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Core Requirements for ATM Working Positions: An Overview of the Project Activity

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Abstract

This document provides an overview of the work being undertaken with the 'Core Requirements for ATM Working Positions (CoRe)' Project. The objective of this project is to improve both the process and outcomes of activities directed at upgrading the working positions of air traffic controllers. The research strategy of understanding existing development methods, identifying shortcomings, establishing requirements for improvement and developing solutions is described together with the main products of the project. These products include a qualitative model of the organisation of the development process, a practical development framework supporting improved Human-Machine Interface (HMI) specification and traceability, evaluation and re-use of requirements, and a fully documented exemplary en-route controller interface.

Keywords

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Human-Machine Interface (HMI) Evaluation	Communication with Industry	Support to Validation
Functional versus Component Models	Socio-technical Development Frameworks	Unified Modelling Language (UML)

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EXECUTIVE SUMMARY

This document provides an overview of a project concerned with improving the process of developing working positions for Air Traffic Management (ATM) applications.

The 'Core Requirements for ATM Working Positions (CoRe)' Project, which it describes, is concerned with understanding the human factors issues that have contributed to difficulties in this development process. Based on this understanding, CoRe is seeking human factors, technical or organisational solutions that can improve the process and its outcomes.

This report explains the context, the development, the strategy and proposed outcomes of the CoRe Project. It is part of a range of deliverables in the form of documents, processes, development methods and demonstrations. Collectively, these are intended to both raise the ATM community's awareness and understanding of the problems and issues, and to support the community in resolving them.

Section 1, 'INTRODUCTION', outlines the institutional background to the project and the objectives and the scope of this report.

Section 2, 'THE EVOLVING ATM SYSTEM AND THE DEVELOPMENT OF THE CONTROLLER WORKING POSITION', sets the operational context of change in ATM working positions. It establishes the scope of a working position, and discusses evolutions within the ATM and human factors communities, which are changing the nature of the development process.

Section 3, 'THE CORE PROJECT', explains the role and objectives of the CoRe Project in providing support for the process of Controller Working Position (CWP) development from conception to effective communication and cooperation with industry.

Section 4, 'ANALYSIS OF PROBLEMS AND ISSUES', presents the history of how the CoRe Project Team has come to take a socio-technical perspective to the understanding of the development process. It presents the results of our analysis in terms of a description of that process and the issues of concern.

Section 5, 'ESTABLISHING A STRATEGY FOR IMPROVING CWP DEVELOPMENT', illustrates the process of moving from the description of issues into a strategy for realising improvement and into a set of related requirements.

Section 6, 'REALISING THE IMPROVEMENTS', presents the action plan for the improvement process. It describes the set of solutions, activities and deliverables with which CoRe is engaged and explains how these are intended to meet the requirements identified in Section 5. A key element is the emphasis on improving organisational and social factors by developing a technical infrastructure to improve the collaborative process while supporting individual points of view. The nature of these technical solutions is explained.

Section 7, 'CONCLUSION', summarises our current position, outlines future issues and activities, and suggests the potential contribution that CoRe and its products might make as tools to support the validation of ATM systems.

ANNEX A, ‘CORE QUALITY OBJECTIVES’, describes the quality objectives that underlie the project.

ANNEX B, ‘A FAMILY TREE OF SOME OF THE KEY EUROPEAN CWP DEVELOPMENTS’, illustrates the relationships between some major working position developments of recent years.

ANNEX C, ‘SUMMARY OF THE FINDINGS OF THE CORE/CENA STUDY’, presents a summary of conclusions from a study into requirements for Human-Machine Interface (HMI) specifications conducted under contract and in cooperation with the *Centre d’Etudes de la Navigation Aérienne (CENA)*.

ANNEX D, ‘A FUNCTIONAL DESCRIPTION FROM THE EXEMPLARY ‘WORKED EXAMPLE’, provides an example of a ‘functional description’ from the CoRe ‘Worked Example’ of an en-route controller working position development.

The final sections of the report provide References, a glossary of the Abbreviations and Acronyms used in this report and a list of those who contributed to this document.

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to present an overview of the activities within the 'Core Requirements for ATM Working Positions (CoRe)' Project.

- It explains the objectives of the project and provides the historical justification.
- It describes the context of ATM development in which the CoRe Project is operating, and explains and justifies the approach.
- It describes the resulting processes and deliverables.

1.2 Scope

This document describes the context and issues in ATM working position development that led to the initiation of the CoRe Project. It provides an analytic description of these problems based on viewing the development process from a socio-technical perspective. It describes the identification of requirements for improvement and the strategy subsequently developed. It then explains how the strategy is translated into a series of activities resulting in deliverables intended to improve the process and outcomes of ATM working position development. The deliverables are described and explained in terms of how they help meet these improvement objectives.

By the end of the document the reader should have a clearer understanding of the process and issues in working position development and how a successful CoRe Project can result in significant improvements against current practice.

1.3 Background and Major Milestones of the Project

The CoRe Project is conducted at the EUROCONTROL Experimental Centre (EEC) as part of the EATMP Human Resources Programme (HRS) [11] which is managed by the EATMP Human Factors and Manpower Unit of EUROCONTROL (DIS/HUM).

The HRS Programme was developed to meet the needs of the Agency's Member States and to support the aims and objectives of the 'ATM Strategy for 2000+' [8]. It provides a framework for an effective human contribution in ATM. The HRS Programme is subdivided into three sub-programmes, Human Factors, Manpower and Training. CoRe constitutes Work Package 6 of the Human Factors Sub-Programme (HSP). Within HSP, CoRe, and its sister project 'Human Factors Integration in Future ATM Systems (HIFA)' [12], are specifically intended at facilitating the integration of human factors into the

ATM development process. HIFA provides an overall framework for this integration, while CoRe is more specifically focussed, addressing itself to issues associated with the development of ATM working positions, emphasising the Controller Working Position (CWP).

Work leading to the CoRe Project in its present form began in 1998 with the 'Generic Controller Working Position (GCWP)' Project as part of the HRS Programme. This work was directly concerned with the development of the controller interface. However, it quickly became apparent that many of the problems encountered in that area were related to the development process and difficulties in transfer from Research and Development (R&D) to implementation (see Section 4).

This led to our recognition that the process of ATM working position development itself needed to be improved, and that one way in which to bring about improvement was to treat that process as the subject of human factors study. Our focus was no longer directed only towards the air traffic controller's activity but also towards the activity of the community which was involved in producing the next generation of support for the controller.

We developed an approach based on trying to understand how this collective activity operated and what difficulties it encountered. Our initial thoughts on the subject were presented to the Third EUROCONTROL Human Factors Workshop in Luxembourg in 1998 [35].

The CoRe Project, in its current form, replaced GCWP and officially became part of the Human Factors Sub-Programme (HSP) of the EATMP Human Resources Programme (HRS), Stage 1 [11], in January 2000.

The main events and milestones associated with the GCWP and main CoRe activities are as follows:

- GCWP Workshop on improvements to EEC's then current Reference Ground Human-Machine Interface (REFGHMI) — November 1997
- Paper: initial requirements for radar label anti-overlap — January 1999
- Guidance material on font selection and evaluation: Study contract placed with Cara, Broadbent & Jaegher (see [13]) — May 1999
- CoRe as part of the HRS Human Factors Sub-Programme (HSP), Phase 1 — January 2000
- Establishing Requirements for HMI specifications Study contract in cooperation with the *Centre d'Etudes de la Navigation Aérienne (CENA)* (see [25]) — April 2000

• Development of an exemplary documented platform for HMI evaluation (see Section 6)	September 2000
• Development of a process and supportive framework for the definition and evaluation of ATM Working Position HMI (coupled with an end-to-end example based on en-route ATM)	
▪ Draft process and exemplar	December 2000
▪ Complete process and exemplar	December 2001
• CoRe Handbook – Requirements Module	December 2001
• CoRe Handbook – Design Module	December 2002
• CoRe Handbook – Evaluation Module	December 2002

1.4 Structure

The structure of this document follows the logical development of the CoRe Project itself.

Following this introduction, Section 2 establishes the context of the project. It identifies the ATM working position as a focus, where many planned ATM developments will have a major impact. It then looks more closely at the changing factors which influence the way in which interactive working positions are developed, reviewing both the main influences from cognitive science and the initiatives from within the ATM community.

Section 3 describes the objectives of the CoRe Project in mitigating this impact by improving the development process.

The scene having been set, Section 4 begins the description of our CoRe activity by analysing the development process and its difficulties from a socio-technical perspective.

Section 5 describes the process of formulating a strategy to address improvement from within this socio-technical perspective. It describes the CoRe strategy and also discusses requirements which the resulting actions and activities should meet.

Section 6 presents the activities of CoRe and the three main deliverables through which we hope to realise improvement: the qualitative model of the development process, the supportive development framework and the illustrative example which forms the starting point for re-use processes.

Section 7 summarises the project's current progress, outlines our activities until project completion at the end of 2002, and discusses the role of such activities in providing process and tools in support of the validation of evolutions in our ATM systems.

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2. THE EVOLVING ATM SYSTEM AND THE DEVELOPMENT OF THE CONTROLLER WORKING POSITION[1]

2.1 The Controller Working Position as a Focus of Change

2.1.1 The context of change

Air Traffic Management currently finds itself in a state of evolution. At political and economic levels we have seen the movement towards ‘privatisation’ of service providers become a reality. The debate on how the division between regulation and service provision can be managed is now conducted at the broadest and highest political levels [27].

At the level of the ATM activity itself many new initiatives are in the course of development and implementation, such as Reduced Vertical Separation Minima (RVSM) [9], Flexible Use of Airspace (FUA), which impacts on civil military coordination [6], the System Supported Coordination (SYSCO) extensions to OLDI [7], ground air datalink innovations [14] and Collaborative Decision-making [23]. While these initiatives are based on a variety of different operational or technological innovations, one thing that they all have in common is that they will change the information environment of the front-line, air traffic controllers and supervisors.

2.1.2 Managing the information environment

In many cases the developments will make significant quantities of new information available; in others the form of the information will be changed. In the latter category the tendency, reinforced by the evolution of display equipment and graphics technology, will be to take information available on the auditory channel and communicate it visually. While this can have important advantages in reducing congestion on R/T channels [21] or increasing controller autonomy of action [22], it risks to increase the controller’s visual information processing load.

At this point we are dealing not only with fundamental human factors issues but also with the processes which lie at the heart of the air traffic control activity itself. Underlying all ATC activity we find the controller in front of the radar display, observing the traffic situation, integrating flight data information, forming strategy and intervening tactically. The controller’s ability to do this is based on the capacity to efficiently process the different sources of information available: radar, strips, R/T, telephone and verbal (and non-verbal) exchanges with colleagues.

As we manage the transition to the next generation of physical CWP, replacing the monochrome but very high-resolution cursive radar display with

[1] The term ‘Controller Working Position (CWP)’ is employed in a very rich sense. The scope of the term is discussed more fully in 2.2.1.

large screen colour, raster scan devices, we are changing this information environment radically. This process has begun and can be seen today in Amsterdam, Rome, Paris, etc. Within the year new systems will begin to be introduced in Copenhagen, Stockholm and Malmö.

The process of managing this change of visual and other information raises issues in the areas of requirements capture, good design, completeness of information, context sensitivity, etc. Evaluation of new solutions must address efficiency, reliability, usability, and both HMI and system performance.

2.1.3 Changes in roles and working method

For a number of years it has been conventional wisdom that the limit of the current ATM system lies with controller workload. It has been recognised that, while some 'tuning' is still possible, re-sectorisation is close to reaching its limits as a technique for capacity enhancement. Increases in coordination effectively offset the advantages of adding controllers. Effort has focused on increasing controller efficiency through the provision of controller support tools. These tools will help the controller to focus more resources on 'problem' aircraft, by identifying potential problems earlier, by furnishing monitoring capability, by supporting visualisation of potential problems or even by proposing remedial actions.

While some of these activities, such as the Programme of Harmonised ATM Research in EUROCONTROL (PHARE), have been clearly within the R&D domain, others, such as the French ERATO [38] and the advanced EATMP functions [15], Medium-Term Conflict Detection (MTCD), Monitoring Aids (MONA), and Conflict Resolution Assistance (CORA), are much closer to implementation. Indeed, some forms of tools are already in operation, such as the User Request Evaluation Tool (URET) at Memphis and Indianapolis; and Verification of separation and Resolution Advisory (VERA), the conflict-probe at the Maastricht Upper Area Control Centre (MAS UAC).

It is accepted that most such tools will change the controllers' working methods, workload and role. As such, they impact on the requirements for the CWP to support these new activities.

Particular issues associated with these new approaches relate to how the concepts and working methods can be validated, to training in new working methods and to their acceptance by operational staff. It becomes necessary to have methods that can separate out the effect of concept, working method, HMI conception and HMI realisation. Evaluation has to address not only the interaction level HMI issues described at the end of 2.1.2 but it may also have to deal with more organisational and social issues, e.g. safety, robustness, user acceptance and job satisfaction.

2.2 The Recent History of CWP Development

2.2.1 What do we mean by a 'working position'?

It is very easy to think on the 'working position' as being simply the physical hardware on which the activity is undertaken. For many years this was quite literally the definition of the term. If we take the case of the operational controller, the equipment would consist of a chair, a radar screen, the radiotelephone (R/T) to communicate with aircraft and a telephone to speak to other controllers at a distance. Paper flight strips on a rack would provide flight plan information. Maps, lists, pencil and paper would complete the workspace. The term 'MMI' meant 'Man-Machine Interface' and the approach was very simple, limited almost exclusively to the level of basic ergonomics, legibility and contrast, lighting, button pressing, etc. The cognitive aspects of system design were limited to ensuring that the correct information was available in an acceptable form.

Information was communicated across these interfaces but, with the exception of the flight strips themselves, there was very little interactivity with the system. The activity of managing the traffic was carried out with the strips and with the voice communications channels. Information was extracted from the radar display but the only interaction with it related to minor changes in information presentation (brightness, contrast, switching on range rings, etc.), not with the functional activities of control.

There was little or no coupling between the Flight Data Processing System (FDPS), the radar plan view display (+ surveillance systems) and the communication systems. With only a few exceptions the FDPS was not updated with either controller actions or intentions. This 'classical' structure is illustrated in Figure 1.

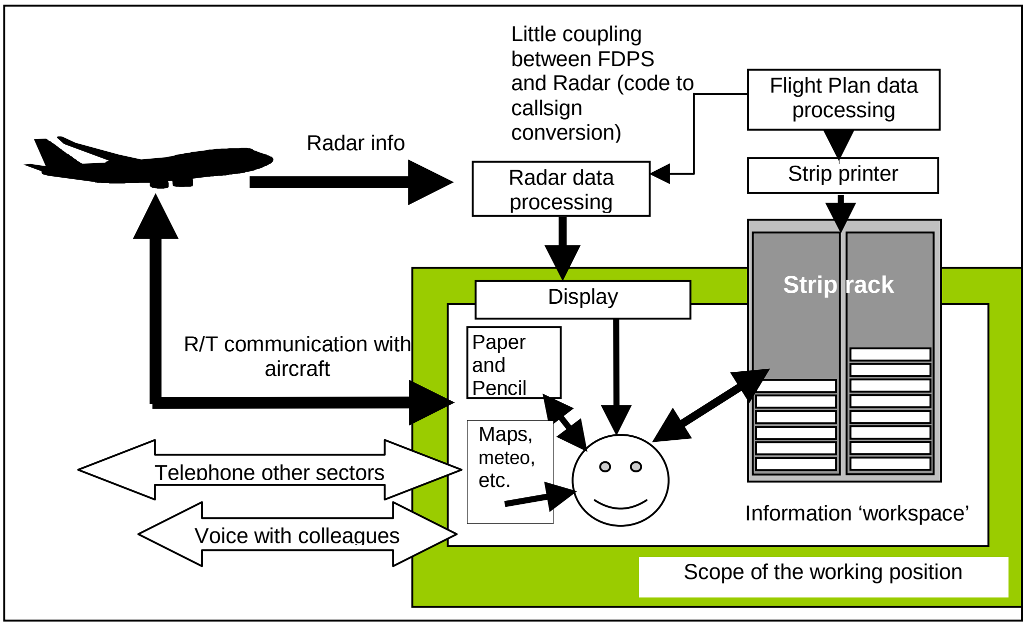

Figure 1: The 'classical' en-route ATM working position

Note that many data flows are in one direction only with little interactivity.

The new generation of CWP being introduced now is very different. This is mainly because of the increasing amount of information which can be made available to the controller and the increasing integration of the surveillance, FDPS and communication systems. The resulting configuration is shown in Figure 2.

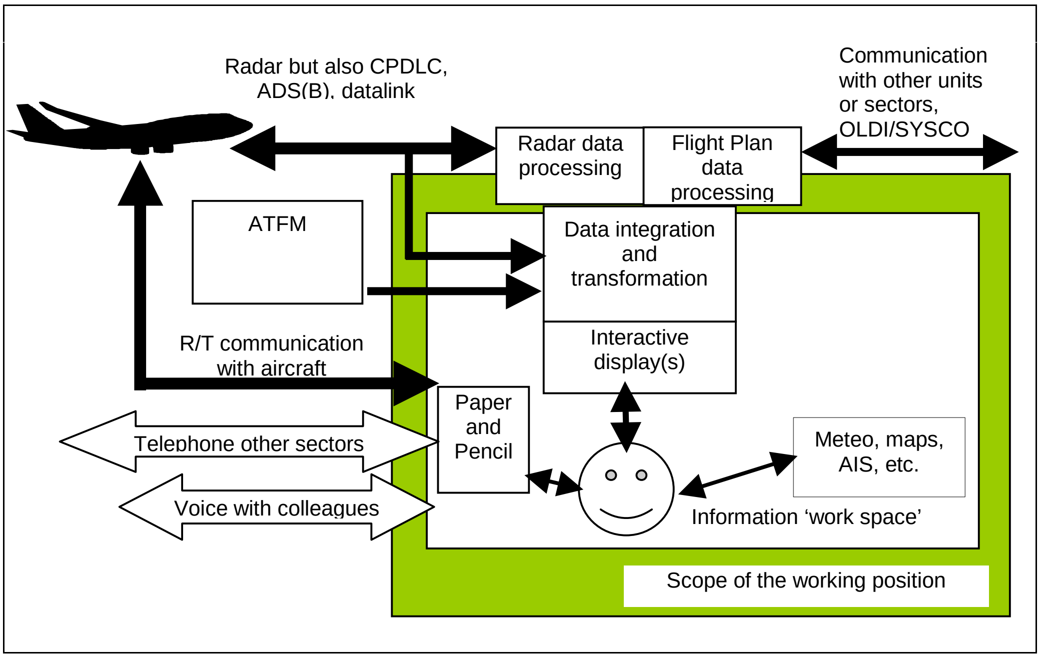

Figure 2: The new generation of ATM working position

HMI has come to mean human-machine *interaction* and graphical user interfaces permit the controller to interact directly with available information making it a part of the work space for undertaking the process of air traffic control. Working position design now includes the development of this information landscape and the means for navigating and interacting with it. This implies considering the nature of the jobs and roles of the controllers, the way information should be represented to facilitate different tasks, the interaction between team-mates, etc. The unit of analysis is often the sector or the team rather than the individual controller [35].

While we have chosen the example of the en-route sector, the evolution in interactivity and complexity is identical for approach, supervisor or even for new roles such as the multi-sector planner.

This is the ATM working position development activity that faces ATM service providers today and defines the scope of the activity that CoRe seeks to support. Ironically, because the physical ergonomic aspects of workstation layout are very context dependent and are also now well understood and documented, they are generally assumed as given for the purposes of the CoRe description.

2.2.2 General changes over recent years: the 'cognitive' revolution

The process of developing ATM working positions has changed dramatically in the last ten years. At that time European HMI development would often be idea-led and carried out by small R&D projects of engineers, perhaps with a contribution from one of twenty or so general human factors experts working in air traffic control.

A number of factors have contributed to changing this context.

The first of these was a combination of the **Cognitive Engineering Approach** and the emergence of **User-centred Design.**

Cognitive Science [28], and later its 'applied' aspect, Cognitive Engineering [44], represent systems, including human activity, in terms of information, its flow and its transformation, that is in terms of cognitive processes, recognition, perception, intention, etc., and in terms of computational 'metaphors'.

This approach grew out of the convergence of a number of information-oriented disciplines (computing science, linguistics and psychology) in the study of first 'information processing' and later 'cognitive' systems (see Figure 3). It provided 'computational metaphors' for understanding human information processing while at the same time providing new ideas for system development and attributes based on 'human' concepts. These in turn provided a new perspective on the study of complex system behaviour. It could be argued that it made such a very powerful contribution because it allowed both human processes and other computational processes to be discussed in terms of the same vocabulary. (This is of critical importance for design because design trade-offs can only be made effectively when they can be expressed in similar terms and at similar levels of detail.)

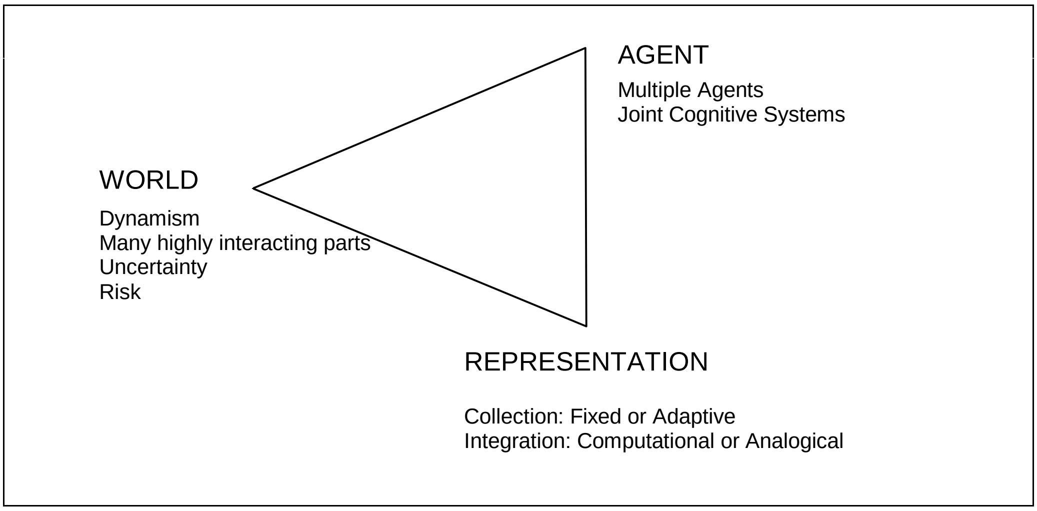

Figure 3: The Cognitive System Triad: factors that contribute to the complexity and difficulty of problem solving (From Woods, 1988). (Some of the key elements and concepts that underlie the cognitive systems approach.)

An excellent summary of the 'Cognitive Systems Viewpoint' and the issues it addresses is provided in [48] from which Figure 3 is drawn.

User-centred System Design [46], like Cognitive Engineering, grew out of Cognitive Science in the early eighties. It is based on the recognition that most information systems are developed to serve human purposes and that they can do so most effectively when they take into account the characteristics (behavioural, knowledge, intentions, etc.) of the human 'users' of these systems. The user-centred approach to design has been central to most of the successful developments in the field of Human-Computer Interaction (HCI) or Computer-Human Interaction (CHI, US), and are now the subject of some excellent standards, such as ISO 13407. As Kelly *et al* ([12], §5.2) have pointed out it also underlies most approaches to the integration of human factors into system development processes. ATC was slow to make this transition. Although researchers at CENA, in France, and RSRE, in UK, began to practise this approach in the mid-eighties, it did not achieve wider acceptance until the circulation of the excellent ICAO Human Factors Digests, e.g. [33], and Billings' important application of the approach to the cockpit [1], [2] in the early nineties.

The explosion in HCI development was closely linked to the emergence of **Graphical User Interfaces** (GUIs) based on **direct manipulation**[2] [31], [49]. The development of these ideas together with **object-oriented programming** (Smalltalk), **multi-disciplinary design teams**, **iterative prototyping**, the linking of individual workstations connected by a network (Ethernet), etc., is generally associated with the Xerox Palo Alto Research Centre in the early seventies. The graphical interface only achieved real visibility for the general public with the advent of the Macintosh computer in the early eighties. Since then, through developments in both the UNIX and personal computer worlds, and eventually through graphical browsers for the Internet, it has become the 'standard' way of conducting human-computer interaction.

An important general consequence of GUIs has been the increase in the proportion of programme code that is dedicated to HMI. Formerly, in development of most applications the bulk of the software investment lay in the development of algorithms central to the function of the application. Some additional code to transmit data to output devices, or receive and handle data from input devices, would be added. Today it is not uncommon for the HMI code in highly interactive applications to account for 80% of the code developed. At industrial and commercial levels HMI code development is recognised as a major activity and a major part of the risk in development of new products. Additionally, since the application is presented to the user by means of the interface, it is perhaps the key element in shaping the user's perception of the system being delivered, its functionality and its acceptability.

Perhaps the most recent relevant developments relate to the closely linked ideas of **Distributed Cognition** and **Ecological Interface Design**, heavily

[2] In a 'direct manipulation interface' the user interacts with the application by using an input device (often a pointing device like a mouse), to manipulate graphical objects presented on the display to compose inputs.

influenced by the ideas of J.J. Gibson [29] and U. Neisser [44]. In the distributed cognition metaphor the 'cognitive work space' and processes are not just 'inside the head', but include the external artefacts and agents that are involved. Interaction with an object helps shape the action possibilities of the user/problem solver. Thus, for example, flight plan information is part of the cognitive workspace of the controller, and the physical and perceptual characteristics of its 'presentation', whether as paper flight strips, tables of data in windows or graphical trajectory presentations, will change the repertoire of possibilities or 'affordances' available.

While the notion of cognitive work space has influenced some ATM HMI design ([20], §6), it is only in recent years that the ideas behind distributed cognition have found clear expression (e.g. Hutchins [32]) and that the principles of ecological design – that is transforming and coding relevant information in forms that allow the user to make judgements and exercise control perceptually rather than analytically (e.g. Vicente [4]) - have been demonstrated in practice.

These approaches appear particularly well suited to ATM working positions where most of the traditional interfaces have 'naturally evolved' to express information in a 'perceptual form'. For example, 'aircraft separation' is a direct spatial judgement on the radar screen, which is changing over time as the controller observes.

2.2.3 CWP development within the ATM community

CWP as a critical element

All the above factors have impacted upon the way in which CWP is developed in ATM. Today the typical CWP development, whether for an R&D activity or for real-world system development, will be organised as a 'project' and controlled using top-down project management methods. It will be structured in phases and will involve, at a minimum, both operational and software engineering experts. In many cases a variety of different human factors, scientific and quality engineering expertise may also be included. The most complete multi-disciplinary approach may also involve graphical designers and social anthropologists.

It is now recognised that HMI and CWP development activities are complex and involve high risk. In particular, their development and acceptance by the end-user population represent one of the major, critical milestones in managing a system change.

This perception has been emphasised by a number of major setbacks leading to cancellations or delays in upgrade programmes over the last fifteen years. The cancellation of the UK's Electronic Display and Data Update System (EDDUS) Programme, the complete and costly re-scoping of the FAA's

Advanced Automation System (AAS) in 1993[3], difficulties encountered by SWISSCONTROL (now known as Skyguide), and delays to NERC (UK CAA), PHIDIAS and EUROCONTROL's ODS Programme can all, to some extent, be associated with difficulties in CWP development and acceptance.

Types of CWP development

We can make a distinction between two main classes of CWP development, the pre-operational and the development for operational implementation. The pre-operational may be for the purposes of a research study (on a future concept, to evaluate a technological of operational change) or as a precursor to an operational development. In the latter case it may be part of a rapid prototyping activity to clarify requirements or evaluation solutions (e.g. the EATMP Rapid Prototyping Facility), or as a complement to the CWP specification for call for tender to industry (e.g. the Denmark-Sweden Interface (DSI) Project [43] or the Italian Interface (ITI) Project [42]).

For the moment the CoRe Project limits its objectives to improvement of the pre-operational process and the process of communication with industry. The choices for the subsequent industrial process lie completely within the responsibility of industry. However, it seems reasonable to presume that, if we can employ similar techniques and tools to those favoured by industry, both the process of communication and their impact on industries subsequent activities will be facilitated.

Harmonisation versus diversity

One declared difficulty for European industry has been the apparent diversity of requirements for CWP from the large number of potential clients within Europe. In 3.2 we shall observe that a significant part of the high-level design of the CWP is often undertaken by the Member States. Under these circumstances the resulting call for tender is often based on a comparatively detailed (but not necessarily complete) HMI specification that describes the interaction mechanisms, colour conventions, etc., of the CWPs. The resulting interfaces can be very different one from another. There are a number of elements that contribute to the diversity, a major one being user-centred design. The process of involving the current controller population in the design and development of the system is important in ensuring not only the appropriateness of the functionality, but also in the process of assisting the controllers in taking ownership of the new system. This may lead not only to a certain tendency to emphasise continuity with the predecessor system, but also to a tendency to 'customise' the system, that is to tailor it to the local controller population and culture.

While these characteristics may seem advantageous to the service provider seeking to manage an upgrade, the diversity makes it very difficult for the

[3] $1.5 billion was written-off following the re-scoping of the FAA's Advanced Automation System (AAS) in 1993. Source US Gov. General Accounting Office.

supplying industry to anticipate the requirements of the market and to manage economies of scale.

In effect there is a tension between the customer who wants 'made-to-measure' and the supplying industry that would wish to have 'standards' to which it can work.

This dilemma has been recognised for some time and attempts have been made to resolve it. In 1991 the EUROCONTROL Agency coordinated a multinational effort to produce the Common Operational Performance Specifications for the Controller Working Position (COPS/CWP) [17]. While COPS addresses some HMI issues it concentrated more on the architectural elements of the CWPs and proved influential in the transition to Graphical User Interfaces (GUIs) based on a client-server architecture.

In 1993 this was complemented by the EATCHIP Operational Display and Input Development (ODID) Report and Guidelines [5] which provided ATM community oriented HMI guidelines based on experience with the first three ODID simulations (ODID I, II and III). Effectively, the ODID studies, particularly ODID III [18], introduced the international community to the practicality of GUIs, and when ODID IV took place in 1994 it was treated as major source of inspiration and even something of a standard[4]. Elements of the ODID documentation began to be copied into other specifications, and, in response to client interest, 'ODID compatible' began to be quoted alongside 'COPS compliant' at industrial presentations and demonstrations.

The ODID IV specifications were also employed as the starting point for all the ground-based HMIs of the PHARE Programme.

Recognising this pattern of re-use the EUROCONTROL Experimental Centre (EEC) produced a Reference Ground HMI (REFGHMI, [20]) in 1995. This document integrated the more stable elements of ODID and the PHARE baseline conditions, and presented a richly illustrated HMI specification organised by functions (following the ODID model), complemented by an explanation of the HF rationale and principles behind the design – effectively a simple style guide. This document also recognised that the design would not necessarily be complete and consequently included elements of rationale behind particular design choices. The REFGHMI was placed in the public domain, and, with the universal use of word processors, has been cut and pasted as an input to many other specifications (EATCHIP III, DSI, ITI, etc.).

Another important contribution in this area has been the set of EATCHIP HMI Catalogues [10] providing exemplary HMI specifications for the Baseline, Basic and Advanced EATCHIP Operational Requirements [17] as developed by the EATCHIP (and later the EATMP) Operational Requirements and Data Processing Team (ODT). These catalogues are also based on the ODID principles, with some baseline elements taken from the REFGHMI. In all these

[4] With hindsight, perhaps inappropriately, as unlike COPS it had never been intended for this purpose. ODID was an experimental programme and, while many elements of the interface were stable across studies, others were intentionally speculative.

examples the emphasis at the HMI level tends to be on solutions rather than on requirements.

One important consequence of all of this re-use of specification elements from one project to another is that there is actually much more interdependence between the HMIs being proposed for CWPs than might initially be imagined. Annex B shows the relationship between many of the key European programmes of the last twenty years. It should, however, be understood that much of this connectivity is circumstantial, deriving from re-use of elements in real-time simulation preparation or from the movement and availability of 'experienced' personnel.

Thus, while in one sense the interconnections and re-use appear encouraging and seem to indicate the possibility for harmonisation, as we shall see in 4.2.1, indiscriminate re-use of specifications, like unplanned re-use of software, can be a source of difficulties instead of the intended economies.

3. THE CORE PROJECT

3.1 Objectives

3.1.1 High-level objective

It is with the recognition that development of the working position lies on the critical path to almost all of the proposed ATM system improvements, that the CoRe Project sets out to improve our understanding and our practice of working position development.

The high-level objective of the CoRe Project is summarised as:

To consolidate and disseminate the requirements capture, design and evaluation of ATM working positions for European ATM.

3.1.2 Detailed objectives

Effectively, we are seeking to improve the quality of the CWP development process. In a more explanatory form the project's objectives are to:

1. Reduce risk and complexity for teams / Member States beginning the process of defining and developing CWPs, and make sure that their expectations are realistic and met.

2. Give industry a better model of clients' likely requirements.

3. Initiate and support a process of HMI harmonisation at the level of HMI requirements (as opposed to the level of HMI solutions - look and feel or interaction mechanism are likely to remain system specific).

4. Provide a means of learning and consolidation: allowing experience to be passed on from one project to another.

3.1.3 Action plan

The action plan to realise these objectives will be explained in Section 6, but for the moment it can be summarised as follows:

1. Understanding and improving the process of CWP development so that it becomes more efficient and reliable.

2. Improving the quality of the outcomes of CWP development by reinforcing the evaluative aspect and the opportunities for re-usability.

3. Creating a model of the process, which will allow it to be transferred effectively to its potential audience.

4. Creating a framework to support the process.

5. Providing an exemplar of how it works.

3.2 CoRe Audience

CoRe is targeted at the European ATM service provider community and at their interface with supporting industrial suppliers. Specifically it aims to support the managers of CWP development projects and the teams working with them on the HMI of new systems. Since upgrading systems is often a periodic rather than a continuous activity, these managers and members of the teams may have been previously either operational or technical experts, and the development of working positions often represents a shift in role. The CoRe model and tools are designed to help them adapt to the new role by providing a model of the entire process they must undertake. The tools are also designed to support those already experienced in these activities by better meeting needs identified from previous exercises (see Section 4).

The ATM community is comparatively unusual in that the customer / ATM service provider is often responsible for the specification, and even the initial design, of some of its sub-systems (contrast this with the aircraft industry, for example). This is particularly true in the HMI area where even the purchase of off-the-shelf products may be conditional on a long list of HMI modifications. One consequence of this is that there can be an expectation gap between what the customer imagines and what industry is currently able to provide to the highly engineered standards necessary for operational use. CoRe seeks to address the issue of realism of expectations through a more systematic approach to re-use of knowledge as well as software components, and through the notion of baseline requirements. It also seeks to address the issues of communication between the operational functional viewpoint and the architectural component viewpoint, which come more naturally to the two different groups.

This means that industry responsible for implementing new systems is also a potential beneficiary. Industry should benefit by having prior knowledge of the baseline (thus reducing uncertainty), better communication with the clients, clearer requirements and more realistic demands from the customers. To maximise accessibility of its products CoRe tries to adopt industry standard tools and techniques wherever possible.

POSTSCRIPT: The preceding paragraphs describe the initial target audience of the CoRe Project. In recent months, through discussion with States engaged in the process of obtaining regulator approval for new CWPs, an additional requirement and a potential role have been identified. The need is emerging for the capability to trace design rationale from early R&D studies through specification development and implementation. This extension of CoRe to R&D studies is noted but not addressed in detail in the current document.

3.3 The High-level Structure of the CoRe Project

The CoRe Project is made of four broad activities which can be associated with tightly coupled, overlapping chronological phases, as shown in Figure 4.

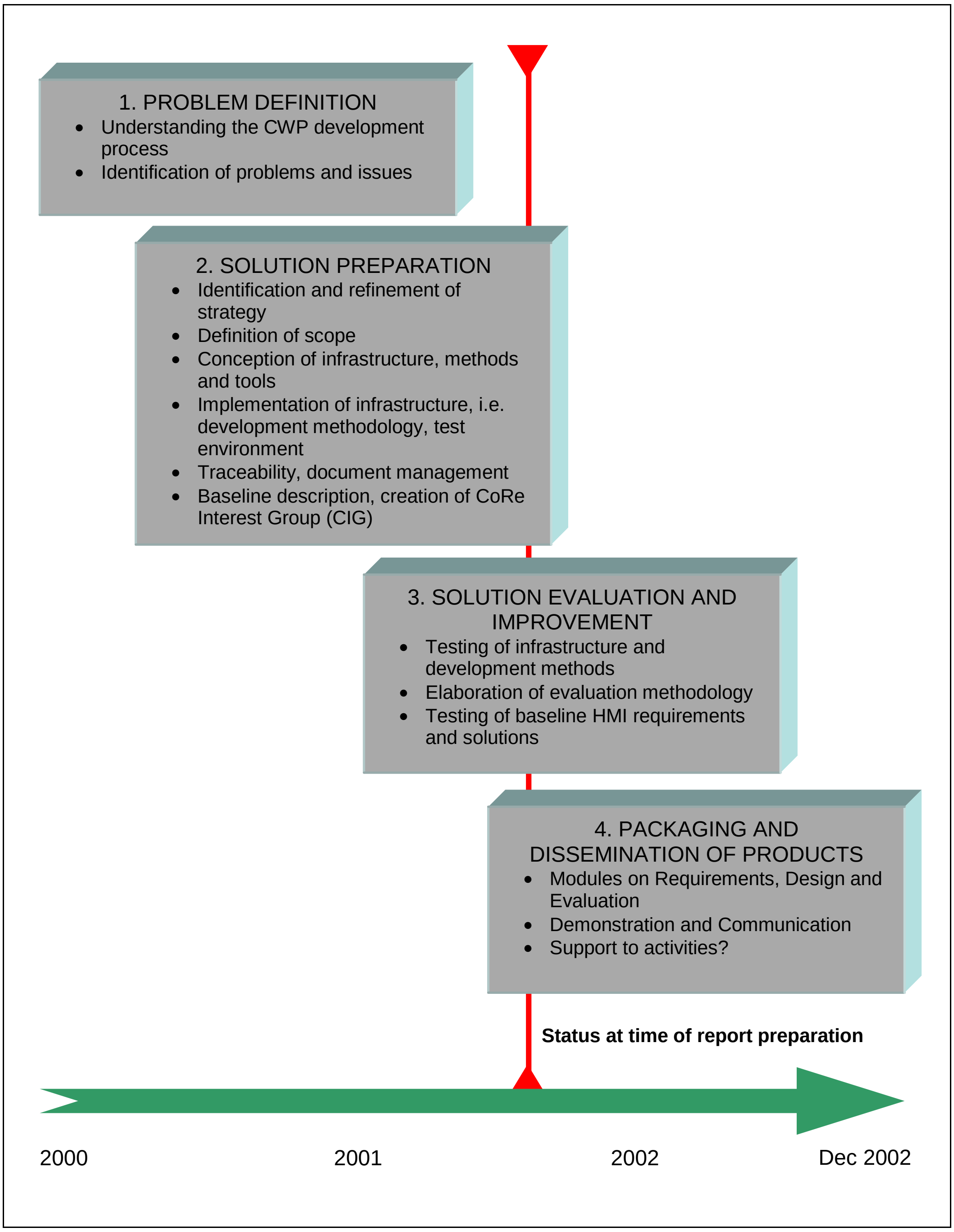

Figure 4: The structure of the CoRe Project

3.4 Framework for Improvement

CoRe, like many 'remedial' or improvement activities, is essentially bottom-up rather than top-down. It did not begin with a theoretical approach to CWP development. Instead, it began with a set of problems that were derived from the real-life experience of trying to define and develop both experimental and operational working positions.

These problems are symptoms of the weakness in the development process. The task of CoRe is to understand the nature of such problems and find solutions. The discussion of the analysis is to be found in Section 4.

The difficulty with such a bottom-up approach is to ensure that the solutions are efficient and coherent, not just patches added to the already complicated and cumbersome process of CWP development. We need a framework of criteria, which can be used to guide our design choices. Our solution was to apply four general 'quality' objectives to our approach to the project.

- integration,
- consolidation,
- harmonisation and
- simplification.

Annex A describes these objectives and their interpretation in more detail.

4. ANALYSIS OF PROBLEMS AND ISSUES

As the simplest way to build a clear understanding of CoRe activities and the rationale that underlies them, this section provides a chronological description dealing with the way in which ideas and events emerged.

Effectively, there was an initial identification of problems and issues, which led to the formulation of the CoRe Project in its current form. Subsequently, within CoRe itself, this analysis was elaborated before being translated into a set of requirements and strategy for mitigating the problems.

4.1 Initial Problem Recognition

In 1997 we held a workshop for the purpose of defining how one of our own products, the REFGHMI, a richly illustrated specification of a basic graphical en-route controller interface [20], could be improved. The workshop involved around ten participants from a number of European countries with backgrounds in operational, real-time simulation, R&D and HMI areas. Topics for discussion addressed both the contents/coverage of the document and the format and structure of the document itself. The outcomes identified three classes of issue:

- operational/functional issues (e.g. with requests for coverage of radar label anti-overlap, system-assisted coordination);
- ergonomic issues (e.g. management of highlighting and focus, warnings and alerts, font selection);
- issues related to the use and objectives of specification documents (e.g. To what extent should design rationale be explained? Does the document have a variety of users? If so, are their purposes and requirements different?).

The operational and ergonomics issues were typical of these we had foreseen in the project. However, the third group of issues led our team to take a closer look at the purpose of our specification documents, and eventually to a much deeper reflection on the nature and effectiveness of the CWP development process itself.

In doing this we came to recognise that there was as much scope for improvement through applying the human factors approach to the activities of the R&D and development communities as there was to studying the work of the operational controllers who deliver the eventual ATM service.

In consequence, the CWP development process became the focus of our human factors study.

4.2 Initial Analysis

This first analysis of the Controller Working Position (CWP) development process was effectively internal, based on:

- experience with projects in which either the EEC or Members of our own team were involved;
- discussion with colleagues working on other European ATM projects;
- publicly available information on national upgrade programmes like ODS France, NERC (UK CAA) and Advanced Automation System (AAS; US).

This analysis led to the identification of a number of problems [35] but also to an explanatory view of the CWP design and development process as a socio-technical system. This collaborative activity involves a number of human agents supported by tools and procedures trying to achieve a collective goal, the goal being an adequate CWP in either a research or an operational context. As we will see, many of the problems and difficulties can then be described in terms of the *communication* between the agents, difficulties in their *roles and responsibilities* (e.g. implicit rather than explicit roles, gaps in responsibility) and *inadequacies in the support tools*.

4.2.1 The issues identified

The main problems identified at this stage (described more fully in [35]) were:

- <u>Synthesising requirements</u>: How to establish sufficiently detailed requirements to design adequately for functions that do not currently exist; (and where observations of today's practices may be insufficient to clarify the requirements).
- <u>Management of re-use</u>: Problems associated with unmanaged re-use of software elements and of specifications. (These problems include hidden constraints, unnecessary functionality and complexity, potential inconsistency of design, etc.)
- <u>Communication problems</u>: Even though multi-disciplinary teams are a key element in the design of complex interactive systems, experts have different interests, objectives, languages, experiences and expectations. More specifically, operational experts and HMI designers tend to think on the interface in terms of functions and HMI objects while software engineers see the system in terms of architecture and components.
- <u>Who should do what</u>: Problems of poorly defined or changing roles and responsibilities amongst the developers, especially as the participation of human factors expertise evolves from post-design evaluation to a wider participation which could include requirements capture and interface design. While we recognised that some of these particular problems might

have been specific to our local simulation context, the problem of managing increasingly multi-disciplinary teams is general.

- Documentation management: Problems of managing documentation and data; keeping documentation up-to-date and consistent.
- Erosion of HMI acceptance and testing: Often as the result of failures in resource planning and underestimation of the effort needed to establish adequate requirements.

4.3 Initial Action Plan

Our initial plan of action to respond to these difficulties operated on several fronts. In general we sought to have a better understanding and description of the development process itself. To do this we integrated two approaches; on the one hand we tried to characterise the process in terms of the information that flows, how it is transformed and needs to be managed if the process is to be successful; simultaneously we considered the process at an organisational level, in terms of the interactions of a multi-disciplinary community of experts.

4.3.1 Improved process description

Firstly we tried to produce a better description of the processes involved in the CWP development which would allow clarification of the roles and responsibilities of the different actors involved. This resulted in the elaborated 'V' model reported in [35] and reproduced as the upper part of Figure 5.

The 'V' model was chosen in preference to 'spiral' and other software development models ([12] provides an overview of models) because of the clarity with which it expresses the need for test plan development and the importance of evaluation. The model was augmented with additional stages to reflect the increasing relative importance of the HMI component and to show the possibilities for more structured evaluation. By emphasising the possibilities for iteration (e.g. including rapid prototyping) between one or more stages it presents a general framework that can be used to express many of the key issues of CWP development. It is interesting to note that the recent MEFISTO Project [41] also prefers a model of this general type.

4.3.2 Roles and responsibilities

For each one of the stages shown in the diagram we identified the objectives and products, the assembly of expertise which should be involved, and we suggested the skill type which was most significant as the lead role. The lower part of Figure 5 relates the stages to the skill sets and appropriate stage leaders. It is important to note that the discussion focuses on roles and functions, not on individuals. In practice, one individual may fulfil more than one of the necessary roles; for instance, the project leader often has technical or operational skills, or the same cognitive engineer may perform the HF analysis and the HMI design.

Conversely, there may be occasions on which methodological reasons demand that different individuals should provide the same class of expertise. This may be true in the evaluation stages, where it may be better if the operational experts or the usability specialists involved are not those who were responsible for the original design.

4.3.3 Communication and products

We also identified the need for dialogue and negotiation between the stages, particularly on the design limb. Each (current) stage on the design limb must be responsible for communicating increasingly elaborated requirements to the following stage, but also for ensuring that the previous stage understood the constraints arising within the (current) stage.

In this context the products of the stages take on a key role as a support for communication. They need to support this ‘overlapping’ between stages. If we take the example of the HMI specification, it is produced under the responsibility of the HMI designer. It is a major input to the software system design process (the major input for the HMI software elements) and, as such, it should be highly ‘usable’ to support the software design process. However, it must also be comprehensible (for review) by all those diverse experts involved in the preceding stage (HMI requirement definition), especially the domain experts.

Given the range of expertise involved this is a very demanding requirement, and goes someway to explain the controversy which has continued within the ATM community for a number of years as to whether HMI specifications should be ‘functionally’-oriented or ‘component’-oriented. In fact, there seems to be a dilemma.

The functional representation, which is natural for operational experts and even HMI designers, is probably essential for the process of requirement clarification and capture. On the other hand modern software development processes are organised around component and conceptual object views. In fact, these different perspectives seem to be naturally dominant at different stages of the development cycle. This is illustrated in the table element of Figure 5.

4.3.4 Initial requirements for methods and tools

Finally, we identified, in general terms, some of the characteristics appropriate for support tools and methods:

- to support the specific activities and objectives of the stages;
- to be comprehensible to all the actors operating within a given stage;
- to act as a communication support between phases;
- to assist in tracking ideas, changes and the consequences of changes.

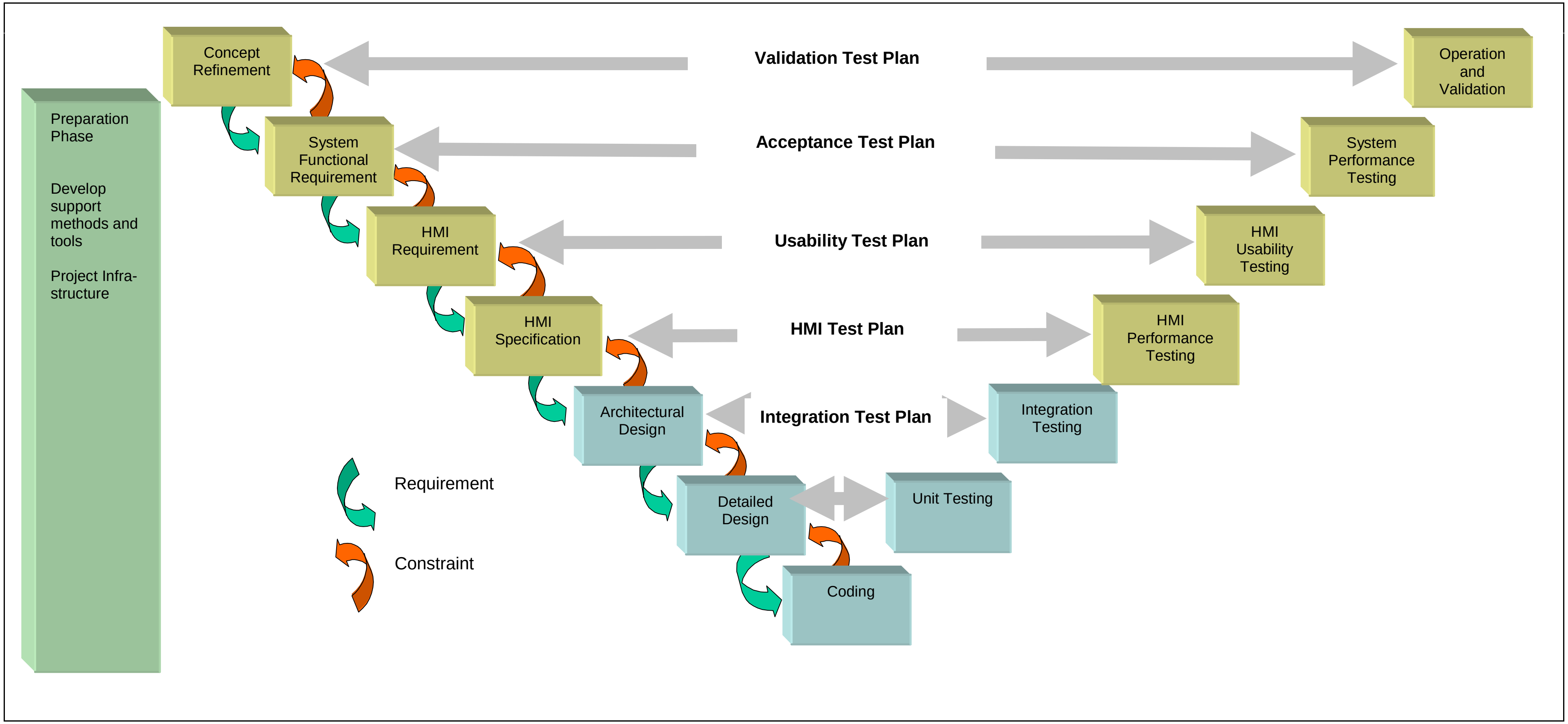

Figure 5: The 'V' Model adapted to ATM HMI development

Explanations are provided in the table on next page.

Phase	Preparation	Concept Refinement	System Functional Requirement	HMI Requirement	HMI Specification	Architectural Design	Detailed Design	Coding	Unit Testing	Integration Testing	HMI Performance Testing	HMI Usability Testing	System Performance Testing	Operation and Validation
Lead Role	Quality engineer	External clients or PL[5]	PL[5]	Analyst HF/HMI	HMI designer	TPL[5]	Software designer	Software engineer	Software designer	TPL[5] or software designer	HMI designer	HMI analyst	PL[5]	External clients or PL[5]
Skill Sets	Quality control, development methodology, PL[5] + representatives of other actor groups	OPS[5]/domain expert, technical experts, some HF expertise	OPS[5]/domain expert, technical experts, some HF analyst	OPS[5], technical experts, HF analyst, HMI designer	HMI designers, TPL[5], HF/HMI analyst, training expertise	TPL[5], HMI designer, software designers and engineers	TPL[5], software engineers	Software designer	Software engineer, TPL[5]	Software designer, software engineer, TPL[5]	HF expertise, experimental design and analysis, technical experts and operational users	Usability testing, Operational users, and technical and training expertise	Operational, experimental design and analysis, training expertise	Operational, technical, HF
Methods and Tools	Quality engineering methods, software engineering methods	Brainstorming, scenario walkthroughs Fast time modelling Documentation support	Requirements capture techniques, Focus groups, etc. Modelling and rapid prototyping Documentation support	Requirements capture, cognitive and scenario walkthroughs, HF and HMI guidelines, task modelling. Functional matrices, HMI rapid prototyping Documentation support	HMI guidelines HMI prototyping and test Design experience Human performance models Documentation support environment	Appropriate object-oriented design methodology Support environment	Software design methodology with consistency and completeness checking Documentation support	Software development tools and environments. Editors, debuggers, component libraries Documentation support	Unit Test Plans, Test Harness Reporting	Integration Test Plan, Test Harness	HMI Performance Test Plan, performance criteria measures and analysis	Usability Test Plan, usability assessment techniques and checklists	Acceptance Test Plan System measures	Validation Test Plan Socio-technical system measures
Products	Project working method and support tools	Concept document, scenarios, task model	Functional/ operational requirements. The operational task objects	HMI requirements, team roles, job design, outline procedures	HMI specifications, draft controller working method and detailed procedures	URD[5], SRD[5]	ADD[5], SSDD[5]	Coded unit applications	Individually tested units ready for Integration	Technical CWP platform	HMI meeting basic performance criteria	Usable platform ready for acceptance testing	System and concept ready for operational validation	Go / no go decision in R&D or operational acceptance in implementation
Domain View	**Synthetic**	**Functional**				**Component**					**Functional**			
CENA Phase (4.4.1)	P0[5] – Initiation phase: setting up the methods		P1[5] – Identification of operational requirements		P2[5] - HMI specification (conception and recurrent assessment) P3[5] – Coordination with the HMI Software Development Team									

[5] ADD: Architectural Design Document – OPS: Operations – P0, P1, P2, P3: Phase #0, Phase #1, Phase #2, Phase #3 - PL: Project Leader – SRD: Software Requirement Document – SSDD: Software Specification Detailed Design – TPL: Technical Project Leader - URD: User Requirement Document

4.4 Additional Analysis in the CoRe Project: Contextual Issues

It was at this stage that our current project, CoRe, was launched with the specific objective of improving the basic processes of CWP development for ATM. Our approach, described in Sections 5 and 6, is based on establishing a set of methods, traceable and re-usable requirements, and solutions for the development and evaluation of CWPs. It is important to understand how we arrived at the particular strategy that we finally adopted.

4.4.1 The CENA Study

The project was based on the foundation described in the previous sections, supported and elaborated by complementary studies. The first of these was concerned with a specific HMI issue, the definition of screen fonts for advanced ATM workstations [13]. The second study, conducted for us by colleagues at CENA, acted as both a 'validation' and extension of our initial analysis [25].

This study looked at the nature of requirements for ATM HMI specifications themselves. It was based on an examination of a small, but representative, number of projects ranging from small-scale experimental studies to the introduction of ODS France.

The detailed conclusions of this study are included as Annex C. They confirmed many of the conclusions of our earlier work in relation to the important role of requirements, constraints and communication between experts, but they also introduced a number of new issues.

Firstly, the report described the CWP specification activity as being made up of the following four phases:

- Initiation phase: setting up the method,
- Identification of operational requirements,
- HMI specification (conception and recurrent assessment),
- Coordination with the HMI Software Development Team.

The inclusion of an initiation phase is an important addition. It makes explicit the need for organising the process, and for establishing a methodology and tools.

Secondly, the document raised a number of issues concerned with the organisational aspects of the relationship between the service provider responsible for the specification and the industrial supplier who must furnish the system.

Both these points were important. The second coincided with the recognition within CoRe that, although our view of the development process was useful and identified areas for improvement, it was too narrow.

In practice, many of the factors that seemed to contribute to difficulties in developing new CWPs and introducing them into the operational context related to institutional and organisational aspects of the development process. Others seemed to relate to aspects of our ATM culture and the limitations of the tools and methods which we have available for *validation* (that is collecting the information necessary to establish a consensus amongst a wide range of stakeholders that the proposed CWP is an adequate solution). We needed at least some awareness of the other processes in which the CWP development was embedded.

To illustrate let us look more closely at some of these problems, using two examples that emphasise cultural and organisational aspects of context.

4.4.2 Example #1: How to 'validate' a CWP? Requirements *versus* solutions

In recent years developing new CWPs for operational use has encountered many problems. Many of these relate to technical issues, e.g. a dramatic increase in the amount of code associated with graphical user interfaces, inadequate requirements capture, etc. However, one recurrent pattern has been to plan a comparatively dramatic change to a new operating concept (e.g. removal of paper flight strips), to develop the project on that basis and, at a late stage, decide to reduce the innovative functionality element 'to reduce the risk'[6]. (An example would be deciding to remain with paper strips during a transition phase, e.g. AAS, NERC.) It is not clear what is happening in such cases. There would seem to be two complementary possibilities as follows:

- information is accumulating which suggests that a choice will not be valid;
- the information needed to convince some key stakeholder group that a choice will be valid is not being established.

In practice, the second possibility is as likely as the first, for the truth is that in the domain of CWP/HMI our evaluation processes are quite inadequate. While we can perform basic usability and ergonomic analysis of HMI mechanisms, the decision that a CWP meets operational requirements is generally based on an iterative set of simulations or reviews with technical operational and management experts. Despite many attempts to improve the situation [3], [40] we had already concluded, *many of our large scale pre-operational evaluations are much closer to demonstrations of feasibility than measured activities* [37]. Currently it is very difficult, even in a small-scale experimental simulation, to separate out the effects arising from different factors. Our 'concept' evaluations confound the effect of the concept itself, the design of the HMI, the implementation of the HMI, the system performance, the adequacy of controller training and understanding, etc.

Awareness of this difficulty was one of the reasons for the adoption of the 'V' model of system development (see Figure 5). The 'V' makes the relationship

[6] This may not actually be a reduction of risk. If the concept was designed to support a particular working method, based on a particular interface, the resulting compromise solution may lack in coherence.

between requirements and testing very clear. It emphasises the need to establish test plans at an early stage based on the assumption that, when a requirement is identified, it should be possible to identify the criteria for establishing whether it has been met or not.

We now consider that requirements are the key to both the evaluation and subsequent validation issues. We believe that our operational ATM and simulation sub-cultures tend to be 'solution-oriented' - perhaps as a natural consequence of their emphasis on pragmatism. However, we consider that CWP development has to become 'requirement- oriented' and to justify this we see four key roles for requirements:

- as the basis for an adequate DESIGN;
- as the basis for EVALUATION – to check that the design meets the requirements;
- as the basis for HARMONISATION[7] between different systems while allowing flexibility for locally appropriate solutions. Systems that meet commonly agreed requirements are much more likely to be interoperable.
- as a basis for RE-USE. When considering a new CWP or function, the discussion can begin from the current system and the requirements it meets. Identifying differences in requirements is an intermediate step to defining a new solution consistent with existing elements.

Our ability to perform effective validation of CWPs is reduced by our inadequate processes of evaluation and by our emphasis on solutions rather than requirements and how they are met.

4.4.3 Example #2: Relationship between service provider and supplying industry

While the following descriptions are clearly over-simplifications, we believe that they reveal a number of important points.

In the European ATC situation the service provider identifies the need for a new system and sets up a team to manage the procurement. For smaller service providers this may involve establishing requirements, or it may involve passing directly to industrial suppliers to inspect the products the latter have available (usually based on the system they have most recently furnished). A selection and negotiation phase will follow, in which the candidate system is customised to better meet the procurer's stated requirements. In this type of procurement a large part of the technical and operational design is inherited from the previous supplied system.

The situation is slightly different for larger service providers. In most cases they undertake a large part of the high-level system design, often following a

[7] A key objective within the European multi-service provider context and to improve opportunities for industry.

process of rapid prototyping, conducted in their own facilities, supported by industrial specialists, or in cooperation with ATM research centres such as the EEC. Effectively they develop the CWP specifications (including those of the HMI) themselves and then put out a competitive call for tender to the supplying industry. The HMI part of these specifications is generally structured in a functional format. Industry must analyse this call against what they currently have available and make a proposition. A number of problems have already been identified in this type of context.

DESIGN OF AN HMI SPECIFICATION: High risk that the specifications produced by service providers could not be easily understood by industry, especially in the potentially short time available. It was in this context that the DSI Project Team worked with the EEC to develop a working prototype of their specification [43], a model subsequently followed by the ITI Project [42].

Note, however, that in transferring from the designer/client to the industrial implementor, we have exactly the same potential communication difficulty as was identified within the ‘V’ model in the earlier part of this paper. The functional description suited to operational and HMI design specialists needs translation into a component view for the software design process. However, the problem is now potentially exaggerated because the ‘functional’ and ‘component’ communities are not within the same organisation, and the lines of communication between them are even harder to establish and maintain.

REALITY GAP: A major risk that HMI functionality requested by the client cannot be readily achieved in practice. It is not normally the role of a service provider to maintain a technology watch, and the practical possibilities and limitations of new technologies may not be fully understood. Further, the design is often derived from simulation studies where, by definition, functionality can be simulated that may not yet exist in ‘the real world’. The weakness of evaluation processes in simulation has a double impact here in that, even when evaluation takes place, less rigorous technical criteria are employed and the technical feasibility of the system is not established. A complementary risk is that performance requirements in HMI specifications, when they are stated, may be conservative and over-specified.

REQUIREMENTS NOT EASILY VISIBLE TO INDUSTRY: The variety of different designing agencies (wide range of service providers), the emphasis on specifying HMI mechanisms rather than on requirements and poor reality testing against the current technical ‘state-of-the–readily-achievable’ make it almost impossible for industry to anticipate the demands of the client.

As mentioned in 2.2.3 this difficulty has been recognised for some time and a number of initiatives have been taken to try to provide a more visible starting point for industry and increased harmonisation between the developments of different States. The most important of these initiatives was the ‘Common Operational Performance Specifications for Controller Working Position’ (COPS/CWP) [17] developed in 1991 and still very influential.

There are a number of other issues which can be identified (for example those associated with re-use, both by the designer cutting and pasting from previous specifications without necessarily understanding the design rationale behind them and the supplier trying to maximise re-use of material from previous implementations). However, the purpose in this section is to show how the social and organisational context shapes the nature of the development process and dictates the nature, if not the number, of difficulties to be overcome. To complete the illustration let us make a comparison with another context, the airframe development/procurement process.

In this case it is the airframe supplier who identifies the need or opportunity for a new product. This is based on feedback on existing products (from airlines and from pilots in training), perceived changes in requirements (understanding the market) and changing technical possibilities. The suppliers undertake the design and realise the implementation with a controlled range of options to allow some customisation for different clients. The suppliers take the investment risk. The Transport Service Provider (carrier) identifies its need for a new purchase (replacement, competition, etc.) and chooses between vendors. Comparatively, few vendors compete for a relatively homogeneous market defined to some extent by the competition between the transport providers.

The impact of this difference in process is significant. On the one hand the client reduces both technical and investment risks, which are effectively transferred to the supplying industry. On the other hand the client has little control of the technical solution and has narrower choice (although the choice is effectively the same as is available to their competitors[8]).

For supplying industry the financial and technical investment is much greater but visibility of the technical risk better. The suppliers understand the technical possibilities and determine the degree of innovation they consider to be desirable and achievable. There is continuity between design and implementation. The degree of innovation is one of the main areas of competition between suppliers. High risk for the supplier is in correctly anticipating the market.

The objective of the comparison is not to claim that one institutional context is better than the other; they are simply different for a number of reasons that cannot be explored here. We need to identify particular issues for CWP development and to show that these can be overcome in other contexts. In particular we must try to:

- ensure that technical realism constrains the design process more effectively;
- link design, implementation and evaluation more closely;

[8] An important difference is that ATM service providers are not, at the moment, in direct competition with each other.

- provide supplying industry with greater visibility to better anticipate service providers' needs (compare with the argument for commonly agreed CWP requirements).

4.5 The Need for a Multi-level Approach

The general conclusion of our consideration of the type of argument presented above is that, in order to improve the process of CWP development, dealing with the mechanics of the process and the quality of the outputs is not likely to prove sufficient. We must also deal with the context within which it takes place.

This has already been recognised in other areas where system qualities have to be improved. In considering 'safety' it is widely understood that the nature of the collective culture and attitudes play a key role in the creation and maintenance of quality [47]. Fortunately, work in the safety area has also shown that you can take such a wide view of the system and still achieve genuine improvements in system quality.

Thus we accept that the scope of CoRe should be to improve CWP development in a wide sense, to seek improvements for the type of organisational and contextual issues described above as well as for the internal workings of the process. Consequently, industry and service providers are included in our list of stakeholders and potential clients.

5. ESTABLISHING A STRATEGY FOR IMPROVING CWP DEVELOPMENT

5.1 Moving from Analysis to Action

In Sections 2 and 4 we have described the context and subsequently the problems identified by our analysis activities. The current section describes the process of establishing objectives for improvement of the development process and using these and the analysis to generate requirements for appropriate solutions.

The section concludes by explaining the strategy that has been evolved to achieve solutions. The solutions themselves are described in Section 6.

5.2 CoRe Targets

To focus the strategy we identified a number of objectives to be attained. These objectives form the basis for establishing the requirements for adequate solutions. The objectives fall into two general classes, cultural change and process improvement objectives.

5.2.1 Cultural objectives

The two most important improvements we identified for the CWP development process imply changes to the work culture. Consequently they are potentially difficult to achieve.

These related objectives are:

- to create an orientation towards *evaluation;* to accumulate evidence that can be the basis of a consensus as to the potential viability of new CWP systems (i.e. support to validation processes);

- to shift from a *solution* culture and approach to an alternative which focuses on *requirements* that are *usable* as the basis of solutions.

Fortunately, there are already indications of some collective awareness of these needs. This transition is already being reflected in parts of the EUROCONTROL Agency strategy. For example, the EATMP Operational Requirements and Data Processing Team (ODT), recognising common requirements as the basis of interoperability, have produced detailed operational requirements [17] to form the basis of a broad set of basic and advanced functions to support the evolution of European ATM.

A suitably planned approach within CoRe should support this cultural transition.

5.2.2 Process objectives

The most important improvements to the process relate to the support of communication and information transfer between stages and actors. We can identify three types of communication linkage, which an improvement strategy should support. To illustrate these we describe their functions in terms of our simple 'V' model.

5.2.3 Stage loop: between stages of the 'V'

To support the design process, increasingly specific *requirements* have to be delivered from one stage to the next (left to right) and *constraints* have to be clearly communicated to previous stages (right to left). This bi-directional communication between stages is potentially more critical at those boundaries where the dominant representation changes from the *functional* perspective to the *component* view (see Figure 6).

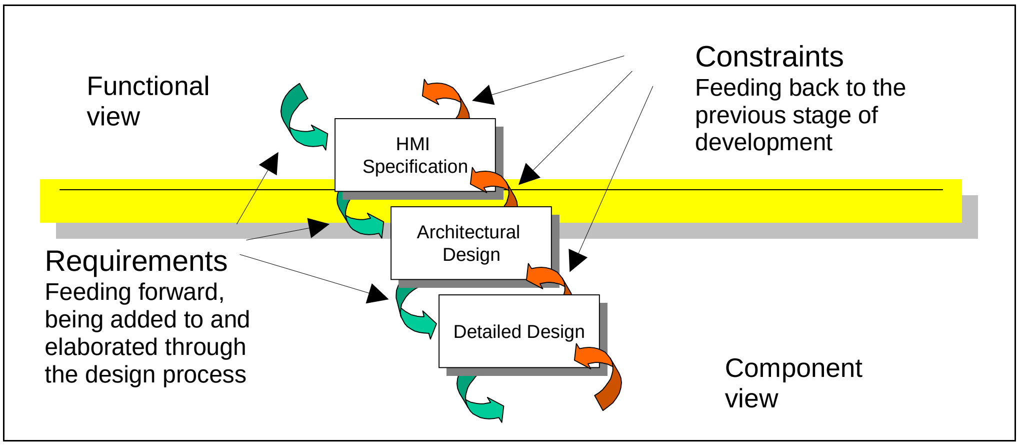

Figure 6: Communication between stages in the design process

The process has to support *visibility* and *comprehensibility* of activities in related stages to allow the actors to ensure that they, and the other actors, are meeting their responsibilities. The nature and implications of constraints have to be understood and recognised. The way in which requirements are realised through the design of the following stage has to be verifiable.

5.2.4 Testing loops: through the body of the 'V'

This second linkage is the basis of the structured evaluation processes that allows separation of the potential sources of variability and avoid trying to measure everything at once. The linkage is once again bi-directional. When a requirement is identified at the operational, HMI or technical levels, *evaluation criteria* should also be identified. The criteria can be incorporated into the appropriate test plan and used to determine whether the result complies with the requirement (see Figure 7) or not.

However, while a yes/no answer is important, the evaluation process becomes most useful when it can be used as the basis for the identification and correction of inadequacies. For this to be possible it is also necessary to be able to *trace* the interpretation of the requirement forward through the design process to the appropriate testing level. This requires that as well as requirement and specification, information on the *design rationale be maintained* throughout the development process. Nancy Leveson, in her evolving methodology for designing systems, which are both human-centred and safety-oriented, emphasises the need for this type of information as an element of her *Intent Specifications* [39][9].

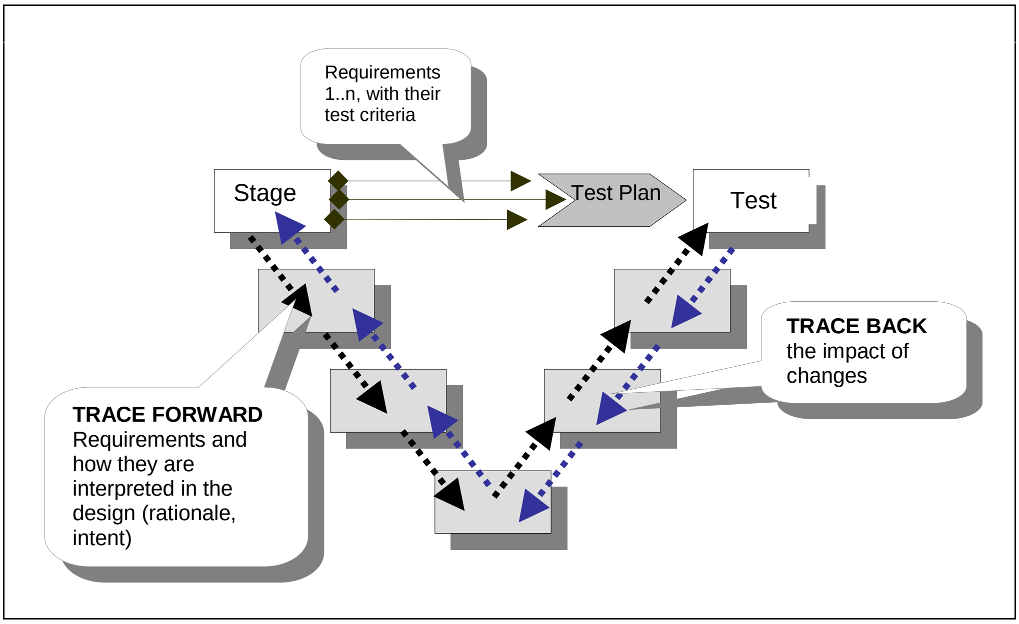

Figure 7: Testing and traceability

Traceability has to be bi-directional in order to support backtracking to identify all the aspects of the system impacted by a system change (in either requirement or design solution).

5.2.5 Transfer of experience: across instances of the 'V'

This third level addresses the re-use of an instantiation of the process, and the transfer of information:

- from one project to another,
- from a research process to a pre-industrial process or
- from a pre-industrial process to an industrial process.

Although software/code is the most generally recognised subject of re-use, in the case of CWP development there has historically been much re-use of

[9] As HMI designers we prefer to employ the term 'design rationale', reserving intent and intentionality to refer to the system user. With this minor clarification Leveson's contribution to the study and development of safer systems is a major one, and we regret that the timescales of CoRe have not allowed us to explore the implications of her work more fully.

parts of specifications from one study project to another (documents like COPS [17] and the REFGHMI [20] were intended to support this).

We would argue that, to realise this transfer effectively, the Project 'Body of Knowledge' (see Figure 8) would need to contain:

- the structured requirements (functional, HMI, HF safety, etc.) + their evolution;
- assumptions and constraints;
- the design products (specifications, design documents, documented software, etc.) + the design rationale;
- the evaluation products (test plans, outcomes, study results) + change history.

To be effective all the above information has to be captured and expressed in a form accessible to the communities who will use it. We have already noted the importance of this requirement in the context of transfer from R&D to industry.

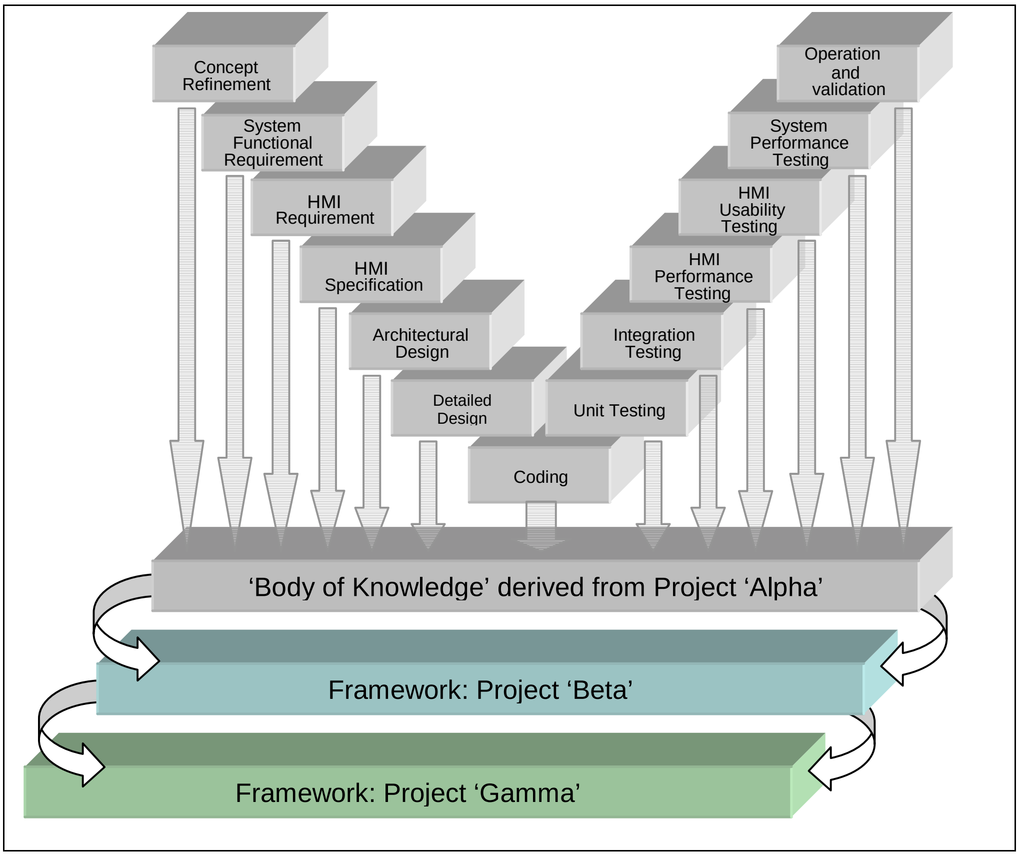

Figure 8: Transfer of experience from one activity to another

5.3 Characteristics Necessary for a Support Framework

The preceding discussion leads on naturally to consideration of requirements for the supportive environment. A number of the characteristics suggested for the process cannot be easily provided without some form of information management support such as those already employed by software engineers, a message confirmed by the CENA study [25]. In this category we identified *traceability* (of what, why and how)*, checking of consistency* and *configuration management.*

Other important features such as *re-usability*, *accessibility to industry*, *efficiency* and *coherence of design* will depend largely on the choice of well-structured, transparent and widely available methods and tools.

Some of the most difficult requirements relate to the communication aspects of the process, in particular to the need to manage and reconcile at least two viewpoints (*functional* and *component*).

Finally, there are elements related to ease of use and cost effectiveness. A balance has to be achieved between the advantages gained and the costs involved in introducing and employing a better process in both financial cost and human effort. This is an area in which the quality of the support can determine success or failure.

5.4 The CoRe Strategy

Our current solution strategy is based on the provision of a supportive framework for the entire CWP HMI development process. The framework should embody an improved process of CWP development and should be tailored to the community who will employ it in the ATM context.

The framework is intended to embody good practice in CWP development but also to directly address many of the shortcomings identified in our analysis by meeting the requirements described in this section. The framework is based on an integrated structure for managing and tracing key information from initial requirements through development to evaluation.

At a second level, by capturing this key information and making it available in appropriate ways for different stakeholders, the framework is intended to become the basis for transfer of information from one ‘project’ to another, supporting re-use not only of software and specifications but also of requirements and design rationale.

The framework is both a support to information management during the project life and subsequently a repository of the body of knowledge.

Our belief is that, if you provide something that works well, is easier to use and understand than the existing practices, and you can get it into the hands of the right people, it will be adopted, become the norm and lead to an evolution in practices.

5.5 Staying Relevant: The CoRe Interest Group (CIG)

5.5.1 The reality requirement

Having established a strategy, key concerns remain:

- How do we ensure the quality and relevance of the work we are undertaking?
- How do we ensure that our work is well adapted to the real world context in which we hope it will have application?
- How do we get the material into the hands of the people who are qualified to judge?

We have already made reference to a general quality strategy in Annex A, but these questions demanded a much more focussed and pragmatic response.

The approach adopted was the identification and creation of the CoRe Interest Group (CIG), a community of operational, engineering and human factors specialists directly involved in the design, development or implementation of modifications to the CWP. Most people in this situation are very busy. We reasoned that they do not have time to come to meetings. Their time is valuable and at both personal and organisational levels they need to get some return on its investment.

5.5.2 The solution

Our solution was to form an informal electronic network of people involved in CWP definition and development. The invitation identified:

> *that the function of the of the network is to operate as:*
>
> *a) an information exchange and support group for people working in the field within different administration;*
>
> *b) a forum to ensure that the issues, methods and solutions addressed in the CoRe Project remained focussed and pragmatic.*
>
> *The group would be invited to identify issues and study topics, e.g. radar label overlap, font selection, management of electronic coordination, based on their practical experience and to comment on/review the proposed and eventual deliverables of the CoRe Project before they are made available to a wider public.*

By emphasising the information exchange and support group aspects we wished to stress the potential advantages to participants.

5.5.3 Current status

The group is established with a community of over thirty participants from sixteen countries, representing the desired range of expertise as well as industry, service providers and researchers. Following an initial survey conducted by email, the group accepted to work by email until a membership controlled discussion group could be established. A first distribution of information has been made by email but we do not really expect discussion to take place until migration of the group to the discussion forum. The developing EEC ATM Forum for which the CoRe Project and the CIG will be a beta-test application is providing this. All previous CIG material has been copied to the Forum and transfer to the Forum is taking place at the time of writing.

Anyone wishing to inscribe to the forum can request membership through the ATM Forum site at www.air-traffic-forum.org.

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6. REALISING THE IMPROVEMENTS

6.1 What CoRe is Providing

As a result of our analysis and strategy, CoRe intends to provide three main products at different levels:

a) At the 'organisational' level: a better understanding of the issues and a qualitative model of the activities involved in developing adequate controller working positions.

b) At the 'activity' level: a supportive framework to facilitate the process of CWP development.

c) At the 'practical' level: a worked example of a en-route CWP which illustrates both 'the what' and 'the how' of the CWP development process but which also acts as the starting point for the re-use cycle; this example is based on both the model and the framework.

The following sections describe these three products in more detail (see also Figure 9).

6.2 Qualitative Model of CWP Development

6.2.1 Scope and objectives

The intent is to provide a better understanding of the organisation of the CWP development process in terms of:

- the development of information based on a requirement-oriented perspective to support staged evaluation;
- the nature, roles and responsibilities of the actors involved;
- guidance material on the key areas of:
  - requirements,
  - evaluation and
  - HMI design.

The intention is to provide a qualitative model which can be used to explain the scope and nature of the process to new participants, which can provide a support to managing the process, the roles and the responsibilities, and can serve as a basis for identifying areas of potential improvement.

The choice of the term *qualitative model* is intended to indicate that the model is neither quantitative nor prescriptive. It is not used to perform calculation. It does not demand that every step in the model must be followed systematically in every context. In fact, in many circumstances it can be radically simplified with different roles and activities being collapsed together. However, the model does provide a framework for understanding behaviour, for example, a means of diagnosis and explanation in cases where the process does not operate as expected (see Donald Norman's seven-level model of action [44]).

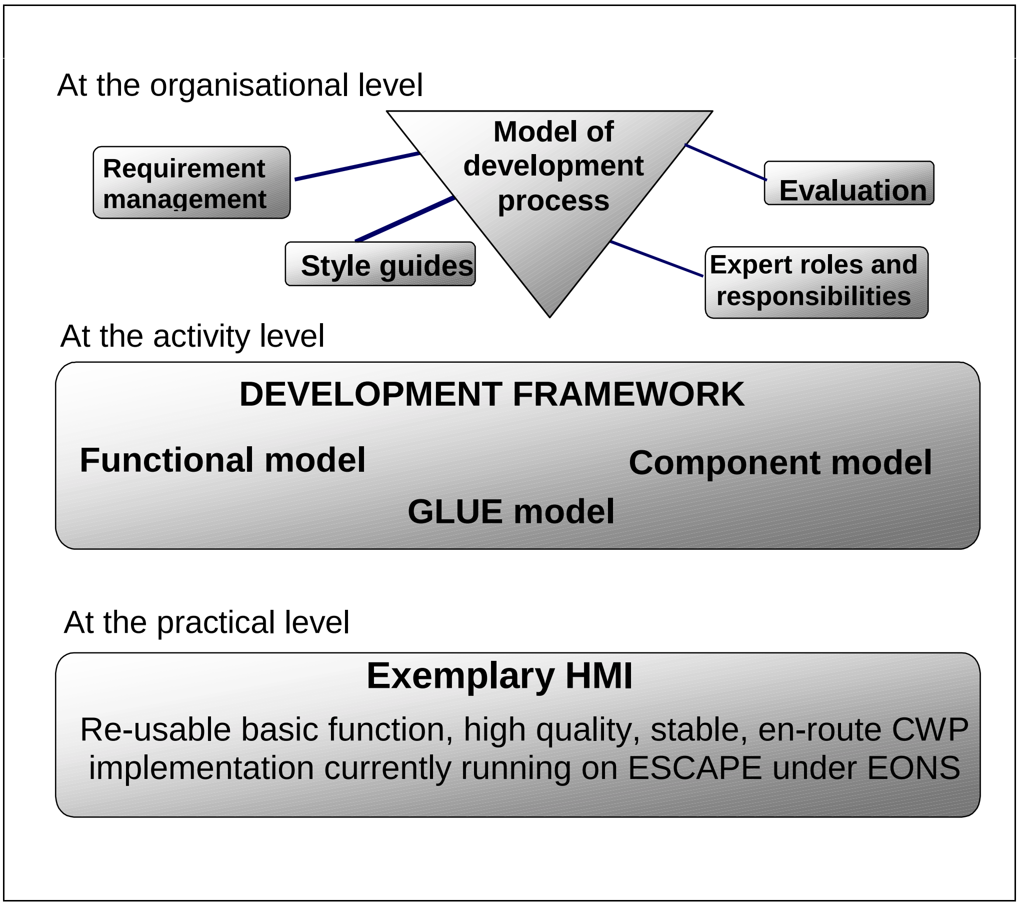

Figure 9: Three levels of CoRe products

6.2.2 Form of the delivery

The basic form of the model and much of its contents have already been introduced and employed in this document. Many of the essential elements are captured in Figure 5. The simple mapping of the 'V' diagram onto the table format provides a mechanism for relating the model to the supportive framework.

The table itself can be expanded and updated to serve as a record of tools and methods chosen for different stages and even as a support to project planning and management.

It is also planned that there will be three modules synthesising information relating to key aspects or activities in the development process: requirements, design and evaluation. These will take the form of guidance material synthesising general good practice, and reflecting the specific experience gained from undertaking these activities in development and evaluation of the worked example for en-route control.

The three modules will be delivered in 2002.

6.3 The Supportive Framework

The key to the success or failure of the CoRe approach lies with the supportive framework. It is the agent through which the change to thinking in terms of requirements and evaluation might be achieved. Only if it provides a natural and intuitive support, while obviously improving the quality of the result, will it be adopted for sufficient time to begin to have an effect.

The original intention had been to create some kind of database supported by a set of tools and methods, deliberately designed to support the refinement of requirements and the specific communications processes between the different actors. For example, the HMI specification would have been designed to be accessible to HMI designers, software engineers and operational experts, and specifically support communication of requirements and constraints between the HMI designers and technical coordinators.

There was already experience of software engineering support tools and configuration management systems in the software development aspects of our activities. With the help of the Software Engineering Unit at the EEC we arrived at two insights:

- firstly, that the use of Unified Modelling Language (UML) allows the possibility of simultaneously supporting functional and component descriptions of the development;
- secondly, that the use of a 'federated' environment such as those supported by tools like Rationale Rose™ could be extended beyond management of the software elements to include both the early stages of requirements capture, development and HMI design and specification, and subsequent evaluation processes.

On this basis, with the help of the EEC Software Evaluation Unit, we have used UML to develop a framework with both Functional and Component models of the system. These are linked and consistently managed by a third element called the GLUE model (see Figure 10). The GLUE model is based on a federating view providing for consistency of all the development process deliverables.

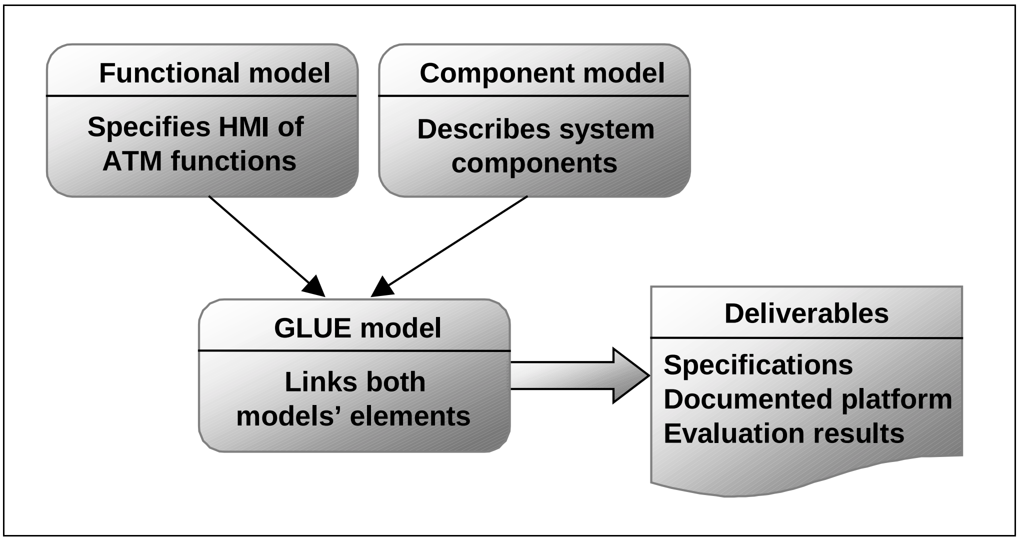

Figure 10: The principal UML elements of the supportive framework

The **Functional** model contains ATC 'business' functions. It describes the relationships between functional and HMI requirements, the corresponding working procedures and the associated HMI objects.

The **Component** software model contains Use Cases[10] sorted by component. Each Use Case is associated with a set of objects, each of these being linked to software modules. Throughout, dynamic and static views are part of this documented design.

The **GLUE** (Generic Linkage for Unifying model Elements) model links the other two models to guarantee consistency throughout, and to lead on to evaluation and final products. It represents the bridge between the ATC and the software worlds, allocating the appropriate software objects and libraries to ATM functions.

Sections 6.3.1 to 6.3.3 describe these three models in some detail in order to allow project managers and other potential users the opportunity to understand the scope and the potential completeness of the support which this approach can provide.

6.3.1 Functional model

Description: This model represents the point of view of the operational ATC world. It is principally managed by the HMI designers, in constant collaboration with the operational experts.

The model is structured by ATC functions and sub-functions (for an example, see Figure 12). These generally correspond to the controller tasks and are based on analysis of the controller activity.

[10] Use Case is a term defined within UML to express the minimum functionality required. A use case description contains the initiating actor(s), the application conditions, the exceptions and the behaviour of the functionality.

Each function is described by four basic elements (see Figure 11):

- The **Actors** that are part of the system, be they human (controllers, supervisors) or components of the technical environment (a function like Short-term Conflict Alert [STCA]).
- A set of **Requirements** (ATM system functional and HMI requirements). These are expressed in text format describing the requirement, each with a unique identifier.
- A set of working **Procedures** (equivalent to **Use Cases**) describing the different action possibilities provided by the function and suggesting the ways in which the controller would use it. A procedure is described by its objectives, the actors involved, the triggering conditions, the necessary pre-conditions and the dialog, i.e. by the sequence of actions/ consequences.
- A set of **HMI objects** which the controller needs to carry out the procedures. An object is described in terms of its objectives, when and where it is available, and how it is presented (with illustration).

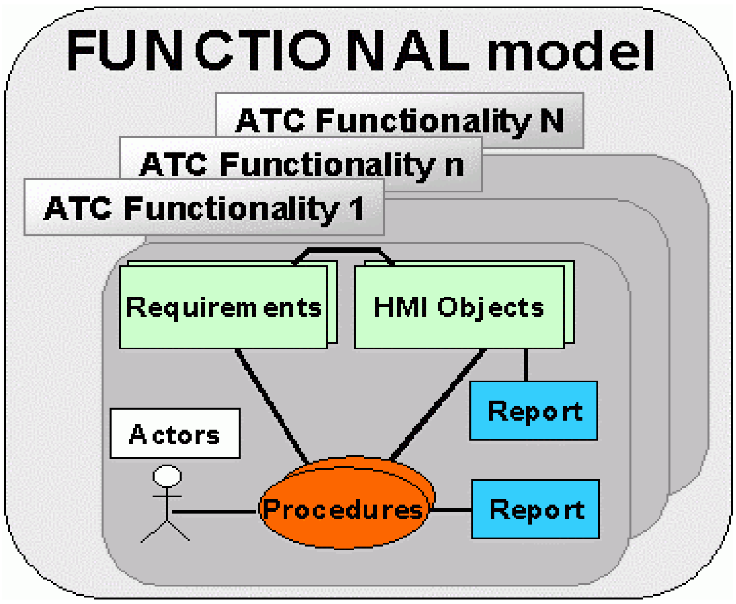

Figure 11: Organisation of the Functional model

The last two elements together describe the HMI solutions proposed to fulfil the expressed requirements.

Links between the elements are a part of their description and can be integrated into any generated documentation as electronic links, improving the document's usability for the purpose of review (by domain experts) or for development (by software engineers).

Behaviour and Use: Following testing or evaluation, any problems detected ('bugs', non-conformance or incomplete implementation, etc.) are described by the (Anomaly) 'Report' component (a special stereotype developed for the needs of our project) and linked to any of the other Functional model components implicated in the problem. The attributes of the Report component allow tracing of the corrections through the different versions of the system (an example of a Report and its attributes is shown in Figure 14). We are currently migrating the 'Reports' from the Functional model to the GLUE model (see below).

The structure created by the quality engineer within Rational Rose allows graphical input and colour coded presentation of the Functional model elements and links. This provides a synthetic view, which is perhaps better adapted to users that are not really familiar with complex modelling tools.

Each of the components is richly documented within the Functional model. The model structure within Rational Rose™ manages the coherence and minimises duplication of information through the links between the four basic elements. This is true for most of the description of each of the elements included in Rational Rose. For the moment some of the information still exists only under the MS Word format. One of the future evolutions of the Functional model is the complete integration of all the data within Rational Rose.

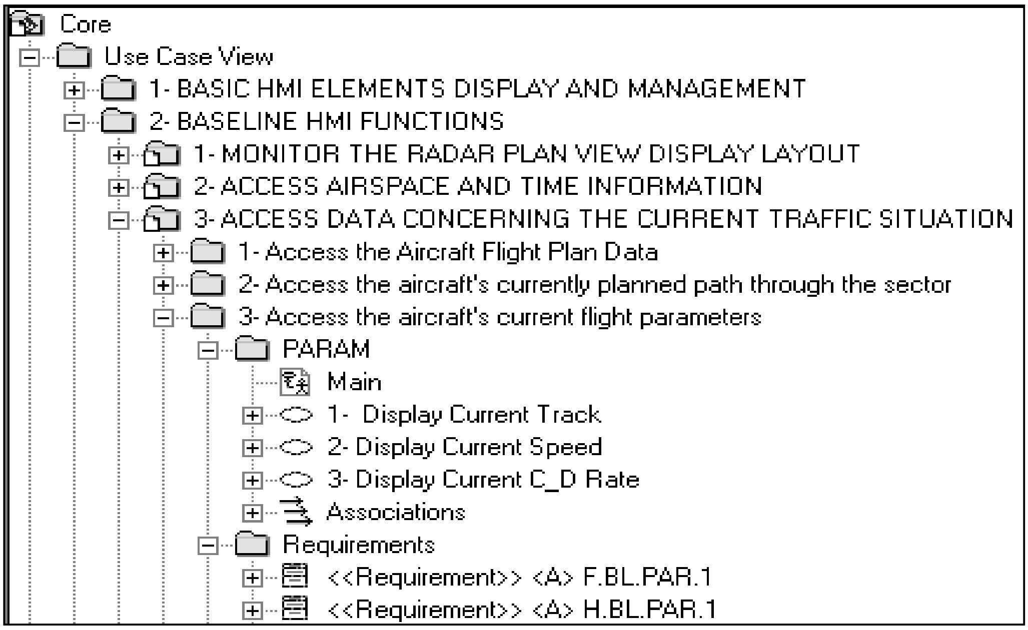

Figure 12: Part of the structure of the Functional model (Objects and Actors not shown)

Figure 13 and Figure 14 illustrate different levels of information present within Rational Rose™ and indicate the kind of detail available.

As these illustrations show, the links between the elements can be unidirectional or bi-directional.

With unidirectional links we represent:

- the logical sequence between Procedures (preceding Procedure ➔ following Procedure) or the fact that two Procedures are equivalent (alternatives);
- the fact that an object initiates a Procedure (HMI object ➔ Procedure) or a Procedure uses an object (Procedure ➔ HMI object).

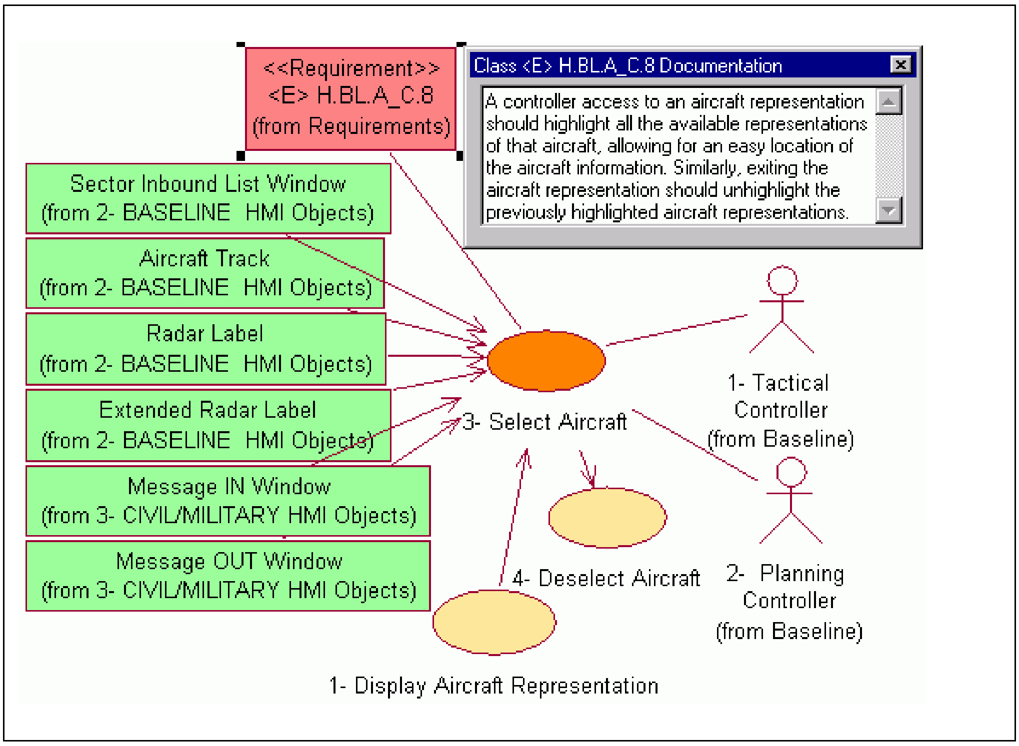

Figure 13: Graphical representation of a Procedure (with links to HMI objects, Actors, Requirements and other Procedures)

This structure and representation allow easy identification of the elements that must be reviewed to identify the impact of any proposed change and check whether it meets the requirements.

This identification and tracing can then be carried on at the software level.

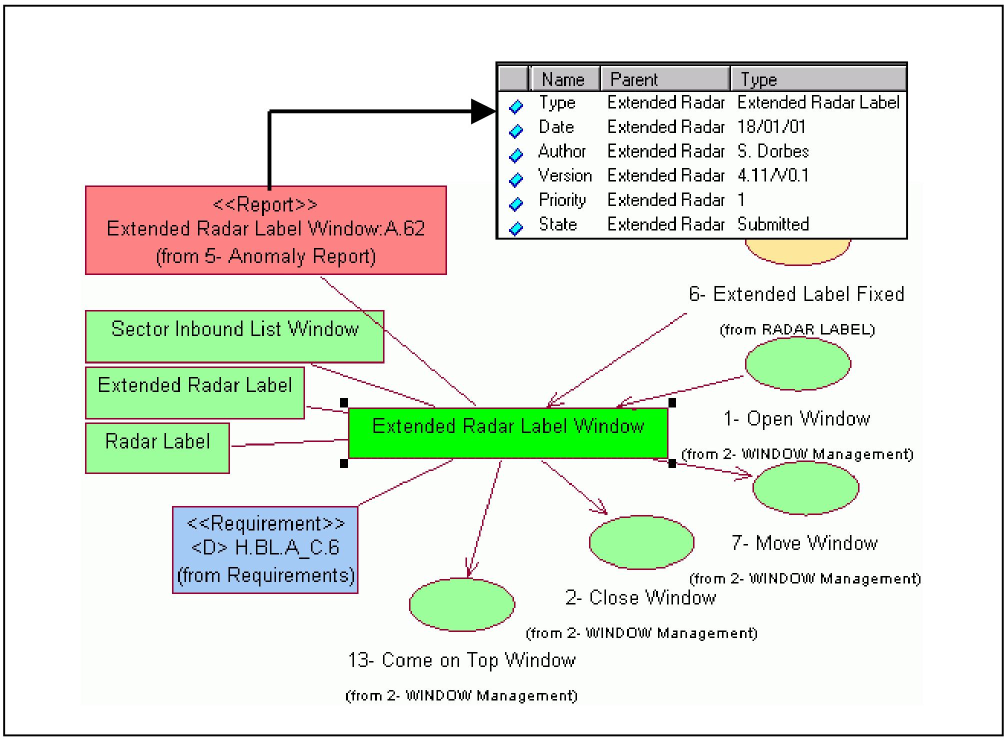

Figure 14: Graphical representation of an HMI object (with links to Procedures, Requirements, other HMI objects and Anomaly reports)

6.3.2 Component model

The HMI Software Development Team manages this model. The objective of this model is to build an object-oriented component library. These components should be as independent as possible to enable re-usability. To further encourage re-usability it is also important to have strong links from the high-level technical specifications to the software module development. Consequently, it is important to have electronic and intelligent links to control this entire data framework. The vertical view of this model is divided into three different layers.

Conceptualisation layer: This is the top layer of the Component model with a high-level of abstraction and generalisation.

First of all, we must describe 'the system' to define what can be built by this Component model. For example, it could be a group of Controller Working Positions (CWPs), a Cockpit Position or a sub-system for Air Traffic Control. In this case the CoRe Project defines the system as a single CWP.

When the system is defined it becomes necessary to know who interacts with it. These entities are called Actors. They allow the description of the interactivity between the system and the external world. As in the Functional model they can be divided into many categories, such as human Actors (air traffic controller, pilot, supervisor), system Actors (clock), ATC Actors (STCA, SYSCO, trajectory predictor), etc.

When this context is completely specified the Component model can be built. It is organised into different packages of components based on categories, like ATC working dialog tools, configuration or communication systems. Each component making up this system belongs to a package. Each package groups all the functionality of a component, together with relevant ATC and HMI objects.

Since the work of the Software Team is based on producing a series of components, it is important to structure the required functionality in terms of components (in contrast to the Functional model).

Specification Layer: Below the Conceptualisation layer the Specification layer provides the technical description of the static and dynamic 'life' of the components. All the servers dealing with the system are also briefly described. Most of the time these correspond to the ATC Actors defined in the Conceptualisation layer.

The static view of the objects consists of a definition of all the descriptive object attributes and object methods (or service interface). All links and associations between objects are defined into class diagrams.

The dynamic view is composed of sequence diagrams (or scenarii), to describe how object services are called into the system. For each scenario the initiator is an Actor.

Conception (Design) Layer: Finally, the Conception layer completes the Component model by describing the different software modules, and their links to the objects, to the imported modules and to the events to which they react.

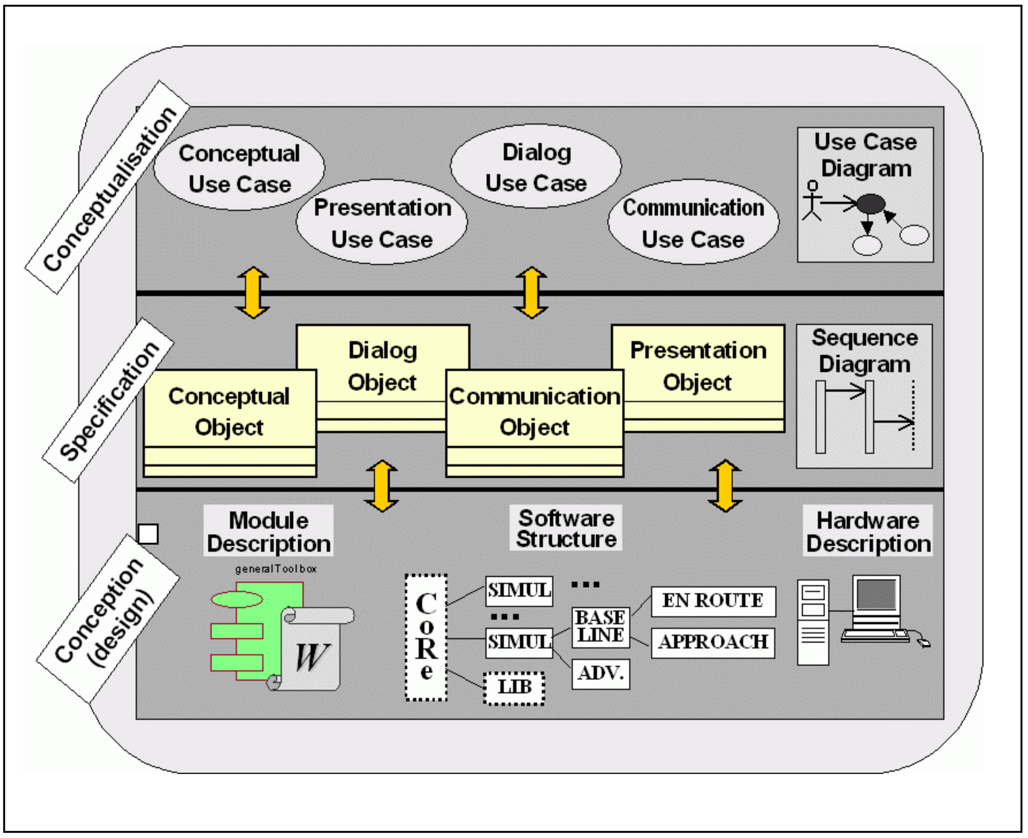

Figure 15: Organisation of the Component model

The Conception layer explains how the system is built, which file tree organisation is used and how the application is organised[11]. The different software versions are maintained in this layer and each software module is documented. Software development syntax advisories are also listed.

The hardware organisation described in this layer allows association of all the ATC and system Actors to the computer resources for each simulation.

Figure 15 summarises how the Component model is organised and how each layer interacts with the others.

6.3.3 GLUE model

The GLUE model is managed by those responsible for the integration and validation of the system, for example the Quality engineer.

This model is the most important because it manages most of the deliveries and monitors the other two models.

[11] In our case typically an ATC simulation or study.

The Functional and the Component Models are both divided into categories. Each category represents a package, which could be delivered independently. These categories are transparent for the users.

Thanks to this global view this model provides traceability of the system. In parallel, the GLUE model defines and manages system integration and validation.

The first task for those managing this model is to manually link the functional Use Cases (Procedures) to the corresponding component Use Cases. This step is called ‘integration’. It makes possible the detection of Procedures, which are not yet developed within the Component model library.

Figure 16 shows the organisation of the GLUE model integration.

The second task consists of testing the system to validate the functionality. Those responsible for ‘validation’ must complete this model by adding the required operational tests to the GLUE Link. If problems occur during the tests Anomaly notes are also added. Figure 17 shows how the validation process is plugged into the GLUE model.

Finally, the GLUE model is used to generate documentation and reports. At the project level only templates have to be defined via Extensible Mark-up Language (XML) to determine the documentation formats (chapters, paragraph order, etc.). The activation of macros (e.g. as in MS Word) associated with these templates allows generation of carefully designed HMI specifications or software documentation.

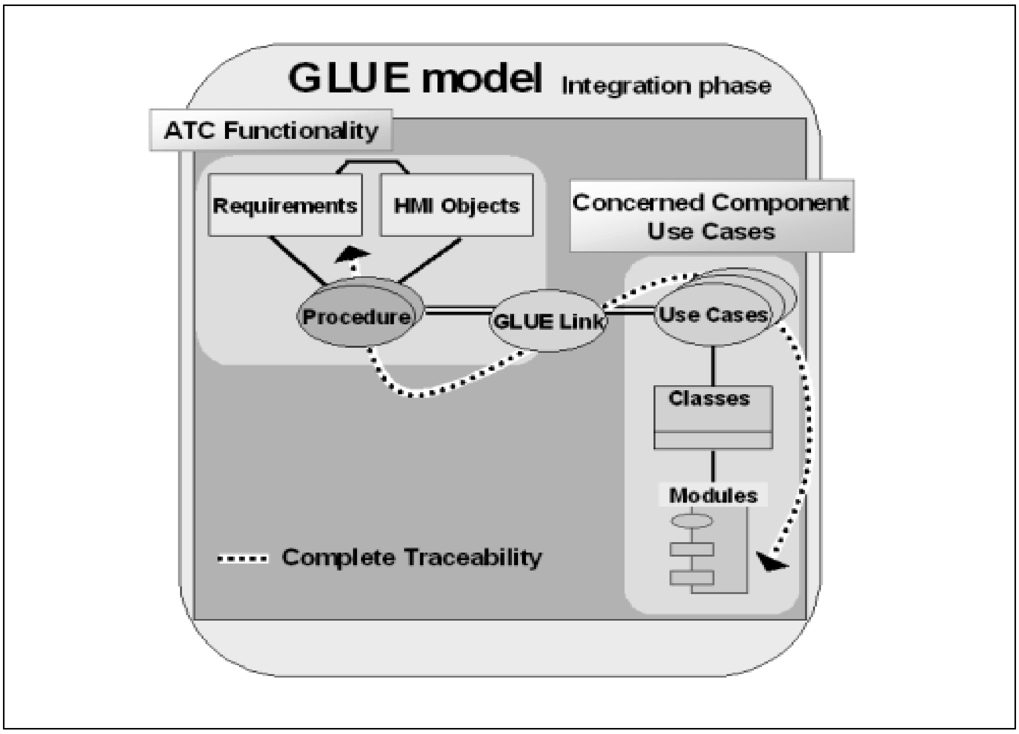

Figure 16: Integration part of the GLUE model

In parallel, other reports such as the Anomaly or the Project Status reports for the project can be generated, analysing the state of development. These provide a list of inconsistencies within the project, e.g. ATC functionality not yet developed, software modules not used, objects not used, bugs, etc.

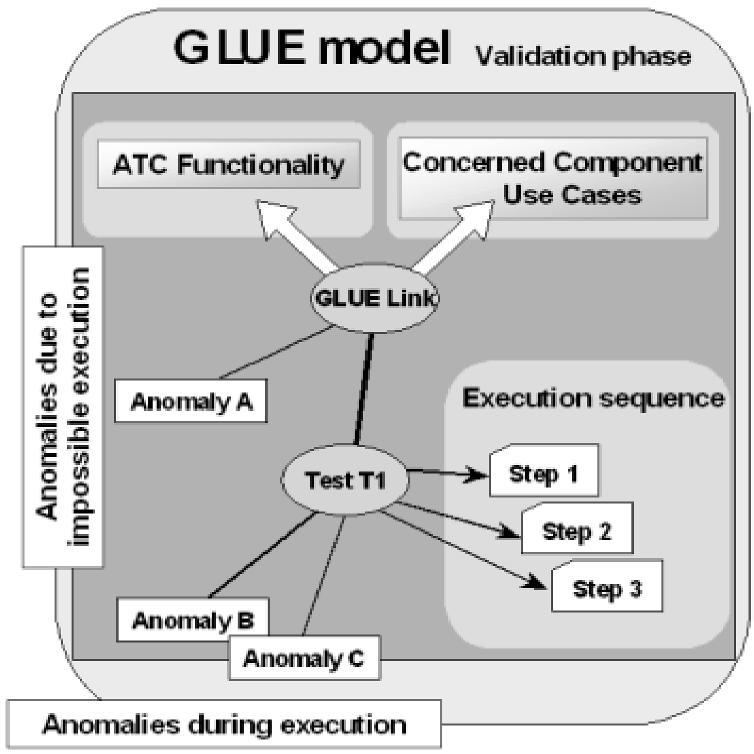

Figure 17: Validation part of the GLUE model

6.3.4 Summary of the framework in relation to our requirements

To summarise this more technical section the combination of UML, supported by a federator, provides us with a number of the key characteristics that we have already identified.

The federator provides **traceability** from expressed requirements, through software components to eventual evaluation, and also furnishes assistance with tracking the consequences of modifications.

We have improved **consistency** because data is recorded only in a single place. This is supported by special macro routines providing reports on consistency issues.

The framework itself provides both **a data repository** and a basic structure, which can be re-used from one project to another. Because we are using industry standard tools and software methods the output is transparent and easily accessible for industry. Up-to-date and consistent documents are generated using templates designed for specific users and purposes, and these can be produced in text or as interactive documentation in Hyper Text Mark-up Language (HTML). Finally, export into XML permits our Rationale Rose™ models to be accessed by a wide variety of other applications.

6.4 The Worked Example

The third deliverable, the worked example, presents a stripless en-route graphical CWP. It has a complete set of basic ATM and HMI functions but does not include advanced controller tools such as medium-term conflict detection, deviation monitoring, and arrival or departure management. Much of the operational and HMI functionality included has been 'tested' in other environments prior to CoRe, even though rarely under conditions of 'scientific' evaluation. Some additional functionality (e.g. for radar label, anti-overlap management [24]) has been added to meet requirements identified in the course of the CoRe activity for providing the controller with additional support in basic information management.

6.4.1 Objectives

The purpose of the example is fourfold:

- It illustrates the approach, the development method and the quality of the product that can be obtained.
- It serves as the basis for developing the methodology further. Currently the main concerns are incorporating design rationale, better structuring of requirements, and developing test plans and evaluation based on requirements.
- It provides a starting point for the re-use process. In particular, by concentrating on basic functions and 'reverse engineering' the (until now unrecorded) requirements for basic window management, radar label interaction, radar label de-confliction, etc., it provides a 'straw-man' for the discussion which can lead to harmonised basic HMI requirements.
- It weakens the common argument against employing structured methods on the basis of their overhead, especially at start-up, by providing a solid, re-usable baseline as a 'flying start'.

6.4.2 Coverage

The basic HMI is a descendant of the ODID family incorporating elements from the PHARE/REFGHMI/EATCHIP III developments. It is based on direct manipulation, graphical interaction in a stripless environment with interaction through the aircraft radar labels, configurable Sector Inbound Lists (SILs) and a number of support tools like tracking tool and dynamic flight leg.

In terms of its basic functionality the initial CoRe baseline represents a synthesis of the experience gained in the ODID development simulations [18], [17], the GHMI elements of the three PHARE demonstrators [26] and the early stages of the EATCHIP III studies [22]. Experience gained from the basic functions of the DSI and ITI Projects has also played a role.

Additionally, several of the issues identified in the 1997 feedback workshop on the REFGHMI have been addressed. CoRe carried out follow-up work on requirements for screen fonts for ATM applications [13] and for management of radar label, anti-overlap systems [24]. These requirements, and the results of studies exploring them, are included in the baseline exemplar.

More generally, while more advanced tools have not been included until requirements become more definitive, CoRe is continuing developments in the areas of ‘better information-management’ providing more direct control of information structuring and prioritisation. Examples include flexible management of flight information lists (from SILs to integrated flight lists) and configuration of radar label information on the basis of operational groupings, e.g. show ground speed for all aircraft inbound to airport X.

The results are potentially complementary to any developments in the area of more advanced controller support tools, and the baseline provides the ‘infrastructure’ that would allow advanced tool studies to pass directly to their focus of interest.

6.4.3 Contents of the baseline: specifications, code, etc.

The baseline exists as a description within the three models (functional, component and GLUE) of the descriptive framework (from which it can also be output in Word Format, HTML or XML), but it is most visible in three main forms as:

- an HMI specification (described in two ways, functional and component),
- code,
- an observable and usable runtime system.

HMI Specifications: The principal form of the specification for use by domain experts and designers is based on operational (or functional) requirements and HMI requirements. We can imagine the HMI requirements as belonging to two general categories:

- general HMI requirements which are independent of function and should apply to all aspects of an interface;
- HMI requirements which are specific to the individual functions generating them.

The current structure of CoRe documentation favours a logical separation between these two classes.

The first class should be defined and presented as a Style Guide providing background guidance material to the entire HMI.

As an example the Style Guide should contain:

- a description of the 'automation' philosophy and the assumptions made about the roles of the humans in the system;
- the basic interaction principles, interaction primitives, focus model and interaction grammar;
- style information, use of colour, transparency, basic window management, button, menus, etc.;
- any other assumptions (e.g. about working method) which have a direct impact on the nature of the design.

The requirements in this class would also be referenced in the description of individual functions where they apply.

The second class should be associated directly with particular operational functions. The information in the functional descriptions typically includes:

- the name of the function,
- the objectives,
- a general description which includes its context of application,
- the conditions under which it is invoked,
- its position within the interface,
- an illustration of a possible visual presentation,
- any particularities,
- the requirements associated with the function,
- the objects associated with the function,
- the procedures associated with the function.

The last three categories of information take the form of hyperlinks allowing alternate views by requirements, objects or functions.

An example of a functional description for the Sector Inbound List (SIL) Window is included as Annex D.

6.4.4 Baseline development process

An iterative process has been followed for the development of the baseline system involving software development, software testing and user-oriented testing in the form of small scale simulation studies.

A number of studies are included in the project development:

- **CoRe Feasibility Study 2000**: Took place in October 2000. Tested the basic robustness of the platform, and conducted a feasibility study into the integration and use of eye-movement recording for HMI evaluation within the EEC's simulator environment.

- **CoRe Study 2001a**:
  - Evaluated the practicability, the usability and the performance of different techniques allowing de-clustering of the radar image and minimising radar label overlapping.
  - Evaluated the usability of some of the basic HMI elements.
  - Made an initial attempt to assess system response and variability.
- **CoRe Study 2001b**: Was conducted at the end of October 2001. Sought improvements in system response time, and extended the data collection of Study 2 on the basic information management facilities and radar label, anti-overlap support.

While the first three studies are conducted formally, and documented with proper hypotheses, experimental and analysis plans, etc., they are principally concerned with the development and testing of the platform, addressing its robustness and the quality of the basic HMI provided.

With a properly established platform any subsequent studies will be more focussed on the development of methodology, the use of organised requirements and the traceable framework to support a structured and documented evaluation process.

7. CONCLUSION

7.1 Summary of the Approach

In the CoRe Project we are trying to improve a socio-technical process, that of developing working positions for ATM applications. We have taken a bottom-up approach to the understanding of the problems involved in integrating a variety of expertise to produce a successful outcome.

We have identified a need for a more structured approach to evaluation and testing. Related to this is the need for a shift to a more requirement-oriented approach, not only for evaluation but also to better support harmonisation and transfer from one project to another.

With the aim of realising both process and ‘cultural’ improvements we are seeking to exploit software engineering technology (UML, case tools, etc.) and methods in order to develop a requirement-oriented process and a support framework. The framework helps to reconcile the functional and component views appropriate to different stages and activities in development, as well as providing consistency, traceability and document management.

To illustrate the approach, permit evaluation and begin the process of establishing a body of re-usable requirements, designs and specifications, we have used the framework to develop a high-quality (but basic functionally) en-route controller working position, typical of those being developed today.

7.2 Where we Are

At the time of writing this report our situation with respect to our three main technical deliverables is as follows:

The **Qualitative Model** is essentially developed, the main issues are the form of documentation and presentation.

The three supportive modules on requirements, design and evaluation are planned for completion in 2002.

The **Supportive Framework** can be considered as existing in three layers: The lowest level, the infrastructure provided by our quality engineers to support the models and allow document generation, etc., is in place. In the middle level we have our UML Functional, Component and GLUE models, which have allowed us to build a very stable and complete baseline HMI (at the top level) to be used for testing and demonstration. This forms a large part of the **Worked Example.** While this worked example can clearly be extended with our existing framework, most of remaining R&D challenges for CoRe (see 7.3) relate to development of the middle layer. We now have the infrastructure we want. We must explore its potential and learn how to use it to maximum advantage.

7.3 The Immediate Challenges

From the R&D perspective there are a number of challenges remaining for CoRe if it is to achieve its objectives completely. At least two of these imply further analyses and development of the description modelled within out framework (the middle layer referred to in the previous sub-section).

These relate to:

a) developing a classification for both functional and HMI requirements which will ease traceability and help to structure evaluation processes;

b) embedding design rationale information throughout the specification.

Our initial thought on these topics leads us to believe that the structuring of requirements should be organised mainly to support the evaluation processes. Further, rather than assigning each requirement to a single category, it should be possible to ‘flag’ requirements as contributing to several categories relating to desirable system functions or characteristics, e.g. to realise function x, to support teamwork, usability, etc. In this later case design rationale may become embedded in terms of the justification explaining how the contribution is to be achieved.

The third major challenge for the final year of the project will be establishing interest and initial momentum within the ATM development community. The only way to do this will be by providing solutions that are not only effective but visibly improve the development environment for all the stakeholders involved.

While it is imaginable that different communities will be prepared to adopt individual elements of the process, and gain benefit, the full advantages of such a structured approach can only come from taking a long-term view to system development and establishing a relatively complete process.

7.4 Postscript: CoRe as a Tool to Support Validation

Firstly, the clearer definition of roles and responsibilities, the improved documentation and visibility, plus the emphasis on evaluation, should help stakeholders to satisfy themselves as to the potential viability of a particular solution. In the case of CWP development this is especially important for operational personnel. They can more clearly see:

- what requirements the system is designed to meet and
- the nature of the evidence that it meets them.

Both of these are key elements in seeking to establish controller acceptance. However, note that this is potentially true for all stakeholders[12].

If validation is the process whereby the community of different stakeholders arrives at a consensus that a particular solution or process is acceptable, then there is a need for tools which support evaluation, consolidate the necessary evidence and information, and make it accessible in appropriate forms to the different stakeholders. These are the kind of tools that CoRe is seeking to develop. Consequently, CoRe supports and complements the work being carried out in developing the EATMP Validation Data Repository (VDR).

More generally, the activities described in this paper have been targeted exclusively at producing a better process for the development of ATM working positions. However, both the approach used in the analysis and the main elements of the support structure should be applicable to many different HMI intensive development processes.

[12] It is not too difficult to imagine the situation in the future, where a service provider has to justify the introduction of a new controller working position to their regulator. Building such a case would be much easier with a fully documented system, with traceable requirements and a design rationale.

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ANNEX A: CORE QUALITY OBJECTIVES

INTEGRATION

The need for integration is related to the fact that the design of ATM working positions requires the integration of a number of key factors:

- operational requirements and ATM knowledge,
- technical possibilities, constraints and knowledge,
- human factors, job design and HMI expertise.

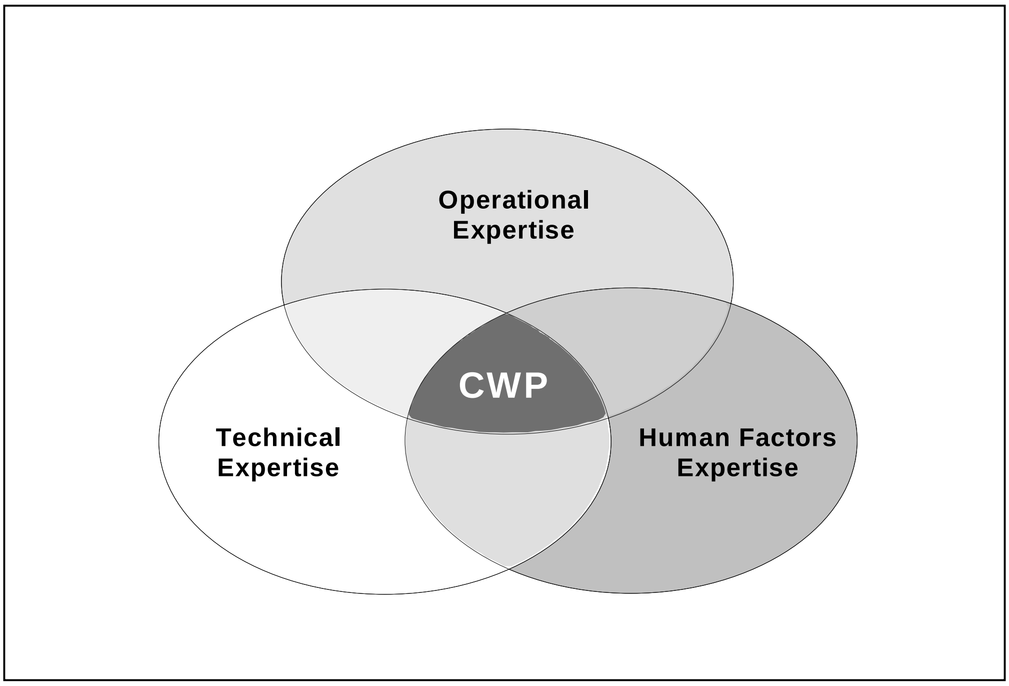


Figure 18: The key elements in CWP design

CoRe is based on the notion of multi-disciplinary design teams (see 2.2.2) and will provide a process model which tries to address the issues of managing the input of these different disciplines in an efficient manner. The different steps in the development cycle will be described in terms of roles and responsibilities, and documentation treated as a communication between different types of expertise.

CONSOLIDATION

Over the last 25 years a great deal of effort has been expended on the development of ATM working positions and HMI. This work has met with varying degrees of success. One common characteristic is that it has generally been very poorly documented. While there has been much re-use, albeit in an informal and unstructured manner, there has also been a great deal of unnecessary duplication of activity. Worse, lessons learnt at significant cost in some projects have failed to impact on subsequent development. The consolidation objective seeks to ensure that relevant knowledge is captured and made available in a suitable form for re-use in related activities.

HARMONISATION

There is a recognised need for ATM harmonisation within Europe. This recognition forms the justification for much of the EUROCONTROL Agency's activities. In the case of HMI and working positions the arguments range from providing a simplification of requirements for industry, increased interoperability between ATM service providers, economies of scale in development and testing, to increased mobility of ATM staff.

The CoRe approach to harmonisation is based on two premises:

- A notion of 'implicit' standardisation, i.e. if well-documented and good solutions are available in the public domain, they will be used. The role models for this approach are OSF, X-windows and Motif.

- An emphasis on shared requirements, both at the functional level and at the HMI level. The idea is simple: Experience suggests that it is impossible (and undesirable) to internationally standardise HMIs at the level of mechanism, look and feel. There are many reasons why variation is necessary. The CoRe Team believes, however, that it is possible to define 'HMI requirements' (clearly derived from operational requirements) which are broadly applicable. This theme is developed in [37].

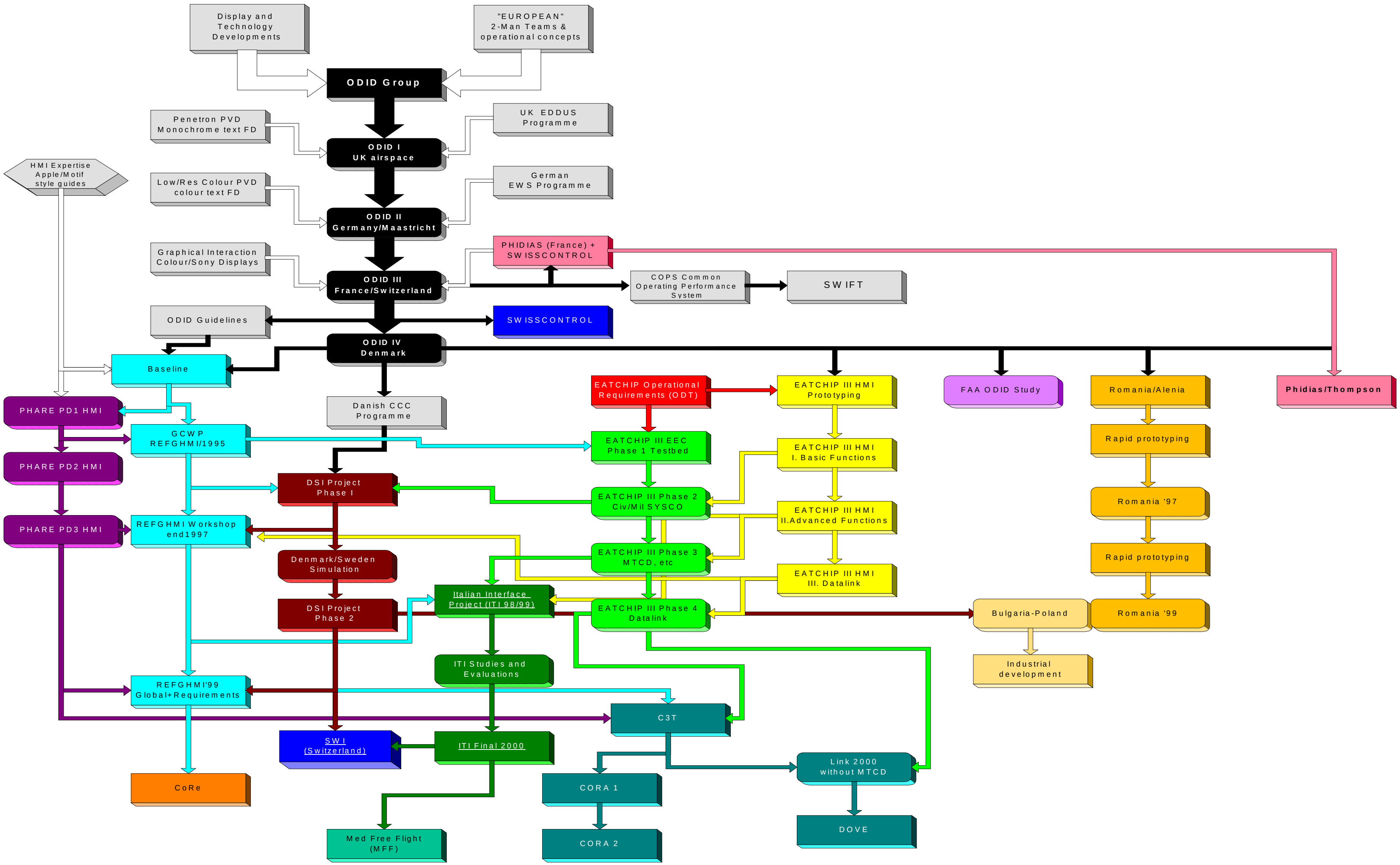
The main action in this area is preparation of clear HMI requirements and candidate solutions, and their eventual validation and incorporation into the baseline. We believe that this approach will provide a basis for increased interoperability and a common language of dialogue, while allowing necessary local flexibility and variation.

SIMPLIFICATION

This is general in scope and is achieved by trying to avoid 'technology-drive' seen as one of the principal sources of unnecessary complexity in systems. Functionality is often added because it is possible rather than because it is useful. Instead CoRe focuses on basic problems and HMI requirements based on:

- the experience of operational staff,
- lessons learnt in attempts to implement new systems and
- ATM system functional requirements.

ANNEX B: A FAMILY TREE OF SOME OF THE KEY EUROPEAN CWP DEVELOPMENTS



A Jackson, September 2001

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ANNEX C: SUMMARY OF THE FINDINGS OF THE CORE/CENA STUDY

Reproduced from [25].

Expression of Requirements for HMI Specifications for ATM CWP

In order to learn from previous experience, a survey was conducted gathering the findings of different European projects in this area. These ranged from short-term projects led by operational objectives through to an R&D project focused on future technology. Though a longer study would have allowed going more thoroughly into the subject, the sample of projects embraced a considerable amount of expertise.

These project experiences are reported on the basis of three chronological stages. These steps have re-emerged consistently as **the major elements of the HMI specification process:**

- Phase #1: Identification of operational requirements;
- Phase #2: HMI specifications (conception and recurrent assessment);
- Phase #3: Coordination with the HMI Software Development Team.

Based on these findings, the following are the high-level requirements which apply to an HMI specifications process and more specifically to support for HMI specification:

- Communication between experts (designers, ATC, engineers) should be established. Documentation should be adapted to the readers; modelling techniques, useful for explaining the often-complex rationale, should be employed.
- Keeping track of the leading idea of the project and of the rationale underlying HMI solutions is essential to the project.

In somewhat more detail:

Initiation Phase (Phase #0): Setting up the method

Constraints/Requirements	Tools/Method
❑ Identifying the different actors of the project, their responsibilities and the means of communication.	❑ A working method should be proposed at the kick-off of the project; at a minimum, the way actors are intended to dialogue should be defined. ❑ This phase may allow training of people for example to modelling techniques that are unfamiliar. ❑ Reassessment of the method should be performed on a regular basis for long projects.

Phase #1: Identification of operational requirements

Constraints/Requirements	Tools/Method
❑ Establishing clearly the operational needs through: • a clear view of system functions, • a clear preview of what would be the operator tasks in the future system.	❑ Field studies to help in building a reference situation, capturing the operational constraints. ❑ Use Cases to structure the operational requirement and distinguish the different Actors (Operator and System). ❑ Task modelling to outline what would be the working method.

Phase #2: HMI specification (conception and recurrent assessment)

Constraints/Requirements	Tools/Method
❑ Proposing HMI specifications which should be: • validated by the end-user group (as a good definition of what should be built), • Understood and implemented by the Software Team. ❑ Proposing HMI specifications which: • stem from operational requirements, • should cope with technical choices and constraints.	❑ The use of a functional hierarchy will structure the dialogue with the end-user. ❑ Use Cases will allow the placement of each individual function in its operational context, promoting a better assessment. ❑ The use of low-fidelity mock-ups or slide shows will exemplify the expected system behaviour and will favour a reliable dialogue between designer and end-user. ❑ The early integration of system specialists and subsequently of HMI software specialists should support the feasibility of the proposed specifications. ❑ Avoid leaving some areas unspecified (placing too much faith in parameterised software).
❑ Maintaining consistency at the HMI specifications level throughout the project.	❑ A team in charge of designing the specifications and keeping them up-to-date throughout the project should be set up.
❑ Keeping track of the design rationale underlying HMI solutions.	❑ Obligatory support which allows keeping track of all the relevant information.

Phase #3: Coordination with the HMI Software Development Team

Constraints/Requirements	Tools/Method
❑ Proposing a structural view of the HMI to be built. ❑ Proposing a coherent system whose working has been assessed, at least on paper.	❑ While maintaining the functional view of the system, an HMI object-oriented view of the system should be established; this view will ease HMI software design. ❑ Complex parts of the system functioning need to be modelled by diagrams, e.g. data models, state diagrams. The use of object-oriented methodology and notation should facilitate common understanding by designer and HMI software specialist.
❑ Illustrating behaviour of the system on request. ❑ Easing the access to HMI specifications supports.	❑ The use of low-fidelity mock-ups or slide shows will exemplify the expected system behaviour. ❑ Specifications support should be electronically usable by software specialists.
❑ Promoting the identification of common and consistent behaviour	❑ The writing of a Style Guide should save time and effort; it should also improve consistency of HMI behaviour.

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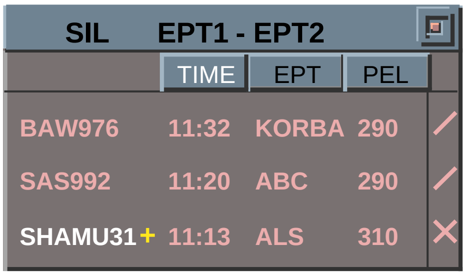
ANNEX D: A FUNCTIONAL DESCRIPTION FROM THE EXEMPLARY 'WORKED EXAMPLE'

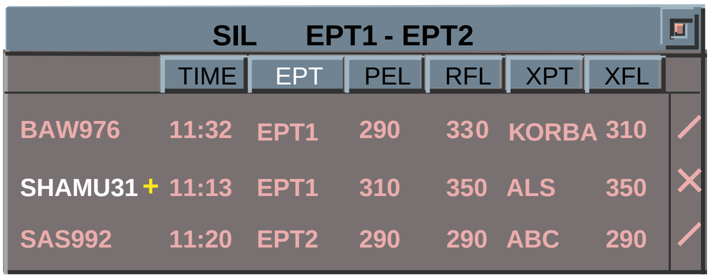
Sector Inbound List Windows	
Objective	To display, in a tabular list format, advanced flight data information concerning any aircraft planned to enter a sector. (The rules to display, remove and update data in a SIL are described in § 4.8.6). Depending on whether a controller grouped or not incoming aircraft in one single list, the information can be displayed in one SIL or distributed across several SILs. (For further details on the grouping of entering aircraft, Ref. the description of the [Preferences Setting Window] and attached procedures).
Requirement Ref.	[F.BL.SIL.2] [F.BL.SIL.3] [F.BL.SIL.3] [H.BL.SIL.1] [H.BL.SIL.2] [H.BL.SIL.3] [H.BL.SIL.4] [H.BL.SIL.7] [H.BL.SIL.8] [H.BL.SIL.9] [H.BL.SIL.10] [H.BL.SIL.11] [H.BL.SIL.12] [H.BL.WAR.1] [H.BL.WAR.2] [H.BL.A_C.8]
General Description	**<u>Data posting in the SIL</u>** Each SIL is linked to a designated tract of sector boundary. This allocation procedure ensures that aircraft on direct routes will be displayed in a SIL that is relevant to the geographical area of the sector border that they cross. Data is presented in a SIL in accordance with the aircraft's geographic boundary crossing into the sector and is not specifically related to its flight planned route. Re-routing can cause the aircraft data to be removed from one SIL and to be posted in another SIL. The controller can group all the incoming aircraft in one single SIL (Ref. the description of the [Preferences Setting Window] and of the [SIL Group] procedure), and ungroup them again back to the default number of SILs (Ref. the [SIL Ungroup] procedure). **<u>SIL content</u>** The SIL contains two regions: 1) **A tabular list** with each line corresponding to an aircraft and the columns corresponding to different flight data related to that aircraft. The displayed flight data depends on the mandatory and optional set of data defined at the Centre level, and of the subsequent selection of the set of optional data by the controller (Ref. the description of the [Preferences Setting Window] and of the [SIL Data] procedure). The following default mandatory and optional data are proposed: <u>Mandatory data</u>: Callsign of the subject aircraft (7 characters) Indication of an intra-sector warning (1 character) (Ref. the [Input Intra-sector Warning] procedure) TIME: Sector entry time, time estimate of boundary crossing for the subject sector (HH:MM format) (default sorting criteria) EPT: Entry waypoint to the subject sector(3 to 5 characters) PEL: Planned Entry Level for the subject sector (3 characters) Planning check mark: system displayed after controller input (selection of any of the displayed fields) to recall which aircraft have already been 'looked at' (this can be considered as comparable to the integration of a flight strip into the active bay). The

Sector Inbound List Windows	
	check mark is different if the aircraft has been 'looked at' by the PC (/) or by the TC (\) or both (✕). <u>Optional data</u>: RFL: Requested Flight Level (3 characters) XPT: Exit waypoint, first waypoint after the boundary exit of the subject sector (3 to 5 characters) XFL: Exit Flight Level for the subject sector (3 characters) DEST: Airport of Destination (4 characters) EAT: Estimated Arrival Time (2 characters for minutes) TYPE: Type of the aircraft <u>The proposed data display sequence</u> in the SIL is the following: Callsign - Marker - TIME - EPT - PEL - RFL - XPT - XFL - DEST - EAT - TYPE - Check mark. 2) **A field title region** displaying above each of the data field a push button labelled with a title identifying the data (except for the callsign). **<u>Display of data</u>** The mandatory data is always displayed. The optional data is displayed only when the cursor enters the SIL Window: the SIL width is then automatically enlarged to fit to the displayed data. If no data is available for a selected field (mandatory or optional), the field is left empty. **<u>SIL size</u>** The SIL size is automatically adapted to its content: it is dynamically resized in width in accordance with the displayed fields. it is dynamically resized in length (number of lines) in accordance with the number of aircraft. An empty SIL is automatically reduced to its minimum size (header). The SIL contains a maximum of 20 lines (parameter). More information automatically adds a scroll mechanism to the SIL Window, allowing the list to be scrolled. **<u>Data sorting in the SIL</u>** By default, the aircraft in the SIL are sorted according to the sector entry time criteria such that the aircraft first entering the sector (earliest time) is presented at the top of the list (i.e. each new information is added at the bottom of the list). Any of the presented data fields can be used by the controller as sorting criteria, using the data field title push button (Ref. the [SIL Sort] procedure). Each new aircraft is then inserted in the list at the relevant location corresponding to that sorting criteria. The entry time is then used as second sorting criteria. **<u>Fonts</u>** SIL text is presented in a non-proportional (i.e. a fixed spacing) font. The font style and size are **TBD**. **<u>Colours</u>** The aircraft callsign and data is presented in the colour corresponding to the aircraft state (see description in the [Radar Label]). The intra-sector warning is displayed in Warning colour. The field titles (push button labels) are in TextUnselected colour, except for the title of the data field currently used as sorting criteria, which is presented in TextSelected

<table>
<tr><th colspan="2">Sector Inbound List Windows</th></tr>
<tr><td></td><td>colour. If an optional data field used for data sorting is removed (Ref. the [SIL Data] procedure), the sorting is still valid but no field title is shown in TextSelected colour.
The check mark is in TextUnselected colour.
The icon of the SIL displays a counter giving the number of aircraft currently present in the SIL, and either the entry point(s) name(s) (in case of several SILs), or the label ‘SIL’ (in case of one grouped SIL).</td></tr>
<tr><td>Invocation</td><td>On system initialisation the SILs are displayed open on the display.</td></tr>
<tr><td>Display position</td><td>SILs are geographically dispersed according to pre-defined sector entry borders.
Incoming aircraft grouped in one single SIL: right bottom side of the RPVD.</td></tr>
<tr><td>Illustration</td><td>



SIL displaying only the mandatory data, with default (sector entry time) sorting activated.



SIL displaying the mandatory and some of the optional data, with sorting by entry point.

Highlighted SIL entry when the corresponding aircraft is selected: the background is in the text colour, the text is Black (Ref. the description of ‘Highlighting Principles and Mechanisms’ in the HMI Global Principles section).

</td></tr>
</table>

Sector Inbound List Windows	
	 Highlighting of selected interactive fields (3 fields are shown as highlighted here): the text is in its nominal colour, the background is in the Button2Depressed colour (Ref. the description of 'Highlighting Principles and Mechanisms' in the HMI Global Principles section).  (a) (b) (c) Icon of a SIL with entry points and a counter (a), grouped SIL (b), and temporarily iconified SIL (c).
Associated Procedures	Subset of the window management procedures according to the behavioural attributes of this window, summarised at the end of this section. [SIL In] [SIL Out] [SIL Update] [SIL Integrate] [SIL Sort] [SIL Data] [SIL Group] [SIL Ungroup] [Select Aircraft] [Deselect Aircraft] [Input Intra-sector Warning] [Remove Intra-sector Warning] [DFL Fixed] [DFL Quick Look] [DFL Remove] [Extended Label Fixed] [Extended Label Quick Look] [Change XFL] [Change RFL] [Input Direct Route_Menu]
Associated HMI Objects	[Preferences Setting Window] [SIL Options Window]
Associated Conceptual Obj.	**TBD**.
Particularities	If the RPVD is re-scaled or re-sized, the SIL position remains fixed relative to the screen. Configuration of the SIL at the Centre level: Allocation of SILs Mandatory data to be displayed in the SIL Optional data that can be displayed in the SIL. Sequence of the presented Mandatory and Optional data. Parameters: The number of lines in the SIL

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ABBREVIATIONS AND ACRONYMS

For the purposes of this document the following abbreviations and acronyms shall apply:

AAS	Advanced Automation System
ACS	ATM Concepts and Studies *(EEC, Brétigny, France)*
ADD	Architectural Design Document
ADS(B)	Automatic Dependent Surveillance (Broadcast)
AIS	Aeronautical Information Services
AMAN	Arrival MANager
ANS	Air Navigation Services
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATSA	Air Traffic Services Authority *(Bulgaria)*
CAA	Civil Aviation Authority/Administration
CDM	Collaborative Decision-Making
CENA	Centre d'Études de la Navigation Aérienne *(France)*
CHI	Computer-Human Interaction *(US)*
CIG	CoRe Interest Group
COPS/CWP	Common Operational Performance Specifications for the Controller Working Position
CORA	COnflict Resolution Assistance
CoRe	Core Requirements for ATM Working Positions (Project) *(EATMP, HUM, HRS, HSP)*
CPDLC	Controller Pilot Data Link Communications
CWP	Controller Working Position
DERA	Defence Evaluation and Research Agency *(Malvern, UK; now known as QinetiQ)*
DFS	Deutsche Flugsicherung GmbH *(Germany)*

DIS	Director(ate) Infrastructure, ATC Systems and Support *(EUROCONTROL Headquarters, SDE)*
DIS/HUM	See ‘HUM (Unit)’
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V. *(German Aerospace Centre)*
DMAN	Departure MANager
DSI (Project)	Denmark-Sweden Interface (Project)
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme *(now EATMP)*
EATMP	European Air Traffic Management Programme *(formerly EATCHIP)*
ECAC	European Civil Aviation Conference
EDDUS (Programme)	Electronic Display and Data Update System (Programme)
EEC	EUROCONTROL Experimental Centre *(Brétigny, France)*
ENAV	Ente Nazionale di Assistenza al Volo *(Italian ATS Agency)*
ERATO	En-Route Air Traffic Controller Organizer *(a controller support tool developed by CENA as part of PHIDIAS evolution)*
FAA	Federal Aviation Administration *(US)*
FDPS	Flight Data Processing System
FUA	Flexible Use of Airspace
GCWP	Generic Controller Working Position *(original name of the CoRe Project)*
GLUE (model)	Generic Linkage for Unifying model Elements (model)
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HFSG	Human Factors Sub-Group *(EATCHIP/EATMP, HUM, HRT)*
HIFA	Human Factors Integration in Future ATM Systems *(EATMP, HUM, HRS, HSP)*

HMI	Human-Machine Interface
HRS	Human Resources Programme *(EATMP, HUM)*
HRT	Human Resources Team *(EATCHIP/EATMP, HUM)*
HSP	Human Factors Sub-Programme *(EATMP, HUM, HRS)*
HTML	Hyper Text Mark-up Language
HUM	Human Resources (Domain) *(EATCHIP/EATMP)*
HUM (Unit)	Human Factors and Manpower Unit *(EUROCONTROL Headquarters, SDE, DIS; also known as 'DIS/HUM')*
IANS	Institute of Air Navigation Services *(EUROCONTROL Luxembourg)*
ICAO	International Civil Aviation Organization
IFATCA	International Federation of Air Traffic Controllers' Associations
IFR	Instrument Flight Rules
ISO	International Standards Organisation *(usual designation)* or International Organization for Standardization *(official designation)*
ITI (Project)	ITalian Interface (Project)
LFV	Luftfartsverket *(Swedish CAA)*
LGS	*Latvian Air Navigation Services*
LVNL	Luchtverkeersleiding Nederland *(ATC The Netherlands)*
MAEVA	Master ATM European VAlidation *(a master plan)*
MAS UAC	Maastricht Upper Area Control Centre *(EUROCONTROL, The Netherlands)*
MEFISTO	Modelling, Evaluating and Formalising Interactive Systems using Tasks and interaction Objects
MMI	Man-Machine Interface
Motif	*A graphical use interface combining a toolkit, presentation description language window manager and style guide. It is produced by OSF.*
MONA	MONitoring Aids

MTCD	Medium-Term Conflict Detection
NATAM	Norwegian Air Traffic and Airport Management
NATS	National Air Traffic Services Ltd *(UK)*
NERC	New En-Route Centre *(UK CAA)*
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium *(National Aerospace Laboratory, The Netherlands)*
ODID	Operational Display and Input Development *(EATCHIP)*
ODS (Programme)	Operator input and Display System (Programme) *(EUROCONTROL)*
ODT	Operational Requirements and ATM Data Processing Team *(EATCHIP/EATMP)*
OLDI	On-Line Data Interchange *(a EUROCONTROL Standard)*
OPS	Operations
OSF	Open Software Foundation
PHARE	Programme of Harmonised ATM Research in EUROCONTROL
PHIDIAS	*The new generation controller working position being introduced in France*
PL	Project Leader
R&D	Research and Development
REP	Report *(EATCHIP/EATMP)*
R/T	Radiotelephone / radiotelephony
REFGHMI	REFerence Ground Human-Machine Interface
RSRE	Royal Signals and Radar Establishment *(UK; later known as DERA Malvern)*
RVSM	Reduced Vertical Separation Minimum/Minima
SDE	Senior Director, Principal EATMP Directorate *or, in short,* Senior Director(ate) EATMP *(EUROCONTROL Headquarters)*
SIL	Sector Inbound List
SRD	Software Requirement Document

SSDD	Software Specification Detailed Design
STCA	Short-term Conflict Alert
SYSCO	SYstem Supported COordination *(an extension to the OLDI standard)*
TPL	Technical Project Leader
UML	Unified Modelling Language
URD	User Requirement Document
URET	User Request Evaluation Tool
VDR	Validation Data Repository *(EATMP)*
VERA	VErification of separation and Resolution Advisory
VFR	Visual Flight Rules
XML	eXtensible Mark-up Language

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