EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION

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Human Factors Integration in Future ATM Systems - Identification of Tasks and Development Scenarios

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Abstract

Human factors is traditionally not well integrated within systems design. The Human factors Integration in Future ATM systems (HIFA) Project aims to redress this situation with respect to Air Traffic Management (ATM) projects. For each phase of the EATMP* life cycle the report identifies the key integration issues and specifies the human factors tasks to carry out and the checklist questions to ask. The roles and responsibilities required to implement the HIFA process are also detailed. The report discusses the application of the HIFA methodology to European ATM project development scenarios including initial feedback on the HIFA guidance material from a selection of ATM project managers. Project development scenarios are discussed and a list of ten scenarios proposed.

* European Air Traffic Management Programme (formerly known as EATCHIP standing for European Air Traffic Harmonisation and Integration Programme)

Keywords

ATM	Human Factors Integration (HFI)	MANPRINT (Manpower, Personnel and Integration)	EATMP
ATM systems	Human factors	Method	System development
Guidelines	Integration	Guidance material	Project management
HIFA	Life cycle	Scenario	Checklist

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This document is concerned with human factors in systems design and in particular making users and stakeholders aware of the importance and benefits of integrating human factors in the ATM life cycle. The report identifies the key integration issues, and specifies the human factors tasks to carry out and the checklist questions to ask. The roles and responsibilities required to implement the Human Factors Integration in Future ATM Systems (HIFA) process are also detailed.

The report constitutes the second part of the larger HIFA Project being carried out by the UK Defence Evaluation and Research Agency (DERA) for the Human Factors and Manpower Unit of EUROCONTROL (formerly the ATM Human Resources Unit). As currently planned the HIFA Project is being carried out in two Phases: in Phase 1 the basic guidance material is being prepared; subsequently, in Phase 2 this material will be made widely available through appropriate electronic media (e.g. Internet).

This document is the second report for Phase 1 of HIFA. The first report (EATMP, 2000) for Phase 1 is a comprehensive literature review of design concepts and philosophies for the role of human factors within ATM systems development. The third report (EATMP, not printed) is a review of human factors methods and tools relevant to the life cycle of ATM systems design.

Chapter 1, 'Introduction', outlines the background to the project, and the objectives and scope of the report.

Chapter 2, 'Project Management and Systems Engineering', gives a summary of the HIFA approach and the relationship between business development, project management and systems engineering within European ATM projects.

Chapter 3, 'Human Factors Integration', describes the need for Human Factors Integration (HFI), its historical development, and overviews its scope, structure, processes, content and roles within system development.

Chapter 4, 'ATM Life cycle and a HIFA for European ATM', gives detail of a typical ATM project management life cycle (EATMP), a top-level view of an HFI for EATMP with a list of required HFI roles and responsibilities.

Chapter 5, 'Detail of HIFA for European ATM', provides details of HIFA tasks and checklist questions appropriate to each phase of a typical European ATM project life cycle (EATMP). Alternative theme-specific viewpoints through the HIFA processes are also discussed.

Chapter 6, 'Application of HIFA in European ATM', reports the results of a questionnaire survey concerning current HFI practices within a selection of European ATM projects. The HIFA guidance material was presented to a selection of experienced European ATM project managers, and their feedback obtained on its suitability and potential implementation. Their comments were extensive, positive and encouraging. The application and tailoring of the

HIFA guidance material to ATM project development scenarios is discussed and a list of scenarios proposed.

Chapter 7, 'Conclusions', presents the overall conclusions of the report.

Annex A of this report consists of the questionnaire employed for the HFI user survey.

There are also a list of References, a glossary of Abbreviations and Acronyms and a list of the Contributors to the document.

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to describe activities and checklist questions and to identify roles and responsibilities of the main people in the process of Human Factors Integration (HFI), within the context of the Air Traffic Management (ATM) project life cycle and typical ATM project development scenarios. The document constitutes the second part of a larger project entitled 'Human Factors Integration in Future ATM Systems (HIFA)' being carried out by the Human Factors and Manpower Unit of EUROCONTROL (in short DIS/HUM or HUM Unit; formerly known as the ATM Human Resources Unit) and contracted to the UK Defence Evaluation and Research Agency (DERA).

The HIFA Project is one of several human factors activities being conducted under the ATM Human Resources Programme (HRS) within the EATMP[1] Human Resources Domain (HUM). The projects accords well with the aim of the 'ATM Strategy for 2000+' (EATCHIP, 1998a) which states:

> *consideration of human factors issues must be part of the technology design and certification process and of the development of operating procedures, and be completed before technology is used operationally to avoid flawed human-technology interfaces which may cause operating problems and additional costs throughout the system life cycle.*

The Strategy document (*op. cit.*) goes on to say:

> *ATM has a poor record for implementing change to time and within budget, and many major infrastructure projects have suffered delays and escalating costs. This indicates that there are fundamental problems in the development of complex ATM systems, and the relationships with equipment suppliers*.

Although the integration of human factors within the system development process does not by itself guarantee that ATM systems will avoid such problems in the future, the proper consideration of human factors issues is an essential part of the solution.

[1] European Air Traffic Management Programme (formerly EATCHIP or the European Air Traffic Harmonisation and Integration Programme)

1.2 Scope of Document

The document is the second of three reports planned for Phase 1 of the HIFA Project. The first report (EATMP, 2000) for Phase 1 is a comprehensive literature review of design concepts and philosophies for the role of human factors within ATM systems development. The third report (EATMP, not printed) is a review of human factors methods and tools relevant to the life cycle of ATM systems design. The present document is intended to identify and describe HIFA tasks, checklist questions and roles of the main people in the process of HFI, in the context of the ATM life cycle and typical development scenarios. Specifically, how is human factors currently used and integrated with system development practices? How can the HIFA recommendations from HIFA Deliverable 1 (EATMP, 2000) be mapped onto the EATMP ATM project life cycle and to the detail of project management tasks? How effective would the HIFA approach be when used on real-world ATM projects?

The information sources employed are largely in the public domain, and include DERA HFI documentation, US FAA reports, relevant EATMP documents and other research papers and project reports. The target audience is project managers at large within the European ATM community as well as in EUROCONTROL. The intended document use is to provide material guidance on HFI in project life cycles and to form the basis for distributing HIFA material on the Internet.

1.3 Background to Project

The HIFA Project was initiated in 1997 as part of the ATM Human Resources Programme (HRS). The main events and milestones, within which HIFA fits, including those anticipated in the future, are as follows:

- Human Factors Module — March 1998

  Title: **'**Human Factors in the Development of Air Traffic Management Systems' (EATCHIP, 1998b)

- Third EUROCONTROL Human Factors Workshop — October 1998

  Title: 'Integrating Human Factors into the Life Cycle of ATM Systems'. Held in Luxembourg, 7-9 October 1998 (see EATMP, 1999a)

- Human Factors Integration Guidance material — November 1999

  Guidance material for HFI in the ATM system development life cycle. Development work contracted out to the British Defence Evaluation and Research Agency (DERA) (see this report and EATMP [2000 & not printed])

- Human Factors Module — December 1999

  Title: 'A Business Case for Human Factors Investment' (EATMP, 1999b)

- Human Factors Integration E-Book — November 2000

  A handbook will be produced on the basis of the guidance material and will be made widely available through Internet and CD-ROM technology

1.4 Structure of this Document

Following this introduction the report is divided into five main chapters. It starts by considering project management and systems engineering approaches to ATM projects in EUROCONTROL and elsewhere (Chapter 2). It then moves on to overviewing HFI and its development (Chapter 3) and to mapping the HFI process with its attendant roles and responsibilities onto the phases of a typical European ATM project life cycle (EATMP) (Chapter 4). The details of this mapping in terms of HIFA tasks and checklist questions for each phase of the ATM life cycle can be found in Chapter 5. A survey of potential HIFA users concerning present HFI practice in European ATM projects, together with the views of a selection of project managers concerning the potential application and tailoring of the HIFA guidance material, is reported in Chapter 6. The conclusions of the report are presented in Chapter 7. The structure of the report is shown in Figure 1.

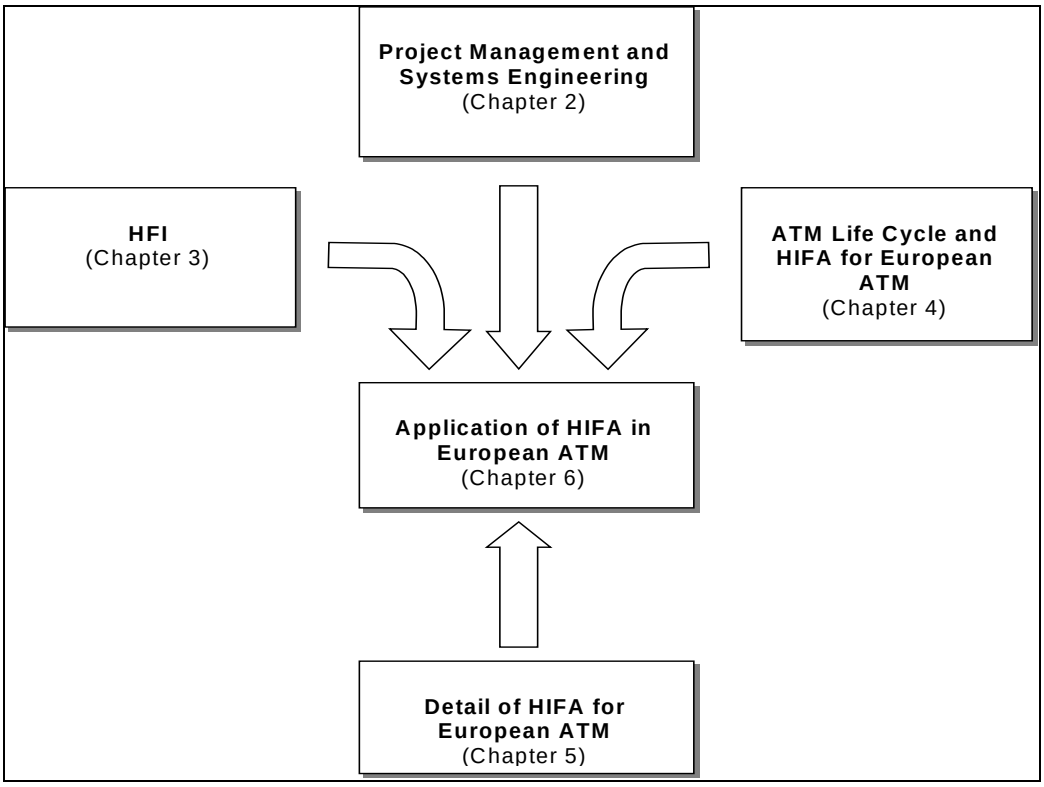

Figure 1: Schematic illustration of topics covered in the report

2. PROJECT MANAGEMENT AND SYSTEMS ENGINEERING

2.1 Overview of HIFA Approach

It is a requirement for EUROCONTROL project managers working within the EATMP area that they adopt the programme/project life cycle from the EATMP Management Handbook (EATCHIP, 1998c) when managing projects and programmes. This is a generic model and umbrella framework for clearly identifying the beginning and end of programmes or projects and for ensuring that they are managed in a phased way with clear decision points between phases. As such it is considered typical of project life cycles for European ATM projects and it is hoped that non-European people and projects could use the material as well. The need for stakeholder and users' involvement is addressed, noting that:

> *The challenge for EATMP is to address the real operational and technical needs of users, and avoid unnecessary change – users are parties who use a product, system, service of information, obtain benefits and may incur costs by doing so. Good practice in the areas of involving users …. Underpins the decisions that are made to satisfy EATMP's stakeholders.*

However, the issue of detailed human factors considerations is not made explicit, despite the case being made elsewhere in business terms for human factors investment (EATMP, 1999b) and ample ATC-specific human factors information being available. For example, there are the EATCHIP Human Factors Module (1998b) and ICAO Human Factors Training Manual (1998).

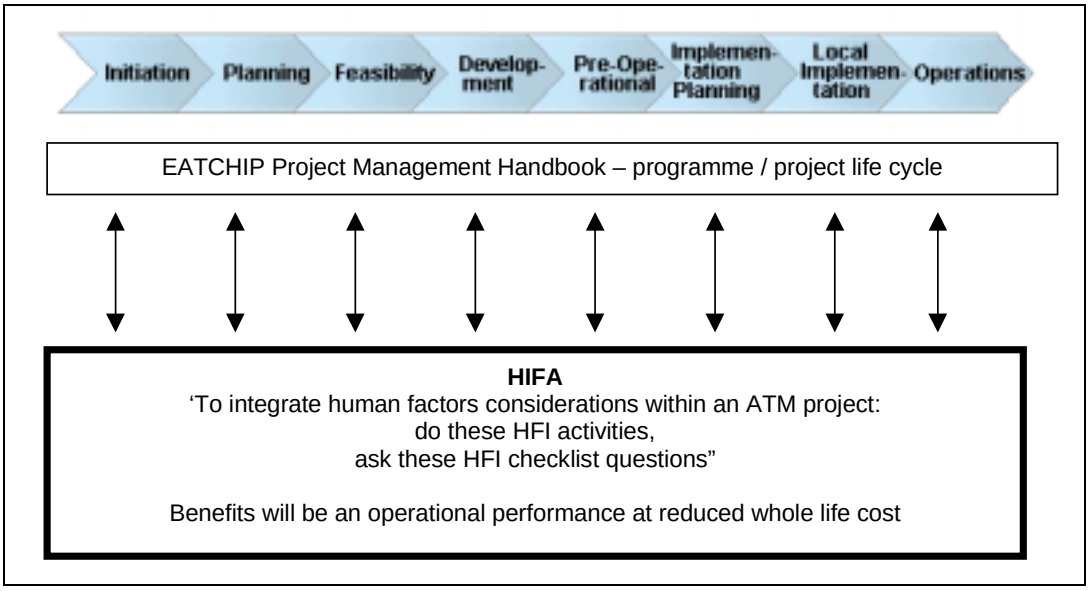

Figure 2: HIFA top-level process within ATM projects

The goal of the HIFA Project is both to raise the profile of the need to consider human factors issues, and to provide a structured top-level process for project managers to follow at set times within the EATMP project life cycle ('do these HIFA tasks, ask these HIFA checklist questions'). This overall process is illustrated in Figure 2. The benefit of including HIFA as a user-friendly and straightforward part of the EATMP management process should result in increased operational systems performance at reduced whole life cost.

Project managers of European ATM projects work to a project management life cycle, such as the generic life cycle contained in the EATMP Management Handbook. HIFA aims to inform managers of the benefits of integrating human factors within their project life cycle, to supply appropriate guidance material and to provide a framework to facilitate Human Factors Integration (HFI) in ATM projects.

2.2 Levels of Process and Control

A key issue within the discipline of systems engineering (Sommerville, 1995) is managing and coping with levels of complexity. Stevens, Brook, Jackson and Arnold (1998) refer to levels of process and control ranging from higher-level business processes, through project management and systems engineering, to low level software coding and hardware and construction. This is illustrated in Figure 3 below.

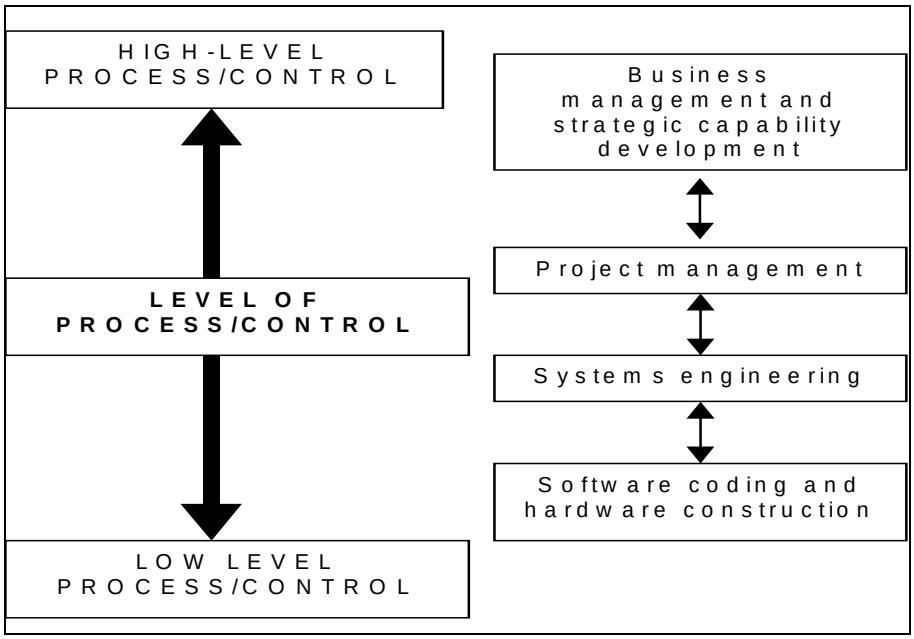

Figure 3: Levels of process / control within projects

Because similar processes are happening at multiple levels in the project structure, the same generic development process applied recursively and concurrently, describes the whole development cycle.

Stevens et al (1998, p. 207) propose a generic systems engineering model of the customer-supplier relationship model to link the upper level customer business processes to the lower level contractor or supplier process via the system development process. This is indicated in Figure 4. Information flows across the customer-supplier interface between the formative and build stages of the system development process are listed in the diagram. The generic process is 'context independent' and applies at the overall systems level and at all subsidiary sub-system development levels. Stevens et al (1998) note that in each context there is at least one customer and many supplier levels. The customer process triggers the process into existence; the supplier interfaces are developed as work proceeds. This process can be applied repeatedly to define the overall development process.

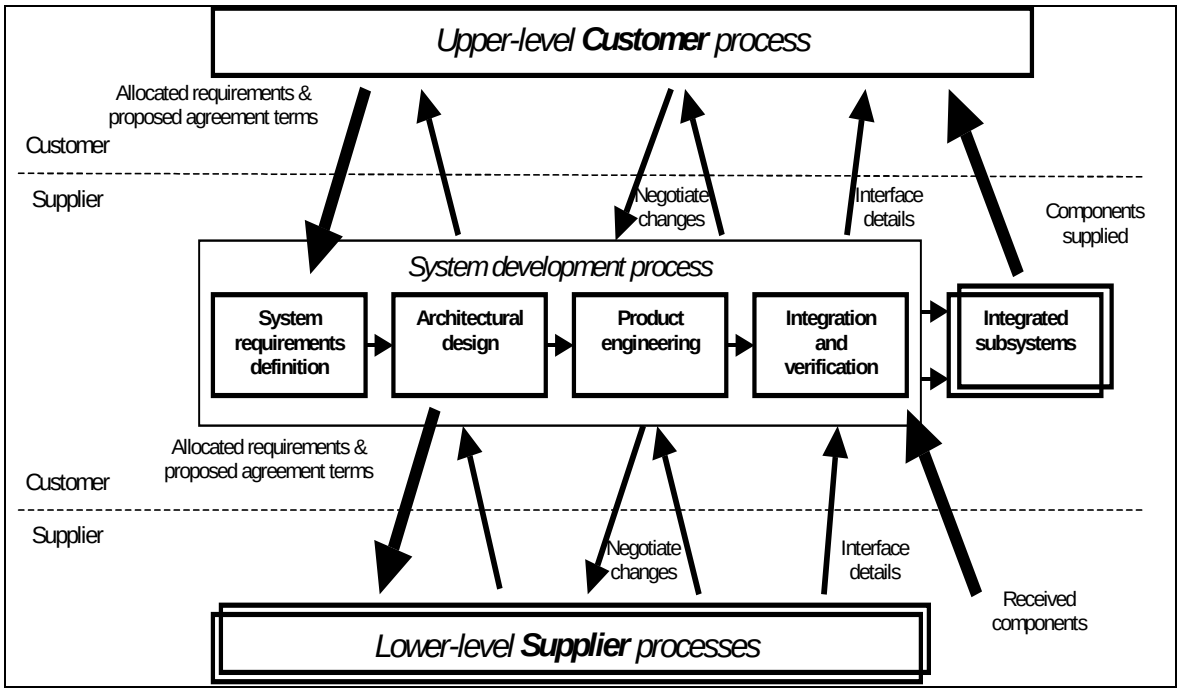

Figure 4: Relationship between customer and supplier

Levels of process and control are discussed. A model is presented linking high-level business management and project management through systems engineering to lower level software/hardware engineering. The flow of information between the customer and supplier, via the system development process, is discussed.

2.3 EATMP Project Management and Systems Development

The EATMP Project Life cycle based on the EATMP Management Handbook (EATCHIP, 1998c) is shown in Figure 5. The handbook states that it *is directive in that everyone must use it, but it is not prescriptive in that it does not have to be used in its entirety all of the time*. For example, an R&D programme/project may include the early life cycle phases, whereas an implementation programme/project would focus on the later phases. *The life cycle is flexible enough that, where appropriate, other life cycles can exist symbiotically within its phases*. It must be stressed that the EATMP life cycle refers to and is aimed at EUROCONTROL and other European ATM project managers – their contracted internal and external projects will be using a specific system development life cycle, depending on the successful contractor's in-house practices.

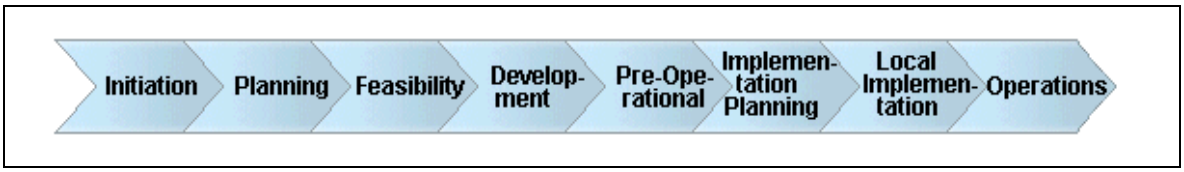

Figure 5: The EATMP project management life cycle (see EATCHIP, 1998c)

In addition, EUROCONTROL (EATCHIP, 1997) has separately initiated a programme for the implementation of a systems engineering process in EATMP at the request of EATMP liaison officers. It gives an agreed set of high-level principles on which this process will be further defined and implemented. The programme concentrates on system engineering at programme level which will ensure overall technical and operational integrity of the programme. It is the customisation to EATMP specific features of system engineering standards used in the industrial world which consider system engineering as aiming to provide integrated system solutions consisting of people, products and processes. The overview of system engineering presented is based on two standards: EIA/European Space Agency EIA/IS-632 interim standard (EIA, 1994) and DERA's draft System Engineering Standard (DERA, 1995). These recommendations are then tailored to the EATMP context.

Of particular interest to the present HIFA study is the diagram reproduced in Figure 6 giving a representation of the role of systems engineering within EATMP.

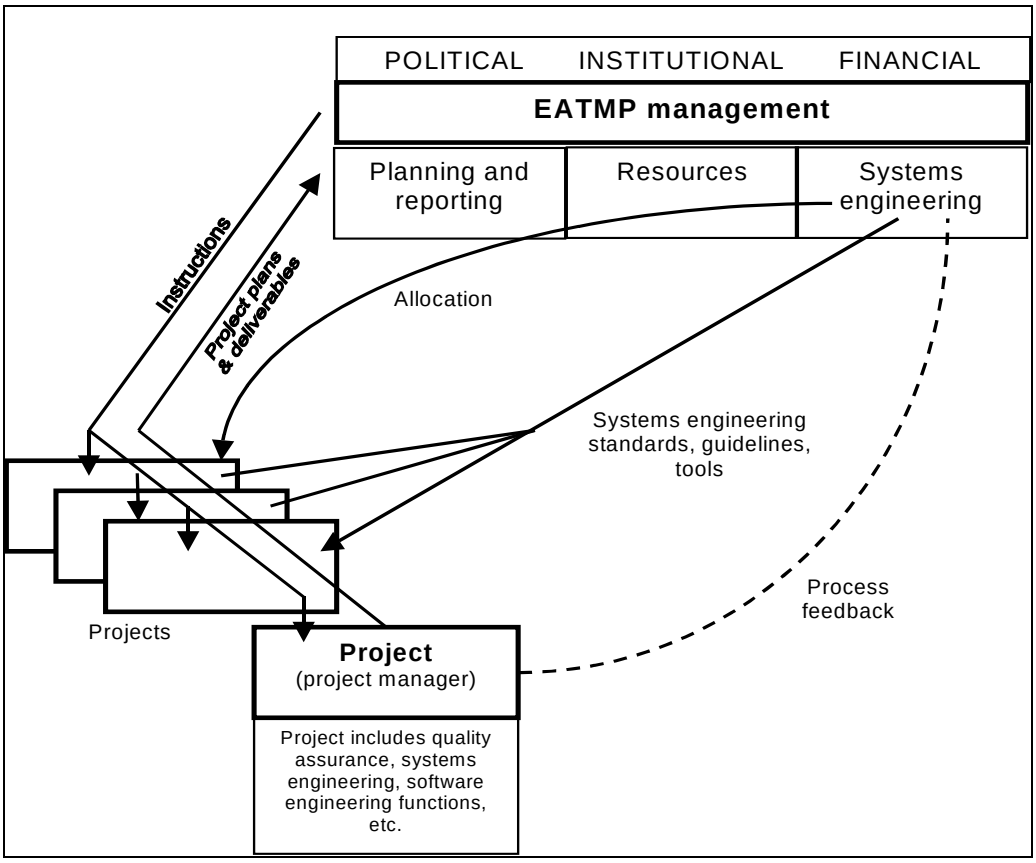

Figure 6: The role of systems engineering within EATMP

EATMP management is linked to project management and systems engineering for specific EATMP projects. Similar to other centres of expertise (political, institutional, financial, planning and reporting, etc.) providing the management of the programme with relevant strategic and tactical advice, systems engineering acts as the centre of expertise dedicated to technical and operational aspects.

At programme level systems engineering directly identifies the relevant needs and integration issues related to Quality Assurance (QA), Cost Benefit Analysis (CBA), safety, Validation and Verification (V&V), risk assessment and mitigation, etc. It ensures the technical and operational integration of projects participating in the accomplishment of the. The integration aims at ensuring an overall consistency and completeness of the set of projects. Systems engineering is responsible for developing and managing the programme life cycle, and must integrate project life cycles and ensure that they are compatible with the overall life cycle.

The EATMP Project management life cycle is described, together with the central role of systems engineering within EATMP.

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3. HUMAN FACTORS INTEGRATION

3.1 The Need for Human Factors Integration

It is noted in the first HIFA deliverable (EATMP, 2000) that the traditional role of human factors in the overall system design process has often been described as 'too little, too late'. This problem has been recognised for many years by both system designers and human factors practitioners alike. Although the importance of human factors is now more widely recognised, particularly as a consequence of the increasing use of computers and computer-based technology, the contribution and systematic integration of human factors throughout the ATM life cycle is still at best fragmentary.

It was also evident from the first HIFA deliverable that a substantial amount of research and development work has been carried out on Human Factors Integration (HFI). In particular, the approach to HFI developed over many years by government and defence industries probably offers the most appropriate approach for the ATM Domain. HFI for ATM is likely to require a combined approach, taking appropriate activities from the UK defence and American FAA processes. Both the FAA and UK defence versions of HFI have the same goals which are to optimise the total system performance and reduce developmental and life cycle costs by ensuring that the human element is addressed as an integral part of system design.

The overall goal of the HIFA Project is to use and adapt existing HFI frameworks to enable potential European ATM users to be aware of the importance and benefits of integrating human factors issues in the ATM project management life cycle. The aim is to give ATM project managers the necessary knowledge and framework – of tasks to perform and questions to ask – to effectively implement such programmes within their organisation. To this end the project aims to provide users with appropriate and effective guidance material about human factors for their projects. It is planned to make the guidance material widely available through modern electronic media (e.g. using Internet, Intranet or CD-ROM technology) in succeeding phases of the project and in its subsequent adoption.

The historical evolution of the MANPRINT[2] / HFI initiatives is outlined in the following section, as their development contains important precedents and information for their application to European ATM projects.

[2] Manpower, Personnel and Integration

The role of human factors in systems development is often 'too little, too late'. Much work on HFI has been carried out by government and defence industries. HIFA aims to use and adapt previous work to the European ATM context.

3.2 Historical Development of HFI

3.2.1 HFI Origins in US MANPRINT Programme

In 1987 an American aircraft crashed on take-off at Detroit airport, killing 156 people. In 1988 the crew of the USS Vincennes inadvertently shot down an Iranian civil airliner, killing all 290 passengers. Reverse engineering analyses of these and other US military incidents concluded that the human factors issues had not been addressed. Doctrine and concepts were incomplete or ill-suited to the soldier, manpower requirements were under-estimated, the human skills and abilities required were unknown or underestimated, training was untested and training devices were unavailable. The US Department of Defense (DoD) MANPRINT Programme (see Booher, 1990) was a response to this problem, aiming to include human factors considerations in a structured way within the development of military systems. Six MANPRINT domains were proposed for the consideration of human issues: Manpower, Personnel, Training, Human Factors Engineering, System Safety and Health Hazard Assessment. One of the strengths of MANPRINT is that it facilitates the debate of 'trade-offs' (an HFI term meaning optimum balances or compromises) between different requirements, for example:

- reduction in manpower numbers vs. the cost of increased automation;
- reduction in manpower numbers vs increased personnel skill requirements;
- simplification of the user interface vs increases in training time;
- reduction in necessary operator manpower vs increases in support manpower and personnel requirements.

The adoption of the MANPRINT philosophy and its associated documentation and handbooks resulted in a number of human and therefore system success stories. For example, in the case of the US light helicopter experimental T800 engine, there was a reduction in training time since there were no unique skills that had to be trained for user-level maintenance. User level maintenance further experienced a reduction from over hundred specialist tools in similar engines to fewer than ten common hand tools. A reduction in the number of

specialist skills allowed a consolidation of maintainer trades and a consequent saving of hundred maintainers per light division.

3.2.2 HFI Development in the UK

From the visible success of MANPRINT in the US, coupled with the need to identify the best balance between people and equipment, it became clear in the early 1990s that changing the way UK military systems were procured could result in similar benefits (Walters, 1992). In 1990 one of the aims of the UK Ministry of Defence (MoD) 'Options for Change' initiative was to ensure high quality, multi-capable forces, with better-equipped, motivated and properly trained servicemen. The Deputy Chief of Defence Staff, responsible for determining the systems and equipment requirements of all three services, stated that he could only meet this remit by taking a very close interest in the personnel as well as the technical aspects of the equipment he wished to introduce. In the past manpower issues (cost and performance) had been considered quite separately from the equipment procurement process. MANPRINT was considered essential to determine whether the manpower requirements of future systems were affordable by ensuring ownership costs of both equipment and personnel (including training and support) were fully anticipated, budgeted for, or reduced by design improvements. Other potential benefits included:

- better MoD project management and MoD-contractor relationships;
- a clearer statement to industry of the MoD requirement – thus ensuring a more cost effective product by avoiding the high cost associated with over-manning, poor performance and error, leading to re-working and compensation claims;
- identification of whole project life cycle costs (manpower, personnel, training and maintenance) from industrial proposals and tenders, via early HFI analyses;
- earlier and more accurate identification of manpower requirements through formal HFI analyses at project start;
- better working conditions, thereby aiding personnel retention and optimising system performance;
- a reduction in the training load by defining and minimising the training tasks, thus reducing overheads in terms of costs and manpower cover.

In 1989 a small MANPRINT team had been established within the Army Department, responsible for overseeing the allocation of available Army manpower between the combat arms. The team was further tasked with producing a set of procedures to allow the application of MANPRINT to the British Army procurement process and was required to provide support in the specification and assessment of MANPRINT requirements for all major new Land Systems. The implementation of the Army MANPRINT Programme was

closely watched by the other services and the logic of adopting a common approach to specifying requirements within the MANPRINT domains became generally accepted.

In 1991 the intention to create a new MANPRINT branch common to all three armed services was announced to industry. This branch was established in 1992 and incorporated the existing Army MANPRINT team and the Royal Navy's Human Factors Integration Programme. Its formation at a time when the MoD as a whole was undergoing a period of contraction indicated the importance attached to this initiative. The new tri-service MANPRINT initiative was renamed Human Factors Integration (HFI). The requirement to address HFI issues throughout was included in the relevant procurement procedures and documentation. The MANPRINT office was disbanded in 1996 since the implementation of HFI within the MoD procurement process had been established. The present-day main HFI activity is within the MoD's Corporate Research Programme (CRP). This is currently undertaken by DERA, reporting to the MoD customer in its research and technology department with a military coordinator.

HIFA has its origins in the military domain, from the US MANPRINT and UK MoD HFI initiatives. There are valuable lessons to be learnt from these programmes.

3.3 HFI Scope, Structure, Processes, Content and Roles

3.3.1 HFI Scope

The scope of HFI is to produce systems that are fully integrated over their whole operational life cycle. People, technology and environmental factors are considered, as in Figure 7.

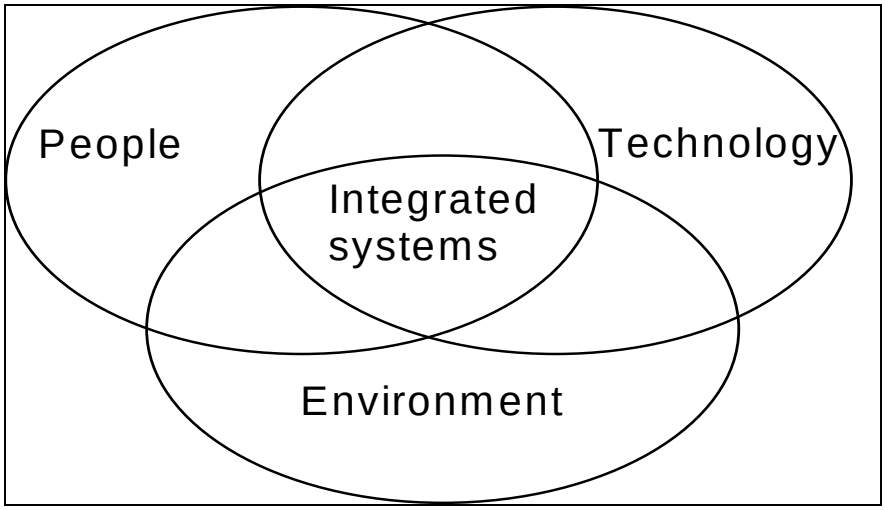

Figure 7: HFI scope

3.3.2 HFI Structure

HFI also operates at a number of hierarchical levels (see Figure 8): it is a high-level policy comprising rules to be followed, which in turn are made up of informing guidelines and mandatory standards. The HFI guidelines in turn comprise sets of techniques to carry out and support tools for the HFI process. Together, the hierarchy of policy, rules, guidance, tools and techniques address the comprehensive needs of and deliver a structured way forward for all involved in the procurement of future systems, with the common goal of increased operational system performance at reduced whole life cycle cost.

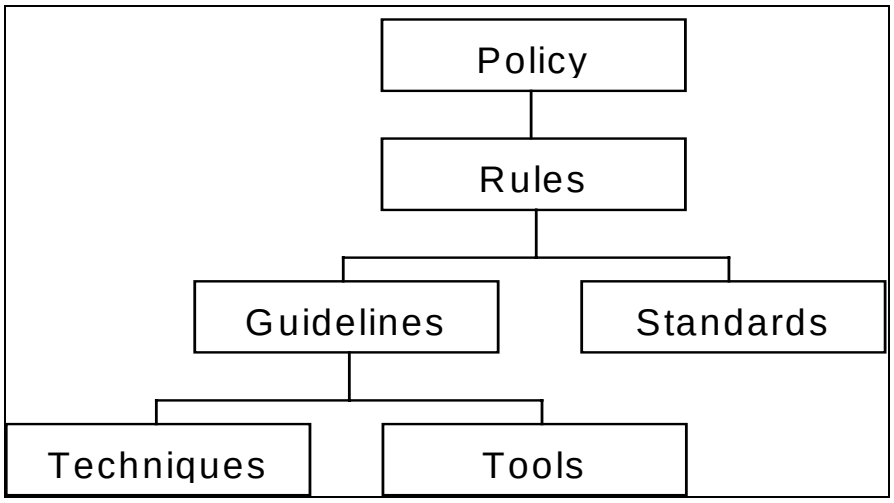

Figure 8: HFI structure

DERA's MoD Corporate Research Programme has taken a hierarchical approach for the development of HFI. The policy and rules have now been put in place mainly through procurement procedures. These are supported by guidelines (supporting the procedures) and standards (supporting the HFI philosophy).

A number of guidance documents to support the HFI process in procurement were produced but are currently being re-written as part of the associated Acquisition Management System to take account of the changes in procurement cycle under the current Smart Procurement Initiative (SPI).

In terms of standards, it was noted in the HIFA Deliverable 1 (EATMP, 2000) that many standards exist. DEF STAN 00-25 (MoD, 1997) is presently under revision and will eventually be subsumed within an HFI standard which includes technical and HFI process information.

Lastly, the guidance for HFI is underpinned by a series of methods and tools. For example, the Early Human Factors Analysis (EHFA) method addresses the consideration of human factors issues in the early project stages. As a complex method, there exists a software tool version called the HFI Key Issues Tool (KIT) which automates much of the process.

3.3.3 HFI Processes: Overall

In order to apply the tools and techniques to case studies, HFI also comprises a process or series of steps to be followed. These are summarised in Figure 9. As can be seen, this figure portrays a complex set of interacting processes.

First, the HFI process is managed at least at two levels: in the customer-level process (top shaded band) and at the supplier-level process (bottom shaded band). An HFI plan controls each management process. The procurer's HFI plan manages the HFI activities which occur in the procurement process, as in the ATM project life cycle, while the supplier's HFI plan manages the HFI activities from contract award, through design, development and acceptance to delivery of the system. The supplier's initial HFI plan is included as part of the proposal for the contract. If there are to be sub-contractors, the prime contractor has to show how HFI requirements will flow down to the sub-contractor and how HFI activities will be integrated and controlled.

Second, the HFI process is shown in Figure 9 as a time-line flowing from left to right. Activities shown on the left describe the contractor selection process and the flow of HFI requirements from customer and/or procurer to the supplier. The contribution of the HFI Capability Maturity Model (CMM) and the HFI plan to contractor selection are shown. These give assurance of the potential contractor's capability, commitment and level of management of the HFI process. Following contract award, the HFI process, the HFI requirements are translated into a specification for the integrated system through an iterative process of analysis, design and assessment.

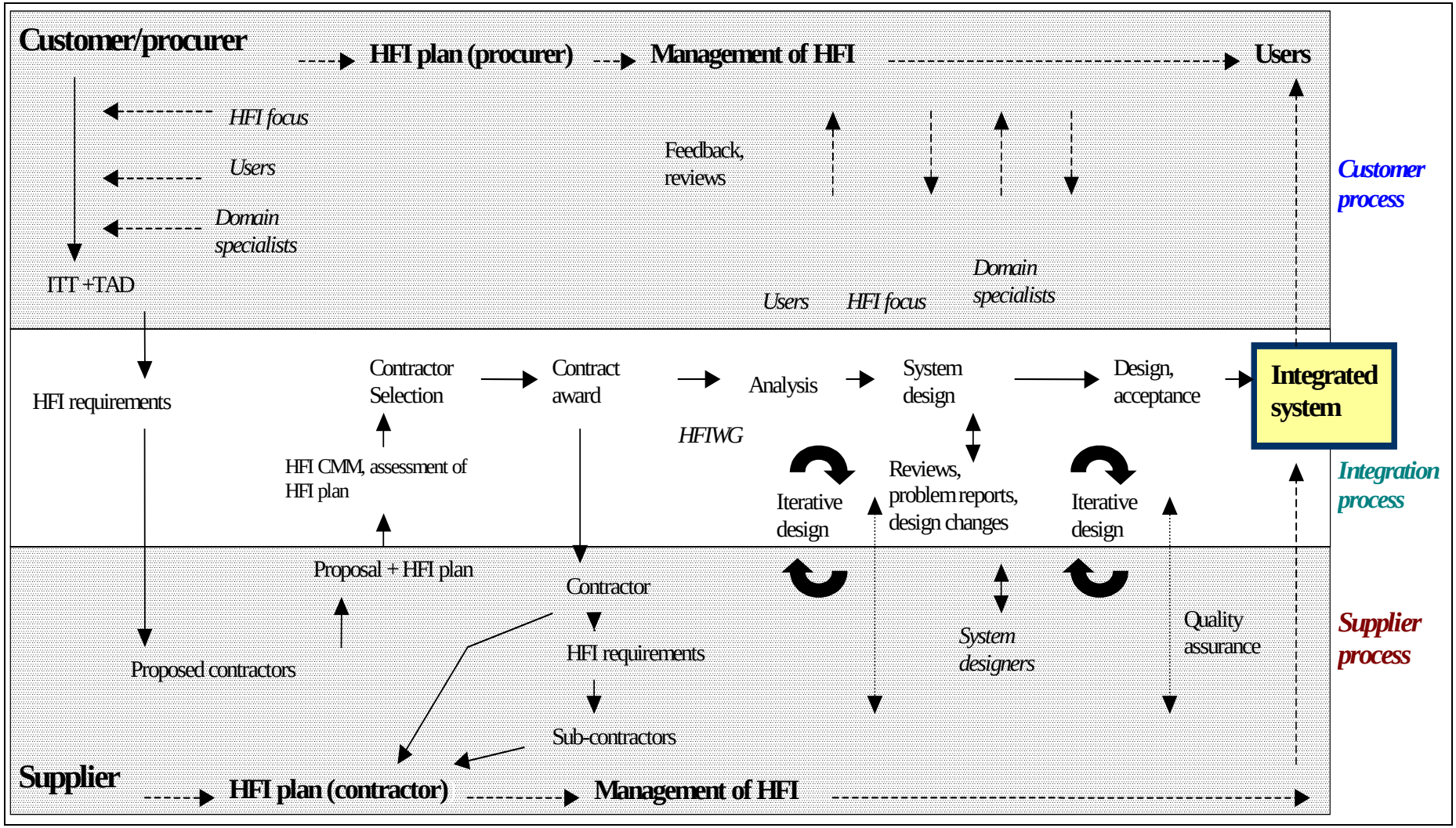

Figure 9: The overall HFI process

The system design and development process is the central activity where the integration happens, between project teams on both sides and at the procurer and supplier interface. On larger projects this is enabled by the HFI Working Group (HFIWG). The project teams on smaller projects are scaled down so that lines of communication for HFI should be easier. Communication between project members on Human Factors Integration (HFI) issues is not sufficient in itself. There needs to be an additional audit trail of requirements, assumptions, risks, design decisions, unresolved problems, design changes, etc., throughout the development process. This information is logged in the HFI plan that is updated regularly. The integration process is iterative and is supported by a series of reviews with input from key HFI personnel (shown in Italics).

Figure 9 does not describe all aspects of the HFI processes. Details of the various HFI processes are contained in the extensive HFI documentation (DERA, 1998a, b, c, d). A key component of HFI is Early Human Factors Analysis (EHFA) and this will be discussed separately.

3.3.4 HFI Processes: Early Human Factors Analysis

The EHFA process (DSD, 1997) for identification and assessment of HFI risks is indicated in Figure 10. One of the strengths (with associated costs) of the HFI philosophy is its emphasis on including human factors considerations from the outset, from the earliest phases of the project management life cycle. The EHFA also enables the project manager to judge more accurately the resources needed to address HFI throughout the project life cycle according to the number of issues raised and the severity of their impact on the project.

The EHFA is conducted by the HFI focus, HFI experts and (on larger projects) the HFIWG. On very small projects one person can carry out the analysis, providing that person has sufficient expertise in HFI. The HFI focus will act as analysis coordinator and will be responsible for ensuring that the EHFA is carried through to completion. The outputs of the analysis are an HFI analysis report that feeds directly into the main project documents such as the HFI plan and User Requirements Document (URD), and the HFI issues register which feeds into the project risk register.

The first stage of the EHFA defines the HFI analysis baseline. This consists of a definition of the concept options, initial project assumptions and the existing human factors constraints for each of the six domains. The HFI analysis coordinator carries out this stage with agreement from the project manager. The next step is to review the analysis baseline and identify whether there are any potential HFI issues which might arise (such as an increase in cognitive workload) from the concepts being considered. An Early Comparability Analysis (ECA) will help to identify potential issues, high driver tasks, assumptions and human factors constraints from lessons learnt from previous or existing similar systems. These assumptions are stored in the HFI assumptions register. As the concepts are developed further, the assumptions are revisited to determine whether they are still correct. If they are still adequate and valid, the potential issues are stored in the HFI issues log. If the assumptions register needs to be updated, authorisation needs to be sought from the project manager.

After approval of issues for analysis by the HFI focus, the potential issues are categorised according to likelihood of occurrence and likely impact on the project (as in a normal project risk assessment). The issues are then analysed further to consider appropriate options to address them and identify appropriate risk reduction strategies. Finally, the issues are then entered into the HFI issues register and are then transferred to the Project Risk Register and managed in the same way as other project risks. The various HFI registers, logs and data sheets provide an audit trail for the purposes of quality control.

The assumptions register and HFI issues register are linked so that if, at a later stage of design, an assumption is no longer valid then the associated issues are removed from the HFI issues register (and Project Risk Register).

All entries into the HFI issues log and the HFI issues register are made through HFI data sheets which state the originator of the issue, description of the issue and domain(s) concerned. This forms an audit trail that remains even if the issue is then discarded at a later date. At later stages of the EHFA, following review and quantification of the potential issues, additional data such as probability of occurrence, impact and mitigation strategy are added to the data sheets and stored in the issues log. When final decisions have been made regarding an issue, it is transferred to the HFI issues register.

Issues identified and taken into account at the early stages of a project, though requiring some effort and resources, are a sound investment, resulting in reduced occurrence of ‘unforeseen’ human issues in subsequent stages of the project life cycle.

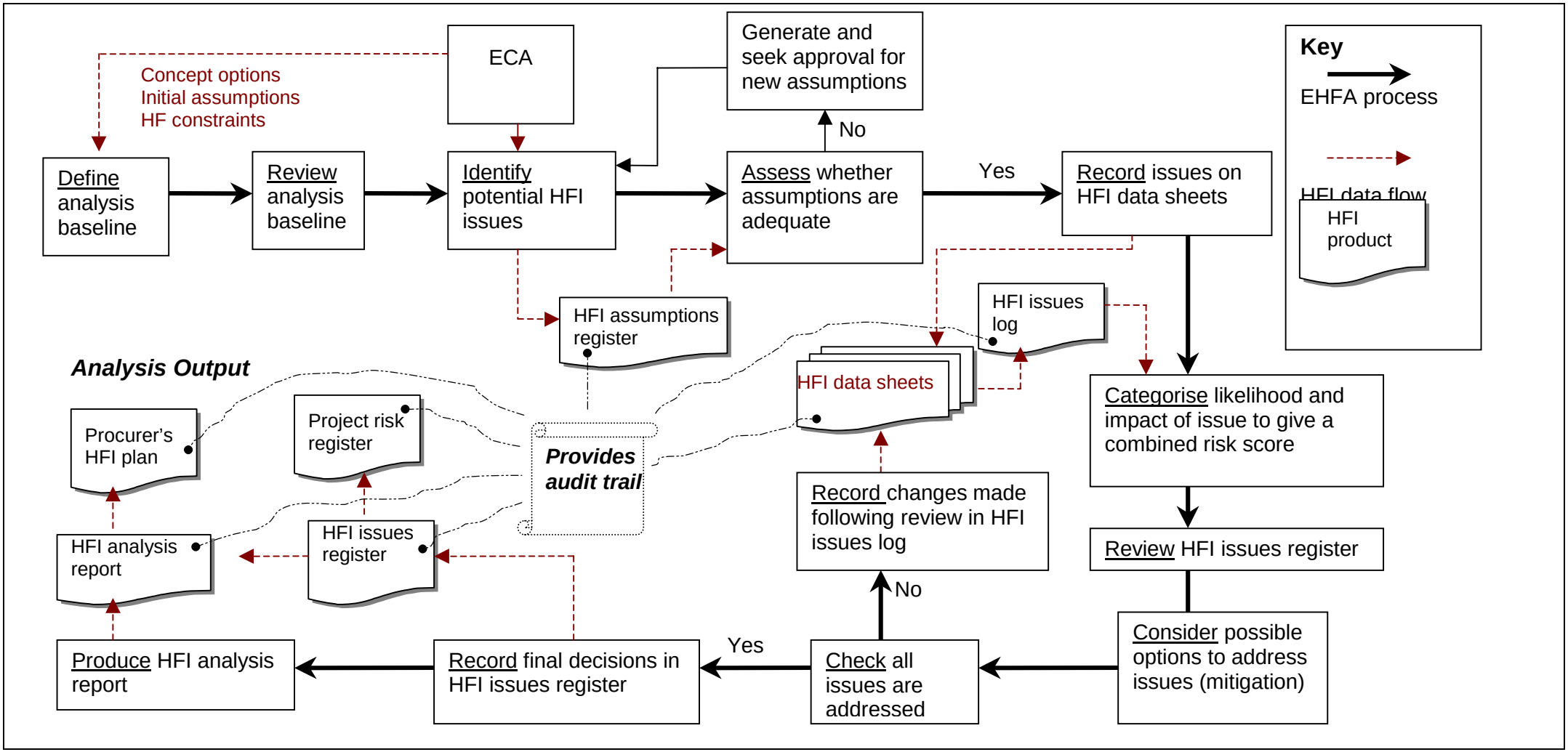

Figure 10: The Early Human Factors Analysis (EHFA) process

3.3.5 HFI Content

HFI covers all human issues of concern to a project, not just the traditional 'human factors engineering'. In terms of content, the human considerations of HFI are conveniently categorised into six domains as described in Table 1 below.

Table 1: HFI domains

	HFI Domain	Description
1.	Manpower (M)	The numbers of personnel, which are required to operate, maintain, train and support the system.
2.	Personnel (P)	The aptitudes, experience and other human characteristics (physical and cognitive) necessary to achieve optimum system performance.
3.	Training (T)	Specification and evaluation of the optimum combination of: instructional systems, education and on the job training required to develop the knowledge, skills and abilities needed by the available personnel to operate, maintain and support systems to the specified level of effectiveness under the full range of operating conditions.
4.	Task and Interface Design (TID)	The comprehensive integration of human characteristics into system design, including all aspects of workstation and workspace design.
5.	System Safety (SS)	The process of applying human factors expertise to minimise risks to total system safety occurring as a result of the system being operated or functioning in a normal or abnormal manner.
6.	Health Hazard Assessment (HHA)	The process of identifying and addressing conditions inherent in the operation or use of a system which can lead to stress or reduction in personal safety

3.3.6 HFI Roles

Finally, in addition to conventional project manager, project team and user representatives roles, a number of key HFI roles are required to be filled within the HFI approach to implement its various processes and manage its required resources. Note that these are specific HFI roles and not necessarily individual people – in practice, it would be possible for one person to fulfil several roles. The HIFA roles include:

- HFI focus – a person nominated to act as a focal point for all HFI activity;
- HFI expert – a person nominated to give expert advice on all questions relating to the details of HFI;
- human factors expert – a person nominated to provide expert human factors consultancy;
- other HFI domain specialist – a person nominated to provide specialist advice in one or more of the six HFI domains (as described above);
- logistics support manager – a person nominated to take care of the logistics, support and maintenance activities of the HFI process;
- member of an HFIWG – a person, such as domain specialist or project manager who, along with others in group, is responsible for ensuring that all areas of concern within the HFI domains are identified.

These roles will be discussed in more detail in Section 4.4 under 'HFI Roles and Responsibilities'.

The scope of HFI is broad and covers total systems. Its hierarchical structure comprises policy, rules standards, guidelines, techniques and tools. HFI contains a number of processes from high-level to detailed level such as an Early Human Factors Analysis (EHFA). The content of HFI is organised into six domains (Manpower, Personnel, Training, Human Factors Engineering, System Safety, and Health Hazard Assessment). HFI implementation requires a number of roles in addition to conventional project management responsibilities.

3.4 HFI within System Design

HFI also seeks to influence business process models and system engineering standards and models. The key word in HFI is collaborative **integration**. To this end, an educational task is inherent in communicating – through presentations, symposia, courses and learnt societies – the benefits as well as the costs of adopting the HFI philosophy within the project management and the systems engineering disciplines.

It should also be noted that HFI is a generic philosophy for considering the human in systems: the philosophy requires to be applied to an actual process, and historically this has been the UK MoD procurement cycle. However, since the HFI philosophy is generic its principles are equally applicable to other processes such as the EATMP Project management life cycle for European

ATM, with suitable adjustment of emphases to encompass the characteristics of the new application domain.

HFI integrates broad human factors considerations within system design and project management. There is an educational and communication need.

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4. ATM LIFE CYCLE AND A HIFA FOR EUROPEAN ATM

4.1 EATMP Project Life Cycle

As previously noted a standard project life cycle comprising eight phases; described in Table 2, has been adopted by EUROCONTROL for the management of EATMP programmes and projects (EATCHIP, 1998c).

Table 2: EATMP project life cycle

Life cycle Phase	Objectives
1. Initiation	To initiate a new programme/project within the scope of the EATMP portfolio that contributes towards the fulfilment of the ATM 2000+ strategy as defined by the Provisional Council and supporting domain strategies.
2. Planning	To gain approval for the detailed structure of the programme, i.e. its portfolio of projects, staffing and funding. It covers the transfer of tasks from the work programme to a comprehensive project plan.
3. Feasibility	To test the technical, operational, and financial feasibility of different development options, and to seek approval for development of chosen option(s).
4. Development	To develop proposed specifications (Common Operational Performance Specifications – COPS) and standards for a well-functioning solution and to produce the specifications for the equipment, functionality, functional and physical interfaces, operational procedures and automated procedures.
5. Pre-operational	To have an extra 'reality check' on the proposed solution by building a pre-operational prototype and/or running a real-time simulation to verify specifications.
6. Implementation planning	To have a detailed understanding of all the practicalities of a successful implementation of the proposed solution and to produce a coordinated implementation plan for all ECAC States and the affected airspace users.
7. Local implementation	To support the local States and the affected airspace users in the implementation: detailed design, development, or customisation of a standard product, integration of the components, assembly and testing, publications, education, training, procedures, implementation, phase-in, phase-out.
8. Operations	To start operations of the final programme / project output as part of the ATM system by the service providers and / or airspace users. To assess and record performance.

It is difficult to be precise about the likely duration of each phase as it depends upon the particular project (see discussion in 6.3). Clearly, the durations will be very variable, from a minimum of several months to several years.

Whilst it can be seen that the EATMP life cycle is closely related to other linear life cycle descriptions such as the classic Waterfall Model (see EATMP, 1999b), it is also evident that it is specifically aimed at the processes for project management within EUROCONTROL and more broadly within European ATM.

There are a number of points to be noted here:

- ⇨ First, there is no explicit Human Factors phase; human factors is an implicit 'input' into each of the phases (assuming it is to be included under considerations of user or stakeholder involvement).
- ⇨ Second, it is clear that an ATM engineering system is composed of numerous sub-systems, each of which has a life cycle of its own, each of which evolves differently, and each of which requires different human factor inputs.
- ⇨ Third, although the ATM system life cycle is not radically different from other systems, from the viewpoint of HFI, the current structuring is not necessarily adequate. Two important requirements are noted here: the need for an EHFA activity, and the consideration of system maintenance and local implementation issues at an earlier (i.e. conceptual) stage than present practice.

Although the eight phases are pre-defined there is scope for inclusion of sub-phases within each main phase to enhance flexibility of descriptions. It is considered that the phases of the EATMP life cycle will need some adaptation for HIFA purposes.

In summary, several modifications at least would seem to be required:

1. The need for an EHFA activity within the early life cycle phases until the requirements are defined.
2. The need to address possible HIFA issues in system maintenance and local implementation at the early stages of the life cycle e.g. Planning and Feasibility life cycle phases.
3. The need to include maintenance, in-service system enhancements, re-cycling and de-commissioning within the Operations phase.

The objectives of each phase of the EATMP project management life cycle are described. There is currently no explicit human factors phase. Whilst retaining the EATMP structure, HIFA puts emphasis on early human factors consideration and on additional detail within the system operational phase.

4.2 Human Factors Integration and EATMP

4.2.1 Management of HIFA

HIFA is a management and a technical process that seeks to provide a balanced development of both the technical and human aspects of system procurement. HIFA provides a process (comprising policy, rules, guidelines, standards, techniques and tools) that ensures the application of scientific knowledge about a broad range of human characteristics through the specification, design, development and evaluation of systems. This structured process also acts as a quality assurance function and gives the procurement authority an audit trail that human factors issues such as usability, safety and personnel-related whole life costs are adequately considered during the procurement process. The goal of HIFA is to identify the most cost-effective trade-offs between the six HIFA domains, and between the domains and other areas such as hardware, software and cost.

Since HIFA is a process it needs to be managed in order to work effectively. This requires a high-level commitment and a method of enforcement by someone in a high level position of project authority[3]. A similar management activity will be required for the integration of the HIFA approach within EATMP projects.

4.2.2 The FAA Perspective

The US FAA has a parallel interest in HFI within its systems development processes, emphasising project management aspects. The FAA generated a Human Factors Policy Order (FAA, 1993) which stated:

> ***Human factors*** *shall be systematically* ***integrated*** *into the planning and execution of the functions of all FAA elements and activities associated with system acquisitions and system operations. FAA endeavours shall emphasise human factors considerations to enhance system performance and capitalise upon the relative strengths of people and machines. These considerations shall be integrated at the earliest phases of FAA projects.*

The National Plan for Aviation Human Factors (FAA, 1995) resulted from the high importance the FAA confers on human factors in relation to aviation safety and effectiveness. Central goals, objectives, progress, and challenges for the future of human factors research and application are prescribed,

[3] In the UK MoD HFI process, this is achieved by the Chief of Defence Procurement Instructions (CDPI) procedures (HMSO, 1998), an auditable document which instructs the Project Manager to perform a number of tasks to initiate the HFI process. These tasks consist of making sure that HFI is a part of the procurement strategy and informing relevant bodies who will be affected by decisions made in the HFI process: finance staff and personnel officers. Other tasks include assigning HFI roles and responsibilities, developing the HFI plan and conducting an EHFA.

together with the required implementation activities. The plan is intended to encompass the whole aviation community …

> *… including flight deck, aircraft cabin, air traffic control, airway facilities, aircraft maintenance, and commercial and general aviation operations, as well as the regulatory and organisational activities affecting these elements.*

The FAA's Human Factors Job Aid (FAA, 1999) is a management process guide describing a set of processes and functions leading to a successful human factors programme. It is based on US DoD standards and handbooks and is intended to serve as a desk reference for HFI. The eight processes within the FAA Human Factors Job Aid are as follows:

1. Develop human factors inputs for Mission Need Statement

2. Develop the human factors programme so as to increase system performance and reduce developmental and life cycle costs.

3. Formulate human factors performance considerations for incorporation into system specifications.

4. Generate human factors requirements for incorporation in the Statement of Work to be placed on contractors developing the system.

5. Specify human factors in contractor selection – a human factors specialist prepares inputs (such as proposal evaluation criteria, Source Selection Plans) for the evaluation and eventual selection of contractors.

6. Integrate human factors in systems engineering, by contributing information relating to design enhancements, safety features, automation impacts, human-system performance trade-offs, ease of use, and workload.

7. Determine human factors requirements in system testing, to ensure that human factors are adequately integrated into the system acquisition-testing programme.

8. Coordinate with the Integrated Logistics Support (ILS) Programme, to coordinate the analyses, information content and flow between the human factors and ILS Programmes.

4.2.3 An HIFA for European ATM Projects

The generic multi-national approaches (i.e. US MANPRINT/UK HFI/FAA HFI) have many strengths. They can be modified for use in European ATM project applications in order to address the human element as an integral part of system design, and thereby to optimise the total system performance and reduce developmental and life cycle costs. It is considered that the use of the six HIFA domains, together with identification and management of the human factors risks in the programme through the Early Human Factors Analysis

(EHFA), makes a modified version of the UK HFI Programme the most suitable approach for EATMP projects. It is suggested that the HFI domains be adjusted for civilian use. The modifications must address the issues of through-life costs, total system performance, and consider the maintainers and support people (e.g. system trainers) as well as operators, the organisational and career development structure.

Human factors integration (HFI) also needs to be mapped onto the ATM life cycle process and integrated into other related processes. For example, the UK HFI and FAA HFI Programmes integrate with Integrated Logistic Support (ILS). There is an equivalent Logical Support Analysis (LSA) process in ATM, and the activities which relate to, and are required by, HFI will need to be incorporated into the ATM HIFA process. This mapping is described in the detailed HFI documentation (DERA, 1998a to d).

HIFA is a management as well as a technical process. The American FAA's human factors integration activity, as well as the US MANPRINT and UK HFI initiatives, form a strong foundation for developing an HIFA for European ATM projects.

Though they are described linearly in this document, in practice the stages of the HIFA activities are conducted mainly in parallel and are iterative. The HIFA plans, requirements, and assumptions are revised and updated as the design develops. Most of the HIFA analyses are conducted in the early design stages where design changes are relatively easy and cheaper to implement. Data collected from the analyses are stored in databases, and there is an audit trail that is managed throughout the system life cycle to link requirements to design decisions.

4.3 Top-Level HIFA for EATMP

HIFA may be viewed at a number of hierarchical levels: as a high-level process and as a set of detailed processes. The following top-level key HFI issues and outputs are presented in Table 3 available in the EATMP Management Handbook (EATCHIP, 1998c).

Table 3: Top-level key HIFA issues and outputs within EATMP life cycle

Life Cycle Phase	Key HIFA Issues (Technical and Operational)	Key HIFA Outputs
1. Initiation	How will HFI be managed?	Establish an HFI focus role.
2. Planning	What are the human factors concerns?	Establish HFIWG and conduct EHFA.

Table 3: Top-level key HIFA issues and outputs within EATMP life cycle (continued)

Life Cycle Phase	Key HIFA Issues (Technical and Operational)	Key HIFA Outputs
3. Feasibility	What are the human factors requirements and how will they be assessed?	Produce HFI requirements document and identify assessment criteria.
4. Development	Are the HFI requirements included in system specifications, sub-contracts and test plans, and are they traceable?	Ensure HFI requirements are made testable and are reflected in both project and proposed system.
5. Pre-operational	Have results of HFI studies been fed into appropriate design activities?	Define HFI aspects of system design and support other design activities.
6. Implementation planning	Have the HFI issues/risks been mitigated?	Assess HFI aspects of system and update requirements documents.
7. Local implementation	Are there any unresolved HFI issues associated with local implementation of system?	Review human factors trade-off analysis and re-assessment of HFI aspects of system operation.
8. Operations	Are HFI aspects of in-service performance adequate and do they meet requirements?	Measurement of in-service performance.

The HIFA process covers each phase of the EATMP project life cycle. It addresses the key integration issues and identifies the key outputs.

4.4 HIFA Roles and Responsibilities

Based on prior HFI experience some *Ab Initio* estimates concerning HIFA roles and responsibilities have been made for European ATM projects. The following Table 4 outlines potential HIFA roles for the various actors within ATM projects, what they are responsible for doing, and the HFI needs or depth of HFI knowledge that each of these roles is likely to require.

Table 4: HFI roles and responsibilities

Role	Responsibilities	HFI Needs/Level of Required HFI Knowledge
Project manager	Responsible for ensuring project delivered to time and budget, and HFI requirements are met.	Needs HFI overview (no detail), cost / benefit justification for using HFI.
HFI focus	Responsible for HFI aspects of system.	Needs HFI detail.
HFI expert	Responsible for providing detailed HFI knowledge and experience.	Needs detailed HFI knowledge and previous HFI experience.
Human factors expert	Responsible for ensuring Human Factors Engineering is integrated throughout system development, product usability, human performance requirements are met.	Needs HFI detail – ability to convert user needs into testable HFI requirements.
Domain specialists	Responsible for providing expertise in HFI domains: Manpower, Personnel, Training, Human Factors Engineering (see above), Systems Safety, Health and Hazard Assessment.	Requires broad HFI knowledge as well as HFI domain specific knowledge.
HFIWG (i.e. user representatives, project manager logistic support manager, six HFI domain specialists	Responsible for ensuring that all areas of concern in the HFI domains are identified so that problems do not fall into 'gaps'. Resolves any potentially conflicting requirements (e.g. safety vs. ease of use), reviews the various requirements documents to ensure that HFI issues are adequately covered, maintains the HFI management plan and monitors its execution.	Requires broad HFI knowledge.
Analysis team	Responsible for project analysis work	Needs HFI overview.
Logistic support manager	Responsible for integrating HFI with Logistic Support activities: Availability, Reliability, Maintainability, and Training.	Needs knowledge of areas of overlap between Logistic support and HFI.

Table 4: HFI roles and responsibilities (continued)

Role	Responsibilities	HFI Needs/Level of Required HFI Knowledge
Safety manager for total system safety	Responsible for total safety aspects of system development.	Requires HFI detail (guided by HFI expert).
Reliability engineer	Responsible for reliability of system and sub-system components, including human element. Part of project LSA.	Needs broad HFI knowledge.
ATCO / system user	Responsible for providing ATC domain and operational knowledge.	Needs sufficient understanding of HFI issues to recognise potential problems in system use.
Systems designer / engineer	Responsible for designing the system and its component sub-systems	Needs HFI overview, no detail.
Software / HCI developer	Responsible for developing software (including HCI) which can be used by the intended target audience.	Needs HFI overview, no detail.
Sponsor	Responsible for understanding HFI aspects of users' needs.	Needs HFI overview.
Contractor(s)	Responsible for delivering system which meets HFI requirements.	Needs HFI detail.

HIFA requires a number of HFI roles in addition to conventional project management role. These roles have specific responsibilities and have a required level of HFI knowledge.

5. DETAIL OF HIFA FOR EUROPEAN ATM

In each phase of the ATM life cycle there is a requirement to make the detailed set of HIFA domains, tasks and checklist questions most appropriate to the EATMP ATM project life cycle.

The detailed HIFA input to the European ATM life cycle being proposed here also covers all of the processes described in the American Federal Aviation Authority Human Factors Job Aid document (FAA, 1999). The evaluation of potential contractors, as in the FAA's Job Aid process number 5 ('Specify human factors in source selections'), is covered by the evaluation of the contractor's HFI plan and eventual use of a capability maturity model for HFI (Earthy et al, 1999).

Table 5 describes the schematic format of the eight sub-sections (5.1 through 5.8) that follow. For each of the eight phases of the EATMP life cycle previously described in Table 2 a set of HIFA tasks (verb-based actions) is listed. The tasks are domain independent within HIFA. The appropriate authority (i.e. the HIFA role or roles) responsible for carrying out each task has also been stated in a separate column.

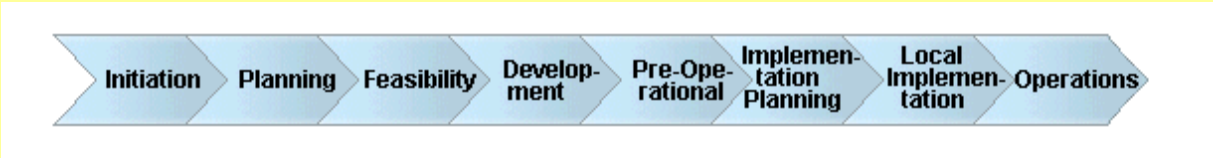
For each of the eight phases of the EATMP life cycle a set of detailed checklist questions is presented that should be taken into consideration. These act as 'prompts' in HFI jargon to consider appropriate human issues at appropriate phases of the project life cycle. The relevant HIFA domain or domains are stated in a separate column. To recap from Table 1, these six domains are:

- Manpower (M);
- Personnel (P);
- Training (T);
- Task and Interface Design (TID);
- System Safety (SS);
- Health Hazard Assessment (HHA).

The guidance material presented here is at a high level, and is supplemented by detailed guidance contained in the HIFA third report on methods and tools (EATMP, not printed). Although these steps are presented as a simplified linear process, it must be stressed that the HIFA process is iterative and parallel, being heavily dependent on feedback from relevant stakeholders, users and HIFA actors at each review stage within the overall HIFA activity.

In a nutshell the HIFA philosophy is distributed over all six domains and can be summarised as: 'Can these people (M, P Domains) with this training (T) perform these tasks with this equipment (TID) under these conditions (SS, HHA)'.

Table 5: Schematic diagram of HIFA tasks and checklist questions for each EATMP life cycle phase



For each phase of EATMP ATM project life cycle:	
Life cycle objectives:	
Key HIFA issues:	
HIFA Tasks *(to be carried out by the responsible HIFA role(s) mentioned)*	**HIFA Role Responsible**
• Verb1 • Verb2 • etc.	HIFA role1 HIFA role2

HIFA Checklist Questions *(applicable to the specific HIFA domain(s) mentioned)*	**HIFA Domain** *(as appropriate)*
• Question A • Question B • Question C • etc.	Manpower (M) Personnel (P) Training (T) Task and Interface Design (TID) Systems Safety (SS) Health Hazard Assessment (HHA)

HIFA guidance material comprises activities to perform and checklist questions to ask in each phase of the ATM project life cycle. The material is structured in a framework appropriate to project manager activities.

5.1 EATMP Life Cycle Phase 1: Initiation

Life cycle objectives: To initiate a new programme/project within the scope of the EATMP portfolio that contributes towards the fulfilment of the ATM 2000+ strategy as defined by the Provisional Council and the supporting domain strategies.	
Key HIFA issues: How will HFI be managed?	
HIFA Tasks	**HIFA Role Responsible**
• Appoint HFI focus role.	Project manager
• Agree HFI strategy.	HFI focus
• Set up HFIWG, which includes users (size of group depends on complexity of project. It may not be necessary to have a representative for each domain).	HFI focus
• Review available information on existing or similar system to identify human factors requirements and issues that need to be examined in current project.	Human factors expert
• Identify existing or predecessor systems or sub-systems.	HFI focus
• Conduct Early Comparability Analysis (ECA) part of EHFA (HFI focus to lead, analysis team to include human factors experts, covering all domains, and users as subject matter experts).	HFI focus and analysis team
• Start to define analysis baseline for EHFA.	Project manager and HFI focus
• Consider liaison with representatives of local State for later local implementation (as appropriate).	Project manager and HFI focus

HIFA Checklist Questions	HIFA Domain
• What are HFI assumptions and constraints? • What are the possible concept options at this stage? • How will HFI be managed? • Will HFIWG be necessary? • Who should be included in the HFIWG? • What are relevant existing or predecessor systems or sub-systems? • What are lessons learnt, human factors constraints and high driver tasks from these systems or sub-systems?	Applicable to all six HFI domains: M, P, T, TID, SS and HHA

5.2 EATMP Life Cycle Phase 2: Planning

Life cycle objectives: To gain approval for the detailed structure of the programme, i.e. its portfolio of projects, staffing and funding. It covers the transfer of tasks from the work programme to a comprehensive project plan.

Key HIFA issues: What are the human factors concerns?

HIFA Tasks	HIFA Role Responsible
• Review new system concept to identify any statements or assumptions relevant to the six HFI domains.	HFI focus (with advice from human factors experts)
• Describe new system concept as fully as possible in terms of domains, covering background information, requirements, constraints, assumptions, issues and risks.	
• Note any likely HFI distinction between options under consideration.	
• Determine HFI analysis baseline - discuss assumptions and outstanding issues on: – system concept of use, – human tasks, – human performance requirements, – technologies and associated human factors issues, – operational environment, – interoperability and supply policies, – policies, requirements, constraints, standards for all six HFI domains, – maintenance policy.	Analysis team or HFIWG
• Conduct remaining steps of EHFA and produce HFI analysis report.	LS manager
• Initiate HFI plan and related plans	HFI focus
• Initiate high-level Target Audience Description (TAD) for operators, maintainers and support personnel	HFI focus and human factors expert

HIFA Checklist Questions	HIFA Domain
What are:	
• existing manpower problems: shortage/surplus, career progression?	M
• manpower options?	M
• current skill shortages?	P
• personnel options: alternative types of user and skill levels, broad allocation of tasks to personnel?	P
• existing training facilities and organisation policy?	T
• training options?	T
• current human factors problems?	TID
• Human-Machine Interface (HMI) options?	TID
• current maintenance policy?	M, P, T, TID
• logistic support options?	All
• current health and safety aspects: fatigue, hazards?	SS, HHA
• Options for optimising health and safety?	SS, HHA

5.3 EATMP Life Cycle Phase 3: Feasibility

Life cycle objectives: To test the technical, operational, and financial feasibility of different development options, and to seek approval for development of the chosen option(s).

Key HIFA issues: What are the human factors requirements and how will they be assessed?

HIFA Tasks	HIFA Role Responsible
• Revise HFI assumptions and issues in light of wider assumptions and decisions.	HFI focus and WG
• Determine constraints on performance, manning, training, potential technical solution and costs in consultation with relevant domain specialists.	As above
• Define:	HFWG
– (possible) future organisation, – Target Audience Description (TAD), – Training requirements, – HMI design specification,	M domain specialist P domain specialist T domain specialist TID domain specialist
– Health Hazard and SS requirements,	SS, HHA domain specialist
– HFI maintenance requirements.	HFI focus and LS manager
• Produce HFI requirements for User Requirements Document (URD) containing:	HFI focus and expert
– HFI-related failings of present equipment; – numbers and organisation by grade of personnel required to operate, maintain and support new system under different operating conditions; – significant changes from present equipment in personnel cognitive requirements; – training policy; – maintenance policy;	As above for all

(continued overleaf)

(continued)

– performance requirements for critical user or maintainer tasks under specified operating and environmental conditions; – requirements for use of specified HMI technologies; – applicable standards for HMI design; – potential health and safety hazards and applicable policy and standards.	As above
• Agree with project manager: – HFI assessment criteria in line with operational requirements; – planned assessment process which will enable proper testing of deliverables against HFI assessment criteria.	HFI focus
• Update HFI plan and TAD.	HFI focus and expert
• Update HFI issues register (from EHFA).	HFI focus
• Trade-off performance, manning, training, potential technical solution and costs within fixed constraints until an overall set of policies, requirements and standards can be defined which is likely to be feasible and acceptable to all stakeholders.	M, P, T, TID domain specialists
• Initiate Training Needs Analysis (TNA).	T, TID domain specialists

HIFA Checklist Questions	HIFA Domain
• What are the: – additional or revised HFI assumptions arising since the Planning stage? – human performance requirements? – accommodation and workspace needs? – training and maintenance policies? – tasks to be trained?	M, P, T, TID
• What are the assessment criteria for: – manpower baseline for acceptance? – personnel specification for acceptance? – training? – HMI, including HFI implications of logistic support strategy? – safety?	M P T TID SS, HHA
• What are the revisions to the TAD?	M P T TID
• What are the potential trade-off areas?	All

5.4 EATMP Life Cycle Phase 4: Development

Life cycle objectives: To develop proposed specifications (Common Operational Performance Specifications – COPS) and standards for a well-functioning solution and to produce the specifications for the equipment, functionality, functional and physical interfaces, operational procedures and automated procedures.	
Key HIFA issues: Are the HFI requirements included in system specifications, sub-contracts and test plans, and are they traceable?	
HIFA Tasks	**HIFA Role Responsible**
• Ensure HFI requirements will be addressed in system specifications, sub-contracts, test plans and requirements traceability systems.	HFI focus and HFI expert
• Ensure each requirement is testable. If this is not possible, identify the activity required to define the requirement.	HFI expert
• Demonstrate through requirements that an integrated approach to HFI has been taken, proposed system designs have been evaluated across all HFI domains and appropriate tradeoffs have been made.	HFI focus and HFI expert
• Update audit trail.	TID focus
• Update TNA.	T TID domain specialists

HIFA Checklist Questions	HIFA Domain
• What are the anticipated:	
– workload limits?	M
– manpower constraints?	M
– expected work/rest cycles?	P
– design constraints associated with physical and mental characteristics of expected users?	TID
– training requirements?	T
• How will the TID requirements be addressed, including:	TID
– excerpts from human factors standards and guidelines?	
– HMI characteristics?	
– types of transaction and user support facilities?	
– required accuracy and speed of HMI?	
– workspace layout and accommodation requirements?	
– accessibility, layout, ease of use and type of user support facilities for maintenance?	As above for all
– interoperability with associated systems?	
– system response times?	
– limits on user interaction with the system?	
– requirements for consistency throughout the interface?	
– use of built-in test equipment or external test equipment and HFI implications?	
• How will the system specification comply with health and safety directives?	SS
• What is the alarm and warning policy?	SS
• What are the limits on environmental stressors?	HHA
• What lighting levels and range of adjustability will be required?	HHA

5.5 EATMP Life Cycle Phase 5: Pre-operational

Life cycle objectives: To have an extra 'reality check' on the proposed solution by building a pre-operational prototype and/or undertaking a real-time simulation to verify specifications.	
Key HIFA issues: Have results of HFI studies been fed into appropriate design activities?	
HIFA Tasks	**HIFA Role Responsible**
• Identify key project milestone which require HFI inputs.	HFI focus
• Review emerging design specifications, drawings, models and prototypes.	HFIWG
• Design HFI aspects of the system as appropriate.	HFI expert
• Participate in design meetings and HFIWG meetings.	HFI expert
• Use HFI requirements and acceptance criteria to provide inputs to trade-off studies.	HFI focus and WG
• Participate in design reviews.	HFI focus and expert
• Ensure results of HFI studies flow into appropriate design activities.	HFI focus
• Produce interface designs for operations and support which: – promote effective task performance, – minimise training requirements, – ensure safe operation, – are compatible with capabilities and limitations of expected users.	HFI expert and TID
Produce HFI Deliverables: • HFI deliverables are used to support a variety of design activities. It is essential that analyses are coordinated to reduce duplication of effort. • Audit trail from HFI risks, through HFI studies to the design. • Results of HFI studies. • HFI progress reports and inputs to design reviews. • HFI plans, schedules, issues register, test plans, meeting minutes, action item responses. • HFI inputs to project deliverables, such as management plans, risk registers, specifications, etc. • Definitions of the HFI aspects of the design such as style guides, workplace layouts, training facilities, specifications, etc.	All involved parties

HIFA Checklist Questions	HIFA Domain
• What evidence will be provided for the following:	
♦ Workload analysis supports proposed manning levels, task allocation and work-rest cycles?	M
♦ Task analysis data has been used to support workload assessments?	M
♦ Role analysis was used to determine key tasks for each role?	M
♦ Skills analysis report has fed into system design, task analysis and TNA?	P,T
♦ HFI requirements have been met in training facilities specifications?	T
♦ Task analysis and TNA data have fed into development of training programme?	T
♦ Skill analysis data have been used to determine best way of training new skills?	T
♦ Task analysis data was used to optimise user and maintainer manual development?	T
♦ Task analysis data was used to identify potential areas for negative transfer of training from existing systems?	T
♦ TNA data was used to combat the potential for loss of basic skills due to automation?	T
♦ HFI requirements have been integrated with hardware and software specifications?	TID
♦ HMI specifications and style guides have been used in design of screen layouts, controls, user input, system feedback, help facilities, etc., for operational and support equipment?	TID
♦ Anthropometric data analysis report was used for proposed workspace layout?	TID
♦ Compliance with human factors and related standards?	TID, HHA
♦ Human performance modelling data was used to support operational analysis and design trade-offs?	TID
♦ Task analysis data was used to optimise task performance?	TID
♦ Task analysis data was used to minimise tools required for maintenance and to reduce Mean Time To Repair (MTTR)?	TID
♦ Cognitive task analysis was use to reduce risk of information overload?	TID
♦ Rapid prototyping was used to facilitate specification of HMI and reduce fitness for purpose risk?	TID
♦ Human error was considered in Hazard and Operability Study (HAZOPS) and Failure Mode Effects and Criticality Analyses (FMECAs) (or equivalent analyses)?	SS, HHA
♦ Human error and human limitations were considered in Safety Hazard Analysis (SHA)?	SS, HHA
♦ Human safety hazards are mitigated by the design as part of the SHA and HAZOPS?	SS
♦ Compliance with health and safety legislation?	SS, HHA
♦ Task analysis data were used to support development of emergency procedures?	SS

5.6 EATMP Life Cycle Phase 6: Implementation Planning

Life cycle objectives: To have a detailed understanding of all the practicalities of a successful implementation of the proposed solution and to produce a coordinated implementation plan for all ECAC states and the affected airspace users.

Key HIFA issues: Have the HFI issues / risks been mitigated?

HIFA Tasks	HIFA Role Responsible
• Review design documentation, models, prototypes, etc., of system operation and determine whether or not HFI issues/risks have been mitigated.	HFI focus and HFIWG
• Conduct final user trials of system.	Human factors expert and WG
• Conduct final training.	T domain specialist
• Identify any deficiencies or areas for further work.	HFI focus and WG
• Conduct final trade-offs to address any remaining conflicting requirements between domains.	HFI focus
• Update requirements documents and test plans as required.	HFI focus
• Update the audit trail that shows that HFI requirements have been included in the design.	HFI focus

HIFA Checklist Questions	HIFA Domain
• Does the proposed manpower allocation include: – an acceptable division of responsibility? – adequate career progression? – acceptable workload levels? – acceptable task performance levels under expected workload conditions? – an assessment of the manpower implications of organisation of functions and levels of automation?	M

(continued overleaf)

(continued)

• Have the capabilities of personnel (as defined in TAD) been accommodated in the proposed design?	P
• Does the proposed training: – achieve required performance standards? – include any new skills to be trained? – include acceptable training media/methods, and is the sequence of learning modules suitable? – incorporate acceptable physical, instructional and dynamic fidelity of training media?	T
• Have the following on-going human factors engineering aspects been addressed adequately: – Did the design adhere to applicable standards? – Are detailed design features (e.g. display legibility) within acceptable limits? – Is task performance effective? – Is overall usability acceptable to users? – Is overall maintainability acceptable to maintainers? – Is the MTTR within acceptable limits? – Is the number of tools required for routine maintenance acceptable to maintainers? – Are user support facilities, on-line help and operations manuals acceptable to users? – Are workstation and workplace layouts acceptable to users? – Are the manuals easy to use by operators and maintainers?	TID
• Have the following on-going system safety aspects been addressed adequately: – consequences of human error on system performance? – mitigation of human error? – hazardous operational conditions? – compliance with safety directives?	SS
• Have the following on-going Health Hazard aspects been addressed adequately: – alarms and warnings? – environmental factors and their effects on critical tasks? – minimum lighting levels? – emergency lighting? – physical and lift limits (e.g. for maintenance tasks)?	HHA

5.7 EATMP Life Cycle Phase 7: Local Implementation

Life cycle objectives: To support the local States and the affected airspace users in the implementation: detailed design, development, or customisation of a standard product, integration of the components, assembly and testing, publications, education, training, procedures, implementation, phase-in, phase-out.

Key HIFA issues: Are there any unresolved HFI issues associated with local implementation of system?

HIFA Tasks	HIFA Role Responsible
• Assess whether there are any unresolved HFI issues associated with local implementation of system.	HFI focus and WG
• Conduct trade-off analyses to determine best ways of resolving issues and address conflicting requirements between domains.	HFI focus and WG
• Update TAD and issues register.	HFI focus
• Review proposed design changes, where necessary.	HFI focus and WG
• Attend design review meetings.	HFI focus and WG
• Review design documentation, models, prototypes, etc., of system operation and determine whether or not HFI issues / risks have been mitigate.	HFI focus and WG
• Identify any deficiencies or areas for further work.	Human factors expert and WG
• Update requirements documents and test plans as required.	HFI focus
• Update the audit trail that shows that HFI requirements have been included in the design.	HFI focus

HIFA Checklist Questions	HIFA Domain
(As in the Implementation phase checklist, plus the following additional checklist questions:)	
• Are there sufficient numbers of available personnel to operate, maintain and support the system?	M
• Are there any skill shortages?	P
• Are there any significant differences between target audience of local State and the TAD used in design of the system?	P
• Are there any training gaps?	T
• Are there significant differences in career structure between target audience of local State and the TAD used in design of the system?	P,T
• Has sufficient training time been allocated for operators, maintainers and support staff (including system trainers)?	T
• Are there any human factors issues associated with local implementation, e.g. differences in population stereotypes, language, shift patterns, organisation?	M, P, T, TID
• Are there any health and safety issues associated with local implementation?	SS, HHA

5.8 EATMP Life Cycle Phase 8: Operations

Life cycle objectives: To start operations of the final programme / project output as part of the ATM system by the service providers and / or airspace users. To assess and record performance.

Key HIFA issues: Are HFI aspects of in-service performance adequate and do they meet requirements?

HIFA Tasks	HIFA Role Responsible
• Conduct measurement of in-service performance: – workload measurement, – Human Reliability Analysis, – training time, frequency of refresher training, training costs, – MTTR (including diagnostic time)	Human factors expert Safety expert
• Update TAD where there are differences in physical and mental characteristics of actual users compared with predicted users.	Human factors expert
• Revise HFI issues for system disposal / upgrade.	HFI expert
• For mid-life upgrade or new system: – Conduct EHFA, etc., as in Planning phase.	Analysis team or HFIWG

HIFA Checklist Questions	HIFA Domain
• Are there sufficient numbers of operators, maintainers, trainers, etc., available to operate, maintain and support the system to the required levels of performance under the required operational conditions?	M
• Is there a high staff turnover?	M
• Do the users have sufficient skills, physical and mental characteristics to operate, maintain and support the system to the required levels of performance under the required operational conditions?	P
• Are there problems in recruiting staff with these characteristics?	P
• Is the training programme sufficient to maintain required skill levels to operate, maintain and support the system?	T
• What are the training shortfalls?	T
• What are training costs?	T
• What is the skill retention for tasks, which are not frequently performed?	T
• How long does it take to train personnel to required skill levels?	T
• Are workload levels too high, too low? Are there peaks and troughs?	M, P, T, TID
• Are there any high driver tasks (tasks that have a high demand on training time, skill levels or resources)?	M, P, T, TID
• Are there any human factors problems associated with the HMI?	TID
• Has the system design provided sufficient means to prevent human error and for error recovery?	TID
• What are the types and frequency of error occurrence?	TID
• Are there any reported incidents / accidents?	SS
• Is the system availability at required levels (MTTR, etc.). If not, what effect does this have on performance levels, workload, morale, etc.?	TID
• Are there any long or short-term health hazards associated with the operation and maintenance of the system (accident or sickness statistics, reports of repetitive strain injuries, etc.)?	HHA

5.9 Alternative Viewpoints of the HIFA Processes

Although the HIFA steps have been presented as a simplified linear activity, in practice the processes are parallel and iterative. As such, systems theory allows a number of different possible views though the processes (Avison & Fitzgerald, 1988). For example, data flow diagrams can show parallel concurrent processes and their dependencies, independent of any timing dimension. Flow charts can show time dependent steps. Entity relationship diagrams illustrate by content entities (stakeholders) and their relationships. It is therefore possible to take one or more alternative orthogonal views through the HIFA processes, as illustrated in Figure 11.

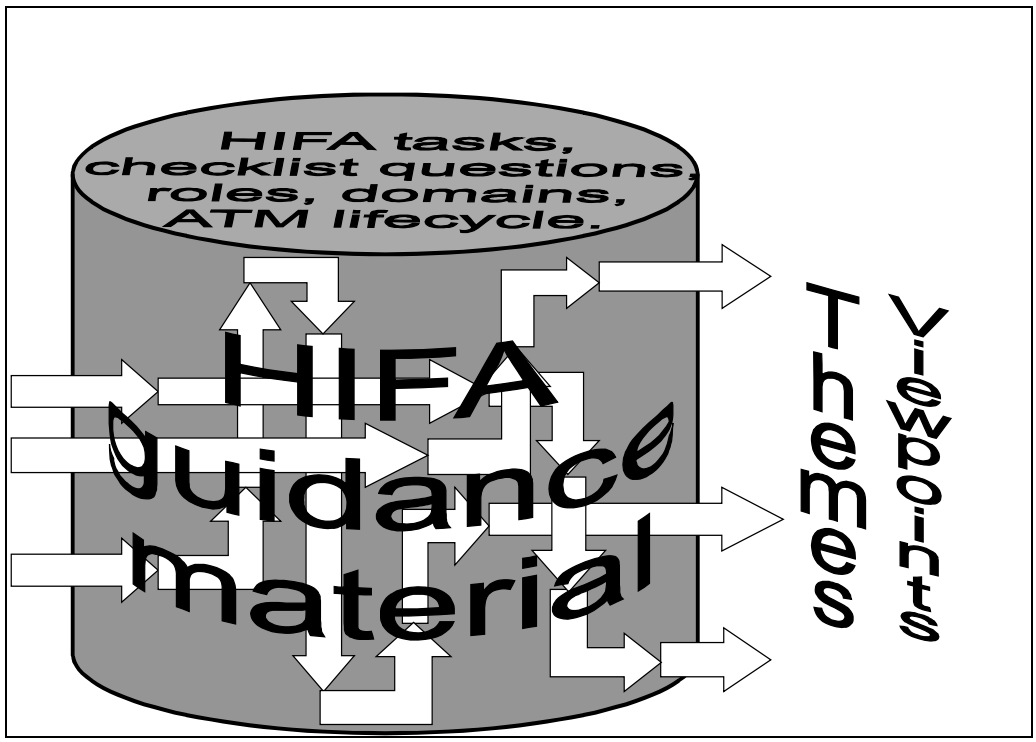


Figure 11: Alternative viewpoints through HIFA material

In the present report the 'database' of HIFA guidance material has until this point been logically organised by content (HIFA tasks and checklist questions) described as a function of HIFA structure (life cycle phases, HIFA domains and roles). However, a potential user may approach the HIFA material with an interest in a particular 'theme' (such as the training theme) or having the responsibility of carrying out a specific role (such as the HFI specialist role). It may be useful for them to be able to follow a specialist path or 'viewpoint' through the HIFA processes for different themes and job responsibilities. These alternative HIFA viewpoints may ultimately make the HIFA guidance material more approachable and relevant for users with particular interests.

Two examples of viewpoints are presented in Figure 12 and Table 6 below. The viewpoint in Figure 12 represents a user with a particular interest in EHFA (which was described earlier in Section 3.3.4 and Figure 10). The activities relevant to EHFA are brought together in one diagram, and the path through the various life cycle phases is clear, showing how EHFA evolves into requirements, design specifications, acceptance criteria, in-service measurement, and the EHFA of system up-grades or replacements. However, often more than one role is involved, so only the person who is most responsible has been shown. In addition, by considering the EHFA activity as a linear process in isolation and forcing it into this format, iteration is not shown and much information is lost. The viewpoint in Table 6 represents a user with a particular interest in, or responsibility for, training.

The facility for additional, user-requested viewpoints increases the flexibility of the HIFA guidance material and enables it to be tailored it to the requirements of a wider user population, so enhancing its usability. As such it can be regarded as a 'good thing'. However, the full picture may be lost if this viewpoint is considered in isolation. HIFA is a sophisticated and complex set of interleaving and interdependent processes, requiring a range of diagrammatic representations to convey its full information potential. Some interesting implementation issues are raised for Phase 2 of the HIFA Project.

Alternative viewpoints through the HIFA processes are possible. One example is the viewpoint of a user interested in the Early Human Factors Analysis (EHFA) theme. Another example is that of training.

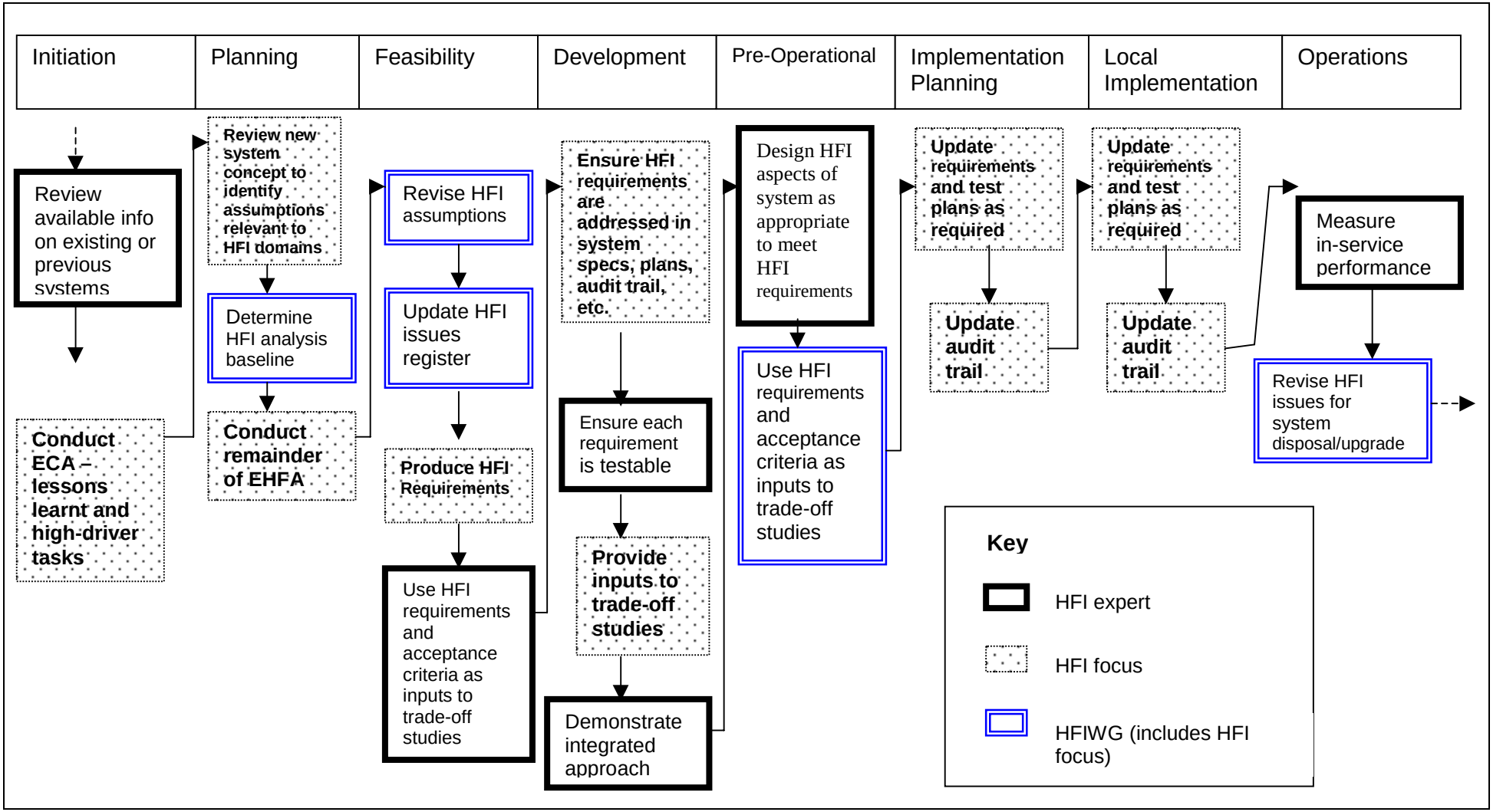


Figure 12: Example of HIFA viewpoint on Early Human Factors Analysis (EHFA).

Table 6: Example of HIFA viewpoint on training

Life Cycle Phase	HFI Tasks	HFI Checklist Questions
Initiation	• Identify existing or predecessor systems or sub-systems. • Identify human factors requirements and issues that need to be examined.	• Check training options. • Check high-driver tasks.
Planning	• Review new system concept. • Determine HFI analysis baseline. • Initiate high-level TAD. • Initiate high-level TAD.	• Check existing training facilities. • Check training options.
Feasibility	• Revise HFI assumptions and issues. • Determine constraints on performance, manning, training, potential technical solution and costs. • Define TAD and training requirements. • Produce HFI requirements for URD containing training policy. • Initiate TNA.	• Check training and maintenance policies. • Check tasks to be trained. • Check revisions to TAD. • Check trade-off areas.
Development	• Ensure HFI requirements will be addressed in system documentation. • Ensure each requirement is testable. • Demonstrate that integrated approach to HFI has been taken and trade-offs made. • Update TNA	• Check training requirements.
Pre-operational	• Provide inputs to trade-off studies. • Participate in design reviews. • Produce interface designs which promote effective task performance and minimise training requirements. • Produce HFI deliverables (e.g. definition of training facilities).	• Check HFI requirements have been met in training facilities spec. • Check task analyses and TNAs have fed into development of training programme. • Check task analysis data was used to optimise user/maintainer manuals. • Check task analysis was used to identify potential areas for negative transfer of training from existing systems. • Check TNA data was used to combat the potential loss of skills due to automation.
Implementation Planning	• Conduct final training. • Conduct final trade-offs. • Update requirements documents and test plans as required.	• Check proposed training achieves required performance standards. • Check it includes new skills to be trained. • Check it includes acceptable training media, methods and learning modules.
Local Implementation	• Assess whether there are any unresolved HFI issues associated with local implementation. • Update TAD and issues register.	• Check for any training gaps. • Check whether there are any significant differences between TAD of local State and the TAD used in system design. • Check whether sufficient training time has been allocated for all staff. • Check whether there are any human factors issues associated with local implementation.
Operations	• Conduct measurement of in-service performance (e.g. training time). • Update TAD. • Revise HFI issues for system disposal/upgrade.	• Check whether training programme is sufficient to maintain required skill levels. • Check for any training shortfalls. • Check skill retention of tasks that are not frequently performed. • Check training time to reach required skill levels.

6. APPLICATION OF HIFA IN EUROPEAN ATM

6.1 Questionnaire Survey of Potential HIFA Users

6.1.1 Introduction

A sample of potential HIFA users was identified through EUROCONTROL contacts. The objective was to investigate how potential HIFA users integrate human factors currently, and how human factors might fit in with their present project management and system development practices. The practical goal was to obtain relevant information about current users of human factors guidance material, what activities they carry out at the moment and what expectations they might have of future (HIFA) guidance material.

A questionnaire was designed by DERA and distributed by EUROCONTROL to members of the Human Factors Sub-Group (HFSG)[4] Resources Team (HRT). The questionnaire was divided into sections and is reproduced at Annex A.

6.1.2 HIFA Questionnaire Results

A total of seven replies to the questionnaire were received.

Since only a small number of replies to the questionnaires were available, it was not possible to carry out any statistical analysis. In addition, one should be cautious about over-generalising from such a small sample size. Nevertheless a number of interesting points were raised by the responses:

1. **Human factors guidance is becoming more important**. Human factors is being treated as a new area that is gaining impetus. There is a wide variation in the availability of human factors guidance material at present, ranging from none to detailed reports.

2. **Involvement of non-human factors specialists**. Non - human factors people are involved with human factors work and there are only a few human factors specialists employed per organisation.

3. **Understanding of human factors guidance**. The human factors guidance material needs to be written at a level that can be understood by non - human factors people. These may include managers, financial staff, clerical officers, air traffic controllers, system designers and computer scientists. This may mean that guidance will have to be provided at different levels according to the role of the guidance user.

[4] Group created by the Human Resources Team (HRT) under the auspices of the European Air Traffic Control Harmonisation and Integration Programme (EATCHIP), which has now become the European Air Traffic Management Programme (EATMP).

4. **Lack of support tools**. Very little is currently provided in the way of support tools or computer-based tools to give human factors guidance.

5. **Breadth of human factors guidance**. As well as low level information on human factors including human performance, guidance is also needed on how to enhance the safety, efficiency and cost-effectiveness of ATM. Guidance is also needed on how to perform tradeoffs (optimum balance between conflicting requirements) and identify operational concept / strategy.

6. **National adaptation**. Guidance needs to be applied to National circumstances and therefore the authors or producers of the guidance material need to know what the local implementation issues are.

7. **Training**. The guidance material by itself may not be sufficient; formal training may also be required.

8. **Practical examples**. The guidance should include practical examples of its use and benefits. For example, where human factors has *not* been integrated, the resulting poor system performance and costly design changes.

9. **Presentation of guidance material**. The guidance needs to be presented in a logical structure with easy access to information since it is likely to be used on a daily basis.

A questionnaire survey of current HFI practices within European ATM was conducted. The survey identified a number of interesting points concerning the design and use of the HIFA guidance material.

6.2 Interview Survey of ATM Project Managers

6.2.1 Introduction

The HIFA approach was presented to a number of experienced project managers of ATM projects, who were then interviewed as a means of obtaining initial feedback on HIFA's likely effectiveness. From DERA the managers of the Departure Manager (DMAN) and the Collaborative Decision-Making (CDM) Projects were interviewed. At EUROCONTROL Headquarters in Brussels a representative domain manager, a programme manager and a project manager were interviewed. The comments were extensive, positive and encouraging.

6.2.2 Interview Results

1. **Benefits of human factors**. Feedback indicated that the need to include human factors early in systems design and the benefits of so doing were well appreciated. A European country that had installed a commercial-off-the-shelf (COTS) product that was later rejected by controllers was cited as a case study.

   Human factors was seen to be important at a practical as well as a management level. The guidance material was felt to be quite high-level. That is, it would also require a means of linking to detailed practical human factors guidelines. (The third HIFA deliverable report on methods and tools provides this detail).

2. **Benefits of HIFA guidance material**. The HIFA guidance material was considered useful, clear and perhaps even straightforward, especially for new project managers when first setting up a project. They would find the checklist questions especially helpful in their level of detail. The guidance material was seen as part of a project manager's overall risk analysis and trade-off activity.

   Where human factors was taken into account at present in ATM projects this was often not systematic. The HIFA guidance material addressed this shortcoming. The current EATMP Management Handbook (EATCHIP, 1998c) stated the need to consider human factors, but did not say how to do so. Good project management guidance material is readily available, but it was much more difficult to find 'digestible' guidance material on human factors.

3. **Users of HIFA guidance material**. Integrated system development teams including potential end users were favoured. The need for early user involvement was stressed, but the timing of this was important – too early (Initiation, Planning phases) and the system consequences might not be thought through, whereas too late, and human-system problems might arise. The Feasibility life cycle phase was considered the optimum time. End-user stakeholders might include pilots as well as controllers.

   The likely audience for the HIFA guidance material would be EUROCONTROL project managers and the smaller European ATC administrations – the larger European ATC national administrations would be likely to already have their own project management framework and support tools. However, the guidance material was felt to be aimed at project managers who were following a life cycle similar to the EATMP project management life cycle, and therefore might be less relevant to those managers working to other life cycles.

   There remained a perceived role for human factors specialists, since users were frequently too involved to stand back from their operational task. Project mangers were often engineers or controllers who had an idea of what human factors was but did not possess detailed human factors knowledge.

4. **Improvements to the guidance material.** The number of HIFA required roles seemed large. In practice, several or all of the HIFA roles might be carried by a single person, such as (in the limiting case) by the project manager.

   Project size was seen as one important way of categorising a project and its level of management activity, but other criteria such as degree of innovation were also important. HIFA requirements for innovative conceptual or feasibility studies could be very different from those of large implementation projects. For example, arrivals management has been done for twenty years and is well established, whereas conflict resolution is much more innovative.

   The concept of 'intelligent tailoring' of the HIFA material to specific project criteria was favoured – all the material could be presented, but with some 'greyed out'. (Though presented at a lower priority, it could still be potentially useful). Example project scenarios of HIFA usage would be helpful.

5. **Application of HIFA guidance material**. HIFA activities and checklist questions forced very early consideration of human factors issues. Although answers might not be available at early project stages, the project manager would still be informed and prepared as to what human factors issues will arise later on. For example, until the system had been defined it was difficult to determine issues around the Human Computer Interface.

   It was thought useful to go through the checklist questions for all eight life cycle phases at each phase, so that the overall activity at each phase could be placed in the context of the other phases.

6. **Validation**. The need for practice projects on which to validate the HIFA framework and assess its usability was stressed.

7. **Presentation of guidance material.** In terms of its implementation, the managers stressed that the guidance material should be readable, jargon-free, straightforward and not too elaborate if it was to be used.

   In terms of electronic media, an Internet rather than a CD-ROM vehicle was favoured for the HIFA guidance material. In electronic form it should be integrated with the EATMP Management Handbook. (EATCHIP, 1998c; project management tools are already indicated in Section 7 of the handbook).

8. **Training**. The question of what training would be necessary to use the HIFA method was raised. It was not possible to give a definite answer to this, but it was thought that a small amount training would probably be necessary. This training could be given as part of a larger training course, for example on the use of the EATMP Management Handbook (EATCHIP, 1998c). More detailed training might be required for those individuals with specific HIFA roles or responsibilities. The issue of training will be considered in more detail in Phase 2 of HIFA.

Initial feedback on the HIFA guidance material from a selection of experienced ATM project managers was extensive, positive and encouraging. Topics covered included the benefits of HIFA, its potential users, improvements to the guidance material, and training issues. Comments on the optimum implementation of the HIFA material will inform Phase 2 of the project.

6.3 Practical Application of HIFA to EATMP Project Scenarios

6.3.1 Introduction

In Section 5.9 the notion of alternative users' viewpoints of or through the HIFA guidance material was put forward. In this section another perspective concerning the types of ATM projects that might use the HIFA material, is identified.

The design and development of ATM systems, just as for most other systems in today's society, is largely a project-based process. The projects vary enormously in terms of their cost, resources required, complexity, duration and so on. For example, one project might be a small concept study involving one or two people over six months; another might entail the construction of an entirely new air traffic control centre involving hundreds of people over a period of five-ten years. Although human factors has a role to play in both projects, their specific HFI requirements will be somewhat different.

An ATM project, or more likely a group of projects, can be thought of as representing a particular development scenario having a set of common project characteristics. A key problem is how to consider and combine all the different factors and dimensions that categorise project development scenarios, and how to subsequently invoke the appropriate level of HIFA guidance material. Clearly, the guidance material is not required equally by all projects.

In the following sections the dimensions of project development scenarios are discussed, and a provisional list of scenarios is identified.

6.3.2 Project Dimensions

A project development scenario can be thought of as a function of a number of dimensions. One major dimension is the size or total financial value of the project. However, the cost of the project is not the only indicator of the level of HIFA involvement. Early Comparability Analysis (ECA) at the Initiation phase will help to determine the level of human factors issues, system safety issues, likely training burden, etc. For example, where automation is introduced the number of potential users plus the level of risk associated with situational

awareness, safety, reliability, etc. should be considered. The degree of innovation of the project may also be an issue, as will the degree of system safety – crucial for ATM systems.

From an abstract point of view, a project can be considered as having three dimensions of 'length', 'breadth' and 'depth' as illustrated in Figure 13. Two further dimensions are size and risk.

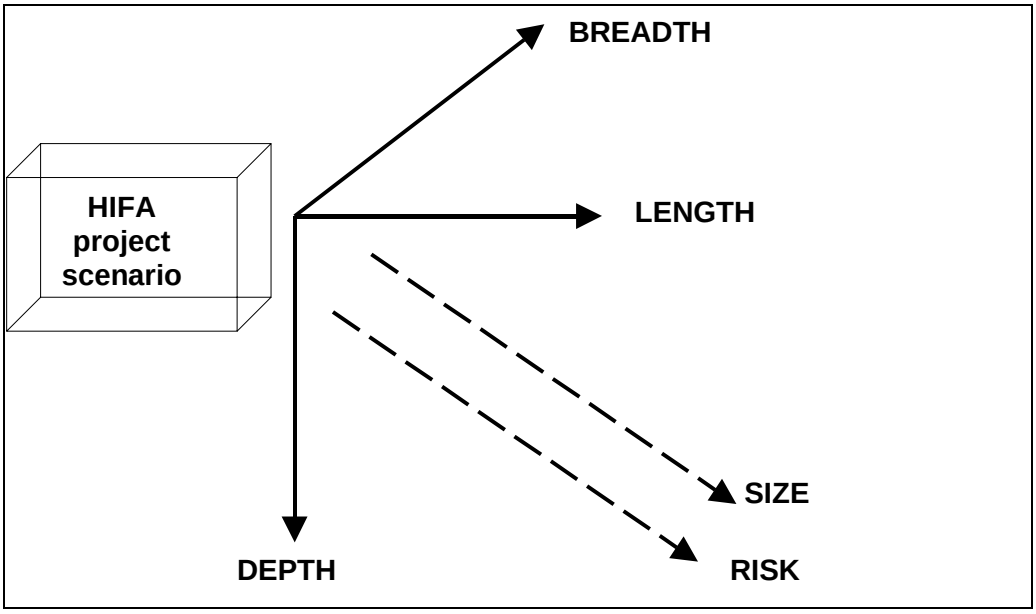


Figure 13: Dimensions of project development scenarios

The dimensions, which are not mutually exclusive, are defined as follows:

LENGTH

- When within the project life cycle is the project located?
- Does the project cover a single life cycle phase or extend over all phases?
- What is the duration of the project?

This dimension will reference **time and sequencing** aspects of the HIFA guidance material appropriate to the relevant phases of the ATM project life cycle.

BREADTH

- Which ATM functions does the project cover?
- Is the project concerned with a single function, procedure, tool, or sub-system, or does it cover a number of linked subsystems, or even a total ATM system?

This dimension will reference the **volume** of the HIFA guidance material appropriate to the number of relevant phases of the ATM project life cycle covered.

DEPTH

- How is the project being carried out? What is being done and to what level of detail?

- Is the project a paper-based study only, or does it involve building prototype systems using real-time simulation, or does it cover every aspect of a complete ATM system?

This dimension will reference the **level of detail** of the HIFA guidance material appropriate to the relevant phases of the ATM project life cycle.

SIZE

- What is the cost of the project? How much effort is available to be expended? For example, is the project very small employing o1 man-month at a cost a few thousand EUROs, or very large involving many man-years at a cost of millions of EUROs?

- Does the project involve other organisations?

- Is the project being conducted at one site in one country, or does it involve many sites spread across several countries?

This dimension, which clearly embraces the other dimensions already mentioned, will influence the **number of personnel** available to fill the HIFA roles as well as the total amount of HFI activity on the project.

It is difficult to provide a mechanism for 'sizing' a project precisely, but a potentially useful approach is already used by many organisations as part of their quality control procedures. For example, an empirical project sizing matrix is used by DERA. The size of a project is determined by first rating its size for each of a number of factors (e.g. cost, size of project team, number of participating organisations, technical complexity, time pressure, degree of innovation). A weighting formula is then applied, and finally a single numeric value is calculated, according to which the project may be sized as 'small', 'medium' or 'large'. The size of the project then determines the degree of quality controls that are applied. Although an empirical rather than theoretic approach, it has been shown to be very effective in practice.

A similar approach could be utilised for the purposes of HIFA. However, instead of the project size determining the level of quality control, it could indicate the amount of human factors effort required and the associated HIFA roles. An example of this approach is illustrated in Table 7.

Table 7: HIFA activity as a function of project scenario size

Project size	Implications for HIFA and Number of HIFA roles required on project
Very small	HFI focus not necessary Project manager + human factors expert + project team
Small	As above, + Stronger HFI presence
Medium	As above, + HFI focus
Large	As above, + Domain experts + HFIWG(s)
Very large	As above, + Higher activity for HFI roles

As can be seen, the required effort and number of roles increase with project size. It must be stressed that the HIFA roles are not equivalent to separate individuals - several roles could be carried by a single person (such as the project manager) depending on the scale / effort of the project.

RISK

- What is the degree of risk within the project?
- Is the subject of the project well-established, or innovative, or totally 'blue-sky' in its degree of novelty?

This dimension determines the degree of project quality control to be administered (and with it the degree of HIFA activity invoked).

6.3.3 Typical Project development scenarios

Based on the above analysis of project dimensions, and also drawing on the earlier feedback from potential users of the HIFA guidance material, a provisional list of ten project development scenarios is put forward. (These each have a particular emphasis, but are not necessarily mutually exclusive.)

1. **A scenario covering a single life cycle phase**.

   An example of this scenario might be a project at the feasibility phase concerned with the concept for a new computer-based support tool for controllers, or perhaps a proposed change to airspace route structure. A project at the Local Implementation phase might be concerned with the

integration of new display equipment in a control room, or perhaps a change in procedures.

2. **A scenario extending over two or more life cycle phases**.

   An example of this scenario might be a project extending over Feasibility and Development phases, involving the prototyping and simulation of a new concept of operation.

3. **A scenario covering the whole life cycle**.

   An example of this scenario might be the design and construction of a new air traffic control centre (e.g. the proposed New Scottish Centre in the UK). Clearly, all HFI tasks would be expected to be carried out, and all HIFA roles would be invoked.

4. **A scenario concerned with an individual sub-system or tool**.

   An example of this scenario might be the development of a collision avoidance system (e.g. Short Term Conflict Alert) which covers all of the life cycle phases from Initiation to Operations. Such a scenario, it should be noted, is likely to be of a long duration.

5. **A scenario of limited scope**.

   An example of this scenario might be a project which is ‘paper-based’ only, or involves analytical modelling, during one part of one life cycle phase.

6. **An experimental scenario**.

   An example of this scenario might be a project that is concerned solely with experimental prototyping and/or real-time simulations. Such a project, which is common to much ATM research and development, might be one part of a larger project being conducted during one or more life cycle phases.

7. **A scenario focused on in-service enhancements**.

   An example of this scenario might be a project involving modifications to in-service operational equipment, or the up-grading of existing systems. The scope of the development scenario could be fairly limited, or it could be broad and complex (e.g. changing ATC system from paper flight progress strips to electronic version).

8. **A scenario determined by project size**.

   An example of this scenario might be a project that has been graded (by some unspecified scoring matrix) as either very small/small/medium/ large/very large which in turn determines a corresponding number of HFI personnel.

9. **A scenario concerned with particular theme or viewpoint**.

   An example of this scenario might be a project that is concerned only with training issues throughout the whole life cycle (as illustrated in Table 6) or maintenance issues or human-computer interface (HCI) design.

10. **A scenario concerned with Early human factors Analysis**.

    This scenario would involve a project focused on Early Human Factors Analysis (EHFA) only, possibly because it has been identified as a critical activity that required special attention and resources.

6.3.4 Validation

There is a requirement to obtain feedback on the HIFA methodology and to validate it in practice on a range of real-life, European ATM project development scenarios. There is a corresponding need to identify a range of these ATM projects - which should ideally be relevant to the life cycle in the EATMP Management Handbook (EATCHIP, 1998c). These issues will be explored more fully in HIFA Phase 2.

Project development scenarios are discussed and characterised in terms of the dimensions of 'length', 'breadth', 'depth', size and risk. A provisional list of ten scenarios is put forward which can be used to determine the amount and type of HIFA guidance material used on given ATM projects. The HIFA methodology needs to be validated on a range of real-life European ATM projects.

7. CONCLUSIONS

1. The overall goal of the HIFA Project is to make project users aware of the importance and benefits of integrating human factors within the ATM project life cycle, and to give them the necessary knowledge and structured framework to enable them to effectively implement such programmes within their organisation. To this end this document aims to provide appropriate and effective guidance material about HFI for project users.

2. In fulfillment of the second part of Phase 1 of the HIFA Project HFI activities and system development scenarios are identified for including human factors considerations within the project life cycle of European ATM projects.

3. An overview of the HIFA approach is presented, informing project managers of the reasons for considering human factors issues and providing detail of necessary HIFA activities to perform and HIFA questions to ask.

4. A hierarchical process levels model is proposed linking business management, project management, systems engineering, software coding and hardware implementation for European ATM projects.

5. The need for and benefits of HFI are stated. The historical origins of HFI are reviewed, containing precedents for the inclusion of human factors within European ATM project procurement.

6. The total systems scope, hierarchical structure, overall process model and domain content of HFI are described.

7. An overall process model of the EHFA is presented, emphasising the need for consideration of human factors issues at the earliest stages of the project life cycle.

8. Within the EATMP project life cycle, emphasis is placed upon early consideration of human factors analysis, maintenance and local implementation issues, as well as the later operational activities of maintenance, in-service enhancements, re-cycling and system de-commissioning.

9. Based on its MANPRINT / HFI / FAA heritage, a European HIFA modified for ATM projects is proposed. A top-level description of key HIFA issues and outputs is presented for each phase of the EATMP project life cycle.

10. A detailed set of HIFA roles and responsibilities is presented necessary for effective implementation of HIFA within European ATM projects.

11. In a major section of the document, detailed HIFA activities are described for each phase of the EATMP project life cycle, noting the HIFA role responsible for carrying out each task.

12. Some alternative viewpoints of the HIFA process are discussed. An example viewpoint of the EHFA theme is presented.

13. Detailed HIFA checklist questions are listed for each of the six HIFA domains at each phase of the EATMP project life cycle.

14. A questionnaire survey of potential ATM project users of the HIFA methodology was undertaken and the results presented. The need for specialist HIFA guidance presented in an easy-to-use form is confirmed.

15. The HIFA methodology was presented to a selection of DERA in-house project managers and experienced EUROCONTROL project managers to obtain their feedback on its likely effectiveness. Feedback from these presentations provided an encouraging degree of support and many useful comments on the HIFA approach and its potential implementation.

16. Project development scenarios are discussed and characterized in terms of the dimensions of 'length', 'breadth', 'depth', size and risk. A provisional list of ten scenarios is put forward which can be used to determine the amount and type of HIFA guidance material used on given ATM projects. The HIFA methodology needs to be validated on a range of real-life European ATM projects.

In summary this report has shown that it is possible successfully to adapt existing multi-national Human Factors Integration (HFI) approaches to produce human factors guidance material appropriate for the design of future ATM systems. The guidance material, known as HIFA for Human Factors Integration for Future ATM Systems, will be implemented using appropriate electronic media for use and evaluation within European ATM projects in HIFA Phase 2.

ANNEX A: HIFA QUESTIONNAIRE

Human Factors Integration in Future ATM Systems

Questionnaire

The aim of this questionnaire is to ascertain the current role and the future potential use of Human Factors Guidance material in the development of systems for Air Traffic Management, within the European national ATC authorities and ATM industries.

We would appreciate your cooperation in spending 10 minutes answering the questions below. **Please return the questionnaire either by mail or fax before 18 June 1999 to:**

Mr. Johan Kjær-Hansen

Address: **EUROCONTROL, DIS/HUM**
Rue de la Fusée, 96
1130 - BRUSSELS
BELGIUM

Fax: **+32-(0)2-729.9149**

If you have questions regarding the questionnaire do not hesitate to phone Johan on +32-(0)2-729.4773.

***Note*: All replies will be treated in confidence.**

An information sheet on the HIFA project is attached at the end.

A. ABOUT YOU

1. Please provide your name, address and other details (in case we need to contact you for further information or clarification). OPTION OF REMAINING ANONYMOUS.

Name:
Organisation:
Phone:
Fax:
E-mail:
Role in organisation:
Professional background / training:
Occupation:
Years experience in human factors:
Areas of human factors experience:

B. ABOUT YOUR ORGANISATION

2. Name of organisation:

Country:
Role of organisation:
Size:

C. ABOUT HUMAN FACTORS IN YOUR ORGANISATION

3. How many human factors specialists or practitioners are employed within your national administration?

☐ 0
☐ 1 - 4
☐ 5 - 9
☐ 10 - 19
☐ Over 20

4. Do other (non-human factors) employees within your organisation become involved with human factors work?

☐ yes
☐ no
☐ don't know

If 'yes', please specify:

D. ABOUT HUMAN FACTORS ACTIVITY IN YOUR ORGANISATION

5. What main type(s) of human factors activities, if any, are carried out within your organisation?

- ☐ none
- ☐ project support
- ☐ research studies
- ☐ consultancy
- ☐ don't know
- ☐ other (specify) .....

6. **What type(s) of human factors <u>project support</u>, if any, is carried out within your organisation?** (Tick more than one box if required)

- ☐ design specification(s)
- ☐ task analysis
- ☐ prototyping
- ☐ simulation
- ☐ observation and data collection
- ☐ other (specify) .....

7. What type(s) of human factors <u>research</u>, if any, is carried out within your organisation? (Tick more than one box if required)

- ☐ workload assessment
- ☐ selection and training
- ☐ teamwork
- ☐ automation and computer assistance
- ☐ human computer interface (HCI)
- ☐ workstation design
- ☐ displays
- ☐ human factors guidance
- ☐ other (specify) .....

8. What is your view of the role of human factors guidance within your organisation?

E. ABOUT DEVELOPMENT METHODS OR TECHNIQUES USED BY YOUR ORGANISATION

9. What system development methods or techniques does your organisation employ when developing ATM systems?

10. What Project management framework or techniques does your organisation employ e.g. Quality Management System (QMS)

11. What support tools or computer toolkits does your organisation employ?

12. How is human factors currently integrated in the system development process within your organisation?

- ☐ not integrated
- ☐ human factors specialist included in design team
- ☐ in-house specialists tied to the project
- ☐ by external consultants when problems occur
- ☐ don't know
- ☐ other (specify) .....

F. ABOUT HUMAN FACTORS GUIDANCE MATERIAL IN YOUR ORGANISATION

13. Does your national administration currently use any human factors guidance material?

- ☐ yes
- ☐ no
- ☐ don't know

If yes, please explain:

14. Does your national administration intend developing any human factors guidance material in the future?

G. ABOUT THE POTENTIAL USE OF HUMAN FACTORS GUIDANCE MATERIAL IN YOUR ORGANISATION

15. What are your needs from human factors guidance material?

16. Give some typical examples of the questions you might seek answers to from the guidance material

17. In your opinion, how should the human factors guidance material be structured and presented so you could best make use of it?

18. How often might you consult the human factors guidance material?

19. In your organisation, who might be the potential classes of user of the human factors guidance material?

- ☐ ATCOs
- ☐ Project Mangers
- ☐ Financial experts
- ☐ Personnel department
- ☐ Heads of Department / CEOs
- ☐ Human factors experts
- ☐ System designers
- ☐ Computer scientists
- ☐ Engineers
- ☐ other (specify) .....

H. ANYTHING ELSE

20. Any other comments you would like to make?

Thank you for sparing the time to complete this questionnaire.

HIFA
Human Factors Integration in Future ATM Systems
Project information sheet

HIFA Project rationale and overview

The integration of human factors in the ATM system life cycle is an important means in making ATM systems effective and safe and in order to minimise the life cycle costs. A more substantial effort is needed to turn the growing awareness towards these aspects of system development and the life cycle in general into concrete action.

The HIFA Project aims to make users and stakeholders aware of the importance and benefits of integrating human factors in the ATM life cycle, and give them the appropriate support to effectively implement such programmes in their organisation. The project will develop guidance material for users and make it widely available. A discussion forum and network of people will be established to amplify and sustain the use and impact of the guidance material.

The products and services of the project will support managers responsible for system development, human factor specialists and system designers who need guidance in planning Human Factors Integration (HFI) and in selection and applying methods and tools.

The initial phases of the project have concentrated on establishing awareness concerning the issues involved and in establishing an initial forum of practitioners and academics who need support on the subject. Work on guidance material for how to integrate human factors in the ATM life cycle is currently being conducted.

Objectives of the project

The HIFA Project has been established to provide a basis and support for integrating human factors in the ATM systems life cycle. The project will seek to achieve the following objectives:

- To identify stakeholders needs and to establish state-of-the-art on HFI in ATM system development;
- To create awareness to HFI and human-machine systems in ATM system development;
- To organise a network of people interested in issues related with HFI and human factors in human-machine systems;
- To participate and support HFI in ATM system development programmes and projects inside and outside EUROCONTROL.

In order to gain an understanding of the current state-of-the-art on HFI in ATM system development, it was decided to distribute a questionnaire to members of the Human Factors Sub-Group (HFSG).

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ABBREVIATIONS AND ACRONYMS

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

ASATC	Automated Support to ATC
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer / Air Traffic Controller *(UK/US)*
ATD Unit	Air Traffic Control & Data Processing Unit *(EUROCONTROL, SDE, DIS; also known as DIS/ATD)*
ATM	Air Traffic Management
CBA	Cost-Benefit Analysis
CDM	Collaborative Decision-Making
CoE	Centre of Expertise
CDPI	Chief of Defence Procurement Instruction
CD-ROM	Compact Disc – Read-Only Memory
CMM	Capability Maturity Model
COPS	Common Operational Performance Specifications
COTS	Commercial-Off-The-Shelf
CRP	Corporate Research Programme
DCDS	Deputy Chief of Defence Staff
DERA	Defence Evaluation and Research Agency *(UK)*
DIS	Director(ate) Infrastructure, ATC Systems and Support *(EUROCONTROL, EATMP, SDE)*
DIS/ATD	See ATD Unit
DIS/HUM	See HUM Unit
DMAN	Departure MANager
DoD	Department of Defense *(US)*
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme *(now EATMP)*
EATMP	European Air Traffic Management Programme *(formerly EATCHIP)*
EATMS	European Air Traffic Management System

ECA	Early Comparability Analysis
ECAC	European Civil Aviation Conference
ECU	European Currency Unit
EHFA	Early Human Factors Analysis
EIA	European Space Agency
ET	Executive Task *(EATCHIP)*
FAA	Federal Aviation Administration
FMECA	Failure Mode Effects and Criticality Analysis
GUI	Guidelines *(EATCHIP/EATMP)*
HAZOPS	Hazard and Operability Study
HCI	Human Computer Interface (or Interaction)
HFI	Human Factors Integration
HFIWG	Human Factors Integration Working Group
HHA	Health Hazards Assessment *(HFI Domain)*
HIFA	Human factors Integration in Future ATM systems
HMSO	Her (or His) Majesty's Stationery Office
HRS	Human Resources Programme *(EATMP, HUM)*
HSP	Human Factors Sub-Programme *(EATMP, HUM, HRS)*
HUM	Human Resources (Domain)
HUM Unit	Human Factors and Manpower Unit *(EUROCONTROL, EATMP, SDE, DIS; also known as DIS/HUM; formerly stood for 'ATM Human Resources Unit')*
ICAO	International Civil Aviation Organization
ILS	Integrated Logistic Support
ITT	Invitation To Tender
KECU	Thousands of European Currency Units
KIT	Key Issues Tool *(HFI tool)*
LSA	Logical Support Analysis
M	Manpower *(HFI Domain)*
MANPRINT	MANpower, PeRsonnel and INTegration
MoD	Ministry Of Defence *(UK)*
MTTR	Mean Time To Repair

ODIAC	Operational Development of Integrated Air / ground data Communications
P	Personnel (HFI domain)
PATIO	Platform for ATM Tool Integration up to pre-Operational
PHARE	Programme for Harmonised ATM Research in EUROCONTROL
POEMS	Pre-Operational European Mode S
QA	Quality Assurance
R&D	Research and Development
REP	Report *(EATCHIP/EATMP)*
SASS	Surveillance Analysis Support System
SDE	Senior Director, Principal EATMP Directorate *(EUROCONTROL)*
SHA	Safety Hazard Analysis
SPI	Smart Procurement Initiative
SS	Systems Safety *(HFI Domain)*
T	Training *(HFI Domain)*
TAD	Target Audience Description
TID	Task and Interface Design *(HFI Domain)*
TNA	Training Needs Analysis
URD	User Requirements Document
USS	United States Ship
V&V	Validation and Verification
WG	Working Group
WP	Work Package *(EATCHIP/EATMP)*
WWW	World Wide Web

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