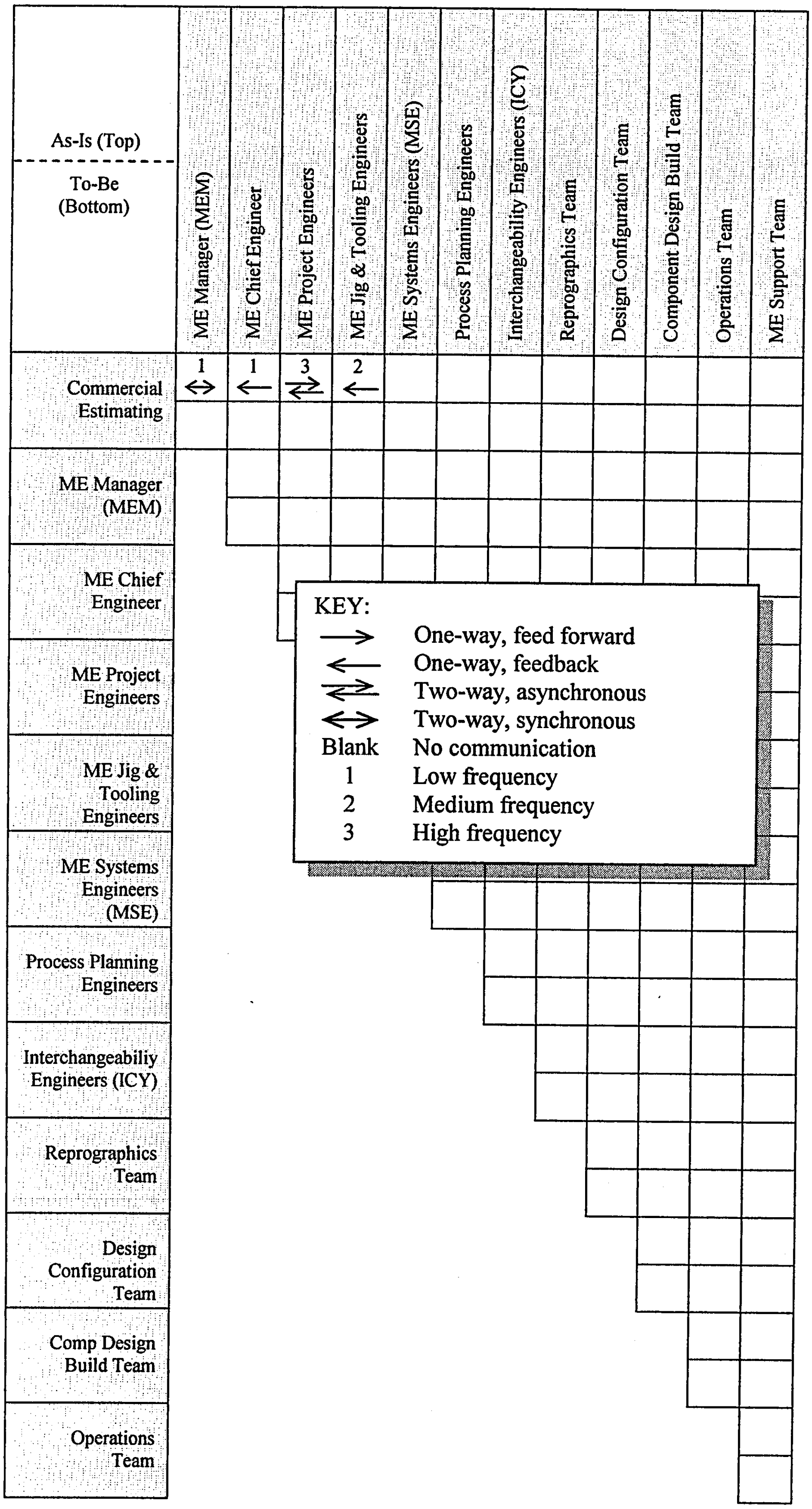

Figure 13: ME NPI Communication Matrix

For each pair of organisational teams/stakeholders in Figure 13, each cell indicates whether ME NPI communication is primarily one-way or two-way. Information pertaining to the direction of communication can be obtained by inference from the ME NPI process model.

After the identification of strengths and weaknesses of the 'As-Is' situation the next stage is to revise the ME NPI Communication Matrix. In order to do this a decision must be made on how teams/stakeholders 'should' communicate. As with the ME NPI Involvement Matrix the starting point is the 'As-Is' ME NPI Communication Matrix. This should be converted into a 'To-Be' version by detailing below the dotted line. The revised or 'To-Be' matrix should reflect the new needs for communication between teams/stakeholders within the ME NPI process.

8.4 Determine 'As-Is' and 'To-Be' Coordination Needs

The intention here is to document the 'methods' used to coordinate between ME NPI teams/stakeholders. Also, the 'quality' of coordination they provide. As in previous matrices, the teams/stakeholders are taken from the 'As-Is' ME NPI process model. Again, strengths and weakness with the 'As-Is' situation should be identified so that a 'To-Be' or improved model can be proposed.

8.4.1 Determine Coordination Needs

In order to create the Coordination Needs Matrix the authors describe five cross functional coordination mechanisms summarised by Mintzberg (1983). The authors used Mintzberg's mechanisms as he had succinctly summarised literature in the field of cross functional integration. The authors quote Mintzberg (1983) as follows:

"Five coordination mechanisms seem to explain the fundamental ways in which organisations coordinate their work: mutual adjustment, direct supervision, standardization of work processes, standardization of outputs, and standardization of worker skills. These should be considered the most basic elements of structure, the glue that holds organisations together".

The authors also briefly describe Mintzberg's five mechanisms, which the matrix is based on, as follows:

1. *Direct Supervision.* One person takes responsibility for coordinating all tasks by telling the others what to do and keeping track of their performance. The supervisor has the big picture and subordinates need only execute their individual pieces, doing as they are told. The traditional authority structure in an organisation uses direct supervision.
2. *Standardization of Work Processes.* Work tasks are programmed in some detail so that party A knows what to expect from party B and when to expect it, even if they have not communicated at all. Traditional assembly line work processes use

this mechanism, but it is certainly not confined to the factory floor. Most design groups have a large number of standards which specify such things as how drawings will be made, what software will be used, or when engineering analysis will be performed. These standards are *coordinating* mechanisms because, if they are followed, each person knows what to expect from the others and what they are expected to do. Thus, two groups that follow a schedule (a way to standardize work processes) know what to do to coordinate their efforts without needing to call a meeting or even make a telephone call. One can, in theory at least, prepare to receive the others work without any added coordination effort at all.

3. *Standardization of Outputs.* The result of someone's work is standardized. Suppliers who provide certified parts to a customer have standardized their outputs so that there is no need to have additional coordination effort. Thus, the customer and supplier don't need to discuss what the dimensions of a part will be when an order for part # xxx is placed; the standards for that part cover all the necessary coordination.
4. *Standardization of Worker Skills.* It is possible to know what someone will do on a given task based on the specific skills they bring to the task. Thus, a journeyman tool or die maker, given a task to produce a stamping die for a part, does all the work necessary to produce that die. Few (if any) further instructions are given (other than schedule, cost, and specifications). No manager, for example, tells the die maker how to produce a given feature in the finished die. While there may be some additional controls placed on the die maker (program reviews, for example), most of the coordination necessary has been done through the training that the die maker has received over the years.
5. *Mutual Adjustment.* Coordination is achieved by continuous, two-way communication between parties involved. This means that there can be real-time adjustment of behaviour and ideas based on feedback from others involved. A vivid example is the operating room team of doctors, nurses, and technicians who need to continually communicate and adjust their actions as the situation changes second by second. Anytime you call someone to discuss how you are going to go about some task, you are using the mechanism of mutual adjustment. Most teams, and indeed most meetings, take advantage of this mechanism.

The authors suggest that the number given in the ME NPI Coordination Matrix for quality of coordination should bc bascd on thc following scalc:

1. = inadequate coordination – *frequent and significant problems arise due to failure to coordinate.*
2. = barely adequate coordination – *occasional problems arise due to failure to coordinate; these are usually not significant.*
3. = very active and useful coordination – *few problems arise from failure to coordinate and these are almost never significant.*

The ME NPI Coordination Matrix is used to document the types of mechanism used and the quality of coordination they provide.

8.4.2 ME NPI Coordination Matrix

Each cell in the ME NPI Coordination Matrix (see Figure 14) shows the mechanisms used for coordinating between ME NPI teams/stakeholders, as well as a number (from 1 to 3) indicating the quality of coordination. The matrix is symmetrical and so only the active cells are populated.

As with the previous matrices an assessment of the strengths and weaknesses of the current state of coordination should be made. Again, this should be done prior to the completion of 'As-Is' ME NPI Coordination Matrix.

As-Is (Top) / To-Be (Bottom)	ME Manager (MEM)	ME Chief Engineer	ME Project Engineers	ME Jig & Tooling Engineers	ME Systems Engineers (MSE)	Process Planning Engineers	Interchangeability Engineers (ICY)	Reprographics Team	Design Configuration Team	Component Design Build Team	Operations Team	ME Support Team
Commercial Estimating	3 W	3 M,O	3 M,D	1 M,S,W								
ME Manager (MEM)		2 D,S										
ME Chief Engineer												
ME Project Engineers												
ME Jig & Tooling Engineers												
ME Systems Engineers (MSE)												
Process Planning Engineers												
Interchangeabiliy Engineers (ICY)												
Reprographics Team												
Design Configuration Team												
Comp Design Build Team												
Operations Team												

Key:
D = Direct Supervision
M = Mutual Adjustment
W = Standardisation of Work Process
O = Standardisation of Outputs
S = Standardisation of Worker Skills
1 = Inadequate coordination
2 = Barely Adequate Coordination
3 = Very Active and Useful Coordination

Figure 14: ME NPI Coordination Matrix

Prior to the 'As-Is' assessment of the ME NPI Coordination Matrix the next stage is to revise the matrix to reflect the new coordination needs. This should be done only when both the ME NPI Involvement Matrix and the ME NPI Communication Matrix have been revised. Having analysed the 'As-Is' matrices the next stage is to determine the 'To-Be' matrices. This will enable your thoughts to be focused on who should do what, and who needs to talk to whom.

8.5 Determine Coordination Mechanisms

The analysis undertaken so far has been focused on; who needs to communicate and how much, who should have various kinds of responsibilities, and generally what coordination mechanisms should be used. The authors suggest that the next stage should be focused on more specific outcomes, such as; what specific teams should be formed, and who should be on them?

In this stage of the methodology the authors provide generic forms and matrices most of which have been adapted for the purpose of application on the ME NPI process at AIRBUS UK. The forms and matrices will enable the design of specific types of coordination mechanisms: teams, communication media, and standardisation mechanisms.

8.5.1 Teams

One obvious and critical coordination mechanism is the team. There are many different types of team and are often used in many forms within companies. The authors have summarised (see Table 12) the circumstances in which four different types of team would be used.

	Low Performance	**High Performance**
Low Task Scope	Task Force	Standing Committee
High Task Scope	Temporary Team	Semi-permanent Team

Table 12: Types of Cross-Functional Team (Source: Fleischer and Liker, 1997)

The authors also provide a generic matrix to determine how all of the possible teams might be set up. The matrix has been developed to suit the ME NPI process at Airbus UK (see Figure 15). The matrix has been developed but not applied to the ME NPI process and so provides and example of how the matrix may look upon application. A more detailed version of the matrix could be developed to show individual participants.

Team Categories	Specific Teams	Establish Manufacturing Systems Technology	Create Build Sequence	Establish Key Interfaces – KC's & Tooling Strategy	Create Build Philosophy Brochure	Create Build Index / Text Network	Define Tooling Requirements	Create Supporting Documents	Create DAP Structure & Manufacturing Sequence	Establish & Agree Drawing Requirements	Create Assembly Process Plans	Build First Article
Task Forces	Commercial Estimating	As Needed										
Standing Committees	Me Project Engineers		X									
	ME Jig & Tooling Engineers							X				
	ME System Engineers					X				X		X
Temporary Teams	Process Planning Engineers											
	Interchangeability Engineers		X	X								
	Reprographics Team			X				X		X		X
	Design Configuration Team											
	Component Design Build Team								X			
Semi – Permanent Teams	Operations Team				X			X				
	ME Support Team		X									

Figure 15: ME NPI Team Matrix

8.5.2 Communication Technology

A second coordination mechanism suggested by the authors is communication technology. With Table 13, the authors define eight categories of communication and suggest the form of communication for which each level of technology would be best suited.

Communication Technology	Richness		Best for
Formal written messages (paper or electronic mail)	Low	←	One way, low frequency
Shared databases	Medium	⇄	Two way, asynchronous, low frequency
Computer Conferences	Medium	⇄	Two way, asynchronous, low frequency
Personal written messages (paper or electronic mail)	Medium	⇄	Two way, asynchronous, high frequency
Voice mail	Medium	⇄	Two way, asynchronous, high frequency
Telephone	High	↔	Two way, synchronous, high frequency
Video Conference	High	↔	Two way, synchronous, low frequency
Face-to-face meetings (coming together from distant places)	Very High	↔	Two way, synchronous, low frequency
Face-to-face meetings (collocation)	Very High	↔	Two way, synchronous, high frequency

Table 13: Prime Uses for Communication Technology (Source: Fleischer and Liker, 1997)

Information from Table 13 should then be translated into a form that will enable the determination of the most appropriate form of communication media (see Table 14). This is done for any given communication need that is derived from the ME NPI Communication Matrix. An example of which is: if the ME NPI Communication Matrix suggests having two-way asynchronous communication at a high (3) level of frequency, then you know that personal written messages and voice mail are required.

Frequency of Communication	Direction of Communication		
	←	⇆	↔
1	Formal messages & shared databases	Databases and computer conferences	Telephone to meetings – depends on content
2	Formal messages & shared databases	Personal messages and voice mail	Telephone to meetings – depends on content
3	Formal messages & shared databases	Personal messages and voice mail	Collocation

Table 14: Interpretation of Communication Matrix (Source: Fleischer and Liker, 1997)

Combining information in Table 14 with the results of the communication needs, (ME NPI Communication Matrix) a decision can be made on the type of communication media required by different teams/stakeholders. It is also recommended by the authors that the teams/stakeholders be educated about the new ways in which they might communicate.

Communication Media Categories	Specific Media Provided	Establish Manufacturing Systems Technology	Create Build Sequence	Establish Key Interfaces – KC's & Tooling Strategy	Create Build Philosophy Brochure	Create Build Index / Text Network	Define Tooling Requirements	Create Supporting Documents	Create DAP Structure & Manufacturing Sequence	Establish & Agree Drawing Requirements	Create Assembly Process Plans	Build First Article
Formal written messages	Internet Email	X	X	X	X	X	X	X	X	X	X	X
	Library Access	X	X	X	X	X	X					
	Guidebooks	X	X	X	X	X	X					
Shared databases	Common File Server Access	X					X	X	X	X	X	X
	Common File Server Access	X	X	X	X	X	X	X	X	X	X	X
	Internet Web Site Access	X	X	X	X							
Personal written messages	Internet Email	X	X	X	X	X	X	X	X	X	X	X
Computer Conferences	Conference Line On Phone			X	X	X			X		X	
	AT&T Conference Systems											
	WWW Site Conferences	X			X		X	X	X	X	X	
	Bulletin Boards											
Video Conferences	In-Building Video Conference Suite	X	X	X	X			X				
	CuCme											
Face-To-Face Meetings	Conference Rooms	X	X	X	X	X	X	X	X	X	X	X

Figure 16: ME NPI 'To-Be' Communication Media Matrix

The ME NPI Communication Media Matrix (see Figure 16) is an example of how the authors' generic matrix can be applied to the ME NPI process at Airbus UK. The authors have only included six of the eight categories of media. The reason for this is that face-to-face categories have been combined. Also, the authors have excluded the telephone as it is widely conceived that everyone has access to a telephone. During the application of the methodology at Airbus UK the matrix may require changes to the specific media provided and the communication media categories to those specific to the company. It is, however, outside the time constraints, and so limitations, of this thesis to apply the methodology to the ME NPI process.

8.6 Design Project Management Approach

The Project Management Worksheet (see Figure 17) is presented as a project management decision aid. The worksheet is provided in order to assist a decision to be made on the type of project management approach to be applied to CE within Airbus UK. The worksheet presented is an example and has not yet been applied to Airbus UK's ME NPI process.

Project Management Responsibilities	Absent	Liaison	Lightweight	Heavyweight	Autonomous	AIRBUS UK
Distribute and share technical information among project members and facilitate problem solving		X	X	X	X	Yes
Distribute reports, minutes of meetings		X	X	X	X	Yes
Set project goals			X	X	X	Yes
Schedule and coordinate project activity			X	X	X	Yes
Allocate funds and equipment for project			X	X	X	Yes
Select staff for project (or have significant influence)				X	X	Yes
Evaluate performance of project members (or have significant influence)				X	X	Yes
Evaluate overall performance of project members					X	No
Long term professional development of project members					X	No

Figure 17: ME NPI 'To-Be' Project Management Worksheet

8.7 Consider Organisation Culture

During the application of the organisational improvement methodology and the 'As-Is' assessments it is likely that cultural issues will arise. These cultural issues could prove serious barriers to the new or improved CE system. Changing the culture of an organisation is a difficult and long term process. It is advised by the authors that such changes be addressed at the beginning and not at the point where they are visibly retarding CE effectiveness and improvements. It is advised that each cultural problem that arises during the assessment is considered. It is also important that consideration be made as to how the culture should be. The authors then suggest that a set of actions be derived for each individual change that would be introduced. A generic example presented by the authors is detailed below in Figure 18.

CE Elements	A-Is Cultural Conclusions	To-Be Cultural Changes	Actions Needed
Work Process	People may not believe that teams are a good idea or that team work is better than individual efforts. May resist efforts to introduce formal processes.	Widespread belief in the value of teams. Acceptance of the need for formal processes.	Top management must participate in teams. Reward team behaviour in reward and appraisal systems.
Internal Organisation	Very authoritarian, may resist participative, team based activity, despite statement from management.	Less authoritarian. More participative.	All levels of management must demonstrate this, especially the top.
Supplier Relations	Supplier relations are very top-down; resistance should be expected from buyers to idea of suppliers participating closely with design teams.	View suppliers as members of our enterprise, as partners where appropriate.	Formal changes in policy and procedure. Training of purchasing staff. Top management commitment.
People	"Can-do" attitude should help with change in the long run. Emphasis on training will help. Status differences will need to be broken down before team based culture can be adopted.	Reduced emphasis on status differences to confirm identity.	Formal systems need to break down status barriers – no more special parking, dining rooms. Mfg engineers pay needs to rise to be near design engineers; offices and other perks need to be equivalent.
Technology	Technology per se will not be a problem, but engineers' attitudes toward soft issues will be a source of resistance to change.	No changes	

Figure 18: To-Be Cultural Change Matrix (Source: Fleischer and Liker, 1997)

9 Conclusion and Discussion

This chapter concludes the results of the research, the contribution to knowledge and makes suggestions for further research.

9.1 Research Conclusions

The objectives and deliverables of this research have been met and presented. The issues facing Airbus UK, when introducing new products via the manufacturing engineering function have been addressed. A methodology to help review and improve the ME NPI process has been developed specifically to suit the process within the sponsoring company.

Improving the management and effectiveness of the new product introduction (NPI) process is widely considered a means of achieving one form of 'best practice' within many companies and academic literature alike. This is certainly the case for the commercial aircraft industry. Where reducing the 'time to market' of an aircraft provides significant competitive advantage. In recent years design and development of the Airbus A380 was estimated to cost in excess of $12 billion. The company cannot begin to recoup any of the monies invested until the first aircraft is delivered to the customer. It is currently estimated the time from project launch to delivery of the first A380 aircraft will take 5 years. In a highly competitive industry such as the commercial aircraft industry reducing the NPI process time, and consequently cost, through improved NPI process management and effectiveness is of utmost importance.

A review of the literature has shown that there is an ever increasing body of research, yet little can be found to explain in detail how concurrent engineering process management and effectiveness, focused on 'softer' organisational issues, can be practically improved. At a macro level many of the issues are addressed, but this is insufficient to guide an organisational application. The focus group method provided a rich source of primary data, enabling the documentation of the 'As-Is' ME NPI process model also identifying inhibitors to an effective Airbus Concurrent Engineering (ACE) process. This source of data, and 'best practice' literature, helped identify the most appropriate business improvements within the ME function in the area of NPI.

The research showed that effective CE teams provide the main vehicle for improving product development performance, by increasing integration through improved involvement, communication, and coordination. A literature study of 'best practices' identified the major causes of 'waste' within NPI as, poor communication and poor programme management. The research also showed that process modelling not only achieves a better understanding of the processes but also serves as a tool to contribute towards the assessment of CE teams using process based analysis. It was also found that process modelling improves process management within NPI. Process modelling and analysis is applied to the ME NPI process in order that a structured and pragmatic improvement methodology can be developed.

The presentation of the seven stage organisational improvement methodology developed by the research has not been applied to the ME NPI process at Airbus UK due to the time constraints of the research. The improvement methodology has seven stages. Stage 1 determines the team/stakeholder task responsibilities. Stage 2 determines the core design technology need by team/stakeholder. Stage 3 determines the team/stakeholder communication patterns. Stage 4 determines the coordination needs of teams/stakeholders. Stage 5 determines the coordination mechanism required by teams/stakeholders. Stage 6 designs the project management approach to be adopted. Stage 7 concludes the methodology with considerations to the effects on the organisational culture. Each stage of the methodology should be applied initially to determine the 'As-Is' or current process, the stages should be applied a second time to determine the 'To-Be' or improved process.

The presentation of the CE organisational improvement methodology developed by this research provides Airbus UK with a less prescriptive approach to improving their business within the ME function and area of NPI. The application of the methodology is, unfortunately, outside the limitations of this research. However, it is widely purported by ME NPI process stakeholders, and literature, that the most significant improvements to the current process can be realised through the improvement of 'softer' organisational issues.

9.2 Contribution of the Research

The research showed that although there is good understanding of the benefits of effective teams within concurrent engineering, there is little detailed knowledge and research about how to pragmatically improve the effectiveness of such teams. The combination of data collection activities, particularly the literature review, and focus group meetings has culminated in the development of a novel and innovative organisational improvement methodology. This incorporates both concurrent engineering improvement theory and practice.

9.3 Recommendations for Further Research

The research presented and the organisational improvement methodology developed by this research, should be applied to the ACE process within the manufacturing engineering function at Airbus UK. Recommendations for future work include the application of the methodology within Airbus UK and the subsequent benchmarking of the improved process against appropriate organisations. The methodical assessment and dissemination of the methodology will increase confidence in the approach presented. Little evaluation of the methodology was possible during the timescale to understand the exact impact upon application. The application and further evaluation will provide a deeper understanding of issues relating to concurrent engineering team effectiveness and may lead to further refinements of the methodology.

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APPENDIX 1

Cranfield UNIVERSITY

INTRODUCTION

Stephen Shaw: MRes Student

Engineering & Management of Manufacturing Systems

Cranfield University

Thesis Title: Review and improve the Manufacturing Engineering New Product Introduction Process

Supervisor: Peter Heylings

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Focus Group Introduction

'Establishing the Decision Process within Manufacturing Engineering New Product Introduction'

Focus Group Aim:

- Determine **who** and **what** is involved with the ME NPI decision process.

Focus Group Objectives:

- Identify **Key Milestones** within the ME NPI process
- Determine **Inputs** and **Outputs** to Key milestone activities
- Establish; **Information, Equipment** and **People** that **Enable** and **Control** each of the key milestones

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Focus Group Agenda

- Brief presentation describing four different **Design Definition Models; Sequential, Design Centred, Concurrent** and **Dynamic Models**
- The models will be discussed, briefly, and compared to the current AIRBUS NPI process
- Key Milestones to be agreed within the ME NPI process
- Inputs and Outputs to Key milestone activities to be determined
- The Information, Equipment and People that Enable and Control each of the key milestones to be documented

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Four Models of Design Definition

Based on research from the aerospace and automotive industrial sectors

- Most organisations adhere to **one** form of Product Definition as the **core** of their product development process

- Different design methodologies are the **foundations** upon which a company's NPI process is based

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The Sequential Model

- Found in traditional, **functionally based**, organisations
- Design is developed through various functions
- Product is designed **then** functions add input to the design in a **sequence** of activities
- Process is repeated until satisfactory result is output from last function
- Not satisfactory for today's industrial pressures; **cost, quality**, and **time** parameters are far more demanding than they have been before
- Information is **batched** at each stage then passed on to the subsequent activity **[Fig. 2.]**

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The Sequential Model

28 *B. Yazdani & C. Holmes*

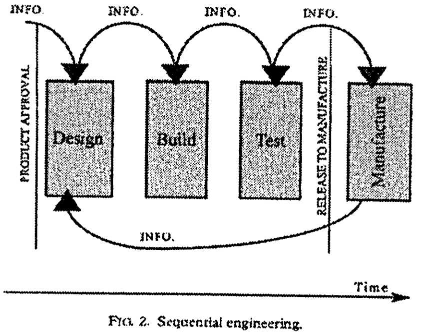

FIG. 2. Sequential engineering.

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The Sequential Model

- Most of the manufacturing changes are normally initiated in the manufacturing process and **taken back** to the detailed design stage
- Parts of the whole process are often repeated
- Measures of performance relating to the **function** rather than the **process**
- Often many layers of management
- Driving forces for employing the Sequential Model; **cost** and **quality** (automotive) and **technology** (aerospace)

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The Design Centred Model

- **Life-cycle consideration** required at the (crucial) design stage
- Tools are used to enable the design function to take account of **downstream activities** when developing the product
- Consideration of other departments requirements are **embedded** in the activities within **detail design**
- Downstream design changes are minimised
- Higher levels of **design analysis** required at the front end of the process **[Fig. 3.]**

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The Design Centred Model

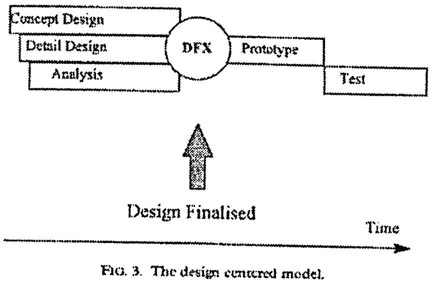

FIG. 3. The design centred model.

The Design Centred Model

- The process is still **predominantly sequential** – *with higher level of confidence in design information*
- Design information is still **batched** and passed to the next stage of the process
- Information is centred around an original detailed design (2D/3D CAD models) – acting as a master
- Tools required are centred around **analysis tools**; (FEA), (DFM), (DFA), (DFE- Environment), (LCC - life-cycle costing)
- At each stage risk is **minimised** before release

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The Design Centred Model

- Departmental integration **not** required – *greater understanding of downstream processes are required in Design Stage (tools)*
- Common approach in **aerospace companies** where **life-cycle analysis** has traditionally been required by the original contractor
- Western culture and education - **support** and are **geared towards** the **Sequential** and **Design Centred Models**
- Driving forces predominantly based on **quality** and **cost of development**

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Concurrent Definition Model

- With the **Design Centred Model** there is need for greater involvement of downstream activities in order to bring specific expertise to the design stage.
- This initiated the development of **Concurrent Product Definition**
- The process required for **Concurrent Definition** is characterised by the **overlapping of design** and the **planning of the process development [Fig. 1.]**

Concurrent Definition Model

26 *B. Yazdani & C. Holmes*

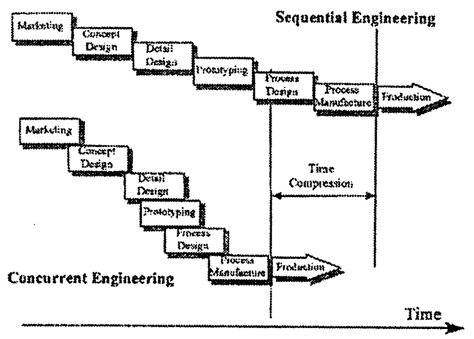

FIG. 1. Concurrent and sequential engineering.

Concurrent Definition Model

- Each **phase** (stage) of development has a **gate attached** *(which has all the downstream activities represented in order to allow the continuation of the master design)*
- **Sub-units** of data can be released to facilitate greater concurrency *(earlier start of prototype testing and production preparation)*
- Information exchange is facilitated through multi-functional teams
- Information exchange is **more informal** – greater intensity at overlapping stages **[Fig. 7.]**

Concurrent Definition Model

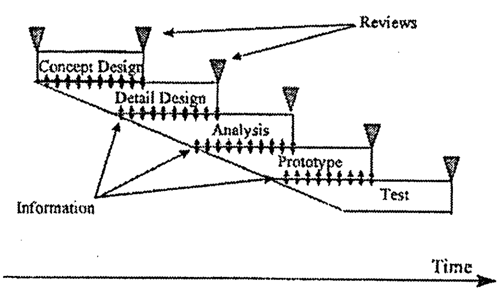

FIG. 7. The concurrent definition model.

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Concurrent Definition Model

- Main driving forces for Concurrent Definition Model are predominantly **engineering quality** and **lead-time based**
- DFX tools can be used but not essential – *as expertise of downstream activities are present in multi-functional team*
- Product definition is more concurrent than previous models
- Premise of the model is **not** design analysis - *relies on expertise of project team*
- Prototyping begins **much earlier** and **overlaps** with the manufacturing of production tooling

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Concurrent Definition Model

- Stage gate phases allow for many **iterations** and **design changes** to take place within each phase **[Fig. 8.]**
- The master is released following every phase review – *however, within the phase, the information has a dynamic nature and is matured before every review and subsequent release*
- The necessity for cross-functional teams requires a **matrix style of organisation** with **fewer layers of management**
- Cross-functional team members require **project management** skills and **process knowledge** as well as their **functional expertise**

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Concurrent Definition Model

32 *B. Yazdani & C. Holmes*

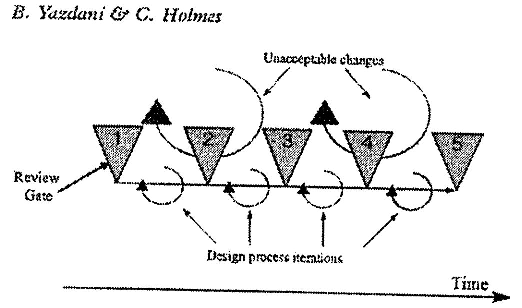

FIG. 8. Design change within a stage gate system.

The Dynamic Model

- Present in some Japanese automotive organisations
- With the stage gate system; the ability to **influence engineering decisions** diminishes over time with each stage.
- Further development of the **concurrent definition** system was to introduce a more **intensive level of communication** - *allowing greater and more timely influence of the design activities*
- The process therefore becomes **much more concurrent** as all activities **start at the same time [Fig. 10.]**

The Dynamic Model

34 *B. Yazdani & C. Holmes*

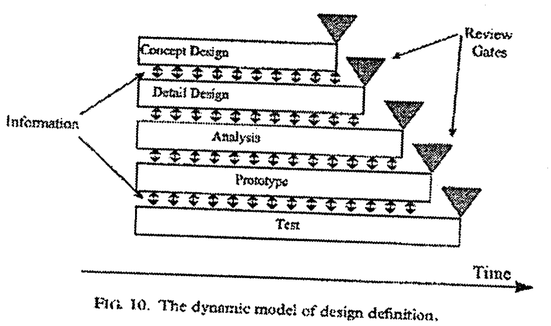

FIG. 10. The dynamic model of design definition.

The Dynamic Model

- Information exchange is far more **intensive** and **informal**
- Prototyping activity can be **prolonged**
- Reduced **lead-time** and **costs** are achieved
- Main driving forces are **time** based
- Data is finalised at the **review point** – this becomes the master model for the next phase

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The Dynamic Model

- IT enablers such as, **electronic product definition** and **product data management** prove very useful for **storage** and **transfer of information**
- To satisfy the Dynamic Product Definition Model; **Information** must be accessible to the **next phase** of the product design process
- A **very simple** change process is required – *controlled by the project team at product and process definition levels*
- Dedicated **multi-functional project team** used with high levels of **technical** and **business** expertise

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End

APPENDIX 2

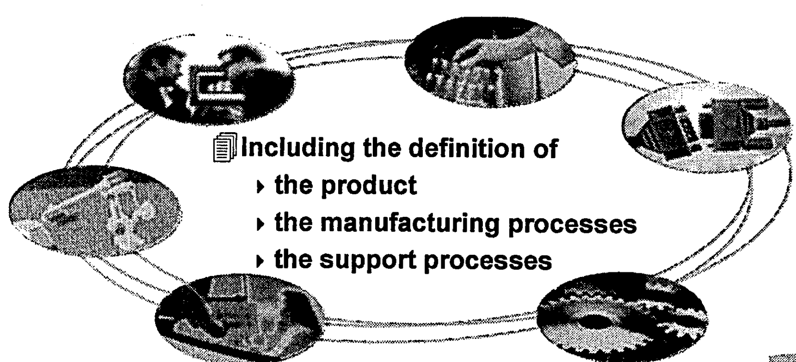
Airbus Concurrent Engineering (ACE)

General Presentation

AIRBUS

Why Concurrent Engineering?

• It is a systematic approach to product design, taking into account all the elements of the lifecycle, from concept to disposal



Types of Benefits Obtained through ACE

CUSTOMERS FOCUS

- Reduced lead-time to accommodate late customer requirements for new, derivative and customised aircraft
- Improved dispatch reliability
- Achieved rapid aircraft maturity (minimal adjustment, high quality of assemblies for system installation)
- Improved customer driven maintainability

QUALITY

- Improved quality of definition dossiers
- Reduced adjustment (fine tuning) - with higher quality of assemblies
- Improved consistency between aircraft and tooling
- Enabled easy transfers between design and definition

EFFORT

- Optimised processes by standardisation of repetitive tasks
- Elimination of physical mock-ups
- Facilitated access to the design or definition data
- Validation of factory flows through digital simulations

TIME

- Decreased time for creation of Definition Dossiers
- Reduced lead time for tooling development
- Improved reactivity to unforeseen events

➡ **ACE acts as a common platform for achieving substantial results**

Concrete Examples of Achievements

Concurrent Engineering Methods and tools have been successfully applied on A340-500/600 and A380 Aircraft Programmes.

QUALITY

- ▸ First rib set production in UK:
- ▸ A340: 500 concessions, 4 months rework versus
- ▸ A340-600: 1 concession, no rework

EFFORT

- ▸ 50 Million Euros savings in Airbus France for the A340-600 first time right
- ▸ 8 Million Euros savings in Airbus Germany for A380 through the optimization of hangar construction and tool optimization by using Digital Factory methods
- ▸ Sheet metal numeric control programming workload divided by 2 for A340-600 in Airbus France

TIME

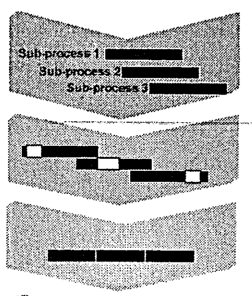
- ▸ Development cycle time reduction by 30% on the A340-500/600

ACE is a proven approach and today's outstanding results speak for themselves.

May 2004 Page 4

What is Concurrent Engineering?

Concurrent Engineering has three major impacts

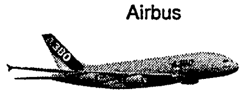
Replace a sequential process with parallel sub-processes		Reduces lead-time
Standardize the product development process		Improves efficiency of repetitive tasks
Integrate sub-processes by a dedicated cross-functional team		Improves communication

A way of working that can radically improve the Aircraft development process

May 2004 Page 5

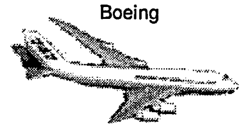
Concurrent Engineering in Aerospace

Airbus



Airliners

Boeing



ACE
(Airbus Concurrent Engineering)

- Launched in 1995
- Central Coordination
- Integrated Approach
- €50 M savings in Airbus France for the A340-600 (first time right, digital simulation, reduced learning curve first 10 Aircraft, less jigs and tools, ...).
- €8 M savings in Germany Hamburg through optimisation of hangar construction and tool optimisation for A380 by using Digital Factory methods.

- **High level customer expectations**
- **"21st century" products**

Lead-time reduction
Non Recurring Cost reduction
Recurring Cost reduction
Quality Improvement

DCAC-MRM
(Develop Configured Aircraft)

- Similar approach launched in 1993
- Some figures:
  - ▸ 1000 persons working on the project
  - ▸ Objectives: -50% rework on definition, -50% on derivative aircraft development
  - ▸ Boeing gained in efficiency for our "time-based" market.

Customer Advantage through competitiveness.

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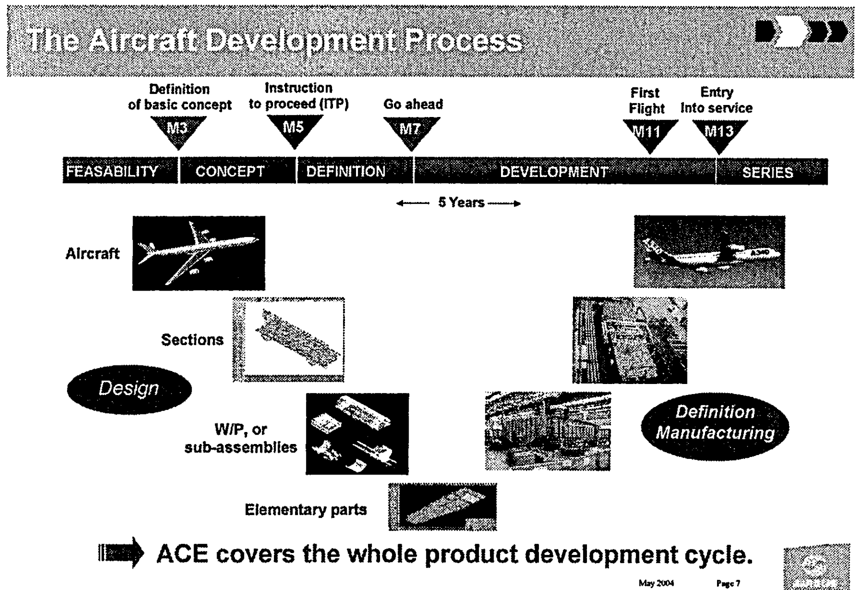
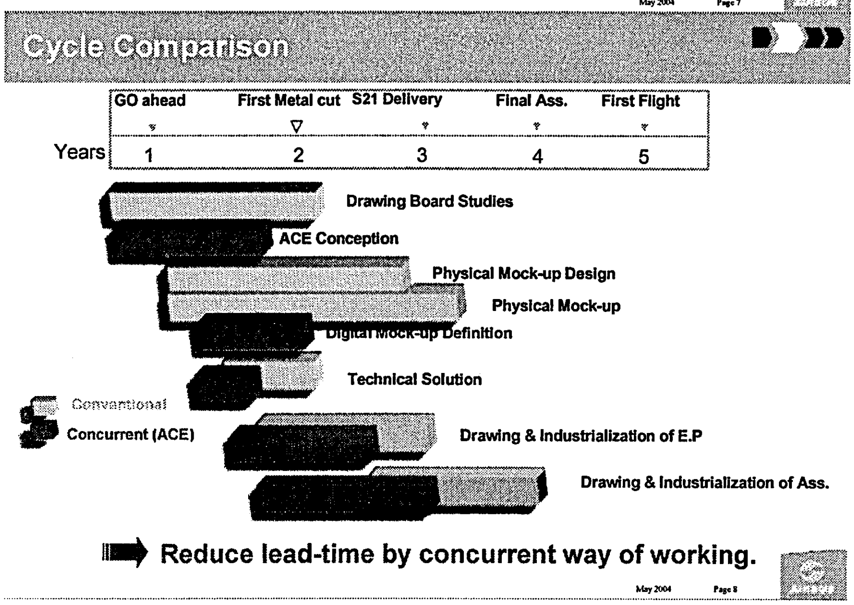
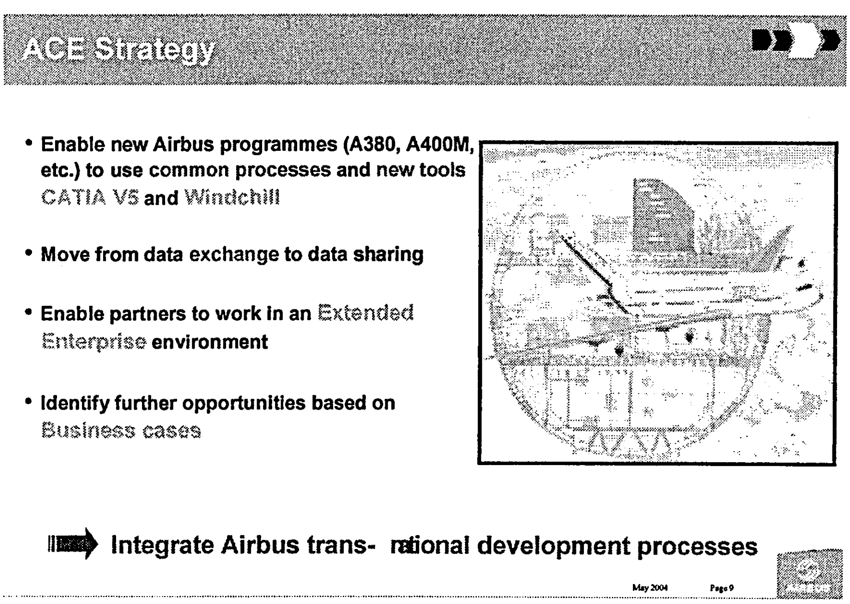
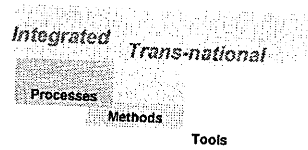

The Aircraft Development Process
Definition of basic concept
Instruction to proceed (ITP)
Go ahead
First Flight
Entry Into service
M3
M5
M7
M11
M13
FEASABILITY
CONCEPT
DEFINITION
DEVELOPMENT
SERIES
5 Years
Aircraft
Sections
Design
W/P, or sub-assemblies
Definition Manufacturing
Elementary parts
ACE covers the whole product development cycle.
May 2004
Page 7


Cycle Comparison
GO ahead
First Metal cut
S21 Delivery
Final Ass.
First Flight
Years
1
2
3
4
5
Drawing Board Studies
ACE Conception
Physical Mock-up Design
Physical Mock-up
Digital Mock-up Definition
Technical Solution
Conventional
Concurrent (ACE)
Drawing & Industrialization of E.P
Drawing & Industrialization of Ass.
Reduce lead-time by concurrent way of working.
May 2004
Page 8


ACE Strategy
• Enable new Airbus programmes (A380, A400M, etc.) to use common processes and new tools CATIA V5 and Windchill
• Move from data exchange to data sharing
• Enable partners to work in an Extended Enterprise environment
• Identify further opportunities based on Business cases
Integrate Airbus trans- national development processes
May 2004
Page 9

ACE Mission and Scope

- **Mission:**
  - Providing Airbus with a competitive advantage by establishing integrated and efficient processes, methods and tools along the whole product life cycle.



- **Scope:**
  - Integrate data and information related to the Airbus development process in the trans-national ACMT Organization. Major focus on A380, A3456 and A400M.

➡ **ACE is a key integration project and enabler for the A380 and A400M.**

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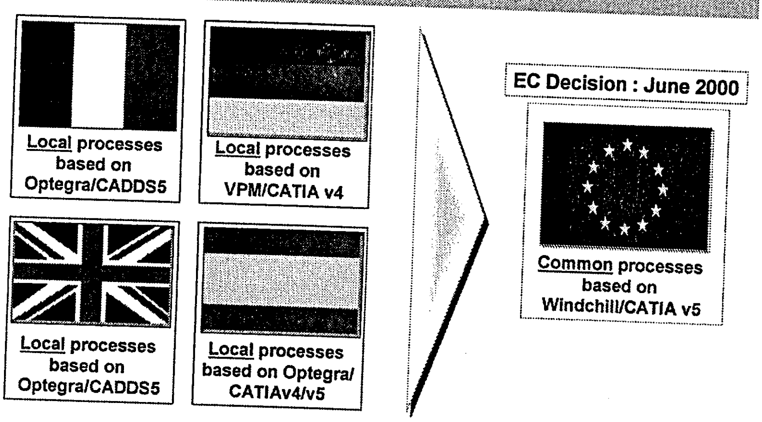
ACE Challenge n°1: Airbus Integration



➡ **Converge to support the integration of the new company.**

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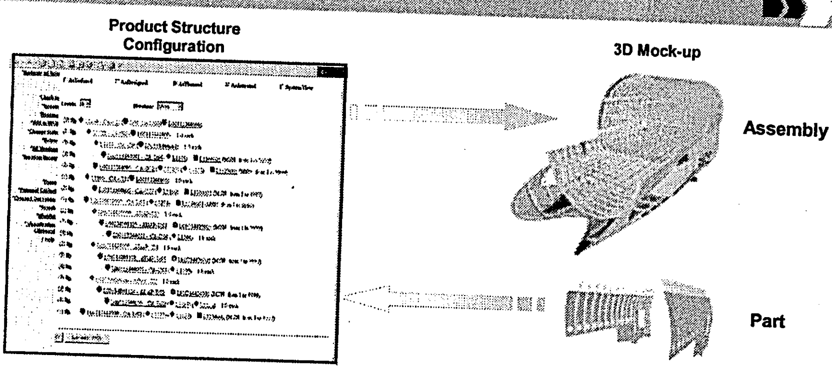
ACE Challenge n°2: Design & Industrialization complexity



PRIMES (Windchill based PDM)

CATIA V5 (IBM/Dassault: 3D design and Mock-up)

➡ **Use best in class technology.**

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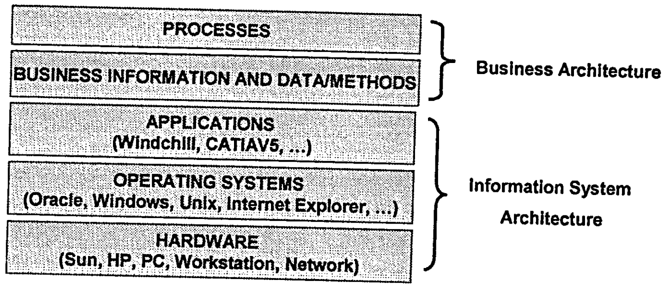
ACE Architecture



ACE addresses all levels or architecture, with the support of multidisciplinary teams representing the different functions and business processes

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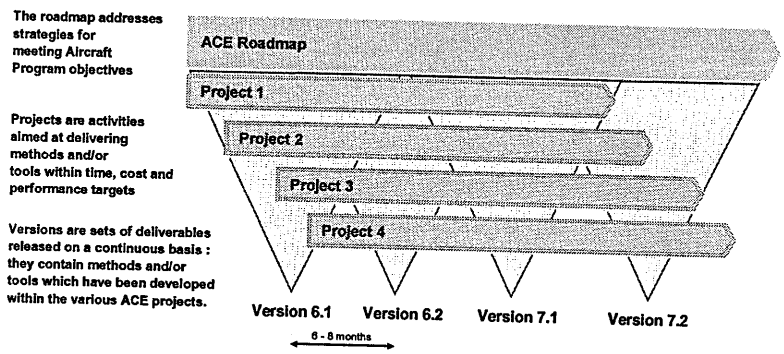
Overview of ACE

ACE is structured on the basis of a Roadmap, Projects and Versions



ACE activities deliver short-term results while supporting the Aircraft Programme's long-term objectives

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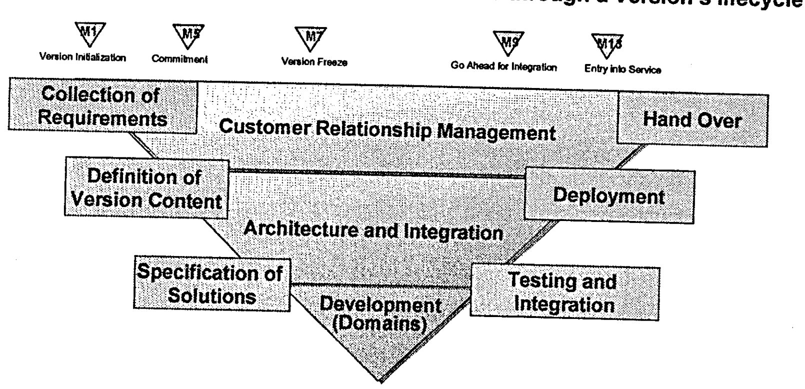
The 'V' Model

The « V- Model » is used to track milestones through a Version's lifecycle



Versions ensure that Project deliverables are released in a timely manner, following Aircraft Programme Planning

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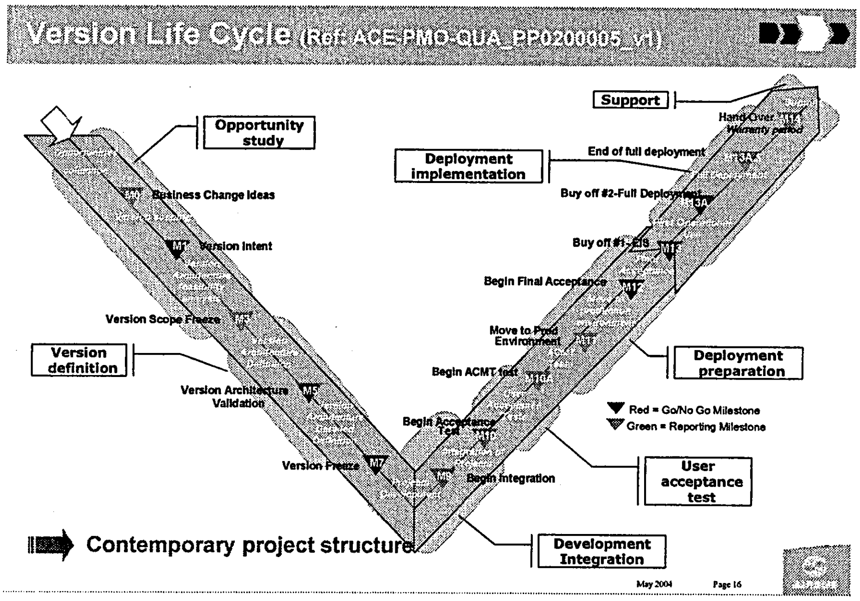

AIRBUS

AN EADS JOINT COMPANY WITH BAE SYSTEMS

APPENDIX 3

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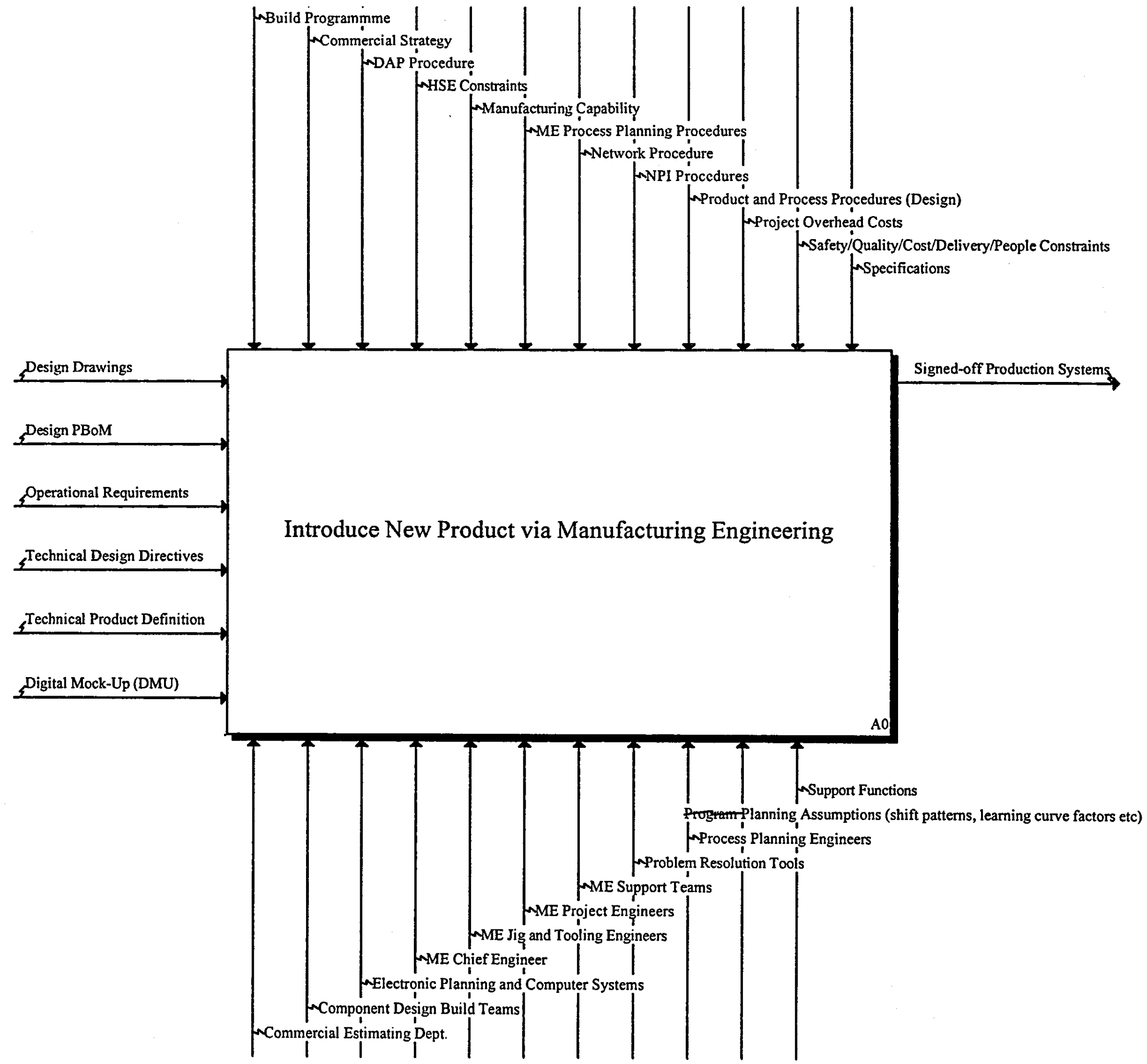

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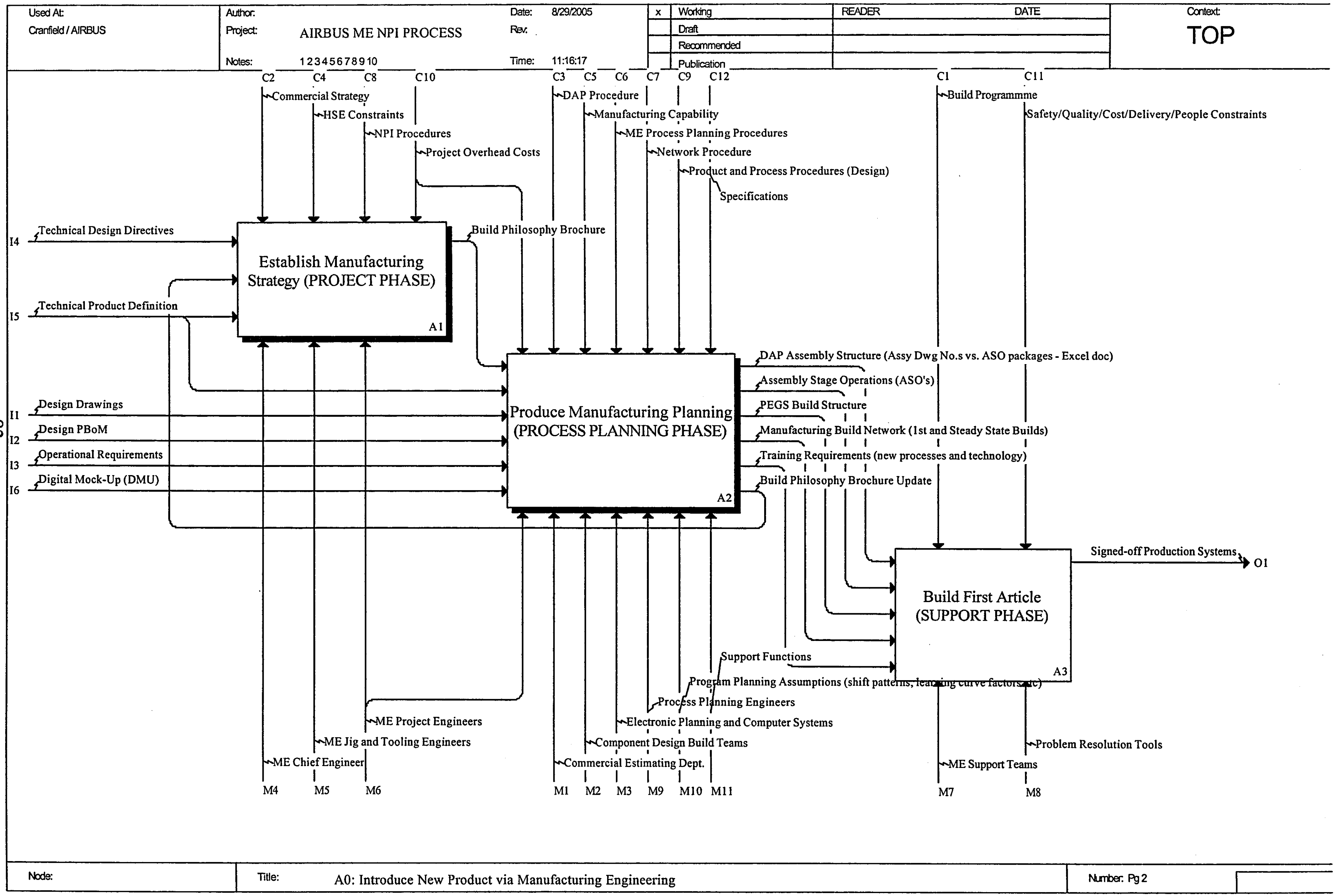
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Rev.
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Recommended
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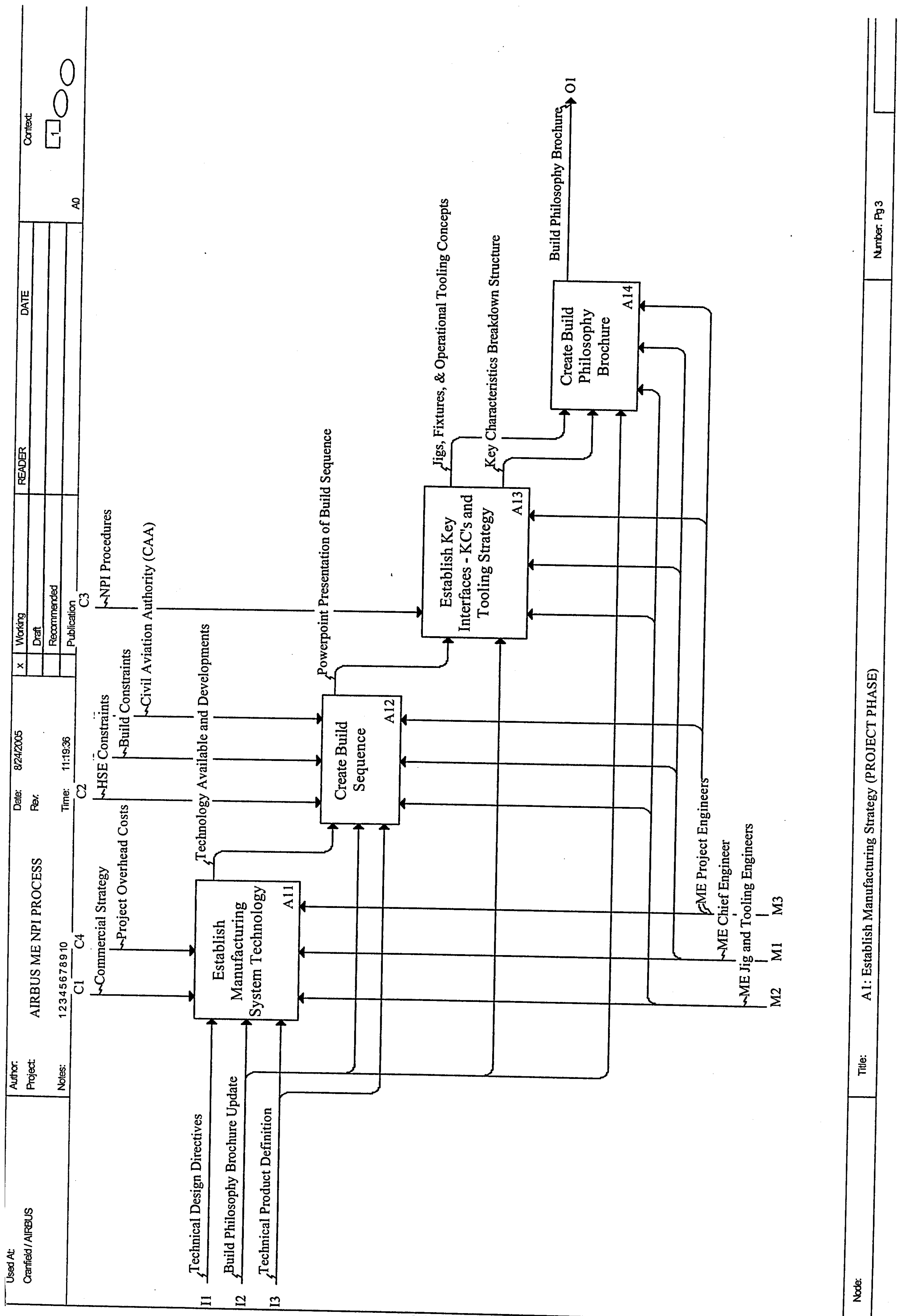
DATE
Context:
TOP
C2
C4
C8
C10
C3
C5
C6
C7
C9
C12
C1
C11
Commercial Strategy
HSE Constraints
NPI Procedures
Project Overhead Costs
DAP Procedure
Manufacturing Capability
ME Process Planning Procedures
Network Procedure
Product and Process Procedures (Design)
Specifications
Build Programmme
Safety/Quality/Cost/Delivery/People Constraints
I4
Technical Design Directives
I5
Technical Product Definition
Establish Manufacturing Strategy (PROJECT PHASE)
A1
Build Philosophy Brochure
I1
Design Drawings
I2
Design PBoM
I3
Operational Requirements
I6
Digital Mock-Up (DMU)
Produce Manufacturing Planning (PROCESS PLANNING PHASE)
A2
DAP Assembly Structure (Assy Dwg No.s vs. ASO packages - Excel doc)
Assembly Stage Operations (ASO's)
PEGS Build Structure
Manufacturing Build Network (1st and Steady State Builds)
Training Requirements (new processes and technology)
Build Philosophy Brochure Update
Build First Article (SUPPORT PHASE)
A3
Signed-off Production Systems
O1
Support Functions
Program Planning Assumptions (shift patterns, learning curve factors etc)
Process Planning Engineers
Electronic Planning and Computer Systems
Component Design Build Teams
Commercial Estimating Dept.
ME Project Engineers
ME Jig and Tooling Engineers
ME Chief Engineer
Problem Resolution Tools
ME Support Teams
M4
M5
M6
M1
M2
M3
M9
M10
M11
M7
M8
Node:
Title: A0: Introduce New Product via Manufacturing Engineering
Number: Pg 2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Rev.
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Draft
Recommended
Publication
READER
DATE
Context:
1
A0
C1
Commercial Strategy
C4
Project Overhead Costs
C2
HSE Constraints
Build Constraints
Civil Aviation Authority (CAA)
C3
NPI Procedures
Technology Available and Developments
Powerpoint Presentation of Build Sequence
Jigs, Fixtures, & Operational Tooling Concepts
Key Characteristics Breakdown Structure
Build Philosophy Brochure
O1
Establish Manufacturing System Technology
A11
Create Build Sequence
A12
Establish Key Interfaces - KC's and Tooling Strategy
A13
Create Build Philosophy Brochure
A14
I1
Technical Design Directives
I2
Build Philosophy Brochure Update
I3
Technical Product Definition
ME Project Engineers
M3
ME Chief Engineer
M1
ME Jig and Tooling Engineers
M2
Node:
Title: A1: Establish Manufacturing Strategy (PROJECT PHASE)
Number: Pg 3

Used At:	Author:	Date: 9/2/2005	x Working	READER	DATE	Context:
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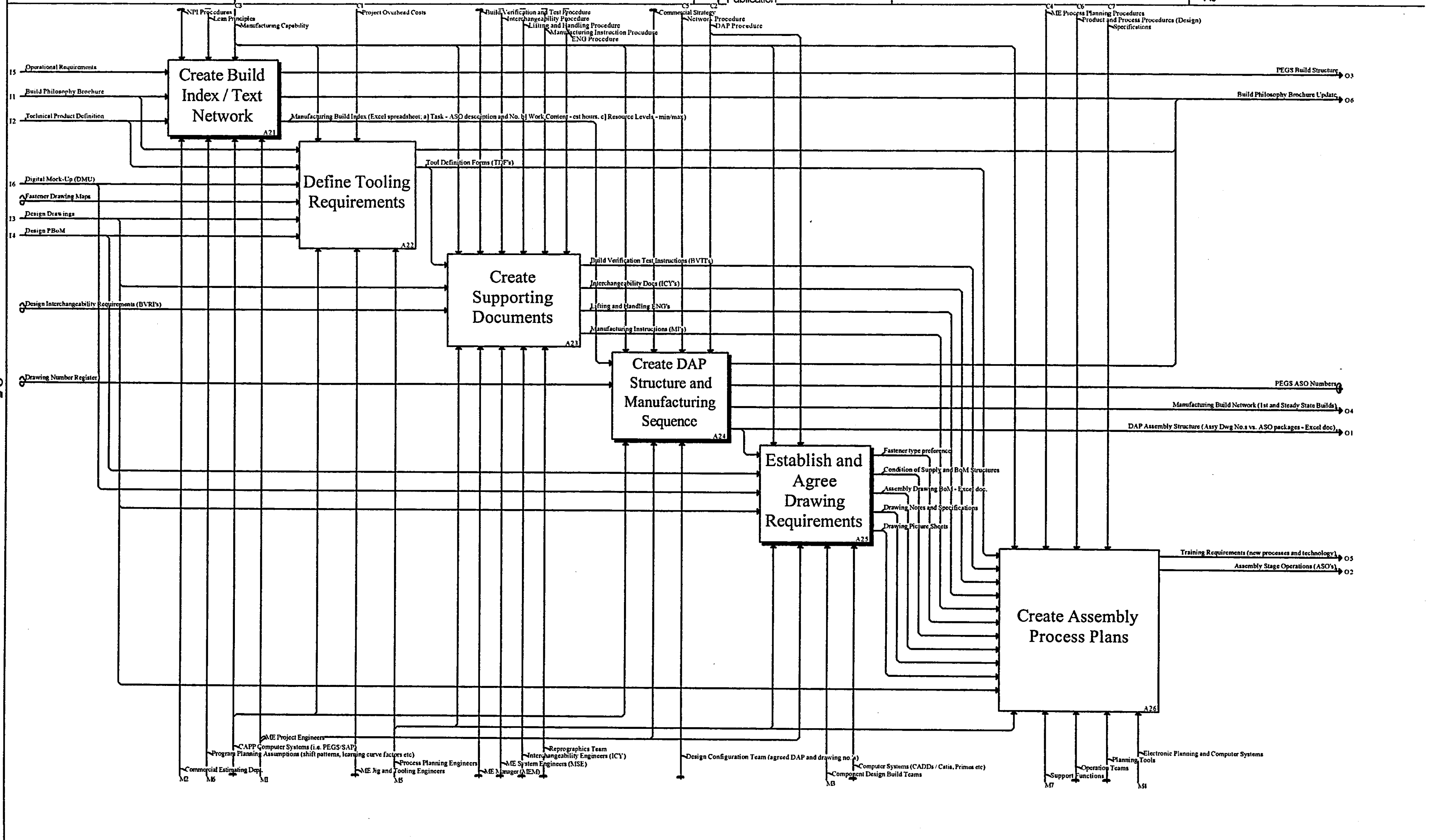
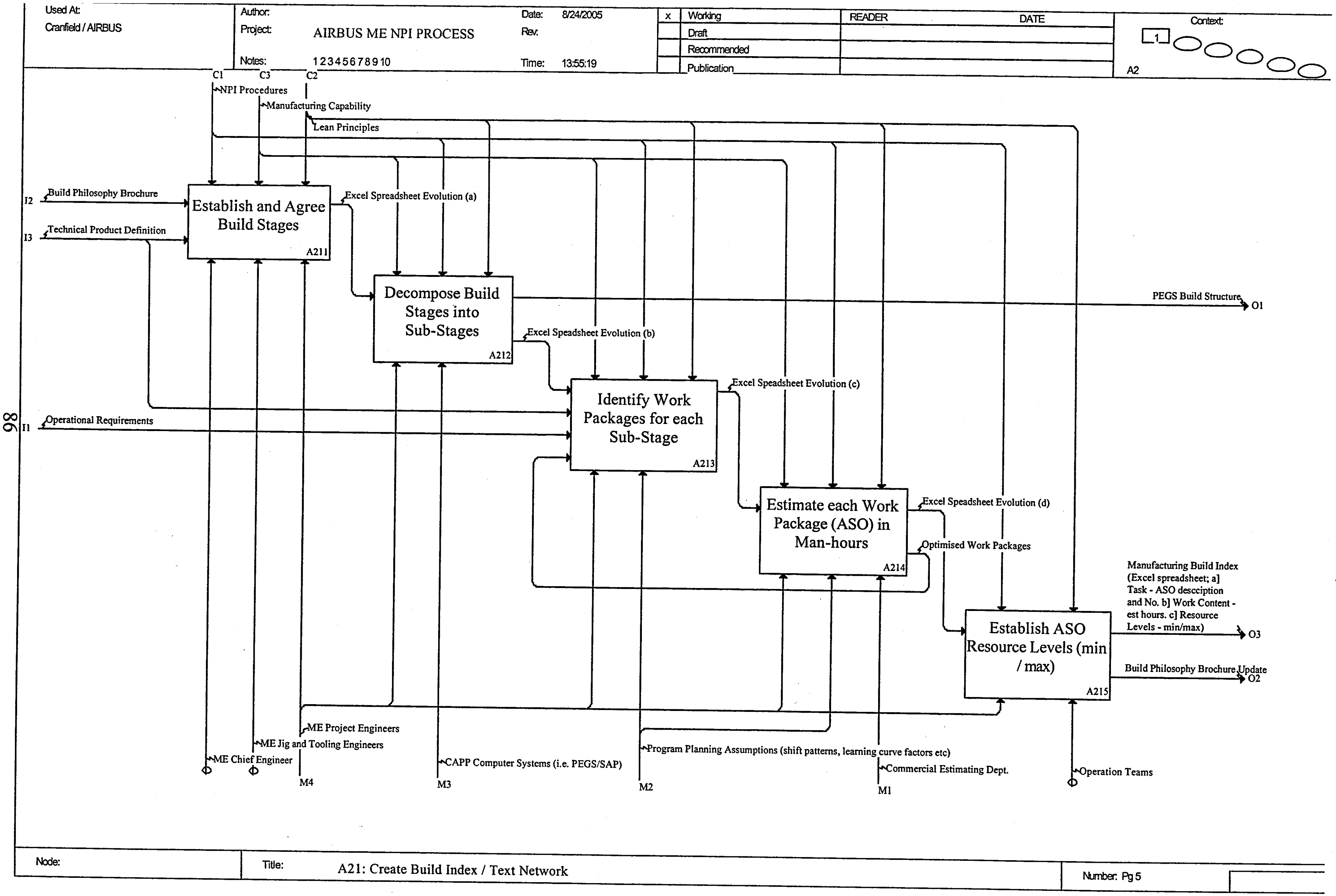


Node:	Title: A2: Produce Manufacturing Planning (PROCESS PLANNING PHASE)	Number: Pg 4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Draft
Recommended
Publication
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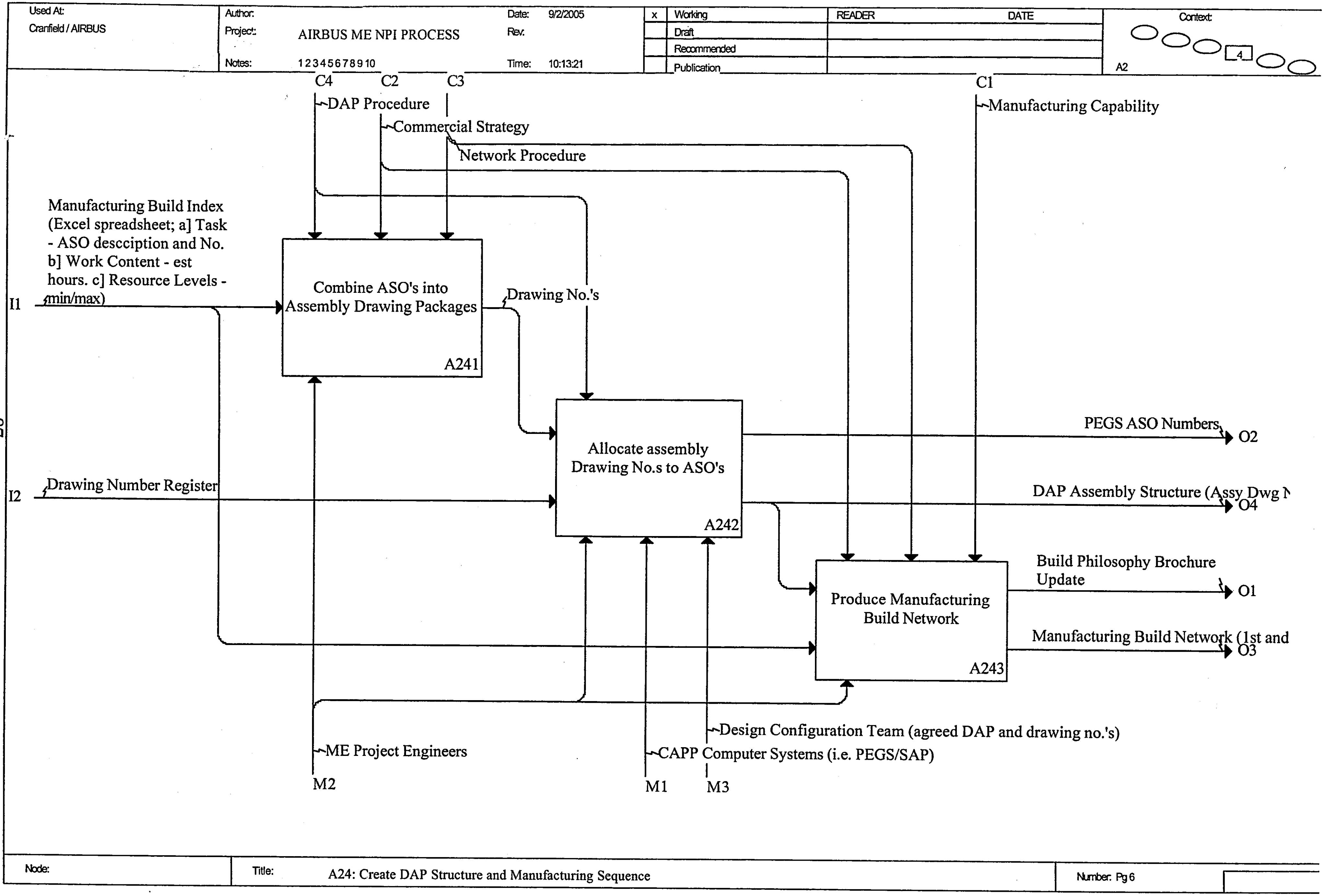
DATE
Context:
1
A2
C1
C3
C2
NPI Procedures
Manufacturing Capability
Lean Principles
I2
Build Philosophy Brochure
I3
Technical Product Definition
I1
Operational Requirements
Establish and Agree Build Stages
A211
Excel Spreadsheet Evolution (a)
Decompose Build Stages into Sub-Stages
A212
PEGS Build Structure
O1
Excel Speadsheet Evolution (b)
Identify Work Packages for each Sub-Stage
A213
Excel Speadsheet Evolution (c)
Estimate each Work Package (ASO) in Man-hours
A214
Excel Speadsheet Evolution (d)
Optimised Work Packages
Establish ASO Resource Levels (min / max)
A215
Manufacturing Build Index (Excel spreadsheet; a] Task - ASO desciption and No. b] Work Content - est hours. c] Resource Levels - min/max)
O3
Build Philosophy Brochure Update
O2
ME Project Engineers
ME Jig and Tooling Engineers
ME Chief Engineer
M4
CAPP Computer Systems (i.e. PEGS/SAP)
M3
Program Planning Assumptions (shift patterns, learning curve factors etc)
M2
Commercial Estimating Dept.
M1
Operation Teams
Node:
Title: A21: Create Build Index / Text Network
Number: Pg 5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Rev:
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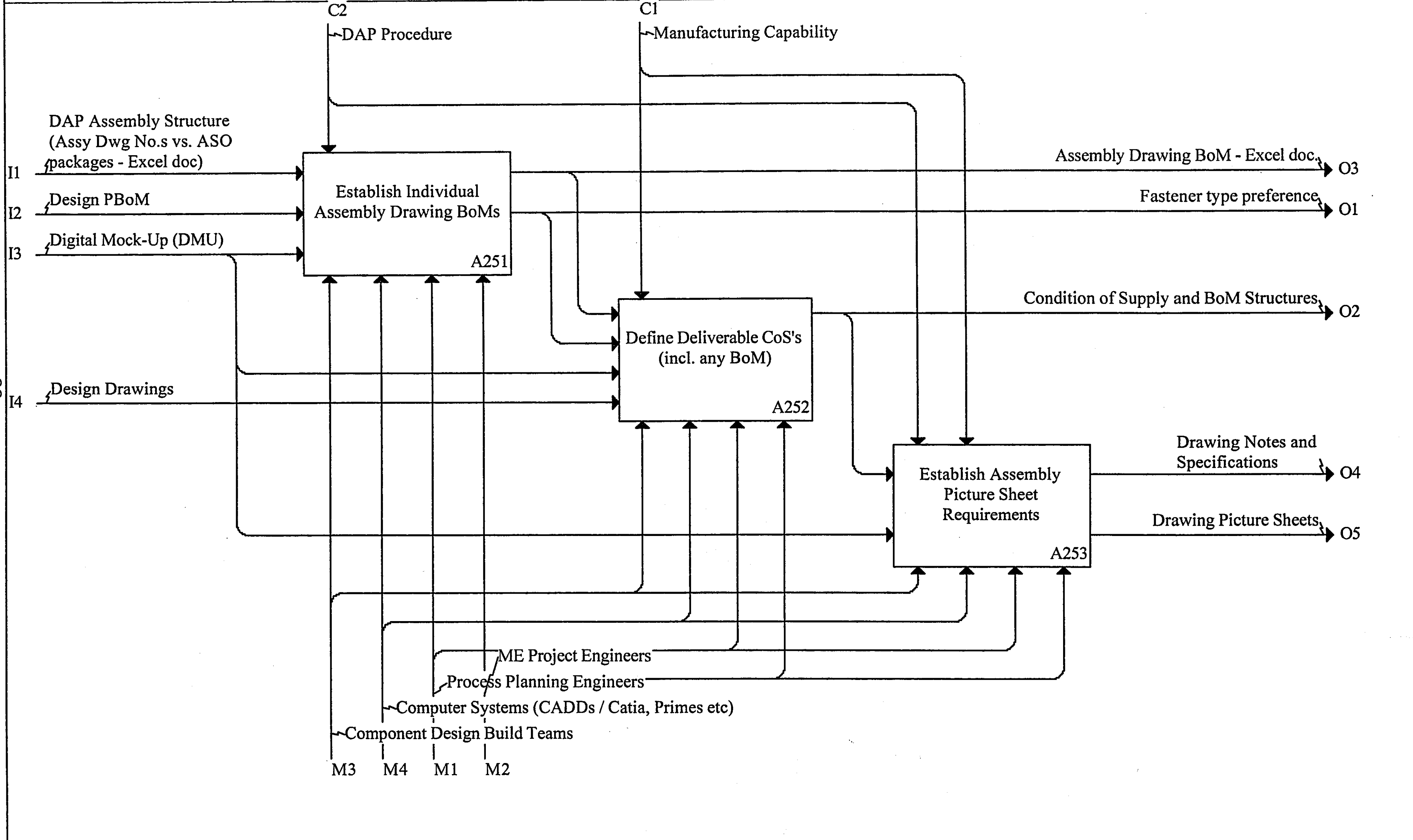
x Working
Draft
Recommended
Publication
READER
DATE
Context:
4
A2
C4
C2
C3
C1
DAP Procedure
Commercial Strategy
Network Procedure
Manufacturing Capability
I1
Manufacturing Build Index (Excel spreadsheet; a] Task - ASO descciption and No. b] Work Content - est hours. c] Resource Levels - min/max)
I2
Drawing Number Register
Combine ASO's into Assembly Drawing Packages
A241
Drawing No.'s
Allocate assembly Drawing No.s to ASO's
A242
Produce Manufacturing Build Network
A243
PEGS ASO Numbers
O2
DAP Assembly Structure (Assy Dwg N
O4
Build Philosophy Brochure Update
O1
Manufacturing Build Network (1st and
O3
ME Project Engineers
M2
Design Configuration Team (agreed DAP and drawing no.'s)
CAPP Computer Systems (i.e. PEGS/SAP)
M1
M3
Node:
Title:
A24: Create DAP Structure and Manufacturing Sequence
Number: Pg 6

Used At: Cranfield / AIRBUS	Author: Project: AIRBUS ME NPI PROCESS Notes: 1 2 3 4 5 6 7 8 9 10	Date: 9/2/2005 Rev: Time: 10:13:42	x Working Draft Recommended Publication	READER DATE	Context: A2 5



Node:	Title: A25: Establish and Agree Drawing Requirements	Number: Pg 7