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FOR THE SAFETY OF AIR NAVIGATION

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Guidelines for Trust in Future ATM Systems: Principles

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Abstract

The purpose of this document is to provide a concise list of principles and guidelines for facilitating and fostering human trust in Air Traffic Management (ATM) systems. It concerns controller trust with computer-assistance tools and other forms of automation support, which are expected to be major components of future ATM systems.

This document, the third one developed within the 'Solutions for Human-Automation Partnerships in European ATM (SHAPE)' Project, is a supplementary note to the first main deliverable which provides a detailed review of the literature on trust (see EATMP, 2003a). It is intended as a support document in practical design issues.

Keywords

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Human Factors	Principles	Self-confidence
Simulation	Solutions for Human-Automation Partnerships in European ATM (SHAPE)	System
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CONTENTS

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EXECUTIVE SUMMARY

This document provides human factors guidelines for facilitating and fostering human trust in ATM systems. In particular, it is concerned with the trust of computer-assistance tools and other forms of automation support, which are expected to be major components of future ATM systems.

It contributes to the first part of a larger project entitled ‘Solutions for Human-Automation Partnerships in European ATM (SHAPE)’ being carried out by the ATM Human Resources Unit of EUROCONTROL, later renamed Human Factors and Manpower Unit (DIS/HUM).

The former UK Defence Evaluation and Research Agency (DERA), now known as QinetiQ, was awarded the investigation of three specific human factors topics concerned with trust (see the current document and EATMP, 2003a, 2003b), situation awareness (see EATMP, 2003c) and teamworking (currently under preparation).

Four additional human factors issues are also in the SHAPE overall objectives: recovery from system failure, workload and automation, future controller skill-set requirements, and experience and age (see EATMP, 2003d).

This deliverable, on the subject of trust guidelines, is the third one for the SHAPE Project. There are two preceding deliverables on trust issues; the first one is dealing with a literature review about trust (see EATMP, 2003a), while the second one provides detailed information about trust principles (see EATMP, 2003b).

Section 1, **‘**Introduction**’**, outlines the background to the project, and the objectives and scope of the deliverable.

Section 2, ‘Principles for the development of trust’, provides general principles for the understanding of trust. It provides the principles to be considered during the development phase of new systems and the principles for the implementation and operational phase defines what is meant by automation, introduces the concept of different ‘levels’ of automation and provides a brief review of human factors research.

Section 3, ‘Conclusions’, summarises the issue of the document what is meant by trust, discusses the different elements or dimensions which trust is composed of, and explains the notion of ‘complacency’. How trust is understood in ATC is discussed.

Section 4, ‘Recommendations’, provides a short overview of principal recommendations for achieving trust.

References, a list of the Abbreviations and Acronyms used in these guidelines and their full designations, and Acknowledgements are provided at annex.

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1. INTRODUCTION

1.1 Purpose

The purpose of this document is to provide a set of guidelines for facilitating and fostering Air Traffic Controller (ATCO) trust in future ATM systems. The guidelines are primarily concerned with the trust of new ATC interfaces, and new computer-assistance tools and other forms of automation support, which are expected to be major components of future ATM systems.

1.2 Scope

The publication contains a condensed description of the trust guidelines and intends to be used as a supplementary document in practical design issues. It is based on two other documents, respectively entitled ‘Guidelines for Trust in Future ATM Systems: A literature review’ (see EATMP, 2003a) and ‘Guidelines for Trust in Future ATM Systems: Measures’ (see EATMP, 2003b). These deliverables contain further information about the issue of trust and possibilities to measure its impact on the overall system performance. The trust issue was investigated in the framework of the ‘Solutions for Human-Automation Partnerships in European ATM (SHAPE)’ Project which aims to understand how automation and controllers can work together effectively.

Whilst the document is concerned primarily with trust, the principles and guidelines have implications for ATM system design such as usability, acceptability and training. The document is intended to provide practical advice to EUROCONTROL project leaders and other project staff who are concerned with such automation design issues.

1.3 Background

The trust ATM presented in this module is embedded in a larger project called ‘Solutions for Human-Automation Partnerships in European ATM (SHAPE)’. The SHAPE Project started in 2000 within the Human Factors Sub-Programme (HSP) of the EATMP Human Resources Programme (HRS) conducted by the ATM Human Resources Unit of EUROCONTROL, now known as the Human Factors and Manpower Unit (DIS/HUM) (see EATMP, 2000).

SHAPE is dealing with a range of issues raised by the increasing automation in European ATM. Automation can bring success or failure, depending on whether it suits the controller. Experience in the introduction of automation into cockpits has shown that, if human factors are not properly considered, ‘automation-assisted accidents’ may be the end result.

Seven main interacting factors have been identified in SHAPE that need to be addressed in order to ensure harmonisation between automated support and the controller:

- Trust: The use of automated tools will depend on the controllers' trust. Trust is a result of many factors such as reliability of the system and transparency of the functions. Neither mistrust nor complacency are desirable. Within SHAPE guidelines were developed to maintain a correctly calibrated level of trust (see EATMP, 2003a, 2003b, and this document).

- Situation Awareness (SA): Automation is likely to have an impact on controllers SA. SHAPE developed a method to measure SA in order to ensure that new systems do not distract controllers' situation awareness of traffic too much (see EATMP, 2003c).

- Teams: Team tasks and performance will change when automated technologies are introduced (team structure and composition change, team roles are redefined, interaction and communication patterns are altered). SHAPE has developed a tool to investigate the impact of automation on the overall team performance with a new system (currently under preparation).

- Skill set requirements: Automation can lead to both skill degradation and the need for new skills. SHAPE identifies new training needs, obsolete skills, and potential for skill degradation aiming at successful transition training and design support (currently under preparation).

- Recovery from system failure: There is a need to consider how the controller will ensure safe recovery should system failures occur within an automated system (currently under preparation).

- Workload: With automation human performance shifts from a physical activity to a more cognitive and perceptual activity. SHAPE is developing a measure for mental workload, in order to define whether the induced workload exceeds the overall level of workload a controller can deal with effectively (currently under preparation).

- Ageing: The age of controllers is likely to be a factor affecting the successful implementation of automation. Within SHAPE this particular factor of human performance, and its influence on controllers' performance, are investigated. The purpose of such an investigation is to use the results of it as the basis for the development of tools and guidance for supporting older controllers in successfully doing their job in new automated systems (see EATMP, 2003d). Note that an additional report providing a questionnaire-survey throughout the Member States of EUROCONTROL is currently under preparation.

These measures and methods of SHAPE support the design of new automated systems in ATM and the definition of training needs. It also facilitates the preparation of experimental settings regarding important aspects of human performance such as potential for error recoveries or impacts of human performance on the ATM capacity.

The methods and tools developed in SHAPE will be complied in a framework in order to ease the use of this toolkit in either assessing or evaluating the impact of new systems on the controller performance, efficiency and safety. This framework will be realised as a computerised toolkit and is planned to be available end of 2003.

1.4 SHAPE and Trust

The first area of investigation in the SHAPE Project has been in the area of trust in automation. Experience in cockpit automation (e.g. Billings, 1996) has shown that trust is an important variable in achieving satisfactory and safe system performance. However, trust is difficult to achieve and maintain, yet easy to lose, and difficult to recover once lost. A literature review, being reported in a separate document (EATMP, 2003a), explores the experience with this variable in a number of fields, and extracts what can be learned from fields as diverse as cockpit automation and nuclear power plant operation. This experience is being fed into the development of a measure of trust that can be applied in prototyping and real-time simulations, so that trust can be measured and tracked throughout the system development cycle. If trust is being lost, then it can be detected early and acted upon.

During the investigation of trust in this work package, certain insights were gained from newly developing and developed centres in Europe, in terms of how these centres are dealing with, or indeed are managing, trust. This current document attempts to capture these insights in the form of principles for developing trust. These principles have arisen more from practical experience than academic study, but nonetheless they do concord with principles found in the literature. The intention is that these principles may help those concerned with new system or tool development and implementation.

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2. PRINCIPLES FOR THE DEVELOPMENT OF TRUST

2.1 Introduction

The principles and guidelines for the development of trust in ATM systems presented in the following sections have been distilled from a number of important sources:

- General human factors experience of conducting real-time simulations, particularly involving the introduction of computer assistance tools and other forms of automation support. In particular the PHARE[1] demonstrations (PD/1, PD/2 and PD/3[1]) have provided many insights.
- Observations of recent real-time simulations at the EUROCONTROL Experimental Centre (EEC), Brétigny, France, in particular the FRAP[1], FREER[1], CORA1[1] simulations.
- Extensive review of research literature on trust and consultation with leading experts in the field.
- Visits to the new Air Traffic Control Centre (ATCC) at Rome and to the developing ATCCs at Malmö and Stockholm in Sweden. During the course of these visits (November-December 2000) practical insights were gained on the subject of how to gain controller trust in new tools and new systems.

The principles set out below have been grouped according to some key issues in system development (e.g. training of controllers) and, as far as possible, for different phases of the system development life cycle, as follows:

2.2. General - Understanding Trust.
2.3. Development Phase - Involving the Users.
2.4. Development Phase - Real-time Simulations.
2.5. Implementation Phase - Controller Training.
2.6. Operational Phase - Training and Transition.
2.7. Operational Phase – The Use of Backup Systems.

[1] PHARE: Programme for Harmonised Air Traffic Management Research in EUROCONTROL
PD/1/2/3: PHARE Demonstration 1/2/3
FRAP: Free Route Airspace Project
FREER: Freer Flight
CORA1: Conflict Resolution Assistant 1

2.2 General - Understanding Trust

1. Trust is a critical factor

The acceptability and use of ATM systems have always depended on trust. Controllers need (it is really a need) to trust their radar and communications equipment, trust the safety of their procedures and instructions, and, ultimately, trust pilots and others to follow those instructions correctly. However, with the introduction of computer assistance 'tools' and other forms of automation support, trust is becoming more important because **it is potentially harder to gain, easier to loose and even more difficult to recover when lost.**

2. The aim of training is appropriate trust

It is NOT the case that the object of training and experience is to "make the controllers trust the system" in a blind or uncritical manner. It is for them to develop trust *at the appropriate level*, neither too much nor too little. There are cases where training should make the controller not trust the system, i.e. when it is not reliable. The different aspects of trust (correct trust, over-trusting, under-trusting) are illustrated in Figure 1.

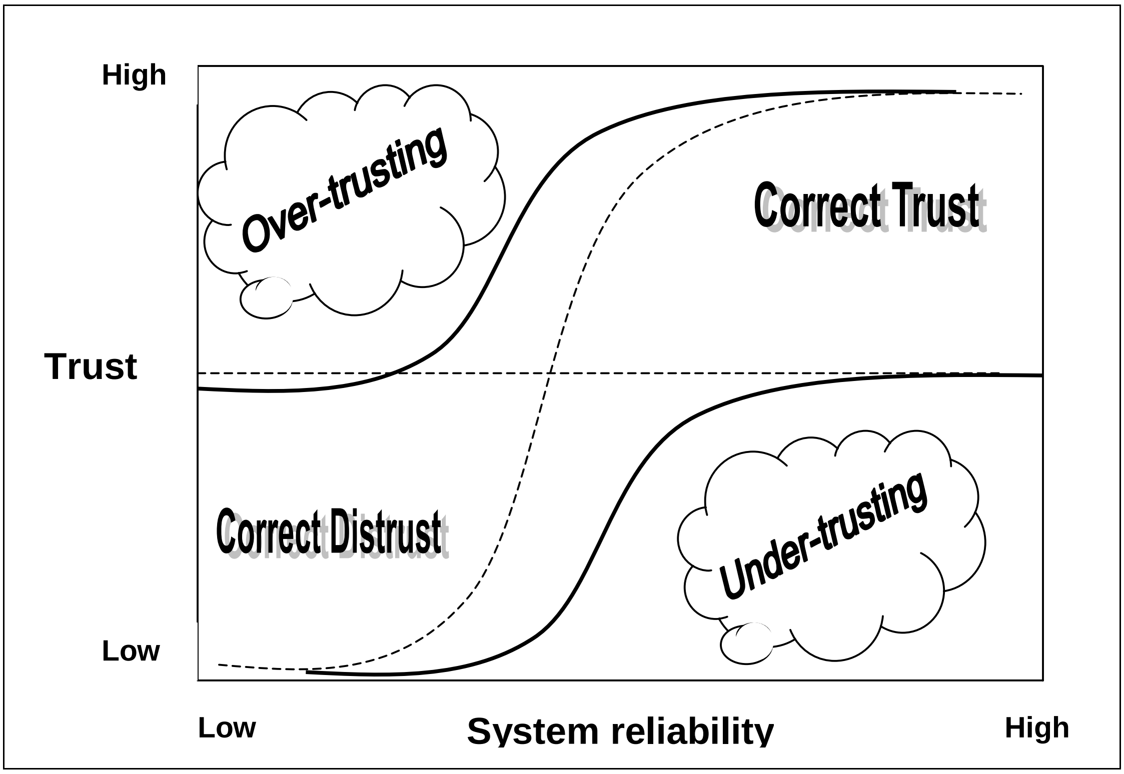

Figure 1: Theoretical relationship between trust and system reliability

3. Distrust is more resistant to change than trust

   Experimental evidence indicates conclusively that *distrust* is more resistant to change than trust. In practical terms this suggests that if controllers lose trust in the automated tools that they are using, it is difficult to regain that trust. This reinforces the message that simulations with new automated tools should not be undertaken unless a reasonable degree of system reliability can be guaranteed (see item 7 in 2.3) and that the controllers have been briefed about known limitations of the tools (see item 12 in 2.5).

4. Dynamics of trust and self-confidence are different

   Trust in the system and trust in one's own abilities (self-confidence) are both needed for optimal performance. The two are related but different. That is, the causal factors driving the dynamics of trust are different from those driving self-confidence. Trust seems to be reduced by **properties** of the system (e.g. real or apparent false diagnoses), whereas self-confidence is reduced by negative **experiences** of the human operator (e.g. experiences of near-miss events and incidents). Therefore, trust will be increased by reliable system performance; self-confidence will be increased by feelings of being in control.

2.3 Development Phase - Involving the Users

5. Involve a substantial proportion of the controllers who will inherit the system

   So as to increase the likelihood that the new system will 'fit' most controllers and the constraints of their tasks, a representative number of controllers should be involved to provide advice and feedback in the development of the system. Not only should this help with system development, but it should also give a reasonable number of controllers a feeling of 'ownership' which they can transmit to their colleagues, thereby helping to facilitate the development of trust.

   In Rome the proportion used was 20% of the controller workforce. NATS (UK) used a similar approach for the New En-Route Centre (NERC), via the NERC Training (or Transition) Team (NTT). In Sweden there are also presently a significant number of controllers involved in the transition to the new system.

6. Involve a representative sample of users

   There is a tendency to take whomever is available on such projects, rather than who needs to be there. It may be, for example, that mainly Area controllers are part of the transition team, even though the system is also planned for Approach controllers. Such aspects can induce a lack of trust in the under-represented 'stakeholder' party. The Swedish CAA

(SCAA), for example, originally formed a representative sample from **all** air traffic services, including small Tower services, based on a division of the country into information areas with dedicated staff from each area.

2.4 Development Phase - Real-time Simulations

7. The system must be reliable

Trust is strongly affected by system reliability (though self-confidence is not). It is important therefore that the system is reliable before commencing any assessments of performance. The exception may be the prototype-testing phase, as long as the participants are fully aware that it is a prototype that is being tested, and therefore have appropriate expectations. Even with such assurances, however, trust may still be affected negatively by the participants' experiences with system unreliability.

It is difficult to trust a system that keeps breaking down, even when the reason is known and understood (e.g. unstable platform, software glitches, etc.). Certainly by the time the formal transition-training period starts the system needs to be virtually 'bug-free'.

8. Avoid the system 'missing'

In order to promote the building of trust in a system, the opportunity for the system to 'miss' (fail to detect what it is trying to achieve) should be made as low as possible. This relates to the primary mission or function of the system. For instance, if it is Medium-Term Conflict Detection (MTCD) it must not miss conflicts that the controller can clearly see. However, it is often the case that by increasing the sensitivity of a system to improve detection rates the number of false alarms are increased. This may not appear to be a problem. However, false alarms give the impression of incompetence and are therefore likely to erode trust in the system, demonstrated by operators ignoring or disabling these systems. It is vital, therefore, that the constraints of the system are carefully considered to instil maximum trust. Experience with Short-Term Conflict Alert (STCA), for example, suggests that a false alarm rate of a few per cent is acceptable, given that the system never misses a real close conflict. Controllers will accept the 'trade' of a small false alarm rate, for a system which occasionally 'saves' them in a difficult situation.

9. Controllers must be adequately trained

Anecdotal evidence from many ATM system simulations suggests that controllers do not always fully understand the functionality of the tools that they are expected to use. There are typically two reasons for this:

a. The new functionality is necessarily quite difficult to understand, and requires a significant change in representation (at the HMI). If this is the case, adequate training must be given.

b. The design of the system HMI is poor (i.e. not user-centred) and the functionality is not transparent enough. If this is the case, the problem is with the developers, not the controllers. **Training should not be used to compensate for poor design.**

To foster appropriate trust in automation tools it is essential that the controllers properly understand the purpose and functionality of the tools they are to use. ‘On-the-job’ training is only appropriate for existing systems where the newcomer can see others operating smoothly and can have all questions answered quickly and authoritatively. With a new system there must be a systematic and programmed approach to training to ensure that controllers are not ‘finding their way’ all the time.

10. Controllers' training must be checked

It should not be assumed that because controllers have completed a preliminary few days of training they understand how a particular tool functions; this should be checked and tested.

11. Measuring controllers' level of trust is useful

Trust can be thought of as an 'enabler' to the introduction of new systems. It is useful therefore to measure controllers' trust during real time simulations. Evidence from many empirical studies indicates that a questionnaire-based technique using rating scales will be most appropriate.

2.5 Implementation Phase - Controller Training

12. Understanding possible errors of a new tool is beneficial

It is very important that controllers understand why, and under what conditions, an automation tool might make errors. Leaving aside the problems of testing a prototype tool in a simulation, even if the tool is working as intended it is unrealistic to expect it to be perfect. Controllers need to be aware of the problems. Trust will grow if operators find compensating strategies for the consequences of an automation error.

STCA provides a good example of the likely problems to be encountered. Even though STCA is now in operational service, it is known to have imperfections - nuisance alerts and other spurious false alarms, but is nevertheless seen as useful and worthwhile (controllers do not want to give it up). The development of future automation tools will inevitably suffer similar problems. It is unrealistic to expect otherwise, and briefing controllers about likely problems and known limitations (rather than them being ‘surprised) will facilitate an appropriate degree of trust.

13. Computer-Based Training (CBT) allows self-paced training and exploration – useful for determining trust, and for building self-confidence

CBT systems are stand-alone training systems that can train theory and a limited number of basic scenarios. Their principal advantage (if well designed) is that the user can proceed at his or her pace, and if there are learning checks in the system, feedback is given rapidly on the progress of learning. To increase the benefit of CBT training it has to be as interactive as possible and include part-task exercises.

Such CBT qualities of flexibility of learning, structured training, and rapid and precise feedback, will transmit the information and give the controller confidence in his or her abilities, and prepare them for handling more challenging scenarios on the simulator. (These are potential qualities of CBT and require careful development and nurturing.)

14. Simulation training is essential

Simulation training allows the controllers to explore the system in a safe environment - no harm can come to them or the aircraft. However, the simulations should also (later on) cover problem areas, such as common errors, possible system degradations and how to detect them and recover from them. This gives the controller confidence to know that even if things go wrong, he or she can still recover. This confidence reinforces trust in the system.

Controllers should be allowed to go and ‘play’ with the system at any time (not only during allocated, formal sessions). Introducing an aspect of play is one of the best learning practices.

15. Shadow mode training is highly desirable

No matter how realistic the simulation, the controller knows it is only a simulation. The controller must therefore be exposed to a more operational environment. Shadow mode operation allows the controller to see that the tools do in fact work with real traffic, and during the non-nominal or emergency events that can occur.

The latter point implies that the shadow mode operation is employing an initial version or prototype of the real system and not a simulation-derived version that typically excludes handling exception and non-nominal conditions.

2.6 Operational Phase - Training and Transition

16. Allow adequate time for transition

Training and transition should take place over a reasonably long period to gain trust. Rome spent some time introducing the system, and there was then an eight-month period of training and transition from October until May. Stockholm and Malmö have similar planned timescales). This extended timeframe also gives system developers the space to more fully test and de-bug the system before it goes operational.

17. Inform the controller population of the implementation schedule

Communication will be a key means of keeping controllers up-to-date with developments and timings, and will generate confidence in those who are bringing in the new system or tools. It is also useful for controllers to know such details as the rotation in which they will all be involved as they near final transition and implementation. Such communication will not cause trust on its own, but may prevent problems arising if controllers feel uninvolved or uninformed, or feel 'surprised' by the course of events.

Communication is needed throughout the development cycle and must be transparent. Mistrust of managers and system developers is always jeopardizing trust in the system.

18. Involve controllers in the training, as trainers

Trust will develop more easily when the messenger is also trusted and understood. Controllers training controllers may be better therefore than, say software engineers or systems specialists doing the training. The latter will undoubtedly know the system better, but not how controllers can operationally optimize it. Controllers may also trust what controllers have to say about the system more than the developers.

19. Avoid introducing new systems under time pressure

As far as is possible, a new system should be introduced before capacity limits have been reached. In practice, this can be a difficult principle to maintain, as usually the new system or tool is being introduced to deal with higher capacity; and often system development and delivery times may slip dramatically (e.g. due to unforeseen software problems). However, learning to trust a system or tool should not occur under significant pressure, so that controllers have the time to get to know the system and are not tempted back into old routines of working, due to workload pressures when using the new system.

20. Night mode training may be useful

As an intermediate stage between shadow mode and full live operation, there is the possibility to use the system at night when traffic is lower. Rome ATCC, for example, started with training sessions between 11pm-4am, then later between 8pm-4am. This gave the controllers confidence that the system was working effectively, at least during low traffic periods.

(However, learning at night is unlikely to be as efficient as normal daytime training because human cognitive capabilities are lower.)

2.7 Operational Phase - The Use of Backup Systems

21. Backup systems can be useful in the early operational stages

During full implementation of a new system (at least in the early stages) it can prove useful to maintain some of the old system so that controllers know there is a fall-back position in case of significant problems. This approach was adopted at the Rome ATCC (although there was never any return to the old system, and so it is being removed). This principle will probably vary for different centres or even different cultures. For example, some ATCCs might prefer to start with a completely new system so that the controllers have to make it work, because there is no alternative. Another fallback could be in terms of extra staff or skilled specialists available in the operations room during the first live sessions.

22. Planning for system failures is essential

There is sometimes a tendency in those developing new automated (or other) systems that are safety-critical or involve high hazard, to under-estimate failure likelihood of those systems. Experience shows that all systems can fail, and often failure rates are much higher during the initial introductory periods with new systems, despite extensive pre-operational testing. We KNOW that they can fail, so it is therefore essential to prepare both the system (hardware and software) and the controller for the eventuality of some form of system failure. Defences can take the form of back up systems (e.g. ability to print paper flight strips, multiple redundant and diverse power systems, etc.), and advanced simulator training to prepare controllers for rare failure modes and emergency situations.

3. CONCLUSIONS

The above principles are aimed at helping future ATM-tool and -system developers in understanding the critical variable of trust, and in achieving an appropriate degree of trust during the design and implementation life cycle of those tools and systems. As noted earlier, these principles are as much based on practical ATCC development experience as they are on scientific research. Nevertheless, it is hoped that they may help inform the development of effective and safe future ATM systems where the controllers have tools they can indeed trust, and use to good effect.

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4. RECOMMENDATIONS

1. Communication about a new system needs to be carefully conducted throughout the development life cycle. It also needs to be transparent in order to promote trust in managers and system developers. Communication is a key element to ensure trust in the system.

2. A representative sample of all the final users must be involved in all phases of the project. This includes the establishment of a Review Group during the life cycle and the participation of final users especially to consider the functional requirements.

3. The training should be developed by controllers for controllers with the support of the system developers and training specialists.

4. Training should include at least two aspects:

   - Knowledge of the system and HMI: functionality, limits and features. Understanding why and under what conditions an automation tool might make errors is essential.
   - Knowledge of 'how to use it', based on process-oriented learning and part-task exercises.

5. Simulation training should include normal, unusual and emergency situations.

6. Simulation training and shadow mode training should be available for 'play' periods in addition to the formal, allocated training sessions.

7. Training for emergency situation such as system failure should be seen as a good opportunity to ask the controllers what should be put in place in order to aid and support them in such a situation.

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ABBREVIATIONS AND ACRONYMS

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

ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATCO	Air Traffic Control Officer / Air Traffic Controller *(UK/US)*
ATM	Air Traffic Management
CBT	Computer-Based Training
CORA1	Conflict Resolution Assistant 1
DIS	Director(ate) Infrastructure, ATC Systems and Support *(EUROCONTROL Headquarters, SDE)*
DIS/HUM	See 'HUM (Unit)'
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme *(now EATMP)*
EATMP	European Air Traffic Management Programme *(formerly EATCHIP)*
EEC	EUROCONTROL Experimental Centre *(Brétigny, France)*
FRAP	Free Route Airspace Project
FREER	Freer Flight
GUI	Guidelines *(EATCHIP/EATMP)*
HFSG	Human Factors Sub-Group *(EATCHIP/EATMP, HUM, HRT)*
HMI	Human-Machine Interface
HRS	Human Resources Programme *(EATMP, HUM)*
HRT	Human Resources Team *(EATCHIP/EATMP, HUM)*
HSP	Human Factors Sub-Programme *(EATMP, HUM, HRS)*

HUM	Human Resources (Domain) *(EATCHIP/EATMP)*
HUM (Unit)	Human Factors and Manpower Unit *(EUROCONTROL Headquarters, SDE, DIS; formerly stood for 'ATM Human Resources Unit'; also known as 'DIS/HUM')*
MTCD	Medium-Term Conflict Detection
NERC	New En-Route Centre
NTT	NERC Transition Team
PD/1/2/3	PHARE Demonstration 1/2/3
PHARE	Programme for Harmonised Air Traffic Management Research in EUROCONTROL
REP	Report *(EATCHIP/EATMP)*
SCAA	Swedish Civil Aviation Authority
SDE	Senior Director, Principal EATMP Directorate *or, in short,* Senior Director(ate) EATMP (*EUROCONTROL Headquarters)*
SHAPE (Project)	Solutions for Human-Automation Partnerships in European ATM (Project) *(EATMP, HUM, HRS, HSP)*
STCA	Short-Term Conflict Alert

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Document Configuration

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