



# Human Performance in Air Traffic Management Safety

## A White Paper

**EUROCONTROL/FAA Action Plan 15 Safety**  
**September 2010**



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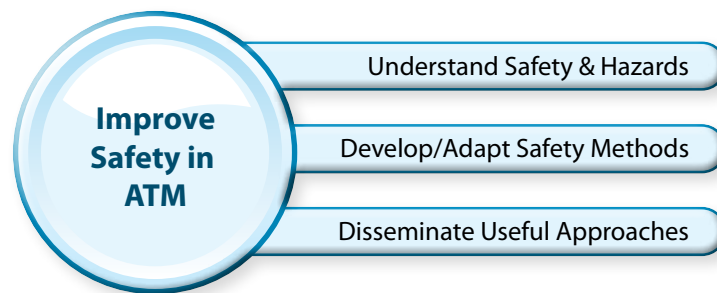


# FOREWORD

**EUROCONTROL / FAA Action Plan 15 on Safety Research** is aimed at advancing safety concepts and practices in air traffic management, via the sharing of expertise from its membership. It has three main axes: understanding system safety, developing new approaches to assess and improve safety, and disseminating its findings into the industry. AP15 came into existence in 2003 and its current terms of reference run until end 2010.

The relationship between human performance and safety has been a long-standing issue in AP15 deliberations, since human performance is such a critical determinant for ATM safety. The AP15 Members hope this White Paper will help understanding of this area, and its critical importance in achieving system performance and system safety, today, and in tomorrow's systems as envisaged by SESAR in Europe and NextGen in the US.

## AP 15 Terms of Reference



## AP15 Membership

- **EUROCONTROL** – Barry Kirwan [Co-chair], Eric Perrin, Herman Nijhuis, and Steven Shorrock
- **FAA** – Joan Devine [Co-chair], Jim Daum, Dino Piccione, Sherry Borener, Warren Randolph, Hossein Eghbali and Michael Sawyer
- **NASA** – Dawn McIntosh, Michael Feary and Barbara Burian
- **NATS (UK)** – David Bush
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# EXECUTIVE SUMMARY

This White Paper is built on collaboration between EUROCONTROL, the FAA, and a number of ANSPs and key research establishments with a common area of interest, namely human performance & safety.

Human performance, in the context of ATM, refers to the performance of jobs, tasks and activities by operational personnel – individually and together. Human performance, as a domain, focuses on optimising the people element in complex work systems such as air traffic management. It covers all aspects of integrating people into systems including such diverse areas as getting the workstation and controller tools right, ensuring there is adequate staffing, and managing ‘human error’. The expertise of human performance specialists and the tools they use have been recognised as key ingredients for both SESAR and NextGen programmes to advance ATM infrastructures in Europe and the USA.

This White Paper has five objectives:

- Show why human performance is important from a **business investment** perspective. If managed well it pays dividends and allows better management control of people issues and budgets – there will be fewer ‘surprises’. If not managed well, unforeseen costs usually arise.
- Describe human performance in an **ATM context**.
- Show how effective human performance is delivered, with a focus on the application of **human factors approaches**.
- Show how human performance and **system safety** work together.
- Outline the key human performance issues for the design and integration of **large-scale future ATM programs**.

The White Paper is aimed at anyone in the aviation industry concerned with people and system performance issues in current or future systems. It addresses a number of questions:

## 1. Investing in human performance

- Is it cost-effective to invest in human performance?
- How are human performance benefits delivered?

## 2. Understanding human performance

- What is human performance in the context of ATM?
- How do human performance concepts apply to the job of an air traffic controller?
- What human performance approaches are available?

## 3. Human performance and system safety

- How do human performance and safety assessment fit together?
- How is human performance considered in a safety case?

## 4. Priority human performance issues for future ATM

- How does human performance fit into future systems?
- What are the common human performance issues for the future of ATM?

The controllers, supervisors, pilots, engineers, and other people in our systems keep air travel extremely safe, and will continue to be central to the next evolution of ATM, albeit assisted by more automation. But the future will demand more of people, as future ATM aims to be more flexible, and at the same time have fewer delays, more capacity and improved safety. The realisation of such goals will depend on how well we have considered human performance in the design and operation of the ATM systems.

It is hoped that this White Paper will answer some of the key questions that ANSPs and other ATM-related organisations may have about human performance in ATM, and contribute in some small way to the achievement of future ATM goals.

## Six Human Performance Challenges for Future ATM

The future of ATM will depend on how the industry handles a number of critical challenges concerning human performance. Six key challenges are outlined below.

### 1. Designing the right technology



Future technology will be a step change from current technology. The focus will shift to collaboration across sectors and centres, and between ground and air, so technology will need to support this new way of working requiring shared 'situation awareness'. Tools will also need to accommodate more advanced planning and look-ahead time, while supporting the flexibility required to deal with unplanned situations. At the same time, it must be ensured that it is possible to safely handle unexpected disturbances and degraded modes. Crucially, the automation must keep the human in the loop and able to maintain control – and therefore safety – in all circumstances.

### 2. Selecting the right people



Major technological and organisational changes may require changes to the type and number of people required to operate the business effectively. This may require changes to manpower planning, recruitment and selection to ensure that we have the right people, in the right numbers at the right time.

### 3. Organising the people into the right roles and responsibilities



A new collaborative approach to ATM will result in new roles and responsibilities for controllers and engineers, as well as other ground staff. In light of increased delegation, such changes will extend to flight crew. Roles are likely to be more fluid than is the case today. The human performance implications of transitioning between roles must be clearly understood and managed.

### 4. Ensuring that the people have the right procedures and training

New technology, people, roles and responsibilities all impact the training and procedures required, for both new and existing staff. Competencies will need to be maintained also for old skills that may be used more rarely in light of new technology, but are still critical when needed. The new collaborative approach to ATM may require new collaborative approaches to training.



### 5. Managing human factors processes at a project and ANSP level

Consideration of human performance issues requires human factors to be fully integrated with system development and safety management. The management goals are to meet the demands for efficiency, enabling capacity gains and safety improvement. Performance indicators can be useful here to benchmark and quantify the maturity of human performance assurance at the organisational level.



### 6. Managing the change and transition process

A successful project depends on a successful change and transition process, where the social, cultural and demographic factors impacting performance are considered alongside the technical & procedural factors.



ATM today is one of very few 'high reliability industries'. Throughout the major changes of the future, we need to keep it this way. Strategic, management-level approaches are necessary to maintain human performance throughout every stage of the design, development and implementation process, then reaping the performance and safety benefits during the operations phase. The right management systems and organisational culture, including safety culture, will help to ensure that the capacity, efficiency and safety benefits expected are realised.

# 1. INVESTING IN HUMAN PERFORMANCE

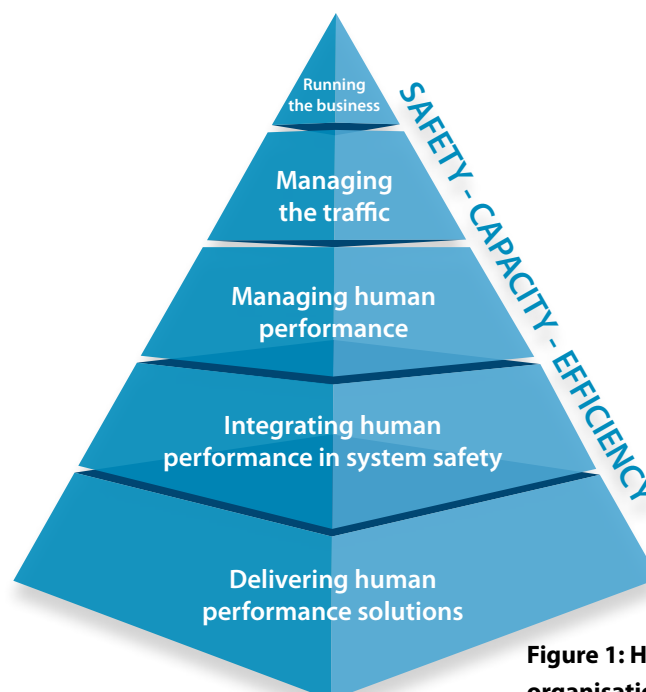
Compared to other high-hazard industries, such as chemical processing, nuclear power, and even aviation more generally, air traffic management is still 'human-centred'. Despite advances in technology, ATM is still critically dependent on the day-to-day performance of highly skilled front-line personnel, such as **controllers, engineers, supervisors and other operational staff**. Operational personnel safely and efficiently handle millions of flights, and effective human performance at the front line makes this happen. Human performance solutions are required to bring the people, procedures and equipment together effectively (see Figure 1) to make running the business more efficient and safer.

In terms of SAFETY, 2006 and 2009 were the safest years on record worldwide. 2008 was the fifth consecutive year in which there were no ATM-related accidents in Europe. Traffic growth is the key challenge to maintaining such a record, because when traffic doubles, risk is squared. The European SESAR programme aims to improve the safety performance by a factor of 10 by 2020. Clearly, the human element will be critical to ensuring that safety is maintained.

The industry needs to gain additional CAPACITY and reduce delays to meet the demands of traffic growth. The SESAR programme aims to enable a 3-fold increase in capacity. Again, this can only be achieved with a focus on those who are managing the traffic. A third priority is EFFICIENCY. SESAR aims to reduce the costs of ATM services to airspace users by 50%.

These improvements make significant demands on human performance, but the financial benefits are significant. According to the European ATM Master Plan, the savings attributable to direct ATM cost reduction, capacity gain and departure delay savings, as well as predictability improvement in case of low visibility conditions, is around €19bn for commercial airlines by 2020, with an additional €12.5bn savings of passenger travel time.

**Understanding and managing human performance is critical for the future of ATM. No matter how advanced the concepts and systems become, humans will be on centre stage as the decision makers, and human performance will remain the key driver of ATM performance.**



**Figure 1: Human performance and organisational business performance**



## Is it cost-effective to invest in human performance?

The future of ATM will depend on the success of new concepts and new technology. Here, the early consideration of human performance is most cost-effective. To illustrate this, consider the three typical 'human factors integration' scenarios in Figure 2. Around 70% of total project cost is determined in the first 10% of the project. It is much more cost-effective (60 to 100 times) to change the design of a system in the initial phases of development than to do so once the system has been built and is in operation.

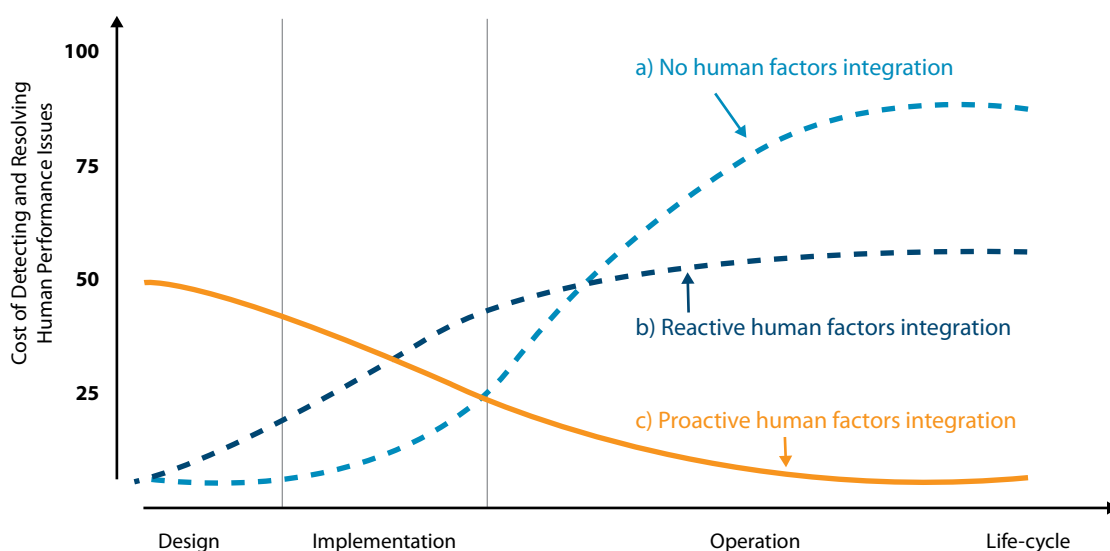
Scenarios a) and b) in Figure 2 were previously more indicative of a typical approach to system development than scenario c). But scenario c) – investing in early detection and resolution of human performance issues during system development – will reduce costs and enhance benefits in later stages of the system life cycle significantly.

Investing in human performance will help to reduce industry costs, and improve overall organisational performance by:

- improving system design, development & implementation processes and outcomes
- improving selection, recruitment, staffing
- improving work organisation
- improving procedures and training
- improving system safety
- improving transition into operations and the social acceptance of changes.

**Achieving safety, capacity and efficiency benefits requires a focus on human performance from the start to the end of a project or change, and subsequently in day-to-day operations**

### Which curve is your organisation on?



**Figure 2: Cost scenarios of three different human performance implementation strategies**

## How are human performance benefits delivered?

At the sharp end of performance in ATM, professionals manage their own performance at a tactical level – controllers, supervisors, engineers, etc. Behind the scenes, other groups of professionals contribute to the improvement of human performance at a more strategic level. These people use various principles and methods for measuring and influencing human performance – directly or indirectly. Three ‘enablers’ of human performance in ATM are noteworthy (see Figure 3).

- **Human Factors (HF)** is a design-oriented discipline and profession which develops and applies knowledge about the performance of people at work to the design of work. It focuses on the task requirements, the equipment and technology people use, the rules and procedures they work under, the ways they communicate, and the physical and organisational environment in which they operate. HF focuses mostly on ‘fitting the job to the person’.
- **Recruitment, training, competence and staffing** are the primary concerns of human resource management (HRM) and occupational and organisational psychology. The priorities are to attract and retain talented and competent staff, as they will ultimately determine the success and sustainability of the organisation. HRM and psychology focus more on ‘fitting the person to the job’.

- **Social factors and change management** refers to a social dialogue and change process, which will pave the way forward for future concepts if accepted and recognised by all parties involved and affected by the changes.

All three enablers are about compatibility or the ‘fit’ between people, their work and the organisation, but the focus of each is different. They overlap in the introduction of large-scale changes, such as **SESAR** in Europe and **NextGen** in the US (see Section 4).

To achieve the right fit, it is necessary to have the right professional resources in the organisation. Whilst HRM and platforms for social dialogue are more commonplace, HF expertise in ATM is less so. Nevertheless, a number of ANSPs now have specific teams of qualified human factors specialists, integrated into design, selection, training, and safety functions. Some also have human performance teams, comprising operational and engineering staff with a special interest in the domain. As human performance issues are a key driver of ATM performance, they need to receive considerable attention in planning, design, operations and maintenance, and should be treated as seriously as other business-critical functions.



Figure 3: Delivering human performance benefits

## PROTECTING CONTROLLERS AND SAVING MONEY

### Background

When a controller has a near-miss incident, there are three potential 'downsides'. The first is of course that it represents a safety-related event. The second is that it can affect the controller concerned, in more serious cases leading to post traumatic stress disorder and an inability to continue functioning as an active controller. The third downside is that if this happens, the organisation must find a replacement, potentially losing years of service from the affected controller.

### Approach

Critical incident stress management (CISM) has been introduced throughout many European ATM centres as a means of coping with the personal and organisational aftermath of these events. CISM supports air traffic controllers in coping with stress reactions after 'critical incidents' in the workplace. These include, for example, incidents involving loss of safe separation between aircraft. Selected ATCOs become qualified CISM 'peers' to support their colleagues after an incident of this type.

### Outcome

The CISM programme is viewed very positively by ATCOs. In a number of recent safety culture surveys, controllers have emphasised that CISM works and needs to be maintained. But what is its economic value to the organisation?

A cost-benefit-analysis was conducted on CISM, involving 11 senior managers of major ATC units, 38 operational managers and 352 ATCOs (including all CISM peers of the 11 units). The cost-benefit-analysis focussed on 66 incidents of aircraft separation infringements. In 48 of the 66 cases the ATCO accessed CISM. All critical incidents were described as emotionally stressful. The stressful period lasted on average 10.8 days. During this period, the ATCOs reported feelings of guilt and uncertainty, leading to over-cautious separation of aircraft.

The ATCOs who had consulted a CISM peer rated what percentage of their performance recovery was due to CISM. The ATCOs estimated that this figure was 36% on average.

### *During the recovery period*

The non-CISM ATCOs reported impaired work, such as deficiencies in planning traffic flow, in checking data, in gathering traffic picture information, and in interacting with technical systems. In particular, the non-CISM ATCOs reported reduced work abilities and rigid work execution (e.g. rejecting airspace user preferences).

The CISM ATCOs reported reduced emotional stability, but work performance was relatively unaffected.

### *Two weeks after the critical incident...*

Half of the non-CISM ATCOs reported impairments of traffic flow. Delays of flights were explicitly mentioned. The productivity loss in the non-CISM group was on average 10% over 7.7 days.

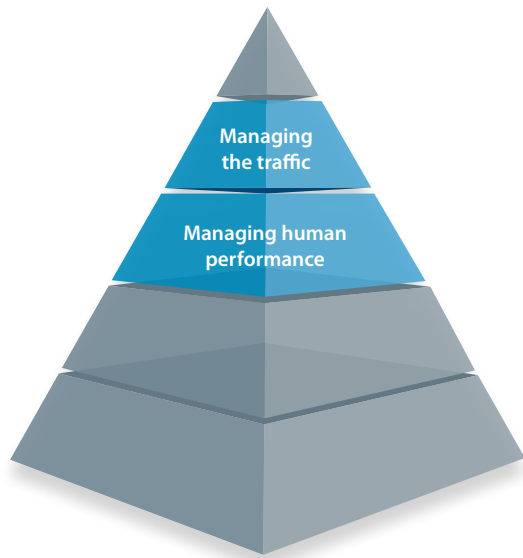
The CISM group reported no productivity loss. On the basis of controlled flight minutes and air traffic control fees for 100 critical incidents, this amounted to 4.68 million euros. A conservative calculation over all sub-groups revealed that every Euro invested into the CISM program returned 2.6 - 3.6 times, respectively.



### Conclusion

CISM clearly pays its way in monetary terms, as well as supporting controllers when they need it most, and enabling them to go on being safe and effective controllers.

## 2. UNDERSTANDING HUMAN PERFORMANCE



Human performance at work has been the subject of intense research in several disciplines for decades. Much is now known about how people perform tasks, and why they perform them in the way that they do. But much of this is hidden away in books and journals for academics and specialists. This section begins to demystify some of these concepts.

### What is human performance in ATM?

Human performance, in the context of ATM, refers to the adequate performance of jobs, tasks and activities by operational personnel – individually and together. As a domain, human performance focuses on optimising the people element in complex work systems such as air traffic management. Designing for human performance and managing human performance involves the application of knowledge gained from research and practice in **human factors**, psychology and management.

In air traffic control, as in other domains, human performance is determined by three key factors (see Figure 4 overleaf).

Human performance depends on both the person and the context of work. In Figure 4, capability refers to the basic characteristics of the individual, e.g. aptitude, abili-

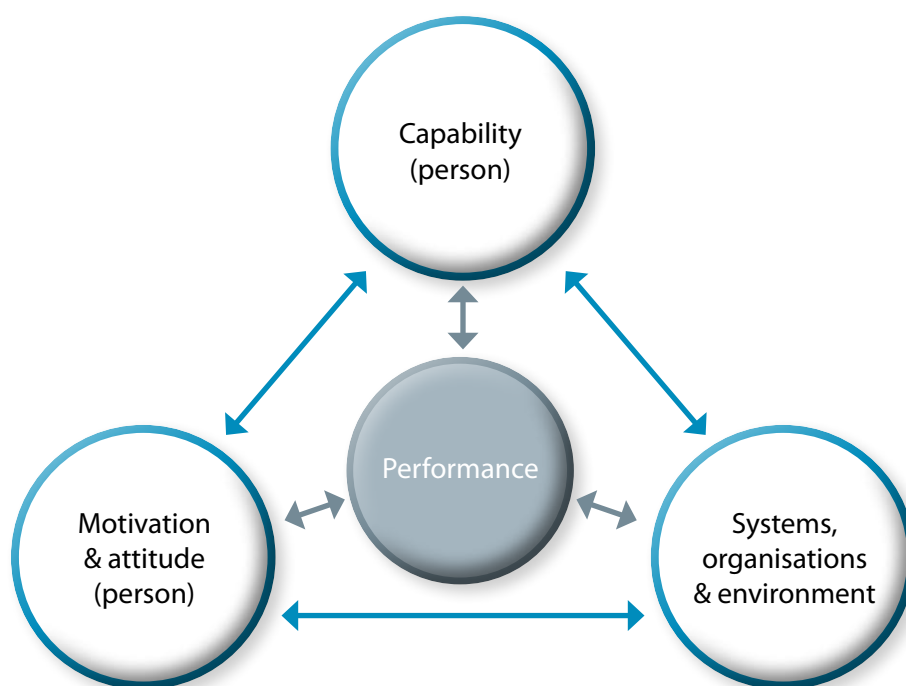
ties, skills, physical capabilities, knowledge, experience and health. Capabilities are assessed during selection and promotion, shaped and enhanced via training, and considered in the design of jobs, tasks/activities, systems and tools.

Motivation and attitude influence the use of the person's capabilities. While a person's motivation varies, it is critical in ensuring that capabilities are fully realised in human performance. Motivation, attitude and trust can be improved significantly with the right approach.

The systems, organisation and environment provide the opportunity for good performance, given sufficient capability and motivation, and include systems and technology, the design of the job and tasks, the workplace environment, training and procedures, and management and support. These can be designed and managed directly, and will be covered in more detail later in this White Paper.

All three need to be considered carefully. Even very high capability individuals will not perform well if motivation is low or if the systems, organisation or environment (e.g. training and procedures) are poor. Similarly, even the most motivated person, with good training and procedures, may not perform well if capabilities are poorly matched to the job requirements.

**Human performance can vary, positively or negatively, depending on the capability, motivation, system support, organisation and environment.**



**Figure 4: Determinants of work performance<sup>1</sup>**

## How do human performance concepts apply to the air traffic controller?

Ensuring that ATM is a high reliability industry means ensuring that human performance is effective, and unlike many other key roles in other safety-critical industries, which have either been extensively automated or are still very manual, the controller's work is very cognitive in nature.

Activities for managing traffic, such as taking over position, solving conflicts, and coordinating traffic are underpinned by processes for managing human performance, such as visual scanning, maintaining situation awareness, and managing mental workload. Here we outline briefly some of these human performance concepts and related issues such as measurement and improvement, in the context of managing the traffic.

### Visual scanning

Monitoring traffic is a critical and complex activity, involving scanning and searching for static and dynamic information from a number of sources, such as a situation display, flight data display, or directly, as in the case of tower controllers. Some scanning methods and strategies are known to be particularly effective, and can be supported via training.

Scanning performance is affected by many internal factors, such as expectations (e.g. about an aircraft's flight path), and external factors, such as display design (e.g. font size). With a thorough consideration of such human factors in design and training, scanning performance can be optimised.

### Maintaining attention

In such dynamic environments as ATC, with short periods of time available for control, lapses of attention can have serious consequences. Maintaining attention is challenging. When dividing attention (or 'time-sharing'), the controller needs to ensure that tasks do not interfere with each other (e.g. monitoring traffic and checking a written procedure). Sustaining attention over long periods when there may be little traffic is difficult, and the controller must ensure that regular scanning is maintained during periods of focused attention. Distractions, fatigue, health and personal factors can all affect attention and must be managed carefully.

Helping controllers to maintain attention presents design challenges. Successful application can ensure that tasks do not interfere (e.g. simultaneous visual tasks) and that alerts and alarms are effective and not disruptive.

<sup>1</sup> - Adapted from: Blumberg, M., & Pringle, C. D. (1982). The missing opportunity in organizational research: Some implications for a theory of work performance. *Academy of Management Review*, 7, 560-569.

### **Keeping the picture**

From taking over position, and throughout their time on duty, controllers manage their situation awareness to build and maintain a mental picture of the current and projected traffic situation and control environment. This is critically dependent on 'working memory' (e.g. keeping flight data in memory for a short time), 'long-term memory' (e.g. knowing aircraft flight characteristics) and 'prospective memory' (e.g. remembering to issue a planned instruction at some point close in the future).

Controllers use their resources to support the picture, for instance by 'kicking out' paper flight strips from the column of strips as a reminder. It is important that such functions are translated to electronic tools. With a proper understanding of situation awareness, for instance via the various assessment methods available, electronic tools, training, procedures and good practice can be designed to support the picture.

### **Making decisions**

Controllers may make hundreds of decisions during each shift, in solving conflicts, managing requests, routing traffic, coordinating traffic, sequencing, take-off and landing instructions, and so on. Few other professional roles make such frequent demands on safety-related decision making. A key determinant of the difficulty of decision making is the number, type and complexity of sources of information.

At the moment, controllers are involved in all stages of decision making. The challenge is to ensure that future technology supports decision making. Well-designed automation can support decision making, in collecting, analysing and integrating information, while the application of human factors principles to the design of training and procedures can ensure that the controller's skills and knowledge are optimal.

### **Communicating and working in a team**

In a busy centre, what is most obvious is the speed and frequency of radio-telephone communication. While particular checks have been put in place (such as read-back-hearback), there is no room for misunderstandings, and the vast majority of transmissions are error-free. This is remarkable in light of the fact that the controller has

so many other things to do at the same time. This all happens with teamwork between members at the same unit and between different units. A routine coordination can turn into a serious incident if teamwork is poor, and handling such an incident may again depend on how well the team works together.

Methods and principles from human factors research can be applied in the context of design, simulation and operations to assess and improve communication and teamwork.

### **Managing mental workload**

The mental workload experienced by a controller will depend on many factors, such as the number of aircraft on frequency, the traffic complexity, and fatigue factors, such as time on duty, time since a break, time of day, etc. When workload is too high (overload) or low (underload), problems may result, such as overlooking a conflict, forgetting about an overflight, or misjudging a manoeuvre.

Human factors can contribute by assessing mental workload and providing guidance for the strategic and tactical workload management based on research findings. There are several methods for assessing mental workload, which can be used during simulations for new procedures and technology. Solutions from HF and HRM may involve staffing, sector design, shift (roster) design, procedure design or technology design.



## Why does human performance vary?

Human performance must vary to deal with variable conditions. Controllers need to make continuous 'micro-judgements' about thoroughness and efficiency with regard to their tasks and activities. For instance, in busy periods, it may be necessary to use electronic flight strips very efficiently. On occasion, input errors will occur, which may cause problems due to missing information; the situation demanded efficiency but (in hindsight) more thoroughness was required.



Alternatively, a tower controller may manage electronic flight strips very thoroughly, but due to the amount of 'head-down' time, the controller may not notice a runway incursion threat developing.

In some cases, the context may change suddenly, as in the case of an emergency, and this needs to be recognised quickly. The controller will continually monitor task performance to ensure that it is maintained within safe boundaries, 'shedding' secondary tasks if required. This requires successfully recognising threats to safety, assessing the need for correction, and completing any corrective actions. The controller is a major reason the ATM system is safe and 'resilient', i.e. able to resist or absorb abnormal events and system perturbations without suffering an accident.

To simply judge normal variability as 'errors', without recognising the constant tradeoffs that are required for the controller to do the job in



sometimes difficult conditions, fails to recognise the complexity of the situation. For the vast majority of time, people perform extremely reliably, and keep our skies safe.

## What about 'human error'?

'Human error' is an issue that captures everyone's interest. We all make errors every day, mostly without consequence. But similar types of actions or inactions in transportation can have disastrous consequences. Even errors of the same 'kind' may vary in their effects depending on the context or conditions of performance, which may

well be outside a person's control. Unfortunately, while the term has become popular, it does not express well the fact that accidents arise not as a result of the person 'at the end of the line', but from total system performance variability.

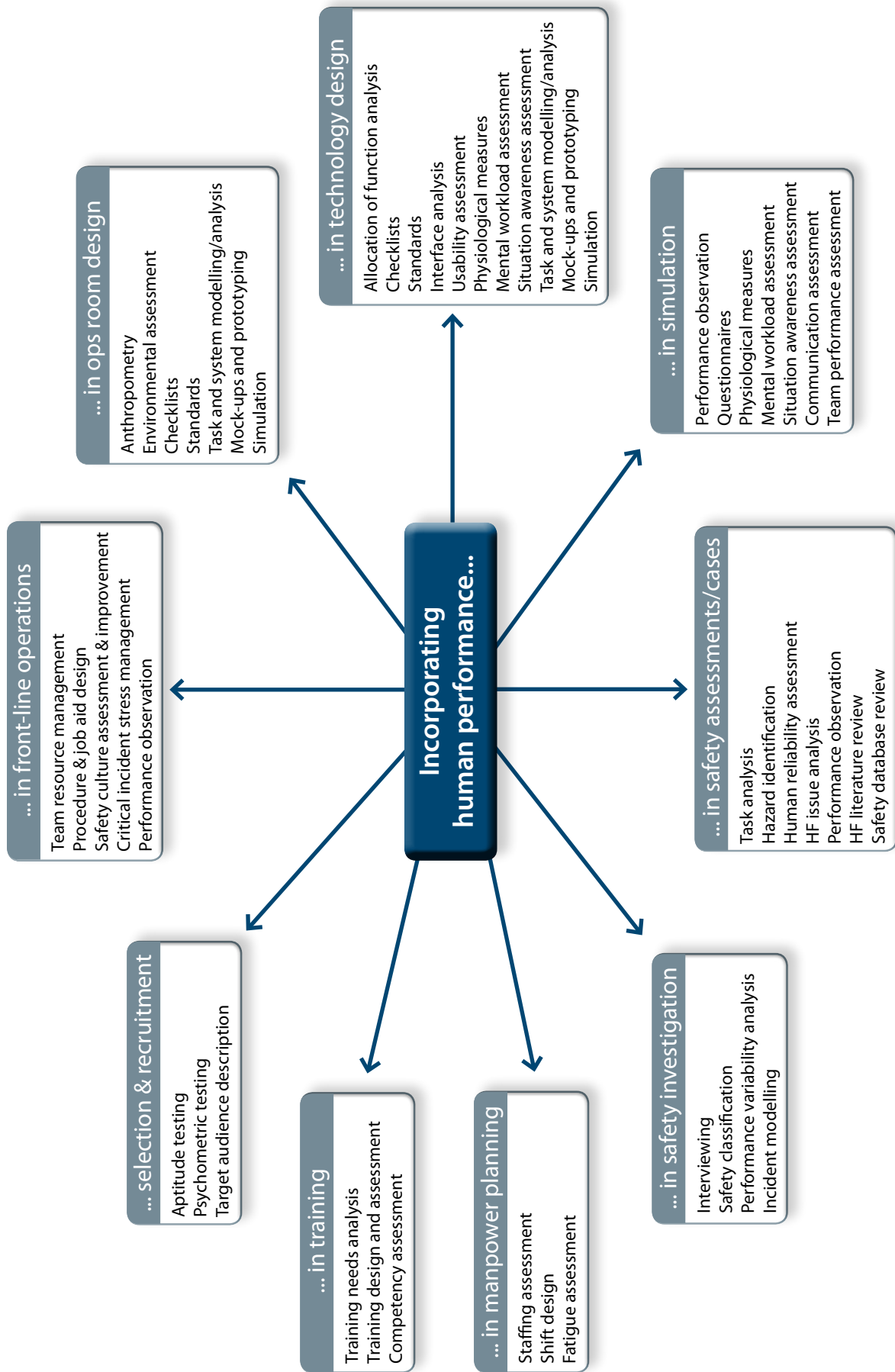
Of course, we do make 'errors', in that our actions don't always achieve the desired effect. And these errors do contribute to incidents and accidents. But these so called 'errors' can often only be judged as errors in hindsight. Nevertheless, as will be shown in the next section, the concept has value in predicting what can go wrong, and then developing appropriate mitigations. But it should always be remembered that what we may call 'errors' are a by-product of normal variability in human performance. The same variability allows the system to be flexible and respond to changing conditions. Errors are the price we pay for having a system that performs extremely well almost all of the time.

**'Human error' is really just a by-product of normal variability in human performance. This same variability allows humans to keep the air traffic moving, and to recover from near disasters. The key lies in ensuring that the system is safe by design and that performance variability is properly handled in both design and management.**

## What approaches are available to help improve human performance?

A wide range of approaches are available to improve human performance, primarily from the discipline of human factors together with human resource management, and these can be incorporated in a range of organisational activities, including the following (see Figure 5):

- front line operations
- control room design
- technology design
- simulation
- safety assessment/cases
- safety investigation
- manpower planning
- training
- selection and recruitment.



**Figure 5: Some typical human factors approaches for assessment, analysis, evaluation and improvement of design and operational performance**



## 'SOMETHING I FORGOT TO MENTION...'

In 1999, an incident pattern was noted in several places in Europe and in the US: incidents were occurring within ten minutes of position handover. In some ANSPs and units, these losses of separation amounted to some 50% of incidents during the position (typically 90 minutes), so clearly something was going wrong.

### Approach

In one large UK ATC centre, a study was carried out by HF specialists into the position handover process, using task analysis, observation, video-recording, incident analysis, procedures review and interviewing techniques.

The handover process varied significantly, ranging from detailed briefing by the outgoing controller, to no briefing at all. In one interview, a controller said that one time, he had just left the ops room and was driving back home, when he suddenly remembered something he'd forgotten to tell the oncoming controller, about an aircraft that was going to be in conflict as soon as it entered the sector. He pulled over and called the oncoming controller with an urgent message: 'Have you seen the Speedbird?' In this case the controller laughed and told him to go home and get some rest; he had already resolved the conflict.

A checklist was developed with the controllers, and an acronym produced to enable them to run through the key items to be discussed (when relevant) for approach and terminal manoeuvring area (TMA; TRACON in US) controllers, as shown in Figure 6.

### Outcome

The checklist increased briefing time from an average 25 seconds to 41 seconds, but decreased 'settling-in' time markedly, from up to ten minutes to a maximum of 4 minutes. PRAWNS also reduced handover-related features in incidents. In particular, there were:

- fewer bandboxing problems
- fewer information transfer errors
- fewer problems with handover to different watch controllers
- fewer read-back errors
- fewer mentor-trainee problems.

The concept was adapted in several other countries in Europe, and is still in use today.

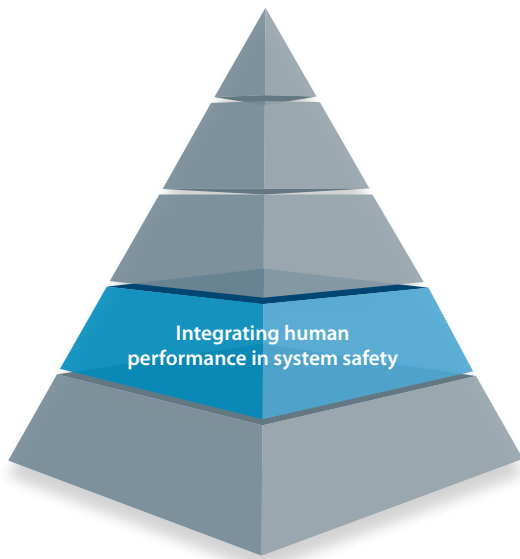
### Conclusion

Handover can be a key risk area for human performance. A simple checklist developed with controllers made the safety-critical process of 'getting the picture' both more efficient and more thorough. The approach is in use and can be readily adapted to other centres and units.

<b>P</b>	<b>Pressure</b> High - Low - Min Stack
<b>R</b>	<b>Runways in use</b>
<b>A</b>	<b>Airports</b> ILS - GAPS - Freqs
<b>W</b>	<b>WX</b> Vis - Avoidance - Winds
<b>N</b>	<b>Non-standard / Priority info</b> NSFs - EATS & holding NavAids - Danger Areas NODE-L Setup - Other
<b>S</b>	<b>Strips to Display</b>

Figure 6: PRAWNS handover checklist

### 3. HUMAN PERFORMANCE & SYSTEM SAFETY



#### How do human factors and safety assessment fit together?

In ATM, safety and human performance are inextricably linked, and can be integrated effectively in a safety case. Consider for example, a new procedure to land more aircraft at an already busy airport. If aircraft landing can vacate the runway quicker, then aircraft following can be brought in to land earlier, increasing the landing rate and capacity of the airport, and ultimately the capacity of the entire airspace system.

This is a worthwhile goal, but there are safety considerations: what if an aircraft accepts the new procedure but for some reason does not vacate the runway? The following aircraft may already be close behind, anticipating landing clearance. There is a risk of a go-around, and in the extreme case, a runway collision. This scenario is almost entirely dependent on human performance: whether the controller detects the static aircraft in time and warns the pilot of the following aircraft, whether the pilots detect it, and whether they perform the go-around safely or not. The controller's decisions and actions will depend on the procedures and training, experience, fitness for duty, data accuracy, the human-machine interface and support tools at the controller's fingertips.

A safety analyst may initially assume that the controller's job is to look out of the tower, and that pilots are trained and motivated to react. Even so, the likelihood of a run-

way collision must be estimated. If its probability is extremely remote, it might be deemed an acceptable risk by regulatory authorities. If, however, it was likely to occur once in ten years, it would not. Such assessments are difficult, but without them decision-making is either paralysed or on uncertain ground. Authorities may be unable to grant approval to such changes, even those that might actually benefit safety. Safety assessments (or safety cases) therefore inform decision-making, and are necessary whether or not they are informed by human factors. But human performance drives safety, and so should play a major role in assessing the impact of changes on system performance.

For such a scenario, a human factors analysis would consider several issues in depth, such as how current operations are done (for instance, procedures, supporting equipment), and how the new procedure would be likely to impact on day-to-day working practices and performance (including visual scanning, anticipation of aircraft behaviour, and controller job motivation). For instance, once the procedure is operational and 'routine', a controller will often be looking at several 'upstream' aircraft, sequencing and distancing them to optimise landing rate. This means that detection of an aircraft stopped on the runway (which will be a rare event) may be delayed, increasing the risk of a difficult go-around or worse. This thorough understanding of the context of the controller's performance should inform most of the stages of safety assessment in Table 1.

It is here that a potential conflict occurs between HF and safety assessment. Human factors tries to take account of the full complexity of conditions affecting human performance, and many HF practitioners do not like to distil all these difficult and fuzzy considerations into a single 'probability of error'. To do so may be seen as too simplistic a representation of human performance and variability. Instead, many HF practitioners will inform the safety assessor of the qualitative factors and perhaps the relative likelihoods (e.g. certain errors and failures are more likely than others), and then leave the rest to the safety analyst. Safety assessment is, however, generally quantitative, and the safety analyst must decide if a change is safe enough or not, according to clear criteria.

Human reliability assessment (HRA) (and approaches that integrate consideration of human performance into safety, such as TOPAZ) can help to bridge this gap between quantitative and qualitative perspectives. HRA aims to predict errors and quantify their likelihood of occurrence, based on studies of actual performance, incident analyses, literature review and real-time simulations. This is standard practice in a range of energy industries and rail transport, but is relatively new for ATM.

In the example, the HF or HRA practitioner might argue that an alarm is necessary in order to assure safety to an acceptable level. This may be possible if there is some kind of ground radar system at the airport. The designer might respond by suggesting that the display icon representing the aircraft that does not vacate turns from a blue colour to red, indicating danger. This might at first sight seem acceptable to a safety assessor. However, the HF analysis may reveal that the controller may not be looking at the display, instead focusing 'upstream' through binoculars to the inbound aircraft. In this instance, an audible alarm is required to attract the controller's attention quickly, with a flashing icon so it is identified in the fastest possible time. HRA can help to assess the probability of late detection for the various design options. The difference in 'error rate' may be a factor of ten, cost-justifying an integrated alarm system over a simple colour change.

The result of such a HF-informed safety case is a richer and more realistic evaluation of safety risk, with the human contribution (both positive and negative) fully represented. This enables decision-makers to make sound decisions.

A further and highly important output from such a study is a set of safety requirements. In the example, these might be as follows:

- the procedure requires a functioning ground radar system with alarms for aircraft which 'fail to vacate'
- the alarm must be audible and visual, directing the controller immediately (within 2 seconds) to the aircraft concerned
- the false alarm rate must be sufficiently low (<0.001) that controllers trust the system, and do not switch it off because of too many 'nuisance alerts'

- the alarm and ground radar display system are safety-critical, and must be developed to a high standard of human factors in design
- training and refresher training must simulate aircraft that fail to vacate
- during the first year of operation, safety-related events must be monitored to ensure that safety is being maintained (without decay) at the predicted and acceptable level.

This partnership between human factors and safety has an added benefit for those concerned with HF and human performance assurance: safety requirements are mandatory. This is a change from the normal situation of human factors in design, where achieving human factors integration is a sometimes protracted process of negotiation, with HF issues competing against other design criteria.

This synergy between HF and safety assessment results in better and safer human performance. Many tools to link HF and safety are already available, while others are under development. The next section shows how these two areas can work together.



## What are the key HF contributions to the safety case?

Safety assessment of an air traffic operation can be based on a seven-stage hazard assessment process, as shown in Table 1<sup>2</sup>. Human performance issues can be incorporated at each stage via a number of techniques. Table 1 also identifies some of the available techniques that have been evaluated for their suitability in ATM. The list is not exhaustive; emerging techniques, and even new paradigms such as resilience engineering, are becoming available and being trialled in ANSPs.

Table 1 is in the context of a hazard-driven safety case. New approaches to safety (called 'positive safety' approaches, including the concept of resilience), aim to ensure that we also focus on what keeps us doing things right, which we tend to do 99.9% of the time. The section following the table deals with techniques which can be applied either within or outside a formal safety case environment.

2- FAA/EUROCONTROL (2007) ATM Safety Techniques and Toolbox (Version 2.0). Safety Action Plan-15.

**Table 1: A generalised seven-stage safety (hazard) assessment process**  
(adapted from FAA/EUROCONTROL, 2007)

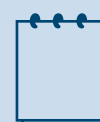
Inputs	Process	Outputs
Depends on local adaptation and the organisation's safety management system (SMS)	<b>1. Scoping the assessment</b>	<ul style="list-style-type: none"> <li>■ Safety plan</li> <li>■ Assignment of safety/risk criteria</li> </ul>
Task analysis (e.g. HTA) ■ Accident risk assessment (e.g. TOPAZ) ■ Functional modelling (e.g. SADT)	<b>2. Modelling the system</b>	<ul style="list-style-type: none"> <li>■ Description of operations and systems</li> <li>■ Safety claims and arguments</li> </ul>
Safety databases (e.g. ASRS) ■ HF literature review ■ Hazard identification (e.g. Human HAZOP) ■ Accident risk assessment (e.g. TOPAZ) ■ HF issue analysis (e.g. HF case) ■ Observation ■	<b>3. Identifying hazards</b>	<ul style="list-style-type: none"> <li>■ Defined hazard set</li> </ul>
Accident risk assessment (e.g. bow tie, TOPAZ)	<b>4. Combining hazards into a risk framework</b>	<ul style="list-style-type: none"> <li>■ Risk model</li> </ul>
Safety databases (e.g. ASIAs, EVAIR) ■ Accident risk assessment (e.g. TOPAZ) ■ Safety modelling (e.g. Collision risk models) ■ Human reliability assessment (e.g. CARA, expert judgement)	<b>5. Evaluating risk</b>	<ul style="list-style-type: none"> <li>■ Evaluated risk model</li> <li>■ Understanding of dependencies</li> <li>■ Understanding of risk against target criteria</li> <li>■ Risk-informed decision-making</li> </ul>
HF expertise ■ HF issue analysis (e.g. HF case) ■ Hazard identification (e.g. Human HAZOP) ■ Hazard logs ■ Human reliability assessment (e.g. CARA)	<b>6. Supporting risk mitigation</b>	<ul style="list-style-type: none"> <li>■ Potential mitigating measures to reduce risk</li> </ul>
Safety databases ■ Operational data analysis (e.g. PDARS) ■ Flight data analysis (e.g. FDM, FOQA) ■	<b>7. Confirming actual risk is tolerable or reducing</b>	<ul style="list-style-type: none"> <li>■ Measurement of safety-related events &amp; data against predictions</li> </ul>
Safety databases ■ Operational data analysis (e.g. PDARS) ■ Flight data analysis (e.g. FDM, FOQA) ■ Hazard logs ■ Safety performance review groups	<b>8. Organisational learning through feedback</b>	<ul style="list-style-type: none"> <li>■ Feedforward of lessons learned to design, safety and operational groups</li> </ul>

## Human Factors Considerations

The safety plan will often include human elements of safety within the scope of the safety assessment. Specific HF techniques may be specified, as well as related required resources such as access to operational personnel, the need for simulations, etc. Safety issues arising in existing operations may require an initial scoping investigation utilising methods such as interviews with operational personnel and classification of HF issues.



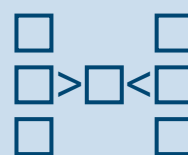
HF techniques can be used to model how the system should nominally behave. Human interactions might be modelled using approaches such as interviews, observation, and task analysis techniques. This gives a 'baseline' against which to determine how actual performance could vary. Going further, sophisticated accident risk assessment and functional modelling techniques may be used.



A variety of HF-related hazard identification techniques may be used, either as stand-alone approaches or integrated into broader safety techniques. Potential hazards may also be identified from past experience (e.g. via incident databases and HF literature) and simulations. For current operations, operations may be observed, and hazard identification integrated with safety investigation of one or more incidents, to determine a robust set of hazards, contributory factors, future risk and mitigations.



At this stage, HF approaches help to aggregate identified hazards and their contributions into a logical or simulated accident risk model for the proposed system or change. These show how hazards can lead either to accidental consequences (such as mid-air collision), or safe states (via mitigations or safety nets), enabling the consideration of dependencies between different human contributions, such as maintenance actions or training issues.



To help quantify human performance contributions to risk, several options are available such as safety databases and human reliability assessment techniques. This helps to inform the global safety quantification in the safety case, so that when accident sequences are identified, their likelihood is accurately predicted.

$10^{-3}$

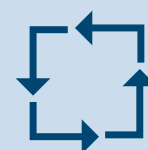
There is a key role to play here to 1) help to set and specify effective safety requirements to eliminate or prevent hazards, reduce their frequency, or aid recovery, thus reducing risk to the required level, and 2) help validate that the requirements have been met and confirm or revise residual risk estimates. This activity is often carried out when using techniques such as issue analysis, hazard identification and human reliability assessment, but is a core element of human factors expertise.



Once the new system or change is approaching and entering implementation, human performance can be monitored to ensure that the related safety requirements remain effective. HF methods such as performance observation and incident classification record safety data, and draw lessons from those data in sufficient time to prevent incidents and accidents. The result is that there is confidence that the safety arguments in a safety case are robust and meet the claims made.



HF specialists can help provide feedback to 1) operations, for their own safety management practices for projects or existing systems (e.g. training, procedures); 2) safety assessors for similar or related systems, who may be able to benefit from the work undertaken already; 3) designers and developers of new concepts, to help them consider safety aspects from a very early stage in their concept formulation.



## What human performance approaches can be used to support safety cases?

Several approaches are available for use at different parts of the safety assessment process, whether qualitative or quantitative. Some of the key approaches that are primarily human performance-oriented are below. Within each broad type of approach, there are several established techniques or methods.

**Human factors literature:** A very large body of scientific literature is available concerning human performance. A review of this will uncover what is known about a problem or issue in the human factors, psychology, safety and engineering literature. It will also help in quantifying issues and setting evidence-based safety requirements.

**Safety databases:** Many human performance issues are already known from safety occurrences in operations with related systems, so a review of existing incidents is essential. Safety databases often use safety classification systems that incorporate a comprehensive range of HF issues. Incidents may also inform the development of scenarios and risk frameworks, and the recommendations for the incidents may support risk mitigation.

**Task analysis:** Several task analysis methods can provide a blueprint for how a controller or engineer should normally carry out tasks, and help to analyse the tasks from various points of view, e.g. information requirements. Task analysis can therefore help in modelling the system, but is useful for many other areas, such as technology, procedures and training design to support risk mitigation.

**HF issue analysis:** This helps to scope initially the issues of interest or concern and the preliminary plans to investigate or address the issues. This is a key stage in a 'human factors case' and in human factors integration, which helps to manage systematically the identification and treatment of HF issues throughout a project lifecycle. Issues can feed into safety assessments, or be taken forward for further investigation or analysis via other methods.

**Performance observation:** Observational approaches look at real performance, using trained observers (e.g. other controllers) during actual operations, shadowing or simulations to see how the tasks are performed. They involve targeted observations of ATC operations over a specific period of time, focusing on, e.g. threats, errors, and undesired states or the utilisation of strategies and behaviours that are encouraged.

**Interviews:** Interviews with front line personnel are fundamental to many stages of safety assessment, and help to ensure that the assessment (e.g. system model, identified hazards, risk values, mitigation strategies) is grounded in reality. Interviews can be standalone techniques and the basis for other techniques (such as task analysis).

**Hazard identification:** These techniques can be used alongside task analysis techniques or with an appropriate system model to consider the different ways in which tasks can fail to achieve their designed objective, and the factors that might influence performance.

**Human reliability assessment:** Various methods for the quantification of human reliability are available, which can be used alone or to help to inform quantitative safety assessment. Some methods exist that have been adapted specifically to ATM.

## What is needed to apply the methods?

These approaches require human factors specialists or other specialists (e.g. safety assessment specialists) with specific training in the approaches. The methods also require a suitable 'platform', or resources on which to apply the methods. The main types that are relevant to ATC include:

**Documentation:** Many HF techniques are used with documentation. For instance, task analysis and human error identification may be informed by procedures and design documentation. Such documentation usually provides information on how the task should be done. It is unlikely to reveal how the task is actually performed, including the full operational context. Documentation

rarely paints a 'rich picture' of the operational reality of tasks. However, it is often a necessarily starting point.

**Operational personnel:** Interviews and workshops with operational personnel such as controllers and engineers are the foundation of many methods for human error identification, issue identification and human reliability assessment. A disadvantage is that experts show certain biases, which have to be managed carefully (e.g. via a trained facilitator).

**Prototyping:** Prototypes often present the first opportunity to collect actual performance data, but have the drawback of limited functionality, and will focus on specific areas of a system rather than encompassing wider system and contextual factors. Prototypes may not offer the level of fidelity required to make finer judgements regarding human performance, but they can offer significant opportunities for design change.

**Real-time simulations:** Controller-in-the-loop simulation in a realistic environment, utilising high-fidelity simulation equipment, may be the closest approximation to actual operations. It is therefore a useful and safe platform to understand or measure performance in a complex and realistic system, both in identifying problems and validating safe performance.

**Shadowing:** Prior to the full implementation of a change, systems may be tested in a shadow mode. This may involve controllers performing tasks as if they were in real operations, but shadowing the tasks of the controllers who are actually controlling the traffic in real time. This may include moving the strips, listening to the RT, coordinating, looking at the display or outside the tower, but not actually talking to pilots, drivers, etc. Shadowing provides a safe environment to apply many HF measures. Although the controllers are not really 'controlling' any traffic, the environment is now the most realistic one available prior to operations, and so can be a useful platform from which to collect data to help validate that the safety requirements have been met, and identify late changes to procedures and working practices.

**Actual operations:** Prior to implementation, operations provide a baseline against which to model system performance and may also help identify problems that may be relevant to a new system or change. Post-implementation, operations are the basis for providing assurance that the system is safe and performs as expected, or justifying modification and upgrade. Many methods are available for use in an operational context, but acceptability to the controllers and supporting personnel is essential, and only unobtrusive methods are permissible.





## HUMAN FACTORS AND SAFETY ASSESSMENT FOR THE NEW HEATHROW TOWER

### Background

London Heathrow airport faced a need to expand in order to meet international air travel demand, and a fifth terminal was constructed on the western side of the airfield. To control arriving/departing traffic in this large terminal, as well as the other four terminals, a new control tower was constructed. The changes brought about by the new tower were complex, including changes to procedures, lines of sight, transition to computerised flight data input and display, different communication methods, and a very different spatial layout. The changes required significant attention to safety.

### Approach

NATS prepared a full system safety case, but this change required a comprehensive focus on human performance. NATS applied a 'human error safety assurance process' (HESAP), a five-step iterative process that is applied throughout the lifecycle technical systems changes. The five steps are:

**Step 1.** Understand – understand the changes to the system and context, and determine the possible effects on task performance.

**Step 2.** Identify – identify and assess the potential human hazard risks associated with the changes, and set safety requirements to achieve an acceptable residual risk.

**Step 3.** Mitigate – specify, plan and (where appropriate) facilitate the specific mitigation activities to meet the safety requirements.

**Step 4.** Demonstrate – gather evidence to provide assurance that the safety requirements have been met and that human hazard residual risks are tolerable prior to implementation.

**Step 5.** Monitor – gather evidence to provide assurance that the human hazard risks associated with implementation remain adequately identified and mitigated in service.

The application of HESAP involved detailed task analysis, hazard analysis, HF literature review and performance observation, utilising all of the 'platforms' described previously. The process identified HF safety issues that would not have been identified without such a focus on human performance. The process also delivered a set of safety requirements and specifications for the safety case, and

delivered evidence to provide assurance that the safety requirements had been met.

This was a resource intensive but successful process. But the analytical approach could not provide a robust argument that task performance would be acceptable. For instance, there could still be significant problems associated with usability and acceptance. Therefore, prior to the opening of the new tower, an observational study was conducted to collect pre-operational data on controller performance, focusing on workload, situation awareness, and teamwork. An HF specialist observed controllers during team-based 360 degree real-time simulation training and 'shadowing' exercises in the new tower.

The observational data showed no negative indicators for task performance. Observation and debriefs suggested that behaviours were consistent during shadowing and simulation. Encouragingly, indicators of workload, situation awareness and teamwork showed signs of improvement from the start of shadowing. The output of the exercise provided evidence that the safety requirements had been met for HESAP Step 4 ('Demonstrate').

A second set of observations was later conducted during live operations. The output of the exercise was used as evidence in the HESAP Step 5 ('Monitor').

### Outcome

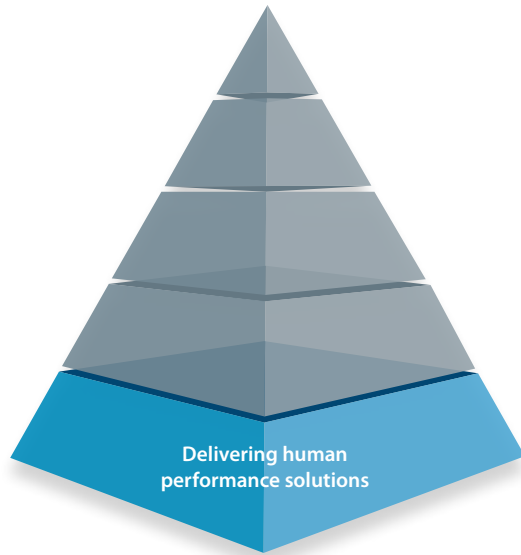
Overall, the process provided robust assurance of both safety and human performance in the tower. In the early hours of 21 April 2007, 60 NATS Heathrow tower controllers, 49 assistants and 19 engineers, as well as management and support staff, moved to the new control tower. The transition to service occurred safely and with minimal disruption to operations, partly due to the significant attention to human performance in safety assessment.

### Conclusion

A blend of HF-safety analysis techniques with more holistic human performance assessment provided a comprehensive approach to assuring safety and human performance for the new Heathrow tower. The process was acknowledged by senior management as integral to the success of the project.



## 4. KEY HUMAN PERFORMANCE CHALLENGES AND SOLUTIONS FOR FUTURE ATM



New ATM concepts such as SESAR (Single European Sky ATM Research) in Europe and NextGen in the US will pose new challenges on human performance. Some of the key challenges are described in this chapter.

### How does human performance relate to SESAR in Europe?

The SESAR programme is the technological and operational dimension of the Single European Sky (SES) initiative to meet future capacity and air safety needs.

SESAR will help create a 'paradigm shift', supported by state-of-the-art and innovative technology. SESAR aims at developing the new generation air traffic management system capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years. While this will involve new technological systems, humans will remain the central decision-makers: controllers and pilots will be assisted by new automated functions to assist decision-making and ease workload.

SESAR proposes a redistribution of functions between air and ground and between human and automation. Advanced automation will support specific tasks and

thus the nature of human roles and tasks within the future system will evolve. Hundreds of thousands of people may be affected. To ensure a successful outcome for SESAR the approach to human performance management will need to adapt substantially. SESAR will affect current staff selection, training, system design and other human factors and human resources considerations.

### How does human performance relate to NextGen in the US?

In the US, the NextGen concept involves a transformation of the entire national air transportation system to meet future capacity demands. State-of-the-art technology, new procedures, and new airport infrastructure will allow the FAA to safely handle dramatic increases in the number and type of aircraft, without excessive congestion.

The goals for NextGen focus on significantly increasing the safety, security, and capacity of air transportation operations. These benefits are achieved through a combination of new procedures, technologies and air-field infrastructure deployed to manage passenger, air cargo, general aviation, and air traffic operations.

The overall philosophy driving the delivery of NextGen ATM services revolves around flexibility and distributed decision-making. NextGen must accommodate flight operator preferences to the maximum extent possible and impose restrictions only when a real operational need exists, to meet capacity, safety, security, or environmental constraints; the ATM system will be demand-led. The inherent limitations of today's system - including human cognitive processes and verbal communications - make the transformation to NextGen ATM necessary. Key attributes include performance-based operations, net-centric services, and shared situational awareness.

Table 2 summarises some of the key SESAR & NextGen challenges, and issues associated with each challenge, for which solutions will be sought over the coming years.

**Table 2: Key future challenges and issues for human performance in ATM**



## 1. Designing the right technology

- Supporting collaboration
- Integration of interfaces
- Supporting advanced planning and better system predictability
- Managing complexity and uncertainty
- Supporting variable workload
- Keeping the controller in the loop
- Sharing situation awareness
- Promoting appropriate trust



## 2. Selecting the right people

- Ensuring manpower availability
- Maintaining job attractiveness
- Forecasting staffing requirements
- Designing the target audience description and selection criteria
- Evolving the right selection tests



## 3. Organising the people into the right roles, responsibilities and work patterns

- Assessing role changes
- Clarifying responsibility between the controller and flight deck
- Understanding the effect on team and inter-team structures, interactions and relations
- Assessing and managing fatigue and stress
- Managing critical incident stress

**Ensuring that human performance in ATM remains effective**



#### 4. Providing the right procedures and training

- Providing usable and realistic procedures
- Developing effective procedures and training for distributed tasks / decision-making
- Identifying new training needs
- Maintaining rarely used but critical skills
- Designing and maintaining competence standards
- Reducing negative transfer of training
- Training for collaboration



#### 5. Managing human factors processes at a project and ANSP level

- Integrating human performance issues and methods into the safety case
- Integrating HF processes and tools into system engineering processes
- Specifying and managing user requirements and design specifications
- Making the human performance 'case'
- Setting and meeting HP KPIs
- Promoting human factors maturity



#### 6. Managing the change and transition process

- Identifying, assessing and managing change and transition issues with regard to human and system performance
- Managing the social, cultural and demographic factors that impact performance
- Ensuring that positive gains in human performance are sustainable

**Ensuring that ATM remains a high-reliability organisation**

### OUT WITH THE OLD, IN WITH THE NEW...

#### Background

In the early 1990's in Sweden, it was decided that new ATC workstations needed to be developed for the controllers to increase efficiency and capacity, as part of a general modernisation programme.

#### Approach

The management sent some of their controllers for human factors training, and these personnel worked together with Lund University in Sweden, to develop the new workstation human machine interface.

The development process utilised a mix of HMI design guidance, and user-centred design processes, including prototyping simulations to get things working right, followed by real-time simulations to ensure it all worked effectively and safely with realistic traffic patterns. During the implementation and testing phase, hazard logs were kept so that controllers could raise problems they had encountered with the system, which could then be prioritised and addressed.

#### Outcome

As a credit to management leadership, the final system was delayed a number of times, despite external pressure, while these issues were resolved. This meant that when it did go operational, there was a smooth change-over to the new system.

#### Conclusion

With the right HF methods and processes, and with a collaborative approach, the introduction of new equipment and technology can be implemented successfully, ensuring a successful design and user acceptance, and increased human performance.

1980s



2003



2009



Figure 7: Original and new controller workstations

## 5. SUMMARY AND CONCLUSIONS



In ATM, human performance and safety are inextricably linked. This White Paper has shown how these two domains work together to produce safe, operable and productive systems. It has also provided an overview of the tools and data available to harmonise safety and productivity, and used case studies to illustrate some of the process and outcomes.

Attention to human performance pays good dividends, ensuring that productivity targets are met, and performance losses or accidents are avoided:

### Human Performance + Safety = *Good Business*

However, early investment pays most dividends, and unfortunately often human performance considerations are often left until later rather than tackling them at the conceptual stage. Since ultimately such issues cannot be ignored (poor human factors will need to be corrected if the system is to function effectively), it is better to address them early on when they are easier to fix. Otherwise, increasing implementation delays – often of the order of years rather than months – as well as escalating costs, can be the result.

While the disciplines involved in improving human performance are themselves continually developing and improving, the techniques to identify and resolve these issues exist. They need to be embraced and integrated into the system developers' and project managers' 'mindsets' and practices.

As ATM continues to evolve in terms of NextGen improvements in the US, and Single Sky, Functional Airspace Blocks and SESAR in Europe, this will create new challenges for human performance and safety, as well as generating system performance advantages (if we get it right).

There will need to be a strong focus on the 'human performance and safety' partnership. This has been recognised publicly in many high level meetings and summits, for example, the High Level Conference on implement-

ing the European 'Single Sky', attended by the European Commission, numerous Member States and ANSPs, the FAA, EUROCONTROL, and EASA (the European Aviation Safety Agency). This 'Madrid Declaration'<sup>3</sup> as it is now known, named five key objectives, of which one was safety (achieving the highest safety standards), and another was human performance (acknowledging the human factor as the over-riding enabler of change). Essentially, without paying serious attention to both of these elements, in synchrony, it is unlikely that the advantages of future systems will be realised. It is notable that since the Madrid Declaration, EASA is in the process of setting up a new group to consider human factors, and a new Human Performance and Safety Sub-Group has been created in Europe, attended by ANSPs and EUROCONTROL.

#### **The human factor is the over-riding enabler of change – Madrid Declaration 2010**

It is perhaps obvious that safety depends on human performance, and that they need to work together. What is less clear sometimes is how they can work together in practice. This White Paper has aimed to show that there are techniques, approaches and data sources which allow a strong synergy to take place between these two disciplines which share a common goal. It is hoped that it may encourage ANSPs, their managers, engineers, safety and human factors professionals, and researchers, to find effective ways to work together so that ATM can continue to enable aviation to remain the safest system of public transport, now and in the future.

3 - [http://ec.europa.eu/transport/air/single\\_european\\_sky/doc/2010\\_02\\_26\\_madrid\\_declaration.pdf](http://ec.europa.eu/transport/air/single_european_sky/doc/2010_02_26_madrid_declaration.pdf)



## 6. FURTHER INFORMATION

### Human Factors Tools

These websites and documents describe a wide variety of HF-related tools and techniques in the TM domain.

- 1) EUROCONTROL HIFA. The HIFA (Human factors Integration in Future Air traffic management systems) database website identifies the issues that need to be considered during the ATM system life-cycle, the tasks to be carried out, and the HF methods and tools for performing those tasks. In addition, it explains the HFI domains and the roles and responsibilities of those involved.  
See [http://www.eurocontrol.int/hifa/public/subsite\\_homepage/homepage.html](http://www.eurocontrol.int/hifa/public/subsite_homepage/homepage.html)
- 2) FAA Human Factors tools. This site provides searchable and browsable HF tools and techniques to researchers and HF practitioners with a comprehensive description of tools to facilitate HF research and analysis activities. There are nine categories of tools, including safety, human-computer interaction, and human-system performance. See <https://www2.hf.faa.gov/workbenchtools>
- 3) FAA Human Factors Workbench. This online portal provides information on HF process (such as how to integrate HF), over 300 HF tools with online comparison of tool features, HF training on the fundamentals and a facility to search for FAA reports. See <http://www.hf.faa.gov/portal/Default.aspx>
- 4) FAA/EUROCONTROL ATM safety techniques and toolbox. This 2007 document describes and evaluates safety assessment techniques for ATM applications, based on the joint experience of the FAA and EUROCONTROL and based on a review of 500 safety techniques from nine industries.  
See: [http://www.eurocontrol.int/eec/gallery/content/public/document/eec/report/2007/023\\_Safety\\_techniques\\_and\\_toolbox.pdf](http://www.eurocontrol.int/eec/gallery/content/public/document/eec/report/2007/023_Safety_techniques_and_toolbox.pdf)
- 5) EUROCONTROL Human Factors Case. This is a five-stage qualitative methodology for identifying human factors issues and integrating them into systems design and development. See [http://www.eurocontrol.int/humanfactors/public/standard\\_page/HF\\_Case.html](http://www.eurocontrol.int/humanfactors/public/standard_page/HF_Case.html)

### Human Factors Guidelines

Guidelines are particularly useful in the design and evaluation of ATM systems. The following is the most comprehensive for aviation.

- 6) FAA Human Factors Design Standard. This is an exhaustive compilation of human factors practices and principles integral to the procurement, design, development, and testing of FAA systems, facilities, and equipment. The HFDS provides a single easy-to-use source of HF design criteria, oriented to the needs of the FAA mission and systems. See <http://hf.tc.faa.gov/hfds>
- 7) Cardosi, K. M. & Murphy, E. D. (1995) Human factors in the design and evaluation of air traffic control systems. Cambridge, MA: John A Volpe National Transportation Systems Center. Comprehensive background material on the capabilities and limitations of humans as information processors. It discusses ATC automation, computer-human interface, workstation design, workload and performance measurement, controller team formation and activities, and human factors testing and evaluation.

## Human Factors Report Databases

Many national and international authorities provide access to their reports on human factors. The following have been identified as useful to US and European aviation.

- 8) FAA Human Factors Portfolio. This is a repository of HF research and development activities in the flight deck and ATC/technical operations domains that support the efforts across the FAA and other agencies in the development and implementation of NextGen capabilities.  
See <https://www2.hf.faa.gov/HFPortalNew/HFPortfolioOverview.aspx>
- 9) EUROCONTROL Human Factors Reports. EUROCONTROL's reports on HF.  
See [http://www.eurocontrol.int/humanfactors/public/site\\_preferences/display\\_library\\_list\\_public.html](http://www.eurocontrol.int/humanfactors/public/site_preferences/display_library_list_public.html)
- 10) ICAO Flight Safety and Human Factors Programme Manuals and Circulars. The Flight Safety and Human Factors Programme has produced various HF manuals and circulars.  
See <http://www.icao.int/anb/humanfactors/Documents.html>

## Human Factors Knowledge: Websites

The following websites provide some basic information on a range of human factors issues.

- 11) SKYbrary. SKYbrary is an electronic repository of safety data related to ATM and aviation safety that enables users to access the safety data made available on the websites of various aviation organisations - regulators, service providers, industry. SKYbrary incorporates The Flight Safety Foundation's operators guide to human factors in aviation (OGHFA) and in 2010 further developments will result in a new Human Factors Portal.  
See <http://www.skybrary.aero/landingpage>
- 12) NASA HF Factsheets. A set of factsheets summarising NASA research on a wide variety of HF-related topics, such as attention management, fatigue decision making and human-centred systems.  
See [http://human-factors.arc.nasa.gov/awards\\_pubs/factsheets.php](http://human-factors.arc.nasa.gov/awards_pubs/factsheets.php)

## Human Factors Knowledge: Books (General readership)

These books have a very accessible style and are aimed at non-specialists in HF, such as controllers, investigators and safety managers.

- 13) Cardosi, K. M. (1999) Human factors for air traffic control specialists: A user's manual for your brain. U.S. Department of Transportation, DOT/VNTSC-FAA-99-6. This free, downloadable document presents the findings of human factors information useful to air traffic control specialists in a succinct and easy-to-read format. Includes information and strategies on controller-pilot voice communications, memory, fatigue, and the effects of stress on information processing. See <http://www.hf.faa.gov/docs/508/docs/volpe/hfatcs.pdf>
- 14) Dekker, S. (2002) The field guide to human error investigations. Aldershot, UK: Ashgate.
- 15) Flin, R., O'Connor, P., & Chrichton, M. (2008) Safety at the sharp end. Farnham, UK: Ashgate.
- 16) Hawkins, F. (1997) Human factors in flight. Aldershot, UK: Ashgate.

- 17) Hollnagel, E. (2009) The ETTO principle: Efficiency thoroughness trade-off. Farnham, UK: Ashgate.
- 18) Isaac, A. & Ruitenburg, B. (1999) Air traffic control: human performance factors. Aldershot, UK: Ashgate.
- 19) Reason, J. (1997) Managing the risks of organizational accidents. Aldershot, UK: Ashgate.
- 20) Reason, J. (2008) The human contribution: Unsafe acts, accidents and heroic recoveries. Farnham, UK: Ashgate.
- 21) Stein, E. S. (1994) The controller memory guide: Concepts from the field. (DOT/FAA/CT-TN94/28). Federal Aviation Administration. See <http://hf.tc.faa.gov/products/bibliographic/tn9428.htm>

## Human Factors Knowledge: Books (Advanced readership)

These books tend to summarise HF research findings in more detail and are aimed primarily at HF practitioners and specialists working in safety and system design and integration.

- 22) Hopkin, V. D. (1995) Human factors in air traffic control. London: Taylor & Francis.
- 23) Kirwan, B. & Ainsworth, L. K. (1992) A guide to task analysis. London: Taylor & Francis.
- 24) Kirwan, B. (1994) A guide to practical human reliability assessment. London: Taylor & Francis.
- 25) Kirwan, B., Rodgers, M. & Schafer, D. (Eds.) (2008) Human factors impacts in air traffic management. Aldershot: Ashgate.
- 26) Matthews, G., Davies, D. R., Westerman, S. J. & Stammers, R. (2000) Human performance: cognition, stress and individual differences. Hove, UK: Taylor and Francis.
- 27) Smolensky, M. W. & Stein, E. S. (Eds.) (1998) Human factors in air traffic control. San Diego, US: Academic Press.
- 28) Wise, J. A., Hopkin, V. D. & Garland, D. J. (2009) Handbook of aviation human factors. Mahwah, NJ: CRC Press.
- 29) Wickens, C. D., Mavor, A. S. & McGee, J. P. (Eds.) (1997) Flight to the future: Human factors in air traffic control. Washington, D.C.: National Academy Press.

## Human Factors Training

A number of human factors training course are available, both in person and on-line, from basic awareness training up to graduate and post-graduate level. Basic training is available from EUROCONTROL and FAA.

- 30) EUROCONTROL IANS HF Training: The EUROCONTROL Institute of Air Navigation Services (IANS) offers selection of courses that support ATM operations and incorporate human factors aspects of the SESAR programme. See the 'Eurocontrol Training Zone' on the following URL: [http://www.eurocontrol.int/ians/public/subsite\\_homepage/homepage.html](http://www.eurocontrol.int/ians/public/subsite_homepage/homepage.html)
- 31) Federal Aviation Administration (FAA) Human Factors Awareness Course: Online course covering basic and applied issues such as cognition, team performance, visual displays, and controls, among other issues. See <http://www.hf.faa.gov/Webtraining/index.htm>



## Associations, Societies and Institutes

Many national and international Societies, Associations and Institutes are available for networking and certification. The International Ergonomics Association (IEA) is the official federation for human factors Societies, Associations and Institutes around the world.

- 32) The International Ergonomics Association (IEA). The International Ergonomics Association is the federation of ergonomics and human factors societies from around the world. The mission of the IEA is to elaborate and advance ergonomics science and practice, and to improve the quality of life by expanding its scope of application and contribution to society. The IEA website links to the many national HF and ergonomics societies, associations and institutes (see the 'IEA Members' link). See <http://iea.cc/>
- 33) European Association for Aviation Psychology (EAAP). The EAAP provides a forum for professionals working European and non-European countries in the various domains of aviation psychology and human factors. EAAP facilitates a professional network to encourage the successful management of human performance in aviation. See <http://www.eaap.net/>

## NOTES





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