ICAO

Doc 10151

Manual on Human Performance (HP) for Regulators

First Edition (Advance unedited), 2021

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Approved by and published under the authority of the Secretary General

INTERNATIONAL CIVIL AVIATION ORGANIZATION

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INTERNATIONAL CIVIL AVIATION ORGANIZATION

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AMENDMENTS

Amendments are announced in the supplements to the *Products and Services Catalogue;* the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by

CORRIGENDA		
No.	Date	Entered by

From ICAO *Assembly Resolutions in Force (as of 4 October 2019)* (Doc 10041), A40-4:

Appendix O: Human performance

Whereas the aims and objectives of ICAO as laid down by the Chicago Convention provide for fostering the development of international air transport ". . . so as to . . . promote safety of flight in international air navigation";

Whereas it is recognized that human performance, as influenced by physiological and cognitive capabilities and constraints, contributes significantly to the overall safety performance of the aviation system;

Whereas it is recognized that the safety and efficiency benefits associated with new technologies, systems and procedures can only be realized when they are designed to enhance the performance of the individuals who use them; and

Whereas it is recognized that implementation of the future aviation systems will result in changes in roles for aviation professionals requiring work across multi-disciplinary teams to support collaborative decision-making;

The Assembly resolves that:

1. Member States ensure the integration of human performance considerations in the planning, design, and implementation of new technologies, systems and processes as part of a safety management approach;

2. Member States promote and facilitate the integration of human performance elements within competency-based training programmes throughout the career of a professional; and

3. Member States include strategies which promote safe, consistent, efficient and effective operational performance of the individual and across teams of individuals to address safety priorities.

TABLE OF CONTENTS

ACRONYMS

ASBU	Aviation system block upgrades
ATC	Air traffic control
ATO	Approved training organization
ATS	Air traffic services
CE	Critical elements
CRM	Crew resource management
FRMS	Fatigue risk management systems
GANP	Global Air Navigation Plan
HCD	Human centred design
HF	Human factors
HP	Human performance
HPP	Human performance principle
ICAO	International Civil Aviation Organization
SARPs	ICAO Standards and Recommended Practices
SMS	Safety management system
SSP	State Safety Programme
TEM	Threat and error management
TRM	Team resource management
UAS	Unmanned aircraft system

FOREWORD

PURPOSE OF THIS MANUAL

This manual highlights the importance of integrating human performance (HP) considerations in the development of ICAO Standards and Recommended Practices (SARPs) and in States' associated regulatory activities. It supports regulators to make it easy for people in the aviation system to do the right thing and avoid negative safety consequences. Regulators do this through the development of appropriate regulatory material, through evaluating, accepting and approving, and through the continued surveillance of how service providers[1] meet these regulatory requirements. This manual addresses HP considerations in all these regulatory activities.

This manual also provides guidance to regulators on HP considerations necessary to meet their obligations under the Convention on International Civil Aviation[2] and the ICAO Annex 19 – *Safety Management* SARPs for the establishment of a State Safety Programme (SSP). It illustrates how HP considerations are embedded in key oversight responsibilities and activities that are included in an SSP. It does not, however, attempt to comprehensively address all aspects of safety oversight, nor all aspects of HP. For instance, this manual does not discuss in any detail issues of physical or mental health, nor questions of individuals' fitness for duty. Nor does the manual focus on HP issues for specific types of aviation personnel. Instead, it takes a system's perspective on human performance, and it brings to focus the human contribution to the global aviation system.

It is not the purpose of this manual to make every regulator an HP expert, but to enable all regulatory personnel to recognize HP considerations in their daily work activities, including in their own internal organization, and to know when the help of a qualified and experienced HP professional should be sought. It is the purpose of this manual to guide and structure the conversations about HP between the regulator and the people being regulated. Finally, the industry can also benefit by gaining an understanding of regulatory expectations related to HP.

This manual supersedes the *Human Factors Guidelines for Safety Audits Manual* (Doc 9806) and complements the following:

- *Human Factors Training Manual* (Doc 9683); and
- *Human Factors Guidelines for Aircraft Maintenance Manual* (Doc 8824)

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[1] In this manual, the term "service provider" is used interchangeably with the term "organization" to refer to any approved aviation industry organization, including air traffic service providers, commercial air transport operators, aerodrome operators, and approved maintenance and training organizations. The guidance is also relevant to designated individuals who provide aviation services on behalf of the State (e.g. pilot examiners, aviation medical examiners, maintenance inspectors, certification engineers).

[2] Commonly known as "The Chicago Convention"

STRUCTURE OF THIS MANUAL

This manual is comprised of two parts.

Part 1 (*Understanding HP*) introduces the basic terminology of human performance, human factors and ergonomics, and focuses on concepts to provide a better understanding of why HP matters to regulators. It provides the foundation for Part 2 and serves to highlight the human contribution to the aviation system. It introduces the notions of *systems thinking* and *human-centered design*, as well as five HP principles.

Part 2 (*HP Implications for Regulatory Activities*) focuses on specific regulatory activities and their associated HP aspects. It provides guidance for the application of HP considerations to assist regulatory personnel to better perform their job functions.

Understanding the basics of HP (Part 1) and the application of that understanding in regulatory activities (Part 2) provide States, their regulators, and those involved in developing ICAO provisions with powerful tools to enhance the safety and efficiency of the global aviation system.

Finally, the Appendices provide a list of documents referenced in this manual (Appendix A) and some weblinks to additional HP-related reference materials (Appendix B).

PART 1. UNDERSTANDING HP

An understanding of HP is relevant and foundational for regulators in doing their job, regardless of what role(s) they have within the regulatory body.

An understanding of HP leads regulatory personnel to recognize how multiple influences throughout the entire aviation system can affect a service provider's safety performance during day-to-day operations. The aviation system is globally and technologically interlinked. Having a broad picture of the system, how and where people work within the system, and the influences upon them, enables regulators to develop and adapt effective regulations and oversight methodologies. This in turn supports people to do their best for the safety of the aviation system. This broad view extends the focus beyond minimum standards towards ways in which the regulator can support safety enhancements within their State, their region and internationally.

Throughout the aviation system, people are both the source of some of the risks and an integral part of identifying and managing all risks.

Historically, thinking about the human contribution to the aviation system has largely focused on the errors and violations people make that adversely affect safety. More recently, there has been a shift in focus to the positive contribution to safety, resilience, and efficiency made by people in the system. People's ability to adapt is often the reason that the system is successful despite interruptions and disturbances, such as storms, mechanical emergencies, and economic downturns. This focus recognizes the value in assessing and understanding, not only when things go wrong, but also when things go right. And most of the time, things do go right.

People's ability to adapt means that the system is more likely to recover from unexpected disturbances, resulting in increased resilience.

The focus on either the negative contribution or the positive contribution of people to system performance may vary depending on the context. Each informs our approach for developing ICAO provisions and national regulations to manage people and their performance. In practice, a blend of these perspectives is often more appropriate than taking either perspective to the exclusion of the other.

Understanding HP can also help regulators to identify when the support of specialist knowledge is needed. Although some States may not have the resources, ideally, HP specialists are part of the regulator's staff, most commonly in functions such as evaluation, testing, approval and development of regulatory and guidance materials. They could also be in a general role of coordinating HP activities that aim to reduce human error and improve human performance. Regardless of whether States have HP specialists on their permanent staff or bring them in as consultants, it is important that they be suitably qualified with appropriate in-depth knowledge.

To provide a foundation for understanding the relevance of HP for regulatory personnel, Part 1 of this manual addresses:

- human performance, human factors or ergonomics?;
- a human-centred design (HCD) process;
- systems thinking; and
- HP principles.

1.1 HUMAN PERFORMANCE, HUMAN FACTORS OR ERGONOMICS?

The terms *human performance, human factors* and *ergonomics* are sometimes confused and are often used interchangeably, even in ICAO documents. This is not surprising because they are closely linked.

For the purposes of this manual, we distinguish between human performance and human factors as follows:

- ***human performance (HP)*** refers to how people perform their tasks. HP represents the human contribution to system performance.

- ***human factors (HF)*** is concerned with the application of what we know about human beings, their abilities, characteristics and limitations, to the design of equipment they use, environments in which they function and jobs they perform[3].

The notion of "design" is used in this document in a broad sense that goes beyond drawing schematics of specific pieces of hardware. This broad notion of design extends to the development of processes and procedures, of job descriptions and task specifications, and indeed to the development of ICAO provisions and SARPs and States' regulatory requirements.

[3] Human Factors and Ergonomics Society, 2008.

Outside aviation, ***HF*** and ***ergonomics*** are terms that are also sometimes used interchangeably, although they tend to be used with slightly different emphasis. *HF* is more often associated with the psychological aspects of the human whereas e*rgonomics* is more often associated with the physical aspects of the human. In aviation, *ergonomics* is considered a subset of *human factors* that focuses specifically on designing technical systems, products and equipment to meet the physical needs of the user.

> ***Human factors (HF)*** *encompasses knowledge from a range of scientific disciplines that support* ***human performance (HP)*** *through the design and evaluation of equipment, environments and work, in order to improve* ***system performance****.*

This manual uses the term HP, but HP cannot be disassociated from HF and ergonomics. HF brings insights and understanding to HP from many different scientific disciplines, such as psychology (including cognitive psychology, industrial and work and organizational psychology, and social psychology), behavioural psychology, sociology, anthropology, medical sciences including aviation medicine and occupational medicine, design and engineering, computer science and statistics.

Regulatory personnel draw on these different disciplines and perspectives to support human performance and improve safety in a variety of roles. Regulators need to apply HF knowledge to evaluate whether their regulations and rules adequately support safety. Regulators should also apply HF knowledge to ascertain that the systems, equipment, workplaces and processes used by those they regulate, are designed and used to adequately support HP. Therefore, regulators should ensure they utilize suitably educated, qualified, and experienced professionals, to evaluate compliance with those specific aspects of the regulations.

1.2 A HUMAN-CENTRED DESIGN PROCESS

People design, build, maintain and operate every aspect of the global aviation system. The performance of the aviation system, including its safety performance, depends on HP. Because humans are at the center of that aviation system, a human-centered approach to the design and development of all aspects within that system is needed.

Human-centered design (HCD) - also known as *user-centered* design – is an approach that helps ensure that the product being designed – such as systems, equipment, procedures, services, or regulations - is useful and usable[4] and will support skilled performance in the workplace so that intended operational benefits can be realized. Designs that are developed using a human-centred approach take into account the HP principles (see Section 1.4) and can result in improved system performance and human well-being.

Understanding HCD has relevance for regulators in evaluating people, processes, procedures, systems and equipment, and in the development of regulations. It also has relevance for regulators in planning for, and supporting the implementation of new technologies, and in the management of change.

The International Organization for Standardization (ISO) describes an HCD approach as having the following characteristics[5] (adapted for this manual):

a) the design is based upon an explicit understanding of users, tasks and work environments (i.e., how the HP principles presented in Section 1.4 below are manifested in the operational environment);

b) users are involved throughout design and development;

c) the design is driven and refined by user-centred evaluation and the use of operational data;

d) an iterative process is used which builds on lessons learned through multiple tests;

e) the process ensures that the whole user experience is addressed under varying conditions of use; and

f) the design team has multidisciplinary skills and perspectives, including individuals with relevant HP expertise.

Therefore, using an HCD approach focuses on a solid understanding of the users’ context and requirements. As a result of users’ involvement and the focus on user needs and capabilities, a development project may see a shortened implementation phase and higher user acceptance. Because a key aspect of an HCD approach is continuous improvement based on lessons learned in testing and trials, following the HCD process reduces the likelihood of being surprised by unintended consequences. Ultimately, following the HCD process can lead to improved safety, which is the regulator’s priority. It can also lead to significant reductions in life-cycle costs.

[4] *Usability* can be defined as the “extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and safety in a specified context of use” (adapted from ISO 9241-210: 2010).

[5] ISO 9241-210: 2010

A complete process that uses a human-centred approach encompasses design, development, production, implementation and monitoring. It typically involves the following steps:

1) *A concept of use (or operation) is identified.* This is the developer's general vision of how the user will interact with the product to be developed. It is based on: a) baseline assumptions about what the users need to know and are able to do; b) how they will do it; and c) a description of the operational context (including assumptions about the environment in which the design will operate and to what other systems it connects). For example, in developing a new technology, it is at this early stage that decisions are made about what functions the technology will perform and what will be the role of the humans interacting with it.

2) *Design requirements are identified.* Design requirements specify what the product being developed must be able to accomplish as well as properties that it must have to "build in safety", recognizing the range of possible responses humans may make when interacting with the product. The design requirements will lead to design features and functions that are needed to support human performance. For example, in developing new airport markings, clear visibility in all lighting and weather conditions would be identified as a design requirement.

3) *Prototype designs are developed.* Prototype design concepts (also known as candidate designs) are developed based on the design requirements and user needs, not to create the perfect design solution, but to make sure the design solution is on target. For example, in developing a new display, several different layouts are drafted and different symbologies may be proposed. A prototype design can be anything from an informal drawing (low fidelity prototype), to a fully functional simulation (high fidelity prototype).

4) *Prototype designs are tested and evaluated.* A test and evaluation programme provides an opportunity to try out prototype design concepts and obtain user feedback to make improvements. Tests and evaluations are also conducted to ensure the product works as intended, is easy to use under varying conditions of use and meets human and operational performance requirements. While demonstrations for potential users provide benefits, they cannot substitute for tests that gather objective and subjective data. It is important to test early and to test often. Each iteration is evaluated to improve the next iteration. Iterative usability testing typically leads to an improved design, with fewer late-stage design changes or the need to develop "work-arounds" post implementation. For example, in developing a new approach procedure for an airport, various approach profiles can be tested in a variety of flight simulators, simulating different aircraft and different environmental and traffic conditions. Each iteration could lead to improvements in the design of the approach procedure.

An HCD approach builds in safety by considering HP principles and how people will interact with the product being designed, and by engaging end-users in the design, prototyping and testing before implementation to make sure that what is being developed performs as expected.

5) *The design is selected.* Finally, from the results of the evaluation of candidate designs and from lessons learned through user testing, the optimal design is selected for development. Once the selected design is fully developed into a product, formal testing, verification and validation rounds are completed with the participation of end-users, prior to implementation.

6) *Implementation guidance is developed.* Guidance needs to be developed to describe how the selected design is intended to be used in the operational context. Implementation guidance should not only explain how to use the design but also identify any changes in user responsibilities and include what, if any, training is needed to use the design. Again, engaging end-users in the development of guidance material can prove highly effective in achieving a smooth implementation. For example, in approving a fatigue risk management system (FRMS), a regulator should expect, as part of its approval process, that an operator presents an implementation plan that identifies to which part of its operations the FRMS applies, the various responsibilities of those involved, and the training they will undertake, as well as how the intended FRMS processes will be used. Similarly, in developing supporting regulatory material for a new regulation, details describing how the change can be implemented and acceptable means of compliance should be included.

Lessons learned using an HCD approach help to build robust implementation guidance to support ICAO SARPs and national regulations.

7) *Performance is monitored after implementation.* Using the implementation guidance, the selected design can be integrated as part of normal operations. Lessons learned through use should result in continuous improvement to evolve the capabilities of existing tools, technologies, processes or procedures, or drive the development of new design concepts. For example, following the adoption of a new departure procedure from an airport, indicators are identified and tracked to measure and monitor traffic counts, ground delays and potential losses of separation. In addition, reports from air traffic controllers and pilots are solicited to document any concerns and unintended consequences. This data and information are then used to determine if any further adjustments are needed to the procedure, or to any other part of the system, including supporting regulations.

How can understanding human-centred design help regulators?

"Design" can relate to the development of anything, whether a piece of equipment, a process, a procedure, a programme or a document. In this sense, regulators are "developers" of regulatory material and processes, as well as being regulators of developers (i.e. those that develop processes, procedures and programmes) and not just approvers of equipment that has already been designed (see Section 2.3.1). Understanding HCD means that regulators can both use this process themselves and support the use of this process by those they regulate in order to have new or amended rules, programmes, processes and procedures that are easily implementable. Examples of using an HCD process to draft regulatory material and to develop safety promotion material are provided below (see Section 1.2.1).

Lessons learned through using an iterative HCD process can also assist with the development of ICAO provisions (which include SARPs, PANS, technical instructions, circulars, policy, and guidance material) that support the implementation of new approaches, regulations, management systems, technologies and procedures.

Such lessons are particularly relevant to provisions associated with the operational improvements outlined in the Global Air Navigation Plan (GANP), and in particular in the aviation system block upgrades (ASBUs) framework. These operational improvements are aimed at increasing the capacity or improving the performance of the aviation system, and involve meeting challenges associated with rapid changes in air traffic, emerging technologies, and innovative ways of doing business. To ensure that the associated implications for the humans in the system are considered from the outset, those involved in the initial identification of the operational improvements are asked to consider the following questions, which are presented in the ICAO GANP portal:

- **Does it imply a change in task by a user or affected others?**
- **Does it imply processing of new information by the user?**
- **Does it imply the use of new equipment?**
- **Does it imply a change to levels of automation?**

The answers to these questions outline the expected changes to people's functions, roles and responsibilities that will need to be supported even before some of the operational improvements have been developed. As the development process unfolds, these questions get asked again and again. Using an iterative HCD approach to develop the operational improvements provides information to allow these questions to be answered in increasing detail. More detailed answers lead to ICAO provisions and regulatory material that better support HP considerations in the implementation of operational improvements.

The same questions can be used in part to ensure that HP principles have been considered by an organisation preparing to implement change (see Section 2.4.6 *Management of Change*).

1.2.1 EXAMPLES OF USING THE HCD PROCESS

a) Drafting regulatory material and guidance material for a new type of system, such as an unmanned aircraft system (UAS)

1) *A concept of use (or operation) is identified.* It is at this early stage that decisions are made about whether a regulation for a new type of system (in this case, a UAS), will be prescriptive or performance-based. Making such a decision is based on understanding the people involved, their activities, tasks and operational contexts, as well as on an assessment of the safety and risks of the new system, the ability to oversee the system in operation and the expected range of experience of the users.

2) *Design requirements are identified.* In this case, the target recipients and scope of the new regulation are identified, as well as setting certain weight limits or a range for the class of UAS, area acceptable for its operation, and demonstration of competence required by those being regulated.

3) *Prototype designs are developed.* Internal discussions within policy teams develop draft proposals of the new regulation based on internal regulatory philosophy and experience.

4) *Prototype designs are tested and evaluated.* The different drafts developed under Step 3 are reviewed internally by those who would oversee them (both legally and in-the-field). Proposals are then checked with the affected operational community (e.g. informally or through workshops). Each iteration leads to further development of the language and structure of the proposed regulation or guidance material to enable it to meet the agreed philosophy of operation. The drafts also specify the surveillance process, including penalties for incorrect use that can be expected.

5) *The design is selected.* The review process then selects the approach, implementation time period, required actions, oversight approach and review process. The selected design is then published.

6) *Implementation guidance is developed.* Guidance material may be needed to support the correct implementation of the regulation. For example, the findings from the review process can be used to develop implementation guidance that identifies acceptable means of compliance with the regulations and describes how to make an application to use the UAS. Findings from the review process can also inform the regulatory processes associated with the oversight process, including penalties for incorrect use that can be expected.

7) *Performance is monitored after implementation.* Once the new regulation is in force, compliance and deviations are tracked through monitoring of performance indicators, occurrence reporting and other relevant routine reporting (e.g. reports on findings of medical assessments). In addition, reports from the operational community are solicited through surveys, workshops or during surveillance activities, to document any concerns and any unintended consequences. This information is then used to determine if any further adjustments to the regulations or the regulatory approach are needed.

b) Developing safety promotion material for the use of the new system

1) *A concept of use (or operation) is identified.* It is at this early point that decisions are made about what is the intended outcome of the safety promotion (e.g. awareness of the regulation, UAS operations best practices, safety concerns around these operations, reporting of issues, etc.). Making such a decision is based on understanding the people involved, their activities, tasks and operational contexts. This

material may be different for different target audiences (the UAS operator, regulatory staff, general public) and the target activities (e.g. during the use of the UAS reporting of issues or concerns during or after use of the UAS).

2) *Design requirements are identified.* Because communication is key to safety promotion, the regulator may use an internal or external communications team, or the internal team who finalised the regulatory material. Focus on what the operator must know. Incorporate positive messages and HP principles (see section 1.4), adjusted to the constraints of the media intended for use. (e.g., internet, social media, speeches, workshops, email, posters, etc.). All of these factors determine the “design requirements.”

3) *Prototype designs are developed.* Different drafts and different media of the safety promotional materials are proposed, for the different messages and target audience groups.

4) *Prototype designs are tested and evaluated.* The drafts developed for the different audience groups are reviewed internally, and shared with the operational community for comments. This allows improvements to the language used, layout, and the media of the proposed material for the particular message and audience.

5) *The design is selected.* From the testing under Step 4, the selected material is finalized for the different audience groups (e.g. UAS operator, regulatory teams, general public).

6) *Implementation guidance is developed.* Details describing how the promotional material can be distributed and used are developed, including a timeline for the activities. For example, this implementation could include registered UAS users and operators or their clubs and associations, internal briefings and promotional activities, and for the general public a launch on social media sites and through newspaper advertisements.

7) *Performance is monitored after implementation.* To measure the effectiveness of the promotional efforts, surveillance activities such as questioning and observing UAS operators, reporting behavior of both the public and the UAS operators, and evaluating relevant external reports, are used to assess trends. Web analytics (how many hits or downloads) could also be used to assess the reach and uptake of materials. All this data can then be used to determine if adjustments to the materials are needed, and how future safety promotion efforts are to be conducted for maximum effectiveness.

1.3 SYSTEMS THINKING

Systems thinking is an approach to view systems in a holistic, integrated manner, rather than as isolated components or parts. It examines the linkages and interactions between the elements that comprise the whole of the system. Systems thinking is particularly useful in addressing complex systems where small changes in one part of the system can lead to large and unexpected effects in the overall system.

ICAO SARPS are designed, through their application in State regulations, to provide for global interoperability and keep the aviation system safe, secure, economically viable and environmentally sustainable. Because every change to any part of the system is likely to impact other parts of it, adopting a systems perspective enables regulators to develop effective regulations and avoid unintended consequences.

A system is a collection of separate, but interrelated parts that work together to achieve a common purpose.

People often think of human performance at a very local level, comprising a single person or a team/crew performing a task. But human performance, individually and collectively, is connected to, and dependent on, other parts of the aviation system. And because the aviation system is a "system of systems", it is important to understand the differences and interactions between the different kinds of systems in it:

- **Simple systems.** These are relatively easy to understand and have predictable performance. Simple systems have one or a small number of known goals or functions and these do not change over time. As such, they are easy to repair and to ensure that they consistently meet pre-identified performance standards. An aviation example of a simple system is the passenger emergency lighting system used to guide passengers out of an aircraft in an emergency.

- **Complicated systems.** The structure, elements and interactions in a complicated system might be difficult to understand but can be understood and quantified with a high degree of accuracy and completeness by experts. Knowledge of these systems is normally developed in a linear way (where an understanding of one element leads to an understanding of the next element and their impact on another can be reasonably predicted) and, like simple systems, can be designed to meet pre-identified performance standards. An aircraft jet engine, which has several goals that remain the same over time (including to produce thrust and generate electricity and hydraulic pressure) is an aviation example of a complicated system.

- **Complex systems.** In a complex system, the whole is greater than the sum of its parts. Everything is connected to, and dependent on, something else. Importantly, the behavior of the system cannot be predicted from examining the behavior of its separate parts and the system cannot be understood by only looking at one component or from one perspective. Complex systems are often subject to random and unpredictable events due to the multiple and changing influences and interactions within the system. Humans are themselves complex systems. An individual may change behavior, adapting to internal influences, such as health or personal mood, as well as to external influences, such as environment or equipment. Any interaction between a human and technology, regardless of whether the technology itself is simple or complicated, changes the nature of the whole human-technology system, making it a complex system.

Because each human being is a complex system, introducing a human to a system renders the whole system complex.

The global aviation system is, therefore, a complex socio-technical system of systems. In other words, it is a network of people, technologies and environments that are all interconnected. Everything can potentially affect something else. Weather changes in one location affect operations half-way around the world. New legislation in one country affects operations in other countries. A small software change for one part of one computer in the network can affect the whole world. Seemingly small changes within one organization can have ripple-effects throughout the aviation system as other organizations try to adapt.

Regulatory actions affect the aviation system through affecting what people do and how they do it, whether directly or indirectly. Regulatory actions directed to a specific group of people may also affect the actions of other groups of people, sometimes in unexpected ways. For example, approving a change in a flight deck procedure at an airline of one country can affect the ground crew at an airport in a different country, which could affect the ramp operation, affecting the airport and other airlines using that airport.

Within a complex system, it is the human contribution that often provides the important safety barriers and sources of recovery.

Therefore, regulators need to use appropriate methods and tools for regulating, evaluating, and approving complex systems. Many regulatory methods and tools in use may be more appropriate for evaluating simple and complicated systems than for evaluating the vast range of socio-technical interactions in and between the complex operational systems that make up the global aviation system.

Why is systems thinking important for regulators?

Systems thinking allows regulators to recognise that the performance of the system as a whole, not just its safety performance, depends on effective human performance. Taking a systems perspective means that regulators:

- assess risks to all parts of the aviation system by anticipating unintended consequences of their regulations and regulatory actions (addressed in Part 2);
- seek to understand the context within which behaviour occurs, when it comes to investigating safety occurrences and analyzing safety reports (see Section 2.1);
- consider who will be directly AND indirectly affected when developing new regulations (see Section 2.2);
- understand that any change, including those related to introducing new technologies, may not necessarily reduce complexity or the possibility of errors, but may shift these to different parts of the system, with different consequences (see Section 2.3.1); and
- can take multiple perspectives on situations, problems and opportunities to support human performance and apply them within their regulatory functions.

1.4 HP PRINCIPLES

This section presents five HP principles that outline how the performance of people is influenced by different factors. These principles are:

- Principle 1: People's performance is shaped by their capabilities and limitations;
- Principle 2: People interpret situations differently and perform in ways that make sense to them;
- Principle 3: People adapt to meet the demands of a complex and dynamic work environment;
- Principle 4: People assess risks and make trade-offs; and
- Principle 5: People's performance is influenced by working with other people, technology, and the environment.

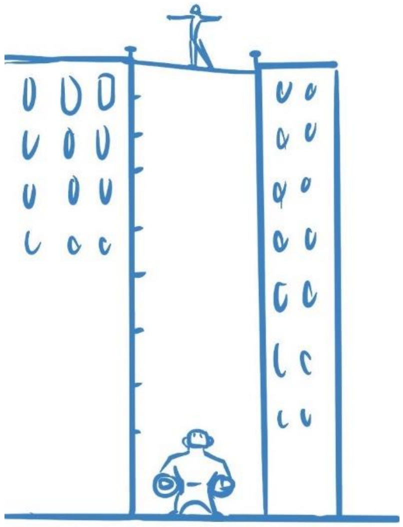
Each of these HP principles is described below. These principles are linked to regulatory activities in Part 2. Awareness of these principles help to shape, improve and maximise the performance of the aviation system as a whole.

The HP principles are informed by research and operational experience. They highlight different aspects of human performance. These principles necessarily interact and overlap to some extent. For instance, the first principle is about human capabilities and limitations. In fact, everything about humans can be described in terms of capabilities and limitations. The fifth principle is about some of the external factors that influence human performance. In fact, all such observations could be described as either internal or external influences on the individual. Thus, these principles are not an attempt to create a categorization scheme, with each category being a discrete building block of human performance. Instead, they provide different insights and perspectives to come closer to a multi-dimensional picture of human performance.

The HP principles apply generally to all humans involved in the aviation system, at the individual, team, and organizational levels. Thus, the HP principles are also relevant to the regulator's own internal organization and processes.

Principle 1: People's performance is shaped by their capabilities and limitations

People have various physical and mental capabilities, such as strength, flexibility, memory, attention, resourcefulness, and creativity. They apply these capabilities in their daily work to keep the system functioning safely, effectively, and efficiently. However, the same abilities that make people so critical to safety, system resilience, and operational success may also make them susceptible to errors and to unwanted behaviour.



People have limitations too. Some are based on physiology. For example, people cannot function well without adequate sleep and nutrition. They cannot lift very heavy weights, cannot see in the dark, and are subject to involuntary responses under stress. Some of these physiological limitations can be aggravated in aviation when flying at altitude (e.g. decreased oxygen delivery to organs, including sensory organs, can result in problems with night vision or impaired decision-making).

People also have cognitive constraints. For example, they cannot always remember what they were told. Nor can they always immediately solve complex calculations in their heads, or maintain attentiveness when they are bored, tired or cognitively overloaded.

To free up cognitive resources for other tasks, people can make quick, automatic responses when performing frequent activities and well-practised routines. Although this ability is mostly effective, this "automatic mode" can also lead to unintended actions. For example, a well-learned response to one situation might be executed in response to a related situation that needs a different response. People naturally use reasoning strategies or mental shortcuts that allow them to "speed up" their decision making. These shortcuts, also called *heuristics,* are often very effective. However, they don't always work, and can result in a variety of *decision biases* (see 2.1.2) that may lead to poor decisions.

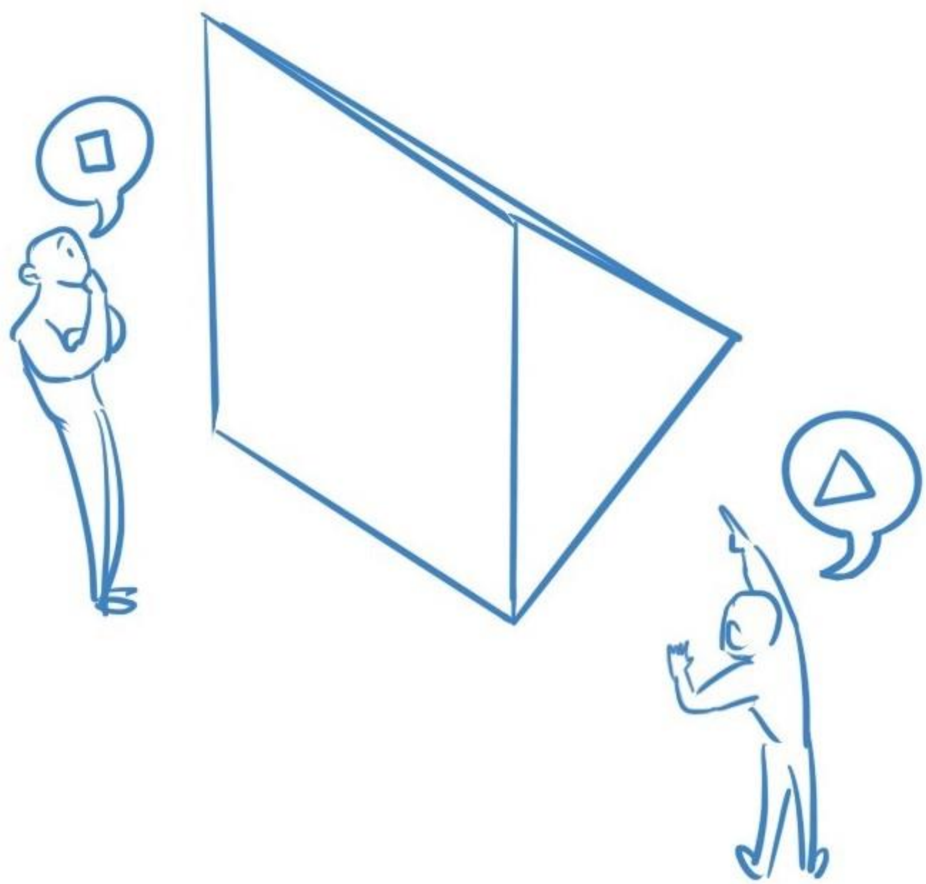
Sensory limitations and information processing limitations can lead to perceptual illusions, and to the failure to notice subtle changes in the environment, especially when attention is focused elsewhere or when experiencing spatial disorientation during flight.

Furthermore, people's performance is variable. No one can perform at the same level all the time, and the level at which people can perform certain types of tasks changes throughout the day. For example, people's performance may deteriorate when they are ill, bored, stressed, or fatigued. However, for all their limitations, when well supported, people are able to manage novel situations, adapting their skills to safely manage the operation. It is this human trait of adaptability that enables the global aviation system to function.

Principle 2: People interpret situations differently and perform in ways that make sense to them

People are always trying to make sense of the world around them. They look for patterns and predictability. Using the information available to them, they make conscious decisions and take actions based on explicit knowledge of facts and procedures as well as on implicit knowledge informed through experience, insights, and intuition. People rely on such implicit knowledge to interpret facts, to judge their credibility, to fit them together and to determine what is relevant. This implicit knowledge plays a particularly important role in the way people make sense of an operational environment where not everything can be predicted or controlled, including the actions of other people. This implicit knowledge is especially powerful when there is little time in which to make a decision.

People do not go to work with the intention of making an error or of contributing to a safety event. Although people can sometimes make reflexive responses that they cannot explain, generally people behave intentionally. They behave and make conscious decisions in ways that make sense to them, and that they think will achieve a good outcome. They analyze and interpret information presented to them, and act according to their understanding of the situation. In hindsight, it is often easy to see how decisions and actions led to an undesired outcome and how it might have been avoided – but at the time the decision was made or the action taken, it seemed appropriate. It made sense. The unintended consequences were unknown and may not have been predictable. People's actions therefore need to be considered in context and understood from the individual's perspective at the time of the action.



Principle 3: People adapt to meet the demands of a complex and dynamic work environment

People are key to the aviation system, creating resilience by constantly adjusting and adapting to overcome delays, adverse weather, and other unexpected situations. Further, within the aviation system, multiple organizations are often working towards the same outcome, although each has different goals, pressures and cultures. Individuals from one organization may be heavily dependent on, and influenced by, the actions of another organization. An example might be a safe and speedy aircraft turnaround between flights, which involves flight crew, cabin crew, dispatchers, maintenance personnel, and ground handlers.

As a result of this continuous adaptation, the work actually performed by people is often different from how the work was originally expected to be performed. Rules, procedures, tasks, and equipment are often designed and planned in an environment where a limited set of variables is considered. In the operational environment, work is performed under conditions in which not everything can be predicted or controlled.

To be effective under these dynamic conditions, people need to be able to do more than simply complete a series of pre-identified procedural steps. Whilst standard procedures support safe and efficient operations, people may need to adjust their work in a way that takes into account potential risks, and manages unanticipated events. Additionally, people must have and be able to integrate the right knowledge and skill with an accurate understanding of the operational environment, and how their actions may affect others.

To address emerging and changing demands, rules and procedures should be reviewed, validated and updated to meet the demands of a complex and dynamic work environment.

Principle 4: People assess risks and make trade-offs

The aviation work environment presents people with conflicting goals. Any activity in aviation must balance safety objectives and other organizational objectives, such as on-time performance, cost savings, and environmental protection. For individuals, these conflicting goals can sometimes translate into difficult operational trade-offs: efficiency vs. thoroughness, speed vs. accuracy, cost vs. benefit, short term vs. longer term benefits, and personal vs. organizational goals. Consciously or not, people evaluate the risks posed by these trade-offs. For example, assessing the risk of a delayed departure against the risk of not performing a procedure thoroughly. And people perceive risks based on their individual characteristics, their own experience, and their ability to anticipate and manage possible outcomes.

These trade-off choices are influenced by personal beliefs, interests and motivations, as well as social, organizational, and cultural factors. These choices are also influenced by the perceived incentives and disincentives in the system. People are acutely sensitive to the perceived incentives and disincentives present in their work environment, even though these may not always be consistent with stated organizational priorities and goals. For example, if a manager continuously claims that safety is the highest organizational priority, but at the same time rewards speedy performance and discourages or even punishes thoroughness when it causes delays, employees learn to value speed over safety.

Trade-offs can sometimes result in errors or in deviations from published rules or procedures. This flexibility might be perceived as a safety deficiency. However, procedures and rules are often prescribed in a limited context or for specific purposes, and it is the responsibility of the people in the system to balance the risks and find the right trade-offs. In making choices, people attempt to make what they think is an acceptable compromise to resolve the goal conflict, while keeping risk within subjectively acceptable limits. The risks perceived by the individual may not align with management's or the regulator's view of risk. Individuals may consider risks to include being embarrassed, being ridiculed, threatening a relationship, or being punished. Also, risks are likely to be perceived differently by different people at different times, especially after an unintended outcome.

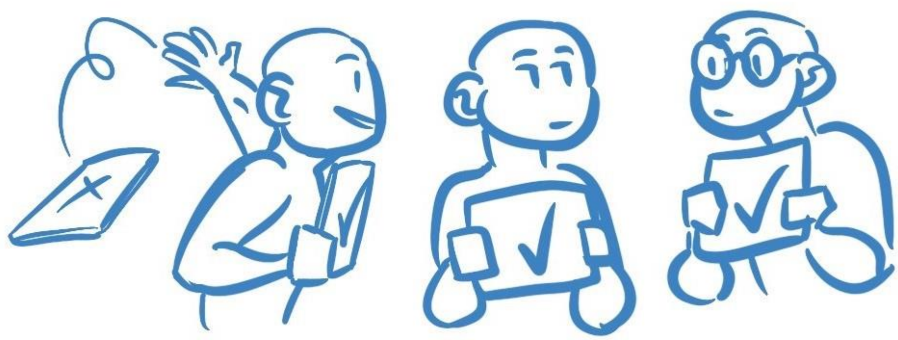
It's worth noting that leaders and managers are also human, and so they too make such trade-offs and compromises.

Although every person is different and can be unpredictable in some sense, each has an inherent ability to understand goals, and to assess risks and make trade-offs in order to provide an overall acceptable solution in a complex aviation work environment.

Principle 5: People's performance is influenced by working with other people, technology, and the environment.

Human performance can be positively or negatively affected by interacting with other people and with all elements of the socio-technical system. We learn and behave within the constructs of the culture we are brought up in and in which we live. Group and organizational cultures provide the context in which people work together. Such cultures reflect assumptions, often unstated, about the nature of the world. These assumptions, in turn, determine how people perceive the world around them, and how they respond to it. The group and the organization establish expectations for "the way things are done around here". The individual and the group can be influenced by the environment in which they work, such as by physical location, weather conditions or national culture. They are then influenced by the equipment and technology they are provided with. Even when provided with the proper equipment, procedures, guidance and training, people's performance is influenced by interactions with others, and everything around them, in ways that can vary from the expected result.

When people work together as a group, they can do more collectively than any individual can do alone. In the same way that some physical capabilities of the group are greater than the individual capabilities of any group member (e.g., the group can lift a heavier weight than a single person can), the group's limitations may also be greater than the limitations of any individual group member. For example, the cognitive bias of "group think" occurs when people's desire for group consensus, harmony, or conformity results in a dysfunctional decision. Individuals in the group may make incorrect assumptions about others' thoughts, values, needs and desires, as well as about those of the group as a whole. At the same time, groups can also help individuals make better decisions, and improve performance by compensating for individuals' limitations, and encouraging and supporting appropriate behaviour and optimal performance.



In the aviation system, there are multiple different groups within which people operate. These groups can be within an individual organization, across multiple organizations that work closely together, or based on job type. Individuals may be heavily dependent on the actions and behaviours of other people from another group, who may be working under different constraints and goals.

Similar to the way their performance is influenced by working with other people, people's performance is also influenced by the technology used and by the environment in which they perform. Well-designed tools allow people to improve their performance, whereas poorly designed or missing tools force people to improvise and might lead to reduced performance. And new or modified tools, even when well-designed, will result in changes to how people perform their tasks and may even change their role and their responsibilities. For example, the introduction of automation can change the role of the human operator from that of an initiator and direct manipulator to that of a reacting supervisor.

Environmental conditions such as lighting, temperature, and space also influence people's performance. People work best with adequate lighting, comfortable temperature and sufficient space to perform their tasks. When such optimal conditions do not exist, people again have to improvise, and their performance might not be as intended.

How does understanding the HP principles help regulators?

From a regulatory perspective, each of the HP principles can be turned into a question taking into account different operational environments:

- **HP Principle 1:** How will the regulatory requirements and/or oversight activities achieve the desired intent, given people's capabilities and limitations?
- **HP Principle 2:** How might people with differing levels of experience and understanding make sense of the regulatory requirements, and apply them in ways that were not intended?
- **HP Principle 3:** How will the regulatory requirements and/or oversight activities achieve the desired intent, given that people will be adapting to varying operational conditions?
- **HP Principle 4:** What kinds of risks and trade-offs might people face in complying with regulatory requirements or when responding to oversight activities?
- **HP Principle 5:** How will the influence of other people, technology or the working environment affect people's ability to comply with the regulatory requirements?

The answers to these questions should have direct consequences for regulatory choices and actions, including identifying what regulatory material is needed, what an acceptable means of compliance looks like and what oversight approaches will be used. Such regulatory choices and actions are examined further in Part 2 of this manual.

The HP principles also have consequences for a regulator's effectiveness, potentially impacting safety and operational issues (e.g. approval of inadequate equipment due to lack of resources, knowledge, time or because of undue political pressures).

PART 2. HP IMPLICATIONS FOR REGULATORY ACTIVITIES

A State Safety Programme (SSP) is the means through which a State can manage the safety risk in their national aviation system. Part 2 of this manual focuses on some key regulatory activities which are necessary for the implementation of an SSP in accordance with Annex 19 – *Safety Management*. Since HP considerations are embedded in many aspects of an SSP, Part 2 provides guidance for the application of HP considerations to assist regulatory personnel in better performing their required job functions. Because the ICAO provisions are developed to direct and support the States' regulatory activities, this part of the manual is also applicable for the development of ICAO provisions.

Throughout Part 2, references are made to the components of an SSP as outlined in Figure 1 below.

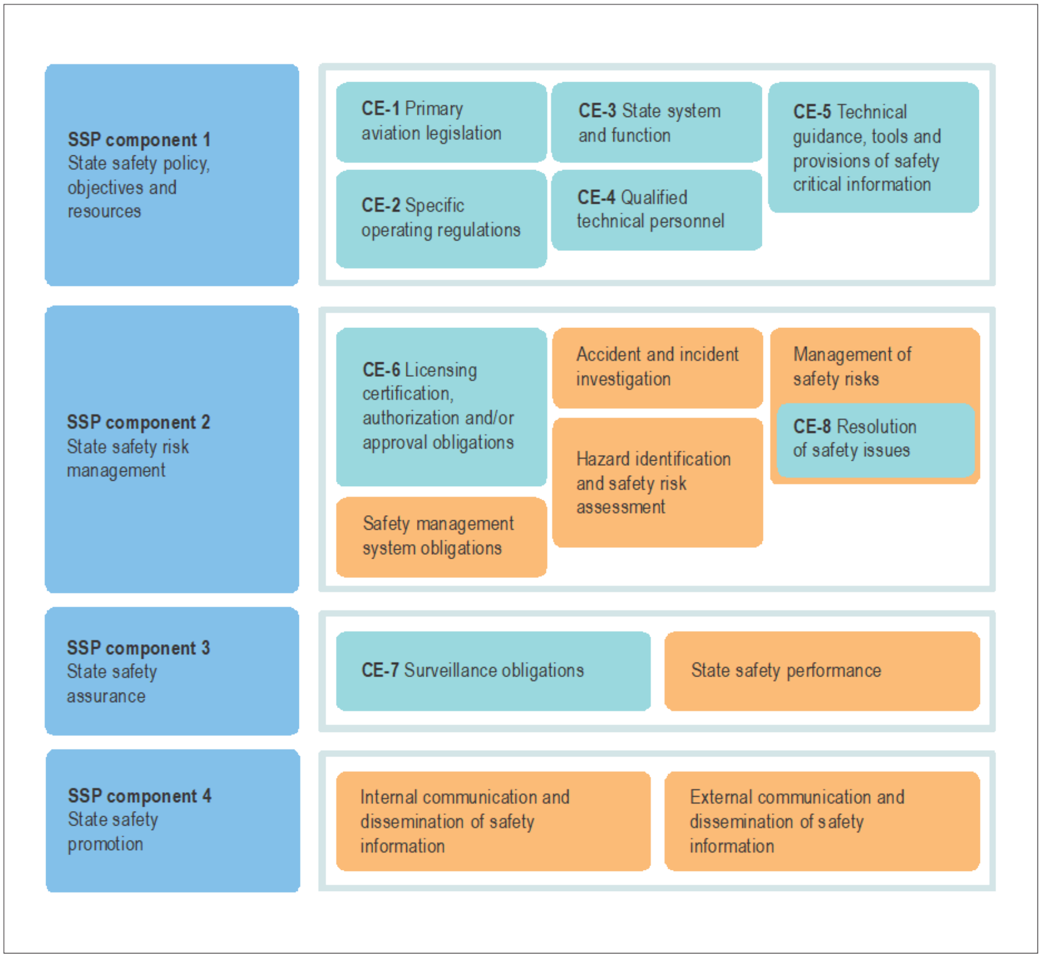


Figure 1. Components of a State Safety Programme. The four components of an SSP include the eight critical elements (CEs) of a State safety oversight system (light green boxes) which comprise the foundation of the SSP and other elements associated with safety management (orange boxes) [6].

[6] ICAO Safety Management Manual, Doc. 9859.

In this part of the manual, specific regulatory activities and their related HP considerations are linked to specific SSP components and their associated elements. Although all the SSP elements apply to every State, how the SSP is implemented will vary based on the State's particular needs and context in order to manage the safety risks in its aviation system. This implementation includes ensuring compliance with the regulations established by the State as well as the assessment of the effectiveness of each service provider's safety management system (SMS) and the ongoing monitoring of their safety performance. Part 2 of this manual does not attempt to comprehensively address all aspects of an SSP, nor does it comprehensively address all regulatory activities. Instead, it highlights regulatory activities associated with those SSP components and their associated elements that have significant HP considerations. Despite focusing on particular regulatory activities, the HP principles have consequences for regulatory choices and actions, and HP considerations should be embedded in regulatory activities. Throughout Part 2, attention is drawn to the HP principles, described in Part 1, to explain particular HP implications.

The particular regulatory activities addressed in the following sections are:

- collecting and analysing data;
- developing regulatory material;
- evaluating, accepting and approving (e.g., systems and equipment, procedures, personnel);
- providing ongoing surveillance; and
- promoting safety.

2.1 COLLECTING AND ANALYZING DATA

Because it is people who create safety, either directly by their actions or indirectly by their design of processes, equipment and systems, the need to collect and analyse HP-related data is central to safety management. The need to gather data and information is reflected in the Annex 19 requirements[7]. Guidance that highlights the need to consider the assessment of HP-related risks is provided in the Safety Management Manual[8]. HP information may be extracted from many different types of data, whether collected on a mandatory or voluntary basis, and whether looking at what went well or at what went wrong. For a regulator, it may include:

- in-service operational data (such as data provided by the original equipment manufacturer (OEM) and airlines);
- hazard identification and safety surveys;
- safety risk assessment data; and
- data obtained through safety reporting systems, medical reporting systems, and the investigation of occurrences.

[7] Annex 19, Chapter 5: Safety data and safety information collection, analysis, protection, sharing and exchange.

[8] Safety Management Manual (Doc. 9859) Section 2.5.6 Assessing human factors-related risks.

Analysing safety data represents an important opportunity to examine the interactions between the human and other system components. The analyses performed on the data collected provides an evidence base that may be used to support HP considerations in the SSP by identifying:

- when new or amended regulations and safety critical provisions are needed (SSP component 1 – CE-2 and CE-5[9]);
- what is effective, to embed these approaches in future regulatory activities (SSP component 29); and
- what isn't working, to manage safety risks (SSP component 29).

Note, the regulator's role in monitoring how a service provider collects and analyses data to examine HP-related issues is addressed later as part of providing ongoing surveillance in Sections 2.4.2 and 2.4.3.

The following subsections focus on the challenges that regulators have when collecting and analysing safety data to examine HP-related issues:

- using different sources and types of data;
- using HP taxonomies;
- analyzing a single occurrence; and,
- aggregating across multiple occurrences.

2.1.1 SOURCES AND TYPES OF DATA

Many safety data collection systems are focussed on the identification and monitoring of outcomes such as technical failures, runway incursions and excursions, and unstable approaches. However, to understand why an unwanted outcome occurs, substantive HP data should be collected, carefully analyzed, and monitored. Such HP data can then provide information on how the humans in the system contributed, both positively and negatively, to the various outcomes. This information could suggest important improvements to technology design, to procedures, and to training, as well as help identify regulatory gaps. To obtain such information, regulators need to look beyond simply counting the number of instances where "human error" was identified as a contributing factor; they must consider detailed contextual information.

The pros and cons of gathering HP information via multiple dedicated reporting systems versus having a single common safety reporting system also need to be considered by regulators. For example, collecting data via a common system is often more efficient than merging and analysing data across different systems. It avoids duplication and places information related to HP alongside information on other subjects, such as technical events. However, it also means that the methods of collecting, processing and analysing the data are less well tailored to examining HP. For example, standardised report forms have to strike a balance between requiring enough information to understand when further investigation is needed and deterring people from reporting because to do so is too onerous. This challenge inherently limits the number of HP specific questions that can be asked on such a form. Another reason to have more than one system for collecting data is to separate those who have access to it before it can be de-identified, from those who can only see the de-identified reports. For example, even when the

[9] See Figure 1.

regulator applies the principles of safety data protection[10], reporting systems where incident reports are received by regulatory personnel may receive fewer reports with less contextual information than reporting systems where reports are received by an organisation independent of the regulator. In the case of the latter, reporters may have greater confidence that they will not be punished on the basis of the report, and that they can still provide information that can be used to improve safety while avoiding regulatory attention.

Regardless of the source, both qualitative and quantitative data offer the prospect of useful HP insights:

- Qualitative data provides a description of a person's experience or perspective in a narrative. While many accident and incident forms ask for subjective narrative about causes, contributing factors and circumstances, this information needs to be coded for analysis.
- Quantitative data is expressed in numbers. Contextual data that can provide HP information may already **be** quantitative (e.g. the date, the time of day, light levels, the number of hours on duty, the amount of fuel used for landing, or the temperature), or be coded to be **expressed** quantitatively (e.g. subjective rating scales).

Coding qualitative data into numbers does not make the quantitative representation objective.

Systemic problems are not always clear and uncovering them requires an in-depth analysis of HP-related data. Sometimes, there is not enough data. The impressive safety record that aviation has set means that analysis of aggregated data needs to include a much wider array of safety data than just accidents. Furthermore, it may be difficult to recruit and retain the right expertise to extract the information or interpret the data. Keeping in mind these particular challenges, States should consider working collaboratively with other States, industry stakeholders, academic researchers and HP specialists in order to have access to the necessary data to gain insight.

2.1.2 HP TAXONOMIES

A taxonomy provides the organising framework (or categorisations of data) for analysis of data. Clearly described categories make it easier to accurately code the data. There are many different taxonomies available for categorising HP data, most of which include several layers of increasingly detailed subcategories. However, a distinction needs to be made between the level of HP detail that is useful for in-depth analysis of a single occurrence or a few occurrences and the level of HP detail that is useful in uncovering the most prevalent national, regional or global HP-related issues.

Good taxonomies should meet the criteria of being comprehensive, usable, reliable, valid and diagnostic.

All taxonomies have limitations. A taxonomy that is too narrowly focused may not help to accurately describe or identify problems. Other common problems arise through the mixing of circumstances, events and outcomes, or through the mismatch in the scope of

[10] In Annex 19, States are required to accord protection to safety data captured by, and safety information derived from, voluntary safety reporting systems and related sources. As a Recommended Practice, States should also extend the same protection to safety data captured by, and safety information derived from, mandatory safety reporting systems and related sources. Further information is provided in Appendix 3 of Annex 19 and in the Safety Management Manual, Chapter 7 (Protection of Safety Data, Safety Information and Related Sources), 7-1.

codes in a taxonomy. An example would be where air navigation services-related issues are described in detail, but all maintenance related issues are covered by a single code. Clearly, the analyst would then discover an overwhelming number of “aircraft maintenance issues” in comparison with “misheard ATC clearances”.

The level of detail of the codes needs to match the scope and purpose of the analysis. A high-level analysis needs to look at high level codes and a detailed analysis needs to use detailed codes. But to truly understand the HP issues and underlying systemic issues such as latent conditions[11], a detailed analysis is often required. Such an analysis might also require specific HP expertise. For instance, it may be simple and easy to code and count the number of times people “failed to follow procedures”. But to understand where the problem lies, the particular procedure and the operational context within which the “failure to follow the procedure” occurred must be coded as well. It might be that the procedure was not designed for the context in which it was used and therefore it was not possible to be followed. In such a case, the solution to the problem would be found in redesigning the procedure or in changing the operational context, rather than in forcing people to follow the procedure.

In some cases, taxonomies relating to HP have cultural biases. For instance, a taxonomy that lists among its examples of impairment and incapacitation: “alcohol”, “illegal drug” and “medication” assumes that alcohol is not an illegal drug. Yet in many countries alcohol is illegal, and in other countries, there are legal alcohol limits applied to aviation personnel. Furthermore, medication may be either prescribed, or bought without a prescription and the same drugs may be taken legally or illegally. In summary, the logic of a taxonomy needs to be scrutinised when it is devised and then again once it is in use, in order to ensure that it is effective and can be consistently applied.

Tests of reliability are usually used to establish whether or not the taxonomy can be applied consistently by different people (*inter-rater reliability*) and consistently by the same people over time (*intra-rater reliability)*.

When analysing any information about humans, it can be tempting to make assumptions, apply our own interpretations, and be potentially biased in the analysis (for more about biases, see below). Therefore, care should be taken to avoid biases in interpreting the HP data, such as assuming causal relationships where there are none.

Regulators should consider the following key points, when looking for HP-related issues in safety data:

a) data collection forms should be designed with a clear understanding of what HP-related information is needed to correctly identify HP issues.

b) consideration needs to be given to selecting suitable taxonomies, given that all taxonomies have limitations, and that different taxonomies provide different insights.

c) when recording mandatory accident and incident data, analysts need to accurately and consistently apply the taxonomy to the HP-related data.

d) people performing the data analyses need to have adequate training. In addition to understanding the HP principles, they need an understanding of the HP implications related to:

- the limitations and reliability of the data sets used;
- the interpretations that can (and can’t) be made using such data sets;

[11] Latent conditions are described in *Section 2.3 Accident Causation* of the Safety Management Manual as follows: *Breaches in safety defences can be a delayed consequence of decisions made at the higher levels of the organization, which may remain dormant until their effects or damaging potential are activated by certain operating conditions (known as latent conditions).*

- latent conditions; and
- when further detailed analysis may be necessary.

e) The limitations of the taxonomy selected need to be reflected in what is concluded from the analysis.

2.1.3 IN-DEPTH ANALYSIS OF A SINGLE OCCURRENCE

The primary objective of any accident or incident investigation is to allow the aviation community to understand not only what happened but also why it happened, in order to prevent recurrences and improve the system as a whole. Accident and incident investigation is an activity that falls under SSP Component 2 (Safety Risk Management), and can be undertaken at different levels, resulting in different roles for the regulators involved:

a) Annex 13 — *Aircraft Accident and Incident Investigation* accident and incident investigations are conducted by a State's accident investigation authority, with the goal of providing an independent and objective understanding of the accident or serious incident. Regulatory personnel may participate in Annex 13 investigations upon invitation from the accident investigation authority. While the accident investigation authority focuses on the identification of causes and/or contributing factors to make safety recommendations, the regulator often needs to act on those recommendations and implement safety interventions.

b) Safety investigations of occurrences that have been identified through a State's safety reporting system (Annex 19) but that are outside of the scope of Annex 13 may also be undertaken by the regulator[12].

Because people are involved in every aspect of the aviation system, HP perspectives are relevant to all accidents and incidents. Lessons to be learned can be gained in recognizing what went well, in addition to what went wrong. Considering the HP principles during an in-depth analysis of a single occurrence assists regulators in better understanding why humans throughout the system behaved or responded in the way they did. The regulator needs to take into account the dynamic aspects of the situation and the factors most likely to have influenced peoples' actions at the time (see *1.4 HP Principles*). This understanding is necessary to be able to identify and accurately describe any systemic issues or latent conditions, so that the most appropriate remedial actions can be taken. Such actions may include: the need for more comprehensive or updated guidance; further safety promotion activities; adjustments to regulatory requirements; and enforcement actions in those rare cases where necessary to maintain minimum safety standards.

Operator error is very rarely the root cause of an occurrence. Usually, some underlying systemic issue is hiding behind it

[12] Service providers also frequently conduct their own investigations into occurrences (see *2.4.3 Safety Investigations* for information on the regulator's role in assessing how well HP aspects have been considered within safety investigations conducted by service providers.

When participating in an in-depth analysis of a single occurrence, a regulator should have a sufficient understanding of HP to recognize their own knowledge gaps and to determine whether to seek further specialist HP expertise.

HP considerations impact on:

- When data should be collected

HP data collection should be initiated as soon as possible after an occurrence, because this data is easily lost or contaminated with the passing of time. Aside from forgetting some details (HPP 1), people tend to create a narrative that "makes sense" (HPP 2), inadvertently adding in extra details based on their expectations and on things they learned after the event.

- The type of information that is collected

The dividing line between relevant and irrelevant HP information is often blurred. Information that may initially seem to be unrelated to the event could prove to be extremely important after other connections are uncovered by further analysis. A variety of sources of available data (from documents, maintenance and airworthiness records, interviews, witness reports, and other related information) may need to be taken into account.

- How interviews are conducted

If conducting an interview immediately after an occurrence, it is important to recognise that interviewees who have experienced a serious event or even a near miss are likely to be strongly affected. Due to attention and perceptual mechanism limitations, those involved in an accident or serious incident cannot process all the information at the time of the event (HPP1). Even interviews of involved personnel conducted following the mandatory reporting of an incident after some time has passed, are likely to be an extremely uncomfortable experience for an interviewee. Interviews should be conducted so as to maximize the retrieval of information about the occurrence and not focus on finding fault with the actions taken or decisions made. Interviews are most productive in the context of a sound safety culture, where it is recognised that taking systemic remedial actions is more beneficial than punishing an individual, particularly when their behaviour can be understood in terms of the HP principles and the operational context. (See Section 2.4.2 for additional information on safety culture in incident reporting.)

Punishing an individual for making an error undermines safety culture and can prevent the development of effective barriers and mitigations.

To improve the effectiveness of interviews, an interviewer can:

a) Select an interview location which maximises the opportunity for a private, warm, friendly and inviting space rather than one that is intimidating. Consider aspects of the location which might be threatening or uncomfortable for women, minority groups or individuals in a power dynamic;

b) Ensure everyone involved in the interview understands the objective of the interview, their roles and responsibilities;

c) Avoid dominating the conversation, but instead spend the majority of time listening actively;

d) Look at and engage with the person being interviewed. Consider having a separate note taker so that the interviewer can be fully focused on the interviewee. If too much time is spent looking down and taking notes, the investigator might miss important non-verbal cues that will help understand the nuances involved;

e) Ask open ended questions;

f) Avoid treating the interview as a "questions and answers" session. Listen for cues in what the person is saying to lead to further questions (rather than strictly follow predetermined questions). Do not interrupt. Wait for a suitable time to ask follow-up questions if the story is not understood;

g) Keep responses neutral and calm. Don't judge the interviewee; and

h) Above all, assume positive intent in the individual – no one started their day intending to have this incident or accident.

- ### Potential biases in interpreting information and data

During the different stages of an investigation, effort is required to separate facts from their interpretation and to also look for information supporting or contradicting these facts and these interpretations. When building the occurrence scenario, the regulator conducting the investigation never has access to all the information. Thus, often only assumptions can be made based on the information available. Such assumptions are guided by the choice of facts considered, as well as the biases to which all people are subject. Among other biases, the regulator must strive to overcome the following biases when investigating an occurrence:

a) *Hindsight bias*: Knowing the outcome of an event has an influence on the way the analysis is done;

b) *Attribution bias:* A tendency to infer causes of behaviours (e.g., to link an operator's error to an operator's assumed incompetence);

c) *Frequency bias:* to over (or under) estimate the probability of occurrence of a particular event;

d) *Confirmation bias:* to notice and accept that which supports prior beliefs and expectations, and to ignore or dismiss those facts which do not quite fit the pattern expected; and

e) *Group conformity:* to agree with the majority decisions in the group of investigators.

When undertaking an in-depth analysis of an occurrence, the regulator needs to be aware of the impact of such biases, and constantly test assumptions made against evidence in order to minimise their effects. It should be noted that interviewees are also subject to various biases which influence their perception and recollection of events.

Properly conducting the analysis of single occurrences and consistently using the same taxonomy results in accident and incident data that, when aggregated, can provide the basis for monitoring organizational, national, regional and global safety performance.

2.1.4 ANALYSIS OF AGGREGATED DATA

To monitor performance and support policy-making, analyzing aggregated data across multiple occurrences, hazards or other performance indicators is necessary. Such data may be obtained through collections of in-depth analyses of single occurrences as well as from occurrence reporting systems, hazard reporting systems and in-service operational data.

High level analysis of HP issues provides an opportunity to find similar underlying causes for a variety of outcomes that otherwise may not be obvious. For example, monitoring the number and rate of incident reports citing time pressure may provide an insight into how busy particular locations are. Such time pressure could lead to misloaded aircraft, incorrect pushbacks, taxiway incursions, stop bar overruns, misheard ATC clearances, altitude deviations and so on. However, to establish whether increased reports of "time pressure" in different locations have the same underlying cause(s), further analyses and examination of contextual factors are needed. Is it increased traffic? Changes to scheduling? Changes to staffing levels, absence rates or contractual arrangements?

Identifying common HP issues even when they have different implications and result in different types of outcomes enables regulators to identify the most effective preventive or remedial actions. For example, a maintenance engineer missing a procedural step may have a very different potential outcome from an air traffic controller issuing a clearance to the wrong call sign, but both could be the result of fatigue. Identifying fatigue as a common issue means that instead of updating each and every procedure that is not followed, a regulator can instead focus on interventions relevant to addressing the more significant underlying HP issue of fatigue.

Therefore, when paired with reviews of individual occurrences and with dialogue with service providers, analyses of aggregated data can be particularly useful in identifying latent conditions, underlying common causes, and systemic issues.

2.2 DEVELOPING REGULATORY MATERIAL

An SSP requires the establishment of regulatory material on a variety of topics, including, but not limited to: operating regulations (CE-2); licensing certification, authorization and/or approval obligations (CE-6); and technical guidance, tools and provisions of safety critical information (CE-5). This can be seen in Figure 1.

Regulatory material may need to be developed or updated for a variety of reasons, but in all cases, it is important that the material addresses appropriate HP considerations. Additionally, regulatory material should be developed based on factual HP information, not just opinion. Such HP information should come from credible sources, have appropriate operational context and include information based on operational data. For example, HP information may come from audit findings, trends identified through the State's mandatory occurrence reporting system and through health status data monitoring, the HCD process (see Section 1.2), or relevant research.

Because ICAO SARPs drive States' regulatory requirements, HP considerations are essential to the development of those SARPs and their supporting guidance material.

Some high-level regulatory material (e.g., public law, ICAO SARPs, or State regulations) mention HP explicitly, including phrases such as "consider human factors principles", or referencing "human performance considerations". Other high-level regulatory material may make little or no specific reference to the terms "human factors" or "human performance", although many still address HP issues. For example, regulatory material may include terms such as "minimum crew", "workload", "reduce the likelihood of error", "fitness for duty", or "take account of human capabilities and limitations", all of which have clear HP implications. To facilitate implementation, these high-level statements should be supported by detailed guidance material regarding HP that is specific to the objective of the regulation. Because the HP topics that need to be addressed often require specialized HP knowledge, it is essential to include specialists with HP knowledge relevant to the topic being addressed in the development of regulatory material, as well as in the official review and coordination process of all documents with HP-related material.

To address HP considerations, regulations need to be developed with the legal, cultural and operational context of those who will be implementing them in mind. Therefore, before adopting other States' regulations, while still striving to keep regulations harmonized as much as practicable, regulators need to give careful consideration to how such regulations will be interpreted and implemented in their own State.

When developing regulatory material, HP considerations include:

a) the conditions and operational environments where it will be implemented;
b) the safety assumptions that have been made, e.g. a high level of user proficiency; user fitness-for-duty; effective use of safety management processes;
c) the specific regulatory context, i.e. the new or amended regulatory material in the context of existing regulations, including relevant non-aviation specific regulations and legislation;
d) the way in which rules and regulations are perceived and followed, given the cultural context.

2.3 EVALUATING, ACCEPTING AND APPROVING

An SSP requires that licensing, certification, authorization and/or approval obligations be met (see Figure 1, Component 2 and CE-6), which results in the need for some form of evaluation or test.

Different States and aviation authorities use a variety of terms to describe this type of activity. For the purpose of this manual, no distinction is made between terms such as *testing, assessing* and *evaluating*, nor between the terms: *certifying*, *approving*, *authorising, accepting,* and *licensing*. In all cases, the regulator's responsibility is to ensure that whatever is being evaluated, complies with the associated regulatory requirements, and that the regulatory requirements and guidance are adequate to enable such an evaluation.

The following sections provide high level guidance on actions the regulator can take to ensure that HP considerations have been adequately addressed when evaluating or approving:

- Equipment;
- Organizations, management systems and procedures; and
- Personnel (through training and licensing approvals).

2.3.1 EQUIPMENT

Because equipment (i.e. hardware, software and systems) is designed to be used by people, either directly or indirectly, there are many equipment-related HP issues to be considered by the regulator in its evaluation and approval. The regulator evaluates products designed by a variety of different types of organizations, often referred to as "applicants". It is the applicants' responsibility to identify the appropriate regulatory requirements, propose how compliance will be shown and then demonstrate compliance. The regulator is responsible for evaluating the completeness and accuracy of the identified list of regulatory requirements. Additionally, the regulator is responsible for accepting the proposed method of compliance and for evaluating compliance with these regulatory requirements for equipment (whether hardware, software, or associated manuals, such as for installation, operation and maintenance).

Examples of equipment that require regulatory approval include:

a) aircraft;
b) flight deck systems;
c) remotely piloted aircraft systems;
d) ATC systems; and
e) aerodromes systems.

It is critical that the applicant provides sufficient evidence to the regulator that supports regulatory compliance. The evidence should include the assumptions made about human performance during the design phase, which are then validated as part of testing, before the equipment is put into operational use. This evidence can be submitted as part of the test plan, to be approved by the regulator. Furthermore, early-involvement meetings between the applicant and the regulator are encouraged, especially to address HP considerations.

The applicant should also demonstrate how the users, their operational context, and the conditions of use, have been considered in the development of the equipment. The applicant should also undertake iterative testing and evaluation cycles to reduce the likelihood of unintended consequences. Designing and developing the equipment and manuals in accordance with an HCD approach (see 1.2) can increase the likelihood that HP issues are identified and addressed early, resulting in a better product.

When it comes to determining whether the necessary HP requirements have been met, specific HP expertise is frequently needed. It is recommended that the level of scrutiny for evaluating and approving equipment reflect the following:

a) potential for safety implications/risk;
b) degree of change in or novelty of design, procedure, layout, tasks and/or operation;
c) potential impact on attention, awareness, tasking, performance and workload;
d) existence and adequacy of current regulatory guidance (e.g., to address the new and novel systems, equipment, programmes, procedures, feature, function, system, design or operation); and
e) potential for confusion, misleading data and/or user error.

Regardless of what type of equipment is being evaluated or approved, there are many considerations relevant to human performance. Such considerations include:

a) *error management (including prevention, detection, and recovery)* - such as human data entry errors and how the system or equipment is designed to catch or ‘trap’ the errors;

b) *task performance* - such as time to complete task(s), procedures needed to perform the task;

c) *workload* - such as the amount or intensity of effort involved in a task, and the task’s sequencing, or overlap with other tasks;

d) *learnability and usability* - such as the degree to which learning to use and operating the equipment can be done effectively and efficiently;

e) *complexity* - such as the number and/or nature of interconnected/interactive components;

f) *context* – such as the particular operational context and conditions of use;

g) *situation awareness* - such as the operator’s awareness of the current and future state of the system and of the task expected of the equipment and the operator under different conditions of use;

h) *maintainability* - such as the degree to which the design allows for ease of maintenance and servicing; and

i) *crashworthiness, survivability and resilience* aspects of aircraft, vehicles and associated systems.

To assess whether the equipment under evaluation for approval adequately addresses these HP considerations, the regulator should evaluate compliance with the appropriate HP regulatory and guidance materials, and systematically look at its:

- **Intended function** (the stated purpose of the system), e.g.:
    - Is the system's intended function sufficiently clear and detailed, including the human role, to allow the regulatory authority to evaluate the system?

- **Design philosophy** (an overarching usability theme that applies across multiple systems, such as within a flight deck or ATC workstation), e.g.:

    - Has the design philosophy been documented and tested?

    - Is the product consistent with the design philosophy? (e.g. where a "quiet, dark flight deck philosophy" has been chosen, are the system status indicators only illuminated when user attention is needed?)

- **Design features**, e.g.:

    - *Displays*
        - *Information elements* (such as information in a data block on the ATC radar display, or system schematics on the maintainer's display), e.g.:
            - Is the right information displayed at the right time to allow the users to safely accomplish their tasks?
        - *Organizing information* (such as layout, location), e.g.:
            - Is the information accessible and usable in a manner consistent with the urgency, frequency, and duration of the users' tasks?
            - Does familiar information have to be accessed from unfamiliar locations?
        - *Information presentation or format* (such as use of colors and symbols), e.g.:
            - Is all information free of clutter, and in a format that is clear and unambiguous at a resolution and precision appropriate for the users' tasks?

    - *Alerts*, e.g.:
        - Do alerts enable effective user awareness and subsequent user action, and with an acceptable level of nuisance alerts?

    - *Controls (such as knobs, buttons, touch pad, track ball, yoke, side stick), e.g.:*
        - Does the system have sufficient controls to accomplish all tasks associated with the intended function, including enabling users to intervene in a manner appropriate to the task?

    - *System behaviour (such as the relationship between control input and system response), e.g.:*
        - Is the operationally-relevant behaviour of the system predictable and unambiguous?

    - *Integration/installation (such as location of the display and aspects of how it integrates with other displays and systems), e.g.:*
        - Is the system's use of colour and symbols consistent with other displays in the same workstation or flight deck? Or consistent across different workstations and flight decks of different aircraft models?

    - *Automated functions:* See *Automated systems* section below.

It is recognized that all States have limited resources, and many do not have specific and extensive HP expertise available. Thus, a State may not have the regulatory resources necessary to undertake a full HP evaluation of all such systems but is still required to ensure regulatory compliance. Even if a particular State chooses to find compliance through delegation or bilateral recognition agreements (i.e., accepting findings of regulatory compliance from another State), the authority and responsibility for approval still rests with the signatory State. In such cases, the signatory State needs to:

a) be assured that the safety analysis undertaken by the State of Design to grant approval has adequately taken HP considerations into account, per the local regulatory requirements and the specificities of the State's operational environment; and

b) consider how this new equipment will be implemented and maintained within the State's local operational environment and within the context of its applicable regulations. This includes the identification of any necessary training that may be required to address local needs.

Approvals of equipment always include assessments of the safety impact of using it, which the applicant is required to submit. One of the key challenges for the regulator in approving hardware/software systems and equipment is understanding the safety impacts related to human performance prior to use in operations. This understanding is much enhanced when a human-centred design process (see Section 1.2) has been used by the applicant to develop the particular hardware or software system.

The means for analyzing safety risks borrow heavily from methods developed solely for technical systems. Likelihood-severity methods assign quantitative values to each, for an overall quantitative risk score. Such methods have limited applicability to addressing human performance because, for example, they:

a) primarily address human error rather than the full range of possible human performance that influence safety outcomes;
b) require likelihood estimates of specific human actions, e.g. "human error rates", that typically cannot be validated, particularly prior to approval; and
c) are impractical for addressing the true context and complexity of operations, and other factors that affect human performance.

Because of these and other limitations with traditional safety risk assessment methods, the applicant's safety analyses would benefit from:

a) an assessment of human-system operations that considers both positive and negative human contributions;
b) qualitative analysis methods in addition to quantitative methods; and
c) a sufficiently detailed and comprehensive breakdown of the related human tasks, and the human and machine interactions, so that representative operational behavior can be addressed.

Automated systems

In meeting SSP obligations, regulatory authorities may be required to evaluate and approve equipment that automates certain functions. Automation entails some specific HP challenges, so this section provides some HP considerations specific to evaluating automated systems.

Automation refers to the performing of a function by hardware and/or software instead of by humans. Therefore, all “automation” is inherently a system, and in this Manual is equivalent to “automated system”.

“Automated” and “autonomous” are different and should not be used interchangeably. Autonomous systems are defined here to be a subset of automated systems that have the ability to apply information (often in complex and dynamic situations) and independently determine a course of action in the absence of a predefined plan to accomplish goals. Autonomous systems should receive particular attention when being evaluated. This is because, unlike other automated systems, the designers of autonomous systems may not be able to state in advance precisely how the system will act to accomplish its goals in all cases. The assessments need to be based in part on the function the autonomous system is expected to perform as well as how humans are expected to interact with it.

Despite the intended benefits of automation, there is an extensive body of literature developed over the past several decades identifying human performance issues associated with automated systems. Because these systems may be in service for several decades, many of these issues persist in the aviation system. It is important for the regulator to know what issues to look for when conducting an evaluation of automation, whether it be an ATC or aircraft or some other system. In considering the design features identified above with respect to automation, it is particularly important that the following HP questions are addressed:

- *Has the rationale for the decision to automate been documented?*
  - It is important to ask why a particular function should be automated, because automation may not always offer the best system solution. Is it for workload reduction? Performance enhancement? System scalability?

- *Does the automation display appropriate information to allow the user to meet their performance obligations and their responsibilities?*
  - Information about system function is critical for users to understand the system, to know what it’s doing, and to calibrate their trust appropriately.
  - Too much information about system functioning can result in information overload and clutter.
  - Lack of feedback on system functioning makes it difficult for the human to be aware of and to understand how the automated system is working and how to predict what it will do next.

- *Does the automation provide the user with the appropriate level of control?*
  - As long as humans are responsible for a task, they must have the appropriate authority to exercise that responsibility[13]. This means that automated systems not only need to provide sufficient information through displays, but also provide means for human intervention through controls (e.g., manual override).

- *Are the human performance expectations and user responsibilities clearly identified?*
  - Automation results in new user interactions that require training and practice, often in addition to what is required for "manual" operations.

  - An automated system that encounters conditions outside the operating environment envisioned by the designer, may suddenly cease to perform its function. In such cases, recovery may depend on a rapid response by the human.

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[13] Billings, C. E. (1997) *Aviation automation: The search for a human-centered approach*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

- *How are automation surprises mitigated?* Automation may surprise the human user when:
  - the user is expecting one behavior, but the automated system exhibits another behavior;
  - the automated system unexpectedly transfers control to the human; and
  - complex system interdependencies result in unexpected changes in state or mode.

- *What knowledge and skills does the user need to manage the automation in normal and abnormal situations?*
  - Lack of practicing a task that has been automated may degrade human proficiency of motor and cognitive skills and knowledge needed when the automation fails.
  - Automated systems change existing tasks, create new tasks, and introduce different error types.

- *Are there unintended adverse effects of automation?*
  - Use of automated systems can reduce workload during traditionally low workload phases but may add workload or interfere during time-critical, dynamic circumstances.
  - When automated systems consistently perform well, the human may develop over-reliance on the automated system, which can contribute to skill degradation.
  - Automated systems may shift the human's role from active controller to supervisor or monitor, something people are not particularly good at doing.

While many of these questions are also applicable to hardware and software systems in general, they are particularly relevant to automated systems.

So how are the HP principles (HPPs) relevant to evaluating, accepting and approving equipment?

The hardware/software system design and operation, system installation and placement, and procedures, may directly affect the user's workload, awareness, ability to respond, and other aspects of human performance (see 1.4). Supporting human performance by design is usually the most sustainable and most effective intervention. Using the HCD process (see 1.2) to design a wide variety of systems and equipment, such as maintenance tools, airport ramps, flight deck displays or air traffic controller's workstations, can all reduce the likelihood of error, and make the task easier, more intuitive and efficient.

It is important that systems and equipment:

1. Accommodate people's physiological needs and physical, as well as cognitive, constraints. Systems, equipment, and tools should be designed to be used appropriately throughout the likely range of the users' performance, and should be fit for purpose. **See *HPP 1*.**
2. Be designed to be used effectively within the actual work environment to achieve the task objectives. Prior to approval, systems and equipment should be evaluated and tested under realistic operational conditions. **See *HPP 3*.**
3. Ensure that information and data:
   - is available when needed, clearly communicated and integrated when possible, to support people in building and maintaining an accurate understanding of the situation. **See *HPP 2***; *and*
   - is presented in ways that assist people in assessing operational risks and potential consequences, and in ways that allow them to reflect and balance trade-offs in their decision-making. **See *HPP 4*.**
4. Be designed, where required, to be used effectively by a group or a team, as well as across different groups who share tasks and activities. **See *HPP 5*.**
5. Be supported by implementation guidance that includes identification of the knowledge and skills needed by the users and how the user is expected to perform.

2.3.2 ORGANIZATIONS, MANAGEMENT SYSTEMS, PROCESSES AND PROCEDURES

As part of the SSP requirements, States have regulatory responsibilities to ensure that HP considerations have been adequately addressed when evaluating and approving the following:

- the organization[14] itself;
- its management systems; and
- its processes and procedures.

The regulator should ensure that the organization provides documentation that sufficiently explains how it complies with regulatory requirements. The organization should also demonstrate how HP is addressed in the operating environment. Such compliance should be shown both at the time of application (seeking approval) and as an ongoing surveillance activity. One way an organization can demonstrate its attention to HP is by following the HCD process (see Section 1.2) and by addressing each of the HP principles (see Section 1.4).

Some of the HP considerations associated with evaluating or approving each of the items above are described further below. HP considerations for ongoing surveillance are addressed in Section 2.4.

[14] The guidance is also relevant to designated individuals who provide aviation services on behalf of the State (e.g. pilot examiners, aviation medical examiners, maintenance inspectors, certification engineers).

a) Organizations

The regulator is responsible for approving a variety of organizations[15]. While detailed information on approving specific types of organizations is provided in other ICAO manuals[16], the focus of this section is on addressing the HP aspects of evaluating and approving any organization and authorising it to undertake particular activities.

Key HP considerations when evaluating an organization for approval include:

- Does the organization's training documentation reflect a commitment to personnel competence, identifying how the organisation selects and inducts its staff, as well as provides them with continued training?
- Is there evidence that the people in the organization are sufficiently qualified and trained to perform their roles effectively? (This includes managers, line staff, technical and administrative staff, instructors/trainers, safety personnel and evaluators.)
- Are there enough people to provide the proposed services?
- Are safety and HP accounted for in all business areas – for example in financial planning where budgets can limit safety and HP resources, as well as in drafting operational procedures?
- Are HP considerations adequately documented in the organisation's evaluation processes and procedures?
- Does the organization seek to identify areas where its unique operating environment requires further mitigations or enhanced procedures in order to ensure safe provision of services?
- Does the organization have a process for assessing and learning from things going right?
- Do training programmes indicate that staff are trained in organizational processes, individual responsibilities and expected behaviours? See 2.3.3a) Training Programmes.

[15] In the case of training organizations, approvals are granted, and surveillance is provided, by a State-designated Licensing Authority, which may or may not be part of the regulatory authority. In this document, the term of "regulator" is used in a general way to refer to those who perform the functions of approving and providing surveillance of any organization, whether as member of a Civil Aviation Authority or a Licensing Authority.

[16] Approval of:

- Training Organizations: ICAO Doc 9841 - Manual on the Approval of Training Organizations
- Air Operators: ICAO Doc 8335 - Manual of Procedures for Operations Inspection, Certification and Continued Surveillance
- Maintenance Organizations: ICAO Doc 9760 - Airworthiness Manual (Part III, Chapter 10)
- Design and Manufacturing Organizations: ICAO Doc 9760 - Airworthiness Manual (Part V, Chapters 2 ,3, 4)
- Aerodromes: ICAO Doc 9774 – Manual on Certification of Aerodromes
- RPAS: ICAO Doc 10019 - Manual on Remotely Piloted Aircraft Systems (RPAS)

Many of these HP considerations point to the organisation's safety culture (discussed further in the blue box following the next subsection: *So how are the HP principles relevant when regulators are evaluating or approving an organization or its management systems?*). All these considerations influence the way an organisation operates its various management systems, discussed below.

b) Management systems

The regulator is responsible for evaluating and approving a variety of management systems including, where applicable:

- quality management systems (e.g. Aeronautical Information Service Quality Management System, Instrument Flight Procedure Design Service Quality Management System);
- safety management systems (SMS);
- fatigue risk management systems (FRMS)[17];
- transportation of dangerous goods (as per Annex 6, Part I and Annex 18 — *The Safe Transport of Dangerous Goods by Air*);
- regulatory compliance systems or internal audit systems (as per Annex 19); and
- training management systems (i.e. the training plan, managing the delivery of the training programme(s), managing trainer competence, and monitoring student progress).

During the initial evaluation of an organization's management system, there needs to be evidence that HP has been considered in the establishment of the system processes and that the management system supports HP to achieve the system's goals For example:

- In an SMS[18]:
  - Are HP-related safety data collected, analysed and acted upon as appropriate?
  - Is there a process that encourages reporting and that enables identification of HP issues and learning and sharing lessons from experiences within the organization (see Section 2.4.2)?
  - Is there a process for informing personnel of organizational actions taken when things do not go as planned?
  - Is there a process for managing safety risks associated with individuals' fitness for duty, including a process for returning an individual to duty after an absence related to being unfit?
  - Does the organization's training programme include addressing individual responsibilities, organizational processes and procedures and their rationale (see *Section 2.4.5*)?
  - Does the organization have an identified change management process that includes appropriate HP training relevant to changing roles and responsibilities (see *Section 2.4.6*)?

- In a Training Management System:
  - Does the training programme integrate HP elements as per regulatory requirements? (see Section 2.3.3a)*;*

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[17] For detailed information on the approval of an FRMS, refer to Chapters 5 and 6 of the ICAO *Manual for the Oversight of Fatigue Management Approaches* (Doc. 9966).

[18] See also sections under *2.4 Providing Ongoing Surveillance*

- Is there a process to ensure standardised assessment of competence? (see *Section 2.3.3b*)
- Are simulators, training aids and devices “fit for purpose”? (see *Section 2.3.3c*)

However, it can be difficult to assess how the system processes actually work and whether the management system sufficiently demonstrates appropriate consideration of HP simply by examining documentation. Prior to approving a management system, a regulator is likely to need to observe people in their day-to-day work and ask questions about how they would carry out their functions within that particular management system. In doing so, a regulator can gain important insights into the likely effectiveness of the management system. For example, the regulator can assess:

- what processes the management system has to inform, and be informed by, other systems in use (allowing people to monitor interactive effects);
- how HP-related hazards are recognised within the risk assessment methodology used;
- when and why personnel actually report hazards or report safety concerns, including those related to HP;
- how well understood are the personnel roles and obligations with respect to the management system;
- whether an HCD approach and an understanding of the appropriate HP considerations is evident in the development of the management system processes;
- whether appropriate processes and procedures are in place for the reporting and management of compliance issues; and
- how effective is the organizational training and how are in-house learning activities used to enhance a “safety culture” and support people to know how things are done and what they are expected to do (see also *2.4.5 Training Activities,* and blue box below).

Similarly, because it may be difficult to assess whether the organization’s proposed assurance methods are suitable and sufficiently address the HP considerations during the initial assessment period, continued surveillance activities are critical. These surveillance activities should include periodic assessments and assurance activities that look for evidence that the approved management systems remain effective in actual operations (see *Section 2.4*).

So how are the HP principles (HPPs) relevant when regulators are evaluating or approving an organization or its management systems?

An organization's culture affects how safety is perceived, valued and prioritized by management and operational personnel. This has a large influence on how effectively an organization manages its safety risks and how managers and employees behave and interact.

The organization strongly influences HP through: effective leadership, using good design practices, providing access to training, and selecting appropriate people in the necessary numbers for the various tasks that must be accomplished. It does so through its management system, including the managers, and the procedures they utilize. As part of evaluating and approving an organization or its management systems, a regulator should look for evidence that:

1. People are selected for and assigned work they are able to perform and are fit to undertake. Work and the work environments offer flexibility and adjustability to accommodate people's needs and variable performance. **See *HPP 1.***

2. The organization addresses risks associated with not being fit for duty. There is an identified method for reporting "not fit for duty", and people are made aware of when to report "not fit for duty" and of the consequential organizational responses. **See *HPP 1.***

3. A focus on continual organizational and individual learning in response to safety events, including close-calls, incidents and accidents is established. This focus should emphasize understanding why the decisions and actions made by the individuals involved in the events made sense to them at the time, rather than focusing on what they did wrong. **See *HPP 2.***

4. Contributions to improving work and procedures based on lessons learned from past experience, are valued. There is a willingness to continually improve, including learning from subject matter experts, from colleagues, and from observing what goes well during operations. **See *HPPs 2 & 5*.**

5. Personnel are encouraged to actively engage in hazard identification, risk assessment and risk mitigation. They are also encouraged to recognise what works well, to utilize best practices, and to report where the equipment, tools or procedures do not fit the reality of the operation. **See *HPP 3 & 4*.**

6. The organization recognizes potential operational trade-offs, and desired behaviors are clearly promoted and reinforced through the organization's processes, procedures, and training. **See *HPPs 4 & 5*.**

7. Managers at all levels across the organization are aware of the likely impacts that their own behavior has on other people and groups. They use multiple methods of communication to achieve a shared understanding of the goals, roles and responsibilities of everyone in the organization. **See *HPP 5*.**

c) Processes and procedures

Air traffic controllers, pilots, air carriers, training schools, and maintenance personnel all use processes and procedures, which may require regulatory evaluation and approval. This section does not focus on the evaluation of processes and procedures as part of the approval of management systems (see 2.3.2b above), but rather on those processes and procedures for which regulators have specific responsibility and authority to approve.

Processes and procedures provide a logical progression of actions and decisions. They support consistency, help manage complexity, and minimize the potential for errors. Because processes and procedures are designed and executed by people, regulators should take HP considerations into account during their evaluations and approvals.

A process consists of various functions and defines a framework or identifies a path necessary to accomplish an objective. The regulations may require the organization to establish a process and may outline a framework, but the organization then develops the specific actions, activities, systems, people or tools that are to be used in order to meet the objective in context.

Examples of processes that regulators may approve include:

- airport-specific foreign object debris (FOD) management;
- airline-specific process for the management of change; and
- training organization processes for the development of courseware.

A procedure, on the other hand, is more detailed, identifying how specific actions are to be undertaken by an individual(s), and in what order, to complete a task. Examples of procedures that regulators may approve include:

- standard operating procedures, such as normal checklists;
- flight procedures, such as a standard instrument departure procedure;
- procedures for the assessment of fitness for duty, (e.g. procedure for medical assessors to reach an Accredited Medical Conclusion that an individual with a borderline medical assessment is certified as “fit for duty”).

The likelihood of the regulator approving an operational process or procedure may be improved by using an HCD approach in its development (see 1.2). This includes taking into account the HP principles (see 1.4) and involving users and stakeholders who may be directly or indirectly affected, as well as those with appropriate operational and HP expertise. It also means that the proposed process or procedure has been subject to multiple reviews, tests, trials, feedback, and revisions.

For the purposes of evaluating and approving, the regulator should check that the process or procedure is:

- formally documented and readily available;
- written at the appropriate level of detail to ensure accurate execution; and
- clear about:
  - what is to be accomplished;
  - when and under which conditions it should be executed;
  - what each step is, and who performs each step; and
  - when non-adherence is permitted (e.g., defined situations and what the potential risks/hazards are if they are not followed).

An application package submitted to the regulator should not only identify the process or procedure itself, but also be clear about the reasons for the new, or any change to existing, processes or procedures and what additional training may need to be provided. It should include a method for review to ensure that the process or procedure remains effective over time.

Because a procedure is more specific than a process in detailing how a task must be performed, when evaluating and approving a procedure the regulator should also check that it:

- is appropriate for the task (e.g., operationally relevant, able to be accomplished with acceptable workload and in a timely manner, can be integrated with other concurrent procedures);
- is unambiguous and able to be applied uniformly and consistently within an operation;
- includes a method to confirm proper completion (e.g., supported by cross checking or being signed off by another party);
- reflects the operational needs and prevents conflicting demands;
- is fit for the range of environments where they will be executed (e.g., at night or in bad weather); and
- is able to be executed by people with a range of physical characteristics (e.g., height, strength).

Additional Considerations for the Approval of Airspace and Flight Path Procedures

Approving airspace and flight path procedures requires special HP considerations to ensure that they are evaluated from the user's perspective (primarily pilots and air traffic controllers).

The complexity of designing airspace and flight paths is increasing. The planning and design of routes, holding patterns, airspace structure and ATC sectorization in both terminal and en-route airspace need to take into account many factors other than simply maintaining separation or flying efficiently from an economic perspective.

Examples of HP considerations for such approvals include:

- pilot management of flight path constraints, including if route is amended, which affects workload;
- number of flight path transitions, which add variability to the flight path and add visual complexity to charts;
- transitions between flight path segments, which affect pilot monitoring and management of energy;
- phraseology and designators which affect voice and data communications and comprehension;
- depiction on charts, which needs to take into account clutter, scaling, etc. Notes on charts, which can be difficult to read when there are too many of them (e.g., from overly complex procedures);
- rejoining procedures after being taken off from an ATS route (e.g., from vectoring), which can be challenging to pilots;
- appropriate balance of operational demands (e.g., pilots vs controllers); and
- variability of aircraft flight management systems (e.g. between different aircraft types), which can affect pilot workload and procedure conformance.

Further information on airspace design and flight (path) procedures development is provided in:

- Annex 11 — *Air Traffic Services*;
- ICAO PANS-OPS, (Doc 8168): *Procedures for Air Navigation Services — Aircraft Operations*; Volume I — *Flight Procedures*; Volume II — *Construction of Visual and Instrument Flight Procedures*; Volume III – *Aircraft Operating Procedures*;
- ICAO PANS-ATM (Doc 4444): *Procedures for Air Navigation Services – Air Traffic Management*.

- ICAO Doc 9905: *Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual*.

2.3.3 PERSONNEL TRAINING AND LICENSING

As part of its SSP obligations, a State is required to ensure that the training requirements for the issue of licences or other authorizations for personnel are met (SSP component 2, CE-6). This obligation is typically addressed through licensing processes and through approval and oversight of personnel training. Human performance is central to the purpose of both personnel training and licensing, because both focus on the competence of those conducting the training and those receiving it.

Licences and ratings are issued on the basis of the applicant meeting Annex 1 — *Personnel Licensing* requirements in relation to:

- age;
- medical fitness[19];
- knowledge (identified through training content and successful completion of examinations);
- skills (demonstrated and assessed during training and at the time of testing for licensing purposes); and
- experience (i.e. hours of flight time, training course length, or on-the-job training).

Each of these is understood to impact an individual's ability to function effectively in their roles.

The medical fitness requirements (including functional and operational limitations) for licensing purposes link directly to HP principle 1 and involve meeting:

- minimum *physical* health requirements, e.g. absence of specified conditions or compliance with specified criteria relating to vision, colour perception, hearing, and cardiovascular, respiratory and other systems of the body; and
- minimum *mental* health requirements, e.g. absence of specified conditions or compliance with specified criteria relating to psychological conditions or mental illness such as anxiety or depression.

Physical and mental health requirements can also apply to revoking or suspending licenses where an individual's altered health status may have adverse safety consequences. This includes when individuals receive or refuse treatments for specified conditions or are taking specified drugs, whether prescribed or taken recreationally.

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[19] The ICAO *Manual on Civil Aviation Medicine* (Document 8984) and Manual on Prevention of Problematic Use of Substances in the Aviation Workplace (Document 9654) are designed to assist and guide designated medical examiners, medical assessors and Licensing Authorities in decisions relating to the medical fitness of license applicants as specified in Annex 1. The manual should also be useful to supplement properly supervised theoretical and practical post-graduate training in aviation medicine.

The knowledge and skill requirements for licensing and rating purposes are associated with identified training requirements for topics to be trained and examined, and the necessary training outcomes (i.e. operational functions to be successfully demonstrated). As such, training requirements are key to the licensing and rating process.

However, not all training that is required for personnel is for initial licensing purposes, or for the purposes of issuing or maintaining a rating. Other ICAO Annexes also identify training requirements related to specific areas and for ensuring proficiency and maintaining currency of both licence-holders and other specified personnel, including:

- recurrent training requirements in Annex 6, Part I;
- upset prevention and recovery training requirements for pilots in Annex 6, Part I;
- initial and recurrent training requirements for dangerous goods in Annex 18;
- initial and recurrent training requirements for designees in Annex 1 (e.g. medical examiners and assessors, pilot examiners, maintenance inspectors); and
- security training requirements for flight and cabin crew in Annex 17.

Yet other training requirements are part of a service provider's management systems obligations (see *2.3.2 b) Management Systems*) and relate to organizational processes, individual responsibilities and expected safety behaviours. These include:

- fatigue management training requirements in Annex 6, Parts I and III and Annex 11; and
- training requirements to meet SMS obligations in Annex 19.

While some of these training requirements must be met by service providers, some training (i.e. that related to the requirements of Annex 1) can only be delivered by an approved training organization (ATO). Such training requires approval and oversight by the State-designated Licensing Authority. While dedicated ATOs typically concentrate on providing initial licensing or specialist training, a service provider (e.g. an airline operator, air traffic service provider, maintenance organisation) that is also an ATO, is able to provide a range of training including that related to:

- ratings and other authorisations;
- ensuring proficiency and maintaining currency of both licence-holders and other specified personnel; and
- training to meet its safety management responsibilities (e.g. SMS or FRMS).

In accordance with the Convention on International Civil Aviation, where training is specified, there is an obligation to ensure that the training provided is suitable and sufficient to prepare people for the role they will be assuming. To ensure that training is fit for purpose, the following sections focus on HP considerations associated with evaluating:

- training programmes;
- personnel assessment processes; and
- the use of training aids, devices and simulators.

a) Training programmes

Because all training is inherently related to HP, the evaluation of the design and delivery of training programmes should be particularly sensitive to the HP Principles (see the blue box below).

It is common in various parts of the aviation industry to talk about "human factors training" when referring to specific training topics such as threat and error management (TEM) and crew or team resource management (CRM or TRM) (see text box below). For licensing or otherwise authorising pilots, air traffic controllers and aircraft maintenance personnel, Annex 1 specifies "human performance" training requirements in the form of "knowledge about" TEM principles and the demonstrated ability to manage threats and errors when performing their operational functions. The TEM framework assists in understanding the relationship between safety and HP in dynamic and challenging operational contexts. While not the only HP related elements of any training programme, both TEM and CRM/TRM are widely accepted as key elements, and national regulations may specify such training requirements for a range of aviation professionals (see text box below).

TEM AND CRM/TRM

TEM training focuses on recognising and preventing or mitigating threats (including those associated with human limitations and capabilities) and errors that can result in an "undesired state". It incorporates the use of skills that are sometimes trained as part of crew or team resource management (**CRM or TRM**) to ensure individuals can function effectively as team members. Both TEM and CRM/TRM training programs focus on key components of HP, including:

- workload management;
- situation awareness;
- problem-solving and decision making;
- communication; and
- leadership and teamwork.

While CRM is the term used among flight and cabin crew, TRM is the term used within the air traffic environment. Other professional groups have chosen to adapt these programmes for their own purposes, e.g. maintenance resource management (**MRM**) for aviation maintenance personnel; dispatch resource management (**DRM**) for dispatchers; and multi crew resource management (**MCRM**) for flight crews and cabin crews, flight crews and controllers, or controllers and ground crews. It has also been adapted for single-pilot operations (**SPRM/SP-CRM**).

Rather than be limited to TEM or CRM/TRM training, the ability to manage risks in operational conditions can also be understood in a broad sense to be the intent of all "HF training", including that related to SMS and fatigue management. In this broad sense, TEM is not limited to demonstrating standard operational responses to a specific list of events and errors seen in the flight deck or ATS units. It extends to the ability of any person working in aviation to identify risks and hazards, and respond adaptively to any actual or potential risks that may be present prior to, during or after everyday operational activities. This includes people's ability to identify hazards and assess risks associated with their own capabilities and limitations, and those of others, and being able to anticipate and avoid even minor hazards so that safety is enhanced. It follows that, for the purposes of safety management, a service provider's training should also address associated organizational processes and individual responsibilities, and opportunities provided for learning and sharing lessons from experiences within the organization (see *2.4.5 Training*).

All training is inherently related to HP. "HF training" is directed at preventing and managing risks in dynamic operational contexts. "HF training" therefore has relevance, not just for meeting technical training requirements, but for meeting organizational safety management responsibilities.

The evaluation of aviation training programmes with licensing or any other aviation personnel authorisation as outcomes should focus on finding evidence that the training aims for the student:

- to have an understanding of:
  - how they are expected to contribute to system performance in their role; and
  - the operational implications of the HP principles in performing their day-to-day duties; and
- to demonstrate that they can use this knowledge to monitor and adjust their own behaviour to improve operational outcomes.

Training supports human performance by preparing people for their jobs, keeping their knowledge and skills current, building motivation and further knowledge and skills for career development. Aside from evaluating its content, other HP-related aspects a regulator should consider when evaluating an organization's training programme include:

- availability and quality of training facilities and tools. Training should be conducted in environments designed to optimize knowledge and skill acquisition through a variety of learning approaches, including cognitive rehearsals, simulations and real-world scenarios;
- whether provisions are made for different students' learning rates and varying conditions;
- whether the training allows the application of knowledge and skills, including those related to risk management, to be practised and critiqued under real operational conditions;
- whether the training is focused on learning and building expertise, rather than on rote memorisation of facts, rules or procedures;
- whether the training explains the rationale for procedures and clarifies people's responsibilities in ensuring they continue to reflect best practice based on lessons learned;
- whether HP considerations are incorporated in the feedback to students (e.g. did the trainee demonstrate self-awareness of limitations and capabilities, and a recognition of system risks? Did the trainee make

adjustments to optimise their own performance during a training operation, based on the mission objectives and their observations?);

- whether the training programme allows students to reflect on their own performance, e.g. training records contain provisions for student self-evaluation;
- whether instructors are able to adapt their conduct according to the situation, setting, and the needs of the student;
- whether the training programme is regularly reviewed to confirm continued relevance to the dynamic operational environment (including the use of operational data to evaluate and improve the training)[20]; and
- whether the training continues across an individual's career and is tailored to his/her learning needs, role and level of experience.

[20] The Evidence-based Training (EBT) philosophy is a good example of a means to ensure training remains relevant. EBT is intended as a means for assessing and training key areas of flight crew performance in a recurrent training system, according to Annex 6, Part I, 9.3, Flight crew member training programmes, and 9.4.4, Pilot proficiency checks. Additional guidance on EBT is available in PANS-TRG (Doc 9868), Part II, Chapter 2, as well as the *Manual of Evidence-based Training* (Doc 9995).

So how are the HP principles relevant when evaluating training for the purposes of licensing or otherwise authorising aviation personnel?

The evaluation of the design and delivery of training programmes should be particularly sensitive to the HP principles, regardless of whether the training has a licensing or other authorization (including ratings, currency and proficiency checks) as the outcome. From an HP perspective when evaluating such training, the relevant State authority (whether the Licensing Authority or the regulator) should strive to ensure that the training:

- takes into account the capabilities and limitations of the trainees; that it optimises knowledge and skill acquisition in the learning environment, as well as retrieval and use in the operational environment. The training should also provide tools for and promote peoples' awareness of their performance variability, capabilities, limitations, and biases, so that they can optimise their fitness for duty* and adapt their behaviours in order to take timely preventative actions and adopt suitable mitigations in the workplace (***HPP 1***);
- supports and promotes peoples' understanding of how they are influenced by different factors that may limit and bias how they make sense of the world. Training should also provide skills and tools so people can mitigate the negative effects of these factors, and understand and apply alternative perspectives (***HPP 2***);
- enables people to acquire, integrate, and maintain the right knowledge, skills and attitudes required to perform well in the actual operational environment including in unexpected situations (***HPP 3***);
- supports and promotes the development of peoples' abilities to assess and analyse risks, and to make decisions in situations that require trade-offs between conflicting goals (***HPP 4***); and
- supports and promotes people in acquiring the understanding and means for effective communication, coordination and leadership required for optimal performance in human-human and human-machine interaction (***HPP 5***).

In summary, in evaluating content of training for the purposes of licensing or otherwise authorising aviation personnel, a State authority should look for evidence that the training of any task includes the application of strategies to anticipate and manage the varying influences on human performance (whether as an individual or as a part of a group) that may occur when performing that task within the dynamic work environment.

**See also Section 2.4.1 Safety Reporting Systems and the ICAO document: "Fitness to Fly"*

For detailed information on the conduct of training, refer to:

- *Procedures for Air Navigation Services - Training,* (Doc. 9868).
- *Manual of Procedures for Establishment and Management of a State's Licensing System* (Doc 9379).
- *Human Factors Training Manual* (Doc 9683).

b) Personnel assessment processes

Aviation regulatory authorities also have oversight responsibilities to ensure that the way in which an individual's performance is assessed is reliable, consistent and suitable, regardless of whether these assessments are done by the regulator or are delegated to authorised persons.

While course instructors undertake ongoing assessments of all their students during training, assessments of the performance of those applying for a licence or rating are undertaken by examiners who are either employed by the regulator or who are designated industry personnel. In accepting or approving assessment processes, a regulator should look for evidence that HP considerations are incorporated in:

- the testing and checking plans, e.g.:
  - test plans provide opportunities for the applicant to be challenged sufficiently and be required to demonstrate effective risk management skills in normal as well as in abnormal or unexpected operational conditions.

- how the assessments or tests and checks are conducted, e.g.:
  - the instructor or examiner demonstrates awareness of how their interpersonal skills affect the applicant's performance;
  - the instructor or examiner is aware of potential biases and makes correct and consistent assessments; and
  - the instructor or examiner incorporates an HP perspective (e.g. management of workload, communication, risk assessment, and consideration of trade-offs) in the feedback to the applicant.

Besides the HP implications for evaluating the assessment process of individual applicants, there are also HP implications for evaluating the assessment process of the training program itself:

- whether there is ongoing assessment of the performance of the training programme, e.g.:
  - records are used by the organization to review and modify the training programme based on evidence, such as altering the training content to address the aviation industry's or particular organisation's identified risks associated with HP.

- how the outcome of tests and checks is fed back to the training organization for continuous improvement purposes, e.g.:

  - deficiencies identified during tests and checks become training topics. Strengths are also recognised and the associated training approaches are used to improve areas with weaker performance; and

  - data on HP issues in daily operation is used to determine training needs and to create realistic scenarios to be used in training.

c) Simulators, training aids and devices

Simulators, training aids and devices are used extensively in training and assessments of all types of aviation professionals. How they are used depends heavily on the device's design and the design of the training programme or assessment activity. Because of the broad possible uses of these devices, aviation regulatory authorities have oversight responsibilities to ensure that there is a proper match between the device's capabilities and its intended purpose. In the case of flight simulation training devices (FSTDs), formal approval is required.

In evaluating simulators, training aids and devices and their use[21], HP considerations for regulators include:

- Is the capability of the simulator, training aid, or device aligned to the training objectives?
  - e.g., if the training objective is to demonstrate mastery of a procedural flow, is a part-task procedure trainer sufficient or is a full simulator needed?
- Is the support for the use of the simulator, training aid, or device developed and updated?
  - e.g., are instructor training and documented guidance on implementation, maintenance and technology support included?
- How successful is the transfer of learning to work situations using the simulator, training aid, or device?
  - e.g., operational assessments are done during and post-training to confirm that the opportunities for negative training are minimised and the opportunities for positive training are maximised when training and assessments are conducted using the device.

Regulators need to be aware that final assessment of these devices requires a high level of experience from the assessor, which can be difficult for some States to achieve. In order to prevent inconsistent levels of assessment it may be possible to contract a more experienced State to provide the assessment.

[21] The ICAO *Manual of Criteria for the Qualification of Flight Simulation Training Devices* (Doc. 9625) provides technical criteria for establishing the simulation fidelity levels required to support training tasks for various pilot licences, qualifications, ratings and type training requirements.

2.4 PROVIDING ONGOING SURVEILLANCE

Each State has the responsibility to verify that organizations continue to meet the established requirements and function at the level of competency and safety required. This is part of its SSP obligations regarding State safety assurance (Component 3 in Figure 1). This is achieved through a State's surveillance activities, including the monitoring of safety performance indicators.

Section 2.3 described the HP considerations for the initial approval of anything, regardless of it being equipment (Section 2.3.1), an organization or its management systems, processes and procedures (Section 2.3.2), or personnel training and licensing (Section 2.3.3). However, all of these aspects under the purview of the regulator, are subject to ongoing surveillance to ensure that they continue to comply with established requirements and are "fit for purpose" (e.g. an aircraft continues to be airworthy; an air transport operator continues to operate according its operations manuals; a training programme continues to deliver competent personnel; and a pilot continues to be fit to fly).

To avoid missing some important HP issues, surveillance has to consider not only continued compliance with individual regulations, but also how the combination of these regulations affects human performance within the operational and organizational contexts.

Surveillance activities and compliance assessments often only capture a single point in time. However, HP by its very nature, is variable and continuously changing and adapting. In undertaking surveillance activities, a regulator should be looking for evidence that a service provider addresses HP considerations in relation to its operational context and environment in order to maintain and improve its safety performance. A service provider would provide evidence of this through its ongoing management of daily operations, which are normally monitored by a State as part of its continuing surveillance of the service provider's SMS. Both the regulated organization and the regulator need to collect, analyse, interpret and then act on data and information that include HP issues.

To find evidence of how effectively a service provider addresses HP considerations in its day-to-day operations, a regulator needs to focus on:

a) how the service provider and its workforce identifies HP issues;
b) how the effectiveness of any mitigations to support HP is monitored; and
c) how lessons learned and user feedback are used to maintain and improve "how things get done".

A regulator needs to both examine documentation and other evidence provided by the service provider, as well as talk to, and observe behaviours of employees at all levels in relation to areas such as:

a) safety reporting;
b) safety risk assessment;
c) safety investigations;
d) fatigue management;
e) training; and
f) management of change.

The following sections further describe the type of HP-related evidence a regulator should be looking for in each of these areas.

2.4.1 SAFETY REPORTING SYSTEMS

Safety reporting is essential for a service provider to be able to identify and understand their risks associated with HP and, where possible, to be able to develop mitigations for them. A regulator should assess both the safety reporting system that a service provider established as well as the outputs of that system. From an HP perspective, it is important that a regulator doesn't just focus on how many safety reports a service provider receives, but whether the service provider has considered the variety of factors that might be influencing why and when people in their organisation report.

Safety reporting should support both mandatory and voluntarily identified safety issues. While regulators need to check that mandatory safety reporting requirements are complied with, it is often voluntarily provided contextual information that can most help a service provider to understand why someone acted in the way they did. That understanding is necessary in order to find better ways to support HP. Such contextual information may include the reporting of specific operational or organizational factors, such as:

a) interactions with other aviation professionals, issues with phraseology and communication and language;
b) work conditions (e.g. level of automation, authority and responsibility, support staff);
c) environmental information (e.g. weather, remoteness, topography);
d) task specific workload (e.g. task intensity (under or over arousal), complexity of the task);
e) experience level of the reporter or those who they were working with;
f) staffing arrangements (e.g. provision of cover for sickness or other absences, authority status of staff, isolation of staff (lone workers));
g) commercial pressures (e.g. financial motivations of a particular company may result in the erosion of safety buffers);
h) shift related factors that impact on fatigue (e.g. shift pattern and duration, stability of the working pattern, use of overtime); and
i) impact of changes to working organizational structures or processes and procedures.

However, requiring such contextual information on a safety report form can deter people from reporting because it is time consuming. Regulators should assess how service providers collect and utilize such contextual information. For example, is the standardised report form used by the service provider designed to enable the collection of enough information to allow the service provider to recognize when further investigation is warranted?

People will only report non-mandatory issues when they understand and trust the system being used, and when they trust their peers and managers with the information provided. To examine whether a service provider seeks to foster such trust and engagement, a regulator should look for evidence that the service provider:

a) has clear expectations for individuals to report risks and hazards, including when an individual considers him/herself unfit to perform safety-critical tasks to an acceptable standard (e.g. in cases of fatigue or mental health issues);
b) has identified the implications for individuals of submitting a report;
c) offers an option for anonymous reporting;
d) has specified how it will respond to reports, and takes appropriate actions consistent with its stated policy;
e) makes it easy to report (e.g. report forms are readily available and easy to complete and submit);
f) maintains the integrity of the safety reporting system and reporter confidentiality;

g) involves operational personnel and HP specialists in reviewing contextual information provided on safety reports and in identifying appropriate mitigations; and
h) provides timely feedback to the workforce on changes made in response to issues or hazards identified through its safety reporting system.

For more information about service providers' safety reporting systems, refer to the relevant sections in ICAO Doc 9859 (*Safety Management Manual*).

2.4.2 SAFETY RISK ASSESSMENT

Safety is all about the management of risk. HP considerations are central to risk assessment. What's more, risks change over time. Just as the service provider's process of safety risk assessment must be continuous, so does the regulator's surveillance of such processes. To assess that a service provider's safety risk assessment processes include HP-related issues, a regulator can observe whether:

a) HP expertise is used appropriately in the organization's safety risk assessments;
b) the service provider uses credible sources of validated HP information to support their risk assessment;
c) the service provider collects and analyses data from their own operations to support their safety risk assessment;
d) a range of operational conditions and human operator performance variability is considered in assessing the safety risk;
e) safety risk assessment matrices/frameworks used are suitable for HP assessment. Assessing the risks associated with human performance is complex and the methodology used to assess these risks should reflect this complexity;
f) the rationale for assigning likelihood and severity values is defensible and is consistently applied. (Currently, there is no universally-accepted, validated method to assign numeric values to the probability of declines in human performance.); and
g) a range of mitigations to support HP is identified, documented and implemented (e.g. assumed levels of proficiency, implementation of scheduling rules, provision of checklists).

Assessing the risks associated with HP is more complex than the risks associated with technology because HP is highly variable, with a wide range of interacting influences internal and external to the individual. Many of the effects of the interaction between these influences are difficult, or impossible to predict. The consequences of variable HP will differ according to the task being performed and the context.

For more information about service providers' safety risk assessment, refer to the relevant sections in ICAO Doc 9859 (*Safety Management Manual*).

2.4.3 SAFETY INVESTIGATIONS

Section 2.1 above focused on the regulator collecting and analysing data to examine HP issues. In contrast, this section focuses on the regulator's role in assessing how well HP aspects have been considered in internal safety investigations conducted by service providers. Such investigations include both those undertaken through the analysis of their safety data as well as through investigations of their own safety occurrences.

While a lot of data may be collected by a service provider, analysing it to identify HP-related risks requires an understanding of the operational implications of the HP principles. Similarly, developing the most effective approach to maintaining safe operations and preventing undesirable occurrences requires understanding not just what safety occurrences happened but, importantly, why they happened. Blaming or just retraining an individual are very poor treatments for circumstances caused by systemic issues.

Reliance on training as the only mitigation should be challenged when changes in processes and equipment may be a more robust barrier in supporting HP.

In providing surveillance, regulatory inspectors and auditors should look for evidence of the inclusion of HP considerations in safety data analysis and investigations, such as:

a) investigators and analysts are trained to have at least a basic understanding of HP and the terminology being used, and know when and where to seek further guidance. If an assessment taxonomy is used, it includes HP categories which are understood by the analysts and investigators and are used consistently;
b) investigators and analysts recognise that identifying an event simply as human error offers little insight. To gain further insight, analysis of safety occurrences includes an in-depth evaluation that requires a thorough understanding of the context;
c) investigation reports contain an assessment of the HP issues and data relating to factors affecting HP, e.g. experience levels, time of day, light levels, environmental conditions;
d) analysts and investigators coordinate regularly to ensure that they are investigating, coding and analysing their data consistently; and
e) broad systemic issues are also considered in the investigations and analyses, e.g. monitoring working time, sick leave and staff retention to understand pressures on individuals.

For more information about safety investigations, refer to the relevant sections in ICAO Doc 9859 (Safety Management Manual).

2.4.4 FATIGUE MANAGEMENT

Fatigue is recognised as a specific safety issue over which aviation regulatory authorities have oversight responsibility for a number of different aviation professionals. ICAO SARPs (in Annex 6 Part I, Annex 6 Part III (Section II) and Annex 11) require that regulations be established, based upon scientific principles for the purpose of managing fatigue. These basic principles relate to:

a. the need for sleep;
b. sleep loss and recovery;
c. circadian effects on sleep and performance; and
d. the influence of workload.

In providing surveillance, a regulator should look for evidence that a service provider adapts its scheduling practices based on:

a) how the organization identifies, assesses, monitors and controls its specific fatigue risks; and
b) whether the organization has and uses a process for the voluntary reporting of fatigue issues.

Additionally, where there are specific fatigue management regulations for certain groups of aviation professionals, the organization must demonstrate how they comply with those requirements, including:

a) provision of adequate opportunities for sleep;
b) limiting extended periods of being awake;
c) addressing circadian factors;
d) management of workload, which could vary based on the operational context;
e) stability of schedules; and
f) methods for managing on-the-day operational disruptions.

For detailed information on fatigue management approaches and oversight, refer to ICAO Doc 9966 (*Manual for the Oversight of Fatigue Management Approaches*).

2.4.5 TRAINING ACTIVITIES

After initial approval of training programmes (as detailed in Section 2.3.3), ongoing surveillance of training activities, whether undertaken by an ATO or a service provider, is necessary as a means of confirming that the training continues to be meeting its objectives. While recognising the need for ongoing surveillance of training programmes which have licensing and other authorizations for aviation personnel as outcomes, this section focuses on the ongoing surveillance of training activities a service provider undertakes as part of its safety management responsibilities.

To support HP, a service provider's training activities need to address organizational processes and individual responsibilities, and enable learning and sharing lessons from experiences within the organization. How they do so is a reflection of the service providers' safety culture. When providing ongoing surveillance of "organizational training", regulators should look for evidence that a service provider's training programme:

a) remains current and relevant, addressing changing needs as identified within specific organizational and operational areas of risk;
b) is tailored to address the HP challenges of the specific workgroup and work environment;
c) develops understanding of HP to improve their workforce's ability to identify and report HP-related risks and hazards, including those that affect an individual's ability to perform safety critical functions; and
d) includes a method for monitoring the training programme's effectiveness (e.g. sampling day-to-day behaviours demonstrated by their staff, examining whether safety reports include feedback on HP issues).

Thus, the regulator should look for evidence that the service provider trains its people to understand the operational implications of the HP principles (see Section 1.4) in performing their day-to-day duties, and that the people are able to use this knowledge to monitor and adjust their own behaviour to take preventative or early corrective actions to address hazards as part of their everyday functions.

For more information on supporting HP through safety management-related training, refer to the relevant sections in ICAO Doc 9859 (Safety Management Manual); and ICAO Doc 9966 (Oversight of Fatigue Management Approaches).

2.4.6 MANAGEMENT OF CHANGE

Each State has the responsibility to ensure that organizations identify changes which may affect the level of safety risk associated with its aviation products or services. Such changes include changes to an organization's business model, their employment practices, key personnel, work practices, or the introduction of new technologies. The potential hazards associated with these changes need to be identified and the risks associated with the potential consequences need to be managed.

When an organization makes significant changes to its business practices, such as a change to its working or employment practices, the implications for HP should be the focus of performance monitoring.

Altering or introducing any new system, piece of equipment, process, procedure or approach to work results in changes to what people are expected to do. When relevant and required by the regulator, the organization should present the regulator with notification of a planned change. However, the regulator needs more information than just a notification of a planned change to determine whether a service provider's implementation planning has adequately taken HP considerations into account. A regulator needs to consider whether the service provider's plan for change has:

a) identified what is being changed (whether it is a system, a piece of equipment, or a process);
b) considered the risks associated with making the change in terms of the overall system (e.g. the potential effects of a planned change may extend to people in different parts of the organization, or to other organizations, or to the environment);
c) identified who will be impacted by the change both directly and indirectly, and in what ways they will be affected; and
d) a process to help ensure successful implementation. HP aspects of a change management process include:
    - if the appropriate stakeholders have been involved in the planning of the change, such as air traffic personnel and airline operators;
    - how leadership supports the change, such as through training resources, and positive discussions of the rationale and benefits; and
    - how those affected by the change can try it in a low-risk environment, such as through simulation, real-time shadow operations, or actual low-workload operations to increase familiarity and user confidence, as well as to minimize the risk of unintended consequences.

To assess whether an organization has adequately addressed the particular HP challenges associated with implementing the proposed change, the regulator may seek answers to the questions below[22]. How these are to be managed should be explained in the service provider's change management plan.

Does the change alter the tasks of a user or affected others? If yes:

- How does it change the task itself?
- How does the change affect other tasks the user or affected others have to perform?
- Does the change alter roles and responsibilities for the users or affected others?
- Do the new tasks/roles require new knowledge or skill?
- Does the change alter the user's work environment?
- What happens if the user does not perform the task exactly as expected, or performs the task late?

Does the change imply processing of new information by the user[23]? If yes:

- How (when and in what format) should this new information be presented?
- How does it relate to other information?
- Does using the information require new knowledge or skill?

Does the change imply the use of new equipment? If yes:

- How does the use of the equipment fit into the user's workflow?
- What level of performance is the user expected to achieve using this new equipment?
- What happens when the expected level of user performance is not maintained?
- What happens when the equipment malfunctions?
- Does the use of this new equipment require new knowledge or skill?

Does the change involve automation? If yes:

- Does the automation change the task the user needs to perform?
- How does the user know what the automation is doing?
- What is the user's role in managing normal and abnormal conditions?
- Does the user require new knowledge or skill to operate effectively? (see also Section 2.3 on evaluating automation)

Does the change take place in parallel with other changes? If yes:

- Has the change implementer explicitly considered the effect of "layered" changes with regard to the current operation, as well as with regard to each individual change?
- Is there time planned to allow staff to get comfortable with one change before having to cope with another change? or

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[22] Many of the same questions are used in the iterative development process for new ASBU modules as part of the ICAO *Global Air Navigation Plan.*

[23] "Processing new information" includes the user having to look at new locations to retrieve familiar information.

- Are there mitigations aimed at the risk associated with the cumulative effect of simultaneous changes (e.g. simulation training in a single change vs training with all integrated changes incorporated)?

Once in place, any change needs to be monitored in operation to provide assurance that it is performing as expected, that there are no negative unintended consequences, and that the impact on HP is being managed in such a way that the change supports HP in actual operation.

For more information about assessing service providers' change management processes, refer to the relevant section in ICAO Doc 9859 (Safety Management Manual).

2.5 PROMOTING SAFETY

ICAO Assembly Resolution A40-4 calls on all Member States to "*ensure the integration of human performance considerations … as part of a safety management approach*." A safety management approach and Component 4 of the SSP (see Figure 1) call for the promotion of safety.

The SSP recognises the need for promoting safety to personnel within the regulatory authority and also the need for safety promotion by the regulator targeting all aviation organizations. Outside of Annex 19, ICAO has other specific requirements for safety promotion activities. For example, Annex 1 (para 1.2.4.3) specifically requires the regulator (Licensing Authority) to implement appropriate aviation-related health promotion for licence holders subject to a medical assessment, to reduce future medical risks to flight safety.

Consider identifying examples of desired behaviours as well as undesired behaviours when developing safety promotional approaches and materials.

Given that it's the people in the system who create safety, either directly through their actions or indirectly through their designs, the promotion of HP considerations is key to the promotion of safety. Understanding human performance, the way people meet the challenges of the aviation system, and why they perform in the ways they do, is critical to the promotion of safety. It is important that people understand that the HP principles apply to themselves and to everybody else. It is also important for people to understand that being aware of the consequences of the HP principles does not make a person immune to them. Because safety promotion deliverables are aimed at people, the development and deployment of such materials should follow the HCD process (see, 1.2.1.b). To further support people in doing the right thing, as part of their promotional activities, regulators should encourage the sharing of HP-related information across organizations and across States.

A parting thought…..

Institutionalising the consideration of HP, whether within a regulatory authority or within aviation organizations, requires the adoption of systems thinking and the understanding of HP considerations, including the HP principles. Such institutionalisation is enabled through leadership from senior managers who understand and communicate the critical significance of human performance.

APPENDIX A REFERENCES

ICAO MANUALS AND DOCUMENTS

The ICAO manuals and documents referenced in the body of this document are listed below. They are available through the ICAO portal (restricted access to Member States) or through the ICAO Store at: https://store.icao.int/ . Where free access is available, the weblink is provided.

Airworthiness Manual (Doc 9760)

Fitness to Fly: A Medical Guide for Pilots (2018) at: https://www.unitingaviation.com/fitnesstofly/

Global Aviation Safety Plan (Doc 10004) at: www.icao.int/gasp

Global Air Navigation Plan at: https://www.icao.int/airnavigation/Pages/GANP-Resources.aspx

Global Air Navigation Plan Portal at: https://www4.icao.int/ganpportal/

Human Factors Training Manual (Doc 9683)

* *Manual for the Oversight of Fatigue Management Approaches* (Doc 9966) at: https://www.unitingaviation.com/publications/9966-EN/#page=1

Manual of Aircraft Accident and Incident Investigation (Doc 9756)

Manual of Criteria for the Qualification of Flight Simulation Training Devices (Doc 9625)

Manual on the Approval of Training Organizations (Doc 9841)

Manual on Certification of Aerodromes (Doc 9774)

Manual on Civil Aviation Medicine (Doc 8984) at: https://www.icao.int/publications/Documents/8984_cons_en.pdf#search=Manual%20of%20Civil%20Aviation%20Medicine

Manual of Evidence-based Training (Doc 9995)

Manual on Prevention of Problematic Use of Substances in the Aviation Workplace (Doc 9654)

Manual of Procedures for Operations Inspection, Certification and Continued Surveillance (Doc 8335)

Manual on Remotely Piloted Aircraft Systems (RPAS) (Doc 10019)

Procedures for Air Navigation Services - Aircraft Operations (Doc 8168)

Procedures for Air Navigation Services – Air Traffic Management (Doc 4444)

Procedures for Air Navigation Services - Training (Doc 9868)

Quality Assurance Manual for Flight Procedure Design (Doc 9906)

Safety Management Manual (SMM) (Doc 9859) – free e-book version and practical examples available on the Safety Management Implementation website at www.icao.int/SMI

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*This manual is a freely available electronic document downloadable from the website above. An official print version of the electronic document is also available at minimal cost upon request at: https://store.icao.int/

OTHER REFERENCES

Other documents referenced in the body of this document are listed below.

Human Factors and Ergonomics Society, 2008 at: https://www.hfes.org/resources/educational-and-professional-resources/new-item

ISO 9241-210: 2010, Ergonomics of Human-System Interaction – *Part 201: Human-Centred Design for Interactive Systems* (First Edition) at: https://www.iso.org/standard/52075.html

Billings, C. E. (1997) *Aviation automation: The search for a human-centered approach*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

APPENDIX B HP WEBLINKS

The links below provide access to further information on various HP topics. These are widely available and include materials published by ICAO and various regulatory authorities. Being listed in this appendix does not infer endorsement and exclusion does not infer the opposite. The references listed are only a small subset of the numerous HP reference materials available and are subject to change.

GENERAL HP

a) Civil Aviation Authorities

EASA – Regulations, guidance and other publications

https://www.easa.europa.eu/easa-and-you

Transport Canada – Human Factors

http://www.tc.gc.ca/eng/civilaviation/opssvs/general-exams-human-brochure-2016.htm

UK CAA – Human Factors

https://www.caa.co.uk/Safety-initiatives-and-resources/How-we-regulate/Safety-Plan/Enhancing-industry-safety-management/Human-factors/

Federal Aviation Administration – Human Factors

https://www.hf.faa.gov/index.aspx

http://www.faa.gov/aircraft/air_cert/design_approvals/human_factors/

Australian Government CASA – Human Factors

https://www.casa.gov.au/safety-management/human-factors

b) Other

- Global Aviation Safety Network (GAIN): https://flightsafety.org/toolkits-resources/past-safety-initiatives/global-aviation-safety-network-gain/
- Flight Safety Foundation: http://www.flightsafety.org
- Skybrary: Operational Issues: https://www.skybrary.aero/index.php/Main_Page#operational-issues
- NASA Human Systems Integration Division: http://human-factors.arc.nasa.gov

DESIGN

a) Airspace Design and Flight Procedures Development

- EUROCONTROL Manual for Airspace Planning Volume 2 - Common Guidelines: https://www.icao.int/safety/pbn/Documentation/EUROCONTROL/Eurocontrol%20Manual%20for%20Airspace%20Planning.pdf
- EUROCONTROL Level Bust Toolkit: https://www.skybrary.aero/index.php/Toolkit:Level_Bust

b) Checklists

- CAP 676 Guidelines for the Design and Presentation of Emergency and Abnormal Checklists, UK CAA, August 2006. http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=158
- CAP 708 Guidance on the Design and Presentation of Electronic Checklists, UK CAA, March 2005. http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=1661
- Human Performance Considerations in the Use and Design of Aircraft Checklists, FAA, Jan 1995. *See* https://skybrary.aero/bookshelf/books/1566.pdf
- HF of Flight-Deck Checklists: The Normal Checklist, A Degani, E Wiener, NASA Report 177549, May 1990. See https://ti.arc.nasa.gov/m/profile/adegani/Flight-Deck_Checklists.pdf
- EASA Research Project.2013.01 Checklist Memory Items https://www.easa.europa.eu/sites/default/files/dfu/Final_Report%20EASA.2013-01.pdf
- NASA – Designing Flightdeck Procedures. 2016. https://humansystems.arc.nasa.gov/publications/Barshi_Procedure_Checklist_Design_NASA_TM_2016.pdf
- NASA – Designing Flightdeck Procedures: Literature Resources. 2017. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170005594.pdf

c) Other

- Guidelines for Auditory Warning Systems on Civil Aircraft, CAA Paper 82017, UK CAA, Nov 1982: https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB83248625.xhtml
- Human Factors Considerations in the Design and Evaluation of Flight Deck Displays and Controls: Version 2.0. FAA & Volpe Dec 2016: https://rosap.ntl.bts.gov/view/dot/12411
- Operational Use of Flight Path Management Systems: Final Report of the Performance-based operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group, Sept 2013: https://www.faa.gov/aircraft/air_cert/design_approvals/human_factors/

SAFETY MANAGMENT SYSTEMS (SMS)

- ICAO Safety Management Implementation website: http://www.icao.int/SMI
- EASA Management System Assessment Tool, providing a common approach to management system assessment and continuous improvement of SMS: https://www.easa.europa.eu/document-library/general-publications/management-system-assessment-tool
- CAP 795 CAA Safety Management Systems Guidance Material, UK CAA 2015 - https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=6616
- EASA practical guide Management of Hazards Related to New Business Models of Commercial Air Transport Operators: https://www.easa.europa.eu/document-library/general-publications/management-hazards-related-new-business-models-commercial-air

FATIGUE MANAGEMENT

- ICAO Fatigue Management website: https://www.icao.int/safety/fatiguemanagement/Pages/default.aspx
- CASA Fatigue management website: https://www.casa.gov.au/safety-management/fatigue-management
- Transport Canada. Fatigue risk management system toolbox for Canadian aviation: https://www.tc.gc.ca/en/services/aviation/commercial-air-services/fatigue-risk-management/frms-toolbox.htm
- FAA Fatigue Risk Management website: https://www.faa.gov/about/initiatives/maintenance_hf/fatigue/

AVIATION MEDICINE

- EASA guidance on use of medication in the aviation environment: https://www.easa.europa.eu/document-library/general-publications/use-medication-aviation-environment
- EASA guidance for Aeromedical Examiners: https://www.easa.europa.eu/document-library/general-publications/ame-working-relations

TRAINING

- Teaching and assessing non-technical skills for single-pilot operations, Advisory Circular 61-08, Civil Aviation Safety Authority of Australia: https://www.casa.gov.au/sites/default/files/ac_61_08.pdf
- Flight Examiner Handbook (2018), Civil Aviation Safety Authority of Australia: https://www.casa.gov.au/sites/default/files/_assets/main/manuals/regulate/fcl/flight_examiner_handbook.pdf
- EASA CRM Training implementation, sharing recommended practices and information on CRM: https://www.easa.europa.eu/document-library/general-publications/crm-training-implementation
- European Helicopter Safety Team Helicopter Flight Instructor Guide: https://www.easa.europa.eu/document-library/general-publications/ehest-helicopter-flight-instructor-guide

ACCIDENT ANALYSIS

- EASA Annual Safety Reviews, published annually since 2005[24]: https://www.easa.europa.eu/document-library/general-publications?publication_type%5B%5D=144
- EASA Annual Safety Recommendations Review, published annually since 2007: https://www.easa.europa.eu/document-library/general-publications?publication_type%5B%5D=2263
- UK CAA in-depth analyses: https://www.atsb.gov.au/media/28363/sir199604_001.pdf

OPERATIONAL PERSONNEL

a) Air Traffic Controllers

- Human Factors Design Standard (DOT/FAA/HF-STD-001B). FAA, 2016: https://hf.tc.faa.gov/publications/2016-12-human-factors-design-standard/
- CANSO Human Performance Standards of Excellence. See https://www.canso.org/system/files/CANSO%20Standard%20of%20Excellence%20in%20Human%20Performance%20Management.pdf
- ATM Automation: Guidance on human-technology integration CAP1377 2016 Civil Aviation Authority See http://publicapps.caa.co.uk/docs/33/CAP%201377%20final%20Mar%202016.pdf

b) Pilots

- Operator's Flight Safety Handbook, GAIN, 2000: https://flightsafety.org/toolkits-resources/past-safety-initiatives/global-aviation-safety-network-gain/
- Propulsion System Malfunction and Inappropriate Crew Response, Flight Safety Digest Nov-Dec 1999, Flight Safety Foundation: http://www.flightsafety.org/fsd/fsd_nov-dec99.pdf
- Safety behaviours human factors: Resource guide for pilots (2nd Edition) 2019: https://www.casa.gov.au/safety-management/publication/safety-behaviours-human-factors-pilots-2nd-edition

c) Maintenance Personnel

- FAA Human Factors in Aviation Maintenance: https://www.faa.gov/about/initiatives/maintenance_hf/
- Safety Behaviours – Human Factors Resource Guide for Engineers, Civil Aviation Safety Authority of Australia, 2019: https://www.casa.gov.au/safety-management/human-factors/safety-behaviours-human-factors-engineers-resource-kit

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[24] Note that every EASA Member State is required to publish a safety review, at least annually, to inform the public about levels of aviation safety. These reviews should be available at national level on the website of either the national aviation authority or the safety investigation authority.

- Aviation Maintenance Human Factors (EASA-145). Civil Aviation Authority of United Kingdom, Dec 2003: http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=275

d) Cabin Crew

- Cabin Safety Compendium, GAIN, 2001: https://flightsafety.org/toolkits-resources/past-safety-initiatives/global-aviation-safety-network-gain/

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