EGHD Expert Group on the Human Dimension of the Single European Sky

EGHD Position Paper (2022_Paper_2): Human factors integration in ATM change management

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EXECUTIVE SUMMARY

With important changes on the horizon, the members of the Expert Group of the Human Dimension (EGHD) expressed during EGHD meeting 26 the expert opinion that human requirements are currently not adequately incorporated into ATM change. The present *position paper* addresses this issue by (i) analysing the current situation and (ii) deriving recommendations for improvement.

Scope

As this paper focuses on the *human dimension* its main focus is that of Human Factors Integration (HFI) in ATM change. HFI consists of a comprehensive technical and management approach to address the human dimension during the introduction of new systems, functions, procedures and equipment. HFI sees the human to be equally important as any other system element and promotes a total system approach in which human, technological and operational aspects are considered together since the start of the change. HFI was first introduced in European ATM by EUROCONTROL in the late 90s as a means to de-risk ATM change and enable the realisation of safety and programme benefits. HFI is the means through which human requirements are systematically identified, traced and integrated in ATM change, through proper involvement and the use of human factors expertise. If HFI is there, human requirements are systematically addressed in time and at the right phase of the change process.

Methodology

As an EGHD position paper the main evidence presented corresponds to the views of the contributing EGHD experts as expressed over the period Sept 2021 - June 2022, during formal EGHD meetings and more informal paper working group meetings. This evidence has been supplemented by:

- A review of the state of the art regarding HFI in the European ATM system today. This comprises a consideration of the relevant HFI methodologies, i.e., the SESAR Human Performance Assessment process[1] and the EUROCONTROL Human Factors Case[2, 3, 4] ;
- A review of binding EU regulations relevant for ATM change and HF;
- A review of (successful and less successful) case studies of ATM change from EGHD members' direct professional experience;
- A review of relevant scientific and industrial literature regarding barriers and enablers to HFI implementation. (This literature has been cited in relation to the relevant section for readability purposes.)

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[1] *SESAR (2018) Human Performance Assessment Process V1 to V3-including VLDs.*

[2] *EUROCONTROL (2004). The Human Factors Case : Guidance for Human Factors Integration.*

[3] *EUROCONTROL (2007). Guidance for Human Factors Integration.*

[4] *EUROCONTROL (2011). Support material for Human Factors case application.*

Main findings

1. HFI is an essential enabler of overall ATM safety and cost-efficiency

- Appropriate implementation of HFI delivers significant benefits in the areas of human performance, safety, change acceptance (by both end users and regulators) and cost reduction.
- The successful case studies provided by members concerned the introduction of solutions which lead to a positive impact on the performance of the concerned human operators, and in turn this generated positive effects at programme and ATM system levels. In line with the relevant literature, these cases appear to confirm that human performance is an enabler of overall ATM performance.
- Cost reduction categories enabled by HFI include: reduced procurement costs, reduced development costs, reduced productivity costs, reduced training costs, lower maintenance and corrective costs. EUROCONTROL states that HFI will require more funds in the early stages of system development but that this initial investment leads to significant cost reductions later on. Such cost benefits have been demonstrated in other industries, in particular the military. For instance, an official review of a HFI programme for the Canadian Department of National Defence reports a payback of 108% in immediate savings (time and resources during project execution) and up to 4000% in extrapolated savings, i.e., savings projected over the operational life of the solution.
- Specifically for corrective costs, EUROCONTROL states that a human factors issue that could be corrected for 1€ at the design stage might cost up to 60€ in the development stage and up to 100€ after entry into service of the solution. This estimate is supported by HFI-related savings already realised in the military domain.

2. The ATM industry as a whole could benefit significantly from better HFI

- While successfully applied at SESAR level (the HPAP is now mandatory in SESAR 3) HFI seems to enjoy limited application at ANSP level. Different ANSPs have different level of maturity and many ATM changes are introduced with little or no consideration of human requirements.
- Evidence from the case studies from members confirm this: 7 out of 11 encountered human performance challenges during deployment, which in turn led to negative ATM system and programme performances. All except one of the seven cases occurred over the period 2010-2022.
- This is a concern because many innovative technological solutions are expected to transform ATM in the medium term, and all such developments will need a thorough consideration of human requirements in order to deliver their intended benefits. On the long path towards a fully autonomous ATM system, the human operator will still have to be able remain in control.

3. EGHD members have identified several key causes of inadequate HFI in ATM

- *Lack of HFI awareness and competence*: Human Factors, Human Performance and Ergonomics are popular terms in the industry but they are often confused with each other. Most importantly many leaders, programme and change managers appears to be unfamiliar with (i) the specific discipline of HFI, (ii) its implementation preconditions and (iii) and its benefits—in particular the safety and cost reduction ones.
- *Unsportive binding regulations:* Implementing Rule (IR) 2017/373 is the identified reference regulation for ATM change and Human Factors. The regulation requires the consideration of the human element in changes to the ATM functional system; however, it does not

mention explicitly HFI, and narrows the definition of HF down to stress, fatigue and the use of psychoactive substances. Furthermore, it is the perception of EGHD members that IR 2017/373 is not uniformly applied by different EASA member states.

The way forward

Based on the analysed evidence, this position paper delivers **six key recommendations** (including 17 minimum HFI requirements for ANSPs) which have been grouped into three categories:

1. HFI Awareness, Emphasis and Competency
2. Promotion of HFI
3. Continuous HFI Improvement

All six recommendations are recorded and detailed in *Section 3* of this paper.

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1 - INTRODUCTION

1.1 - Purpose

The purpose of this EGHD position paper is to promote recommendations aimed at enabling and improving end-to-end integration of HF and front line operator expertise, throughout the change lifecycle, building on existing methodologies (e.g. from SESAR, EUROCONTROL, other industries) and "systems thinking", as appropriate.

This position paper is expected to deliver recommendations aimed at improving HFI in ATM change. This includes an update of the Commission Implementing Regulation (EU) 2017/373 of 1 March 2017, to promote the consideration of relevant HF/HP processes in the context of the ATM change. Implementing rule EU 2017/373 is currently the reference regulation for ATM change and Human Factors. So, it seems sensible to consider this regulation as a baseline for the future developments of HF/HP in Europe.

1.2 - Motivation

ATM changes (including system, process and organisational) have the potential to result in an improved joint cognitive system, resulting in improved ATM performance. They should not prevent tasks from being carried out efficiently and safely. To achieve these goals a "total system overview" approach is essential.
EGHD members consider that in the past, ATM changes have sometimes been introduced with insufficient consideration of the human in the system (including a deep understanding of the needs of the wide range of front-line actors and operators affected by the change) in the design process of the complete system.

The above mentioned type of oversight can lead to several undesirable outcomes, examples of which are:

- poor user acceptance of the change, leading to lack of benefits realisation;
- increased end-user adaptation effort, leading to decreased human performance;
- design flaws, leading to increased potential for unsafe acts and degraded safety levels;
- increased ATM change lifecycle costs;
- the introduction of new (human/system) errors that were unknown until the change was introduced;
- unassessed changes which introduce unexpected new tasks, workload and/or complexity leading to a decline in capacity, increased overall relative cost and/or unbalancing of intended cost-efficiency targets.

1.3 - Key terms

- **ATM change.** ATM change consists of the introduction of new solutions, such as new procedures, team configurations, functionalities, physical equipment, work environments, etc. Examples of relevant ATM changes include the introduction of automation, digitalization, artificial intelligence; new operational concepts such as drones and urban air mobility; hardware changes such as ATC control room and workstation design. The change may concern a front end component, e.g., radar screen, as well as a back end component, radar tracker. Also, a change may be relevant for ATCOs and pilots, as well as other staff, e.g., supervisors, ATSEP, supervisors, instructors (including OJT instructors), ATM flow managers, AIS/AIM personal, FDO, FISO and AFISO. Also these actors are essential for overall ATM performance. Therefore, ATM change may comprise both changes to "the functional" and "non-functional system" (as defined in 2017/373).

- **Human Factors (HF):** The scientific discipline and area of practices concerned with the design for human use[5]. HF is an enabler of Human Performance (HP). In fact, "HF brings insights and understanding to HP from many different scientific disciplines, such as psychology (including cognitive psychology, industrial and work and organisational psychology, and social psychology), behavioural psychology, sociology, anthropology, medical sciences including aviation medicine and occupational medicine, design and engineering, computer science and statistics"[6]. A formal definition of HF from the International Ergonomics Association is available in the glossary in Appendix 2. Usually, the terms HF and ergonomics are used interchangeably, although with slightly different emphasis. HF is more often associated to the consideration of psychological aspects, while ergonomics, to the consideration of physical aspects.
- **Human Factors Integration (HFI).** The processes, managerial and technical arrangements needed to integrating HF aspects into the ATM change. Although building on HF and ergonomics theories, Human Factors Integration is more than this. HFI represents the core topic of this paper and will be further defined in section 3.1.
- **Human performance (HP):** Human performance refers to how human operators perform their tasks. As stated in ICAO doc 10151, "people design, build, maintain and operate every aspects of the global aviation system"[7]. Safe and effective human performance is an enabler of successful ATM operations and shall be maintained or enhanced as a result of the change.

1.4 - Disambiguation

1.4.1 - « Human factors » versus « the human factor »

As mentioned above the expression "*Human Factors*" refers to a scientific discipline and profession. This is signalled by the "s" at the end of the second term: in English many scientific subjects terminate with an "s" (e.g. economics, mathematics, statistics). The expression *the human factor*, without the "*s*" at the end of the last word refers, instead, to the human element of the system. The distinction is important because human factors competence includes both the study and analysis of human aspects (e.g., workload, situation awareness, error, team work) as well as the implementation of processes and practices (e.g., user centred development, human factors integration) to promote the development of a successful joint human machine system.

1.4.2 - Human factors issues or implications

In relevant standard methodologies, the expressions "HF issues" or "HP issues" refer to challenges regarding the interaction between the human, or a team of humans, and the solution introduced by the change. Alternative valid expressions can be HF or HP implications or challenges. These expressions are usually more appropriate than the expression "human factors".

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[5] *McCormick, E.J. (1976) Human Factors in Engineering and Design (4th ed.). McGraw Hill, cited in EUROCONTROL (2004) :): The Human Factors Case : Guidance for Human Factors Integration.*

[6] *ICAO Doc 10151: Manual on Human Performance (HP) for Regulators.*

[7] *ICAO Doc 10151 : Manual on Human Performance (HP) for Regulators.*

2 - ANALYSIS OF THE CURRENT SITUATION

To understand the current situation regarding the consideration of human requirements in ATM change, the EGHD derived evidence from:

1. A review of the state of the art of relevant HFI methodologies in ATM;
2. A review of current regulations;
3. The analysis of ATM change case studies from EGHD members, exhibiting both positive and less positive outcomes.

The remainder of this section summarises the evidence gathered from these sources, and for each of them identifies opportunities for improvement.

2.1 - State of the Art

2.1.1 - Human Factors Integration (HFI)

The overall process of integrating Human Factors principles, analysis, and processes into the lifecycle of the change is referred to as *Human Factors Integration* (HFI)[8]. HFI corresponds to the comprehensive technical and management approach to address the human dimension in the context of ATM change. Its primary goal is the consideration of the human as a critical system element, of equal importance as other system elements, such as software and hardware[9]. HFI brings a "total system approach" perspective, which consider the humans, the technology, the operational context and the interfaces between[10].

HFI ensures that human requirements are identified and Human Factors issues are identified and resolved before the technology is used operationally. Successful HFI execution involves integration of HF in the early planning stages of a project and the execution of relevant HF activities as the project unfolds, with several touch points with the engineering development process. Successful HFI programmes are end-to-end: they integrate Human Factors and Ergonomics into strategic planning, operational concept development, procurement, adaptation/customisation, validation, operations and decommissioning phases.

HFI requires the integration of human factors and operational expertise. An established practice in other safety critical domains, HFI was introduced in ATM by EUROCONTROL in the late 90's through the development of different guidance materials(see e.g., [11]). The latest contribution, *Human Factors Integration in ATM system Design*[12], was released in 2019.

The table below reports a list of typical HF topics addressed in the context of an ATM HFI programme. Note that the list is not exhaustive, and the items have not been listed in a particular order. For the complete list of items the reader is referenced to appropriate sources (see e.g., *Appendix A* of the SESAR HPAP).

Examples of typical HF topics addressed in the context of a HFI programme

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[8] *EUROCONTROL (2019). Human Factors Integration in ATM system design. White paper.*

[9] *Liu, K., Valerdi, R., & Rhodes, D. (2009) Economics of Human System Integration : The Pratt & Whitney F119 Engine.*

[10] *Liu, K., Valerdi, R., & Rhodes, D. (2009) Economics of Human System Integration : The Pratt & Whitney F119 Engine.*

[11] *EUROCONTROL (2000). Human Factors Integration in Future ATM systems – Design Concepts and Philosophies. Technical Report n. HRS/HSP-003-REP-01.*

[12] *EUROCONTROL (2019). Human Factors Integration in ATM system design. White paper.*

• Alarm management • Automation levels • Cognitive Task Analysis • Control room design • Fatigue • Human Machine Interface • Human Automation Interaction • Human error • Lighting design, evaluation • Noise reduction • Physical ergonomics • Roles & responsibilities	• Shared Situation Awareness • Situation Awareness • Stress • Task Analysis • Teamwork and communication • Training Design/evaluation • Transition factors • Usability • User Centred Design • Working methods/procedure design • Workload • Workstation design

2.1.2 - Importance of HFI in ATM change

HFI delivers benefits [13,14,15,16,17] related to:

- **Human performance**, as the solution is defined so that human operator's performance remains sustainable or is improved—but not degraded—compared to the legacy system. As a result of the change the human operator must still be able to perform his/her task efficiently and safely, in order to permit the new solution to deliver the target benefits (e.g., cost-reduction, increase operational safety, capacity, efficiency, etc.). Through the systematic/structured consideration of human requirements, HFI ensures that the impact on the affected human operator, e.g., introduction of new tasks, modification of existing tasks, and their significance, e.g., potential for unsafe acts, workload increase, teamwork and communication, are promptly identified and mitigated through adequate human requirements. In other words, HF/HP issues do not come as a surprise when the system enters operations;
- **Productivity**, it is more cost effective to use operational, maintenance, training and support systems that are designed with end user requirements in mind. Design and functions supporting actual workflows are easier to learn and use, this means that more time can be spent on the main operator task(s), as opposed to being distracted with parasite tasks induced by solutions unfit for human use;
- **Safety**, as the potential for human error induced by design flaws is removed from the system. Moreover, HFI maximises the ability of the human to stay in control, respond to abnormal situations, while minimising the potential for surprises and unsafe responses to system failures. The HFI contribution to safety permits to reduce the frequency of safety occurrences (and the associated costs) and the risk of catastrophic failure;
- **Change acceptance**, as the end user buy-in is secured through the systematic considerations of the requirements of the end user population, also through the use of user

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[13] *EUROCONTROl (1999). A Business Case for Human Factors Investment. HUM.ET1.ST13.4000-REP-02.*

[14] *Krois, P., Farrow, D., Johnson, W., & Bair, D. (2007). Panel: Advancing the Human Factors Business Case. In* 2007 International Symposium on Aviation Psychology *(p. 346).*

[15] *Krois, P., Ahlstrom, U., Bürki-Cohen, J., Jentsch, F., Kanki, B., Lyall, B., ... & King, R. (2006, October). Business case for civil aviation human factors. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 50, No. 1, pp. 20-24). Sage CA: Los Angeles, CA: SAGE Publications.*

[16] *FAA (No date). Value of HF.* https://hf.tc.faa.gov/value-of-hf/*. Accessed on: 09/03/2022.*

[17] *Bias, R. G., & Mayhew, D. J. (Eds.). (2005).* Cost-justifying usability: An update for the Internet age*. Elsevier.*

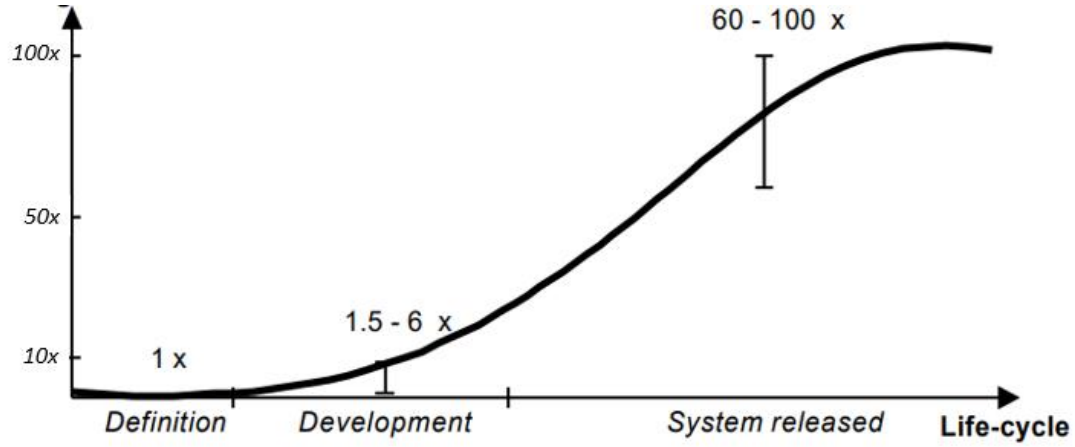
centred design processes. Acceptance from end users is important to avoid programme delays;

- **Regulatory acceptance,** as regulators are provided with evidence—not opinions—, that human related aspects are adequately managed;
- **Cost-reduction,** due to reduced procurement, development, loss-of-productivity, training, maintenance and corrective costs. Specifically for this latter category, the EUROCONTROL *White paper A Business Case for Human Factors Investments* determined that the cost of identifying and resolving HF/HP issues increases exponentially with time along the ATM solution lifecycle:

  > *"…Compared to the cost of changing the design during the definition phase of the life cycle, the cost of the changes made during the development will be increased by 1.5 to 6 times. The cost of the changes made to the system, after it has been finalised and delivered to the end users [operation phase], will be amplified by 60 to 100 times"*[18]

  This amplification logic (see the graph below) suggests that while the lack of or limited HFI investments in ATM change may save some money upfront, they will generate greater corrective costs once the solution is operational. (As EUROCONTROL concluded: "*experience shows that the bill will have to be paid later…with interests*"[19].)

FIGURE 1. RELATIVE COSTS OF DESIGN CHANGE DEPENDING ON TIME OF HF ISSUE RESOLUTION (SOURCE: EUROCONTROL 1999[20]).



Therefore, it is valuable to implement HFI processes to move HF issues identification and resolution as early as possible in the ATM change lifecycle. HFI will require more funds in the early stages of system development but that this initial investment leads to far more cost reductions later on. This conclusion is supported by reports from other industries[21], especially from the military that have looked in to the cost benefit of HFI investments (more on this in § 2.1.4.1).

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[18] *EUROCONTROL (1999). A Business Case for Human Factors Investment. HUM.ET1.ST13.4000-REP-02.*

[19] *EUROCONTROL (1999). A Business Case for Human Factors Investment. HUM.ET1.ST13.4000-REP-02.*

[20] *EUROCONTROL (1999). A Business Case for Human Factors Investment. HUM.ET1.ST13.4000-REP-02.*

[21] *Greenley, Mike, Scipione, Andrea, Brooks, Jeremy, et al. The development and validation of a human systems integration (HSI) program for the Canadian Department of National Defence (DND). CAE PROFESSIONAL SERVICES KANATA (ONTARIO), 2008.*

2.1.3 - Established HFI methodologies

There are currently two main Human Factors Integration methodologies in the European ATM system:

- The EUROCONTROL Human Factors Case (HFC), whose first version was published in 2001;
- The SESAR Human Performance Assessment Process (HPAP). This methodology represents an evolution of the EUROCONTROL HF and the Airbus Human Factors Design process, and can be applied to both ground and cockpit projects. Compared to its predecessor, the SESAR HPAP contains in addition guidance for designing automation support (resulting from a specific SESAR project dealing with the Identification and Integration of Automation Related Good Practices[22]). Developed in SESAR 1 in 2013, the SESAR HPAP has become compulsory in SESAR 2 ad 3 projects.

Both the EUROCONTROL HF Case and the SESAR HPAP provide two valuable evidence-based HFI frameworks to help ensuring that HF aspects related to the introduction of a new solutions are systematically identified, tracked and resolved.

2.1.4 - Related standards

Issued in 2019, the *CANSO Standard of Excellence in Human Performance Management (HPM)*[23] provides a framework to assess the maturity of an ANSP regarding the management of Human Performance. An ANSP can be assessed on 12 HP "core elements"--such as HP policies, strategy and resources, HP investigation and learning, ATM equipment and support tools, procedures, selection, impact of change, etc. The core elements reflect HP areas that traditionally have been managed separately by different departments, while in fact "it is important that all areas that contribute to human performance are managed in an integrated manner" in the organisation. The maturity levels for each element are determined based on a five-level maturity scale, ranging from *Level A-Informal Arrangements* (lowest maturity level) to *Level E-Optimised* (highest maturity level). The application of the standard permits to establish a baseline upon which improvement actions can be determined.

Note that the CANSO HPM is a tool for organizational maturity assessment. While providing a snapshot of the organisation regarding its capability to manage Human Performance, it does not provide the kind of HFI process guidance provided by the EUROCONTROL HFC and the SESAR HPAP (mentioned earlier) as it is not intended for this purpose. Still, its application may help an organization to determine the need to improve HF consideration in ATM change, especially is low maturity levels are determined for the areas of ATM equipment and support tools, operational procedure, and Impact of Change.

2.1.5 - HFI implementation

HFI implementation at SESAR level

HFI in SESAR is applied through the HPAP. It was initially developed for SESAR, and therefore this programme provides the "natural" context for HPAP applications. In particular, the first successful

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[22] *Pelchen-Medwed R. et al. (2021). The Evolution towards a common Air/Ground Framework for Human Performance Assessment in ATM. In I.V. Koglbauer & S. Biede-Straussberger (Eds.), Aviation Psychology: Applied Methods and Techniques.*

[23] *CANSO (2019). Standard of Excellence in Human Performance Management. Available on :* https://canso.org/publication/canso-standard-of-excellence-in-human-performance-management/ .

applications of the methodology in SESAR 1[24] lead to its further adoption in SESAR 2 and SESAR 3 projects. As of today the application of the HPAP is compulsory in these contexts.

HFI implementation at ANSP level

HFI implementation at local ANSP level can in principle rely on the HFC, the HPAP or any equivalent approach although the effective implementation of HFI at ANSP level cannot be assumed. For example:

- At the time of publication, no study reporting on the uniform application of the HPAP or the HFC methodologies by different ANSPs has been published;
- ANSPs with more limited change management resources may find it challenging to implement the HPAP in full, and may lack the ability to adapt or use a "lighter" approach. HFI methodologies should be adaptable to the size of the change;
- HFI implementation in ATM is considered by some HF experts to be "weak and patchy" compared to other high-risk, high performance industries such as nuclear power or the defence domains", whose change initiatives already benefit from HFI;
- It is the perception of EGHD members that although some ANSPs may have a mature HF capability supporting human performance, many do not[25].
- Both anecdotal evidence and industry experience suggest that many organisations still resist or omit HFI in design and change management activities[26,27].
- HFI appears just as an additional costs[28] as there seems to be a limited awareness among ATM stakeholders of the area of HFI and related benefits, especially the cost-benefits ones (see §2.1.2 -), despite EUROCONTROL effort to introduce it in the European ATM date back to the late 90's.

2.1.6 - Opportunities for improvement from the state of the art

2.1.6.1 - HFI awareness and emphasis

According to EGHD members HFI and the benefits (including cost-reduction ones) it can deliver do not seem to be well understood in the ATM industry. Usually, the following can be observed:

- Human Performance and Human Factors (not HFI) are currently popular terms in the ATM industry, however they are often confused/not understood in an harmonised way among non-HF stakeholders;
- In many ANSPs, the application of Human Factors seems restricted to specific relevant application areas—human error management, Critical Incident and Stress management (CISM), Team Resource Management (TRM), Fatigue Risk Management (FRM)—, rather than end-to-end application to the ATM change, through HFI. Note that this is also a consequence of the current regulation and how it is understood by NSA.
- Overall, the broader area of HFI (as defined in § 2.1.1 -) and the benefits it delivers (see 2.1.2 -) appears to enjoy a relatively limited visibility among ATM leaders at least compared to

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[24] Biede, S. (2017). Effectiveness of the application of the Human Performance Assessment Process in SESAR 1 Sharing Lessons Learnt. ATM system seminar.

[25] *Krois, P., Armenis, D., Joly, R., Kirwan, B., Marrison, C., May, N., Piccione, D., & Schwarz, M. (2015). Toward a Human Performance Standard of Excellence in Air Traffic Management. 18th International Symposium on Aviation Psychology, 90-95.*

[26] *Josias, L., Demagalski, J., Donovan, S. (2018). Real World Strategies to Achieve Human Factors Integration. Proceedings of the Human Factors and Ergonomics Society Annual Meeting 61 (1) :460-464.*

[27] *Gilbert, C. (2020). What Is the Place of Human and Organisational Factors in Safety?. In Human and Organisational Factors (pp. 1-4). Springer, Cham.*

[28] *Anthony M. & Boardman, M. (no date) Human Factors Integration (HFI) : The Means of Considering the Human Component of Capability within Acquisition. Presentation.*

other safety critical domains, and despite initial effort from EUROCONTROL to introduce the discipline dating back to the 90's. While HFI is increasingly required due to developments in technology, the limited awareness and a lack of emphasis by regulatory bodies about it limits its application in the industry.

The positive return on investment of HFI is relatively well documented in the military domains, through cost benefit analysis of different weapon system development and acquisition programmes. For instance:

- A HFI cost benefit analysis was conducted across 31 defence projects to validate a HFI programme for the Canadian Department of National Defence[29]. The study determined that collectively $3.331 M were invested in HFI across the 31 case studies, which generated immediate savings of $3.515M (payback 106%), and extrapolated savings of $133M (4000%), with further downstream savings from avoided corrective costs;
- Cost-savings of $268M were attributed to HFI investment of $12M in critical design improvements to the Apache Longbow helicopter[30];
- The US Air Force (2009), Air Force Human Systems Integration Handbook[31] mentions that HFI typically comprises 2%-4.2% of total system acquisition cost and leads to a Return on Investment of between 40-60 times the initial investment. The same handbook cites an evaluation of the implementation of HFI within a fighter jet program which lead to lifecycle cost savings in maintenance, manpower and support in excess of $4B.

Note that similar reviews have not been retrieved in relation to civil ATM.

The European Commission (EC) or other stakeholders should promote awareness and emphasis of HFI in change management at ANSP level. At least the following should be clarified:

- **Basic definitions of Human Performance, Human Factors and Human Factors Integration;**
- **Cost benefit of HFI in ATM change.**

This could be done by:

- **sponsoring relevant initiatives (research, white papers, programme reviews, etc.)**
- **sponsoring the development of a methodology to cost justify HF investments in the planning phase of the ATM change**
- **an oversight activity around HFI in change management to check the implementation of the principles set in the Change Management in the ATM industry Principles and Process document[32]**
- **increasing the visibility of HFI and ATM change in existing industry newsletters and publications (e.g., EUROCONTROL NETALERT, CANSO Newsletters, IFATCA, ICAO), through the publication of industry experience of change and implementation of human**

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[29] *Greenley, Mike, Scipione, Andrea, Brooks, Jeremy, et al. The development and validation of a human systems integration (HSI) program for the Canadian Department of National Defence (DND). CAE PROFESSIONAL SERVICES KANATA (ONTARIO), 2008.*

[30] *Booher, H. R., & Minninger, J. (2003). Human systems integration in army systems acquisition. Handbook of human systems integration, 663-698.*

[31] *US Airforce (2009) Air Force Human Systems Integration Handbook. Planning and Execution of Human Systems Integration. Directorate of Human Performance Integration. Human Performance Optimisation Division.*

[32] *ATCEUC, CANSO, ETF (2018) Change Management in the ATM Industry: Principles and process. http://www.etf-atm.org/2018/11/1113/*

factors integration programmes. A dedicated newsletter could be created, focusing on HFI in aviation, or in transport domains.

2.1.6.2 - HFI competence

The consideration of human requirements through effective HFI initiatives/programmes requires support by:

- *Programme/project leader*. HF recommendations are usually acted upon when understood by the stakeholders having the relevant authority at programme, or project level--typically the chief engineer (or similar role) and/or the custumer[33]. Project and change leaders who do not have formal HP/HF training may struggle to identify whether the particular change should be subject to an HF case nor will he/she be able to assess the quality of the HF case when it is delivered;
- *Non-HF staff involved in projects (e.g., operational experts, engineer and safety experts).* Without an understanding of HF/HP it is difficult for non-HF staff to see the rationale for HFI in ATM change and how to work with them. This situation usually leads to significant sticking points and misunderstanding in the project environment. Also, occurrence investigators who do not have formal HP/HF training may struggle to identify HP/HF-related issues and opportunities. In turn this affects the ability of the organisation to collect evidences from existing systems that can be used for improving or replacing them. Therefore, the presence of in house HF experts should be mandatory. Moreover the complementary use of external Human Factors expertise is recommended since it can provide a wider, impartial perspective, not biased by the in-house culture or constraints.
- *Top management*. Prioritisation of human requirements and HFI requires continuous support from top management. This is not necessarily the case as usually HF aspects tend to become a priority only in exceptional circumstances[34], e.g. in case of incidents, accidents, as well as (major) project or programme failure due to front line operator issues. Effective HFI programmes and consideration of human requirements requires sustained and continuous support by top management. At the same time management who do not have formal HP/HF training may be giving little to no importance to HF/HP.

Today, currently there is no competency scheme for these categories of personnel.

It is recommended that the EC develops a *Human Factors Integration* competency scheme for relevant staff based on industry best practice, including at least:

- **ATM executives**
- **ATM project/programme leaders**
- **ATM non-HF staff involved in projects, at least**
  - **ATM safety practitioners,**
  - **ATM experts,**
  - **analysts**

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[33] *Sirett, P., & Sutcliffe, J. (2010, April). Barriers to successful human factors integration within the military domain. In Contemporary ergonomics and human factors 2010: Proceedings of the International Conference on Contemporary Ergonomics and Human Factors (pp. 183-191).*

[34] *Gilbert, C. (2020). What Is the Place of Human and Organisational Factors in Safety? In Human and Organisational Factors (pp. 1-4). Springer, Cham.*

- **investigators**

Other relevant roles may be identified, notably also depending on the results of the oversight activity around the Change Management in the ATM industry Principles and Process document[35].

2.2 - Review of regulations

Regulations are a powerful driver for HFI execution in modernisation programmes. Today the following relevant binding regulations can be found in ATM:

- Certification Specification 25.1309;
- Commission Implementing Rule 2017/373.

2.2.1 - Certification Specification 25.1309

Certification Specification 25.1309 is a relevant regulation to be considered in the context of cockpit Human Factors certification. In short, this regulation demands an applicant demonstrates that the proposed design is safe to use by a qualified crew under different scenarios. Specific attention is dedicated to the evaluation of flight deck designs for susceptibility to design-induced flight crew errors and the consequences of those errors as part of the type certification process.

2.2.2 - Commission Implementing Rule 2017/373

Commission Implementing Rule 2017/373[36] addresses change management in ATM. Human Factors topics are addressed in the following parts:

- *Section 3 of ANNEX IV*, which addresses Human Factors Requirements for Air Traffic Control Service Providers; that section contains three specific requirements focusing on preventing and mitigating the:
  - (i) risk that air traffic control services are provided by air traffic controllers with problematic use of psychoactive substances (Requirement ATS.03.305);
  - (ii) risk of the negative effects of stress on air traffic controllers to ensure the safety of air traffic (Requirement ATS.OR.310);
  - (iii) risk of the negative effects of fatigue on air traffic controllers to ensure the safety of air traffic (Requirement ATS.OR.315 Fatigue);
  - (iv) risk of roster design not considering the impact on ATCOs' fatigue (Requirement ATS.OR.320).
- ANNEX XIII, which contains training requirements for ATSEP personnel covering Human Factors topics (e.g., Human error, team work, HMI, etc.);
- ANNEXES III and IV, which require a safety assessment considering the equipment, procedural and human elements being changed when performing a change to the functional systems. It also requires a complete identification of hazards. (Requirements ATM/ANS.OR.C.005 and ATS.OR.205)

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[35] *ATCEUC, CANSO, ETF (2018) Change Management in the ATM Industry: Principles and process. http://www.etf-atm.org/2018/11/1113/*

[36] *European Commission (2017). Commission Implementing Regulation (EU) 2017/373.*

2.2.3 - **Opportunities for improvement from the regulation review**

2.2.3.1 - EC implementing rule 2017/373

Key observations from members on Commission Implementing Rule 2017/373 are:

- ANNEX IV, the section dealing with Human Factors Requirements, suggests that ANSPs are not required to consider anything other than stress, fatigue and psychoactive substances. HFI in change management is not mentioned;
- ANNEXES II and IV mandate the consideration of the human element in the context of the safety assessment associated to changes to the functional system. This is indeed a positive development from the perspective of this paper. However, the same reference lacks an explicit reference to relevant human factors terms such as human hazard, human error[37], and in particular HFI integration—i.e., the means through which the human element can be properly considered in the change lifecycle (as discussed in § 2.1). As a result, the non-HF reader may assume that the human element could be addressed indirectly through safety assessment alone, when in fact the main driver for HF adoption in aviation (as well as other safety critical industries) has been the need to bring reliable analysis of human related aspects in the introduction of new system and functions[38] (as opposed to addressing such aspects in an informal/opportunistic manner);
- A potential recommendation for EC might be to update Implementing rule 2017/373 to ensure the explicit mention of Human Factors Integration in the ATM change lifecycle;
- In the view of members, the 2017/373 is not uniformly implemented by different ANSPs. The uniform implementation of 2017/373 should therefore be promoted;
- Also, 2017/373 should promote a constructive communication of ATM change process between management and staff. In other words, the ATM change should not be used as a threat to force staff to accept cost reduction or productivity policies, as this increases stress and impacts negatively human performance and safety nor should a meaningful change be blocked with a demand for higher renumeration. ATM change should be presented in an appropriate and constructive manner highlighting the need for the change and building on win-win aspects for staff and the organisation;
- Likewise, a minimum and sufficient psychological safety standard in the workplace should be promoted to foster optimal overall performance and safety levels.

The EC should take appropriate steps to promote:

1. **Human Factors Integration (HFI) in ATM change at ANSP level, This should start from the consideration of the minimum HFI requirements delivered by this paper (see next section, 2.3.1) and be managed either through an update of EU Reg. 2017/373, or through the development of associated EASA executive decision in consultation with EGHD members.**
2. **A positive communication of the change towards ATM staff;**
3. **Communication and mutual understanding between ATM system designers and frontline operators involving ANSPs, this can be achieved by establishing a focused group funded by the EC enabling this dialogue in a context wider than the usual one of a tender.**

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[37] *Human error is neverteless mentioned in the HF training syllabous for ATSEP*

[38] *Chapanis, A., Garner, W. R., & Morgan, C. T. (1949). Applied experimental psychology: Human factors in engineering design.*

EASA should encourage and promote the effective and uniform implementation of Implementing Rule 2017/373 across EASA Member States.

2.3 - Case studies from EGHD members

EGHD members provided ATM change case studies based on their professional experience, from which lessons can be derived to support the improvement of Human Factors Integration. Two types of studies have been provided:

- Success cases capture changes that brought a positive or neutral impact on human performance, i.e., HP improved or stayed the same as a result of the change;
- Negative case, changes that had a negative one, i.e. degradation of human performance.

The cases are available in Appendix A.

2.3.1 - Background and methodology

During EGHD meeting 26, members expressed the idea that ATM change should better incorporate human requirements. This conclusion was drawn from their professional experiences, in particular the experience of changes that delivered negative human performance outcomes. This experience base, together with the consideration of positive cases of change, was determined to be significant in the development of paper 2. Therefore, a small scale qualitative study was conducted to collect cases of studies known to members, in order to support the development of Paper 2 recommendations.

The methodological aspects of the study are outlined below:

Data collection	• Notes collected from technical support during Paper 2 EGHD opportunity review meeting. • Video recording of these meetings. • Case study template which was prepared, distributed, and filled up by members. Available in Appendix 1, the template covered the following categories: - Context of the change - Year of the change - ANSP - Impact on the user - Corrective action(s) (*negative cases only*) - Impact on ATM KPI (Safety, capacity, cost efficiency, delays, etc) - Success enabler(s) (*positive case only*) or Root cause(s) (*negative cases only* - Lesson(s) learnt
Eligibility criteria	• Only cases from members' direct professional experience, for which adequate information was included in the template.
Data Analysis	• Consolidation of individual case studies through in depth review of the data (including video recordings), and requests for clarifications to members. • Derivation of lessons learnt from individual cases. • Aggregation of lessons learnt. • Integration of lessons learnt with the literature to derive opportunities for improvement.
Limitations	• The evidence was limited to the accounts of participants as reflected in oral exchanges during EGHD opportunity review meetings and through the template.

	• More cases and more evidence were provided for the negative studies from members. This meant that a comparative analysis was not possible.

2.3.2 - Summary of case studies

Overall, a total of 11 case of ATM were collected, 4 of which were success cases, and 7 challenging ones. The cases reported by members covered the roles of ATCOs, ATSEP and AIM/AIS personnel.

TABLE 1. SUMMARY OF SUCCESS AND CHALLENGING CASES

Actors concerned	Success	Challenging	*Total*
AIM/AIS	2	1	*3*
ATCO	1	5	*6*
ATSEP	1	1	*2*
Total	***4***	***7***	***11***

The cases concerned the following type of ATM change:

- major system upgrade (n=3), such as introduction of Remote Tower, new ATM system, new maintenance system;
- new functionalities (n=3), such as new data link functionality;
- operation reorganisation (n=2);
- change to back end ATM system (n=1), e.g., radar update;
- change of shift/rostering (n=1).

The changes reported occurred over the period end-90's-2022, with the majority of the cases falling on the time period 2010-2020 (n. 7). For two of the cases no information about date was provided.

The following tables summarise success and challenging case studies. Relatively more feedback was provided for the challenging cases where more insight was available on the change introduction process. (The complete templates filled up for each case study is available in Appendix 1.)

TABLE 2 : SUCCESS CASES STUDIES

#	Change	Affected Role	Year	HP and programme/system impact
01	New data link ATC clearance delivery functionality	ATCO	*2015*	The solution significantly reduced communication workload for the tower ATCO, especially during peak hours. This also reduced fatigue.
02	Introduction of an internet application for flight plan submission.	AIM/AIS	2017	The solution made flight plan submission faster and more accurate for AIM/AIS operators. At system level, this translated into higher safety, due to reduced risk of errors, and capacity, i.e., more flight plan processed.
03	Centralised Aeronautical Reporting Office	AIM/AIS	*Not reported*	The change from a distributed to a centralised ARO resulted in more evenly distributed workload among ARO operators, quicker response time (i.e. reduced waiting time for the user of the service, which were also provided with a single telephone number).
04	New ATSEP CNS&ATM	ATSEP	2022	The system deliver a set of HP benefits such as reduced number of screens and input devices, thus

	System Monitoring and Control concept			reducing the workload needed to switch between systems, and an integrate monitoring capability which support situation awareness (of different technical systems), ease the task of monitoring system performance and reacting in case of alert.

TABLE 3 : CHALLENGING CASE STUDIES

#	Change	Affected Role	Year	Human Performance Impact	Programme/system impact	Contributory cause
05	Remote Tower	ATCO	2017	Failure to meet human visual requirements.	Entry into service suspended, Initiation of an internal ANSP-level investigation,	Lack of specification/consideration of human operator requirements during the procurement of the RT solution.
06	Radar Upgrade	ATCO	2013	Unintended degradation of the STCA, which translated into a loss of trust and use of the alarm on the ATCO side.	Safety degradation lasting for a period of three months—the time needed to fix the problem.	Radar upgrade assumed to have no impact on operations (the STCA in particular) by developers.
07	New airport CDM functionality	ATCO	2022	Partial adoption of a new--but unreliable--airport CDM functionality. The system delivered unreliable start up data and the tower ATCO had to double check the system calculation manually, eventually dismissing the functionality entirely during busy traffic periods.	Capacity reduction: during busy hours the supervisor had to issue traffic restrictions, which produced a 40% capacity reduction. Delayed benefit realisation. The functionality has been switched off and is currently under improvement.	Engineers overconfident about a small "patch". Lack of previous tests probably due to lack of dedicated resources. Possible impact on operations not taken into account.
08	Staff reduction in tower	ATCO	2010	Heighten fatigue risk and acute stress resulting from extended working hours.	Negative health and safety effects on the workforce. Reported midterms effects included depression, car accidents and family issues among the concerned ATCOs.	Change implemented without an assessment of the potential HP/operational impact.
09	New ATM system	ATCO	Late 90's	Unusable ATM system due to too many system bugs requiring significant workaround by the ATCO. Because of this ATCO did not	Lack of acceptance, 5 programme year delay The problem was realised during the training with the new system. Upon problem realisation, the ANSP set up a dedicated	Engineers overconfident on the solution Assumptions about end users not verified,

#	Change	Affected Role	Year	Human Performance Impact	Programme/system impact	Contributory cause
				accept to work with the system.	team of ATCOs and engineer (still in use today) to improve the system, which entered operations with a delay of 5-years.	No operators and HF experts involved in the change.
10	Creation of a central reporting office and closure of ATS regional reporting office	AIS/AIM	2012	Flight plan not accessible any more for the ATCOs following the centralisation of the ATS office. Degraded services. Operational data not available any more.	Service degradation for 15months due to the plans for staff relocation and lack of availability of operational data to the relevant stakeholders (ATS reporting office was closed at night without the Bordeaux centre to have the data).	Lack of understanding of the total ATM system. Overconfidence in a change which was seen as a "relatively simple one".
11	System upgrade	ATSEP	2015	Extra maintenance effort and time needed for ATSEP staff to solve technical problem.	Higher maintenance costs, longer system downtime, capacity reduction and delays.	Lack of consideration of maintenance requirements during system release. This may be due to: -developer's lack of familiarity with maintenance requirements; -over focus on budget and costs without an understanding of the consequences of unmet maintenance requirements; -unverified assumptions about maintenance operations/requirements.

2.3.3 - Conclusions and lessons learnt from the case studies

Overall, the case studies confirm the importance of considering human requirements in the ATM change process, in fact they showed that:

- ATM change can be challenging, and a positive impact on HP shall not be assumed, as shown by the negative cases;

- Human performance and system performance are linked, as the former contributes to the latter. In the negative cases, poor consideration of human requirements leads to poor

human performance, and in turn this generates negative effects at programme and ATM system levels—reduced safety levels, lack of benefit realisation, programme delays, corrective costs, lowered capacity, unplanned increase in staff. On the other hand, the positive cases brought a positive impact at human performance level, which in turn generated positive effects at programme and ATM system levels. Human performance is an enabler of overall ATM performance, therefore it makes sense to assure HP through adequate HFI in ATM change;

- The proactive consideration of human requirements in the change is important to achieve ATM target benefits. It is unlikely that a change delivers positive human performance unless human needs are adequately considered.

The following table reports the specific lessons learnt regarding the improvement of HFI in ATM change from the case studies. The next sub-section will integrate these lessons with relevant literature in order to derive generalised opportunities for improvement.

TABLE 4. LESSONS LEARNT FROM THE CASE STUDIES

#	LESSONS LEARNT (LL) FOR HFI IN ATM CHANGE	Case study #	Fed into opportunity improvement
01	Verify assumptions about the potential impact on human performance early in the change process, even if the solution is expected: • to be successful by developers. For instance, the consequences of overconfidence are visible for instance on case study 09, where the lack of acceptance resulted on a 5 years delay; • to bring no impact at all on human performance for instance because it is a technical system assumed to have no operational impact (while in fact it may have), as in case study 06, where the radar modernisation was falsely assumed to have no impact visible to ATCOs.	06, 08 09 10	Human requirements specification (3.3.1.1.) Assumption verification (3.3.1.2)
02	Permit personnel that believes they will be impacted by the change to report their concerns to the team leading the change.	06	Assumption verification (3.3.1.2)
03	Understand human needs/requirements not just for ATCO but also for other roles. The cases on staff other than ATCO support this as also their human performance is an enabler of overall ATM performance.	02 04 10 11	Roles to be considered in the change (3.3.1.4)
04	Learn from the experience of change, through return of experience exercises, e.g., retrospective investigations or assessment of the change programme. In case 05 an investigation was launched to understand the causes of failure. In case 9 the programme was halted for running an assessment.	05 09	Learning from ATM change (3.3.1.8)
05	Define operational requirements specific for the target implementation site. Even if a solution works elsewhere or is	05	Human requirements

	available on the market, it does not meant that it is fit to the specific operational context. Operational requirements should be developed prior to procuring a new system.		specification (3.3.1.1)
06	Staff the change with adequate/competent personnel.	05	Staffing levels (3.3.1.9)
07	Ensure adequate involvement of the concerned human operators.	08, 10	Human Operator Involvement (3.3.1.5)
08	Set up of a simulation environment to test, validate and train with the new concept.	04	Iterative development (3.3.1.3)
09	Provide clear explanation of the reason for the change to the user population.	04	Training (3.3.1.6)
10	Provide clear explanations about the limitation of hybrid system during transitions.	04	Training (3.3.16)
11	Dedicate enough time to clarify and mature the concept based on end user feedback.	04	Iterative development (3.3.1.3)
12	Provide adequate staffing levels planned during transition to be better prepared for system failures/degradations.	04	Training (3.3.16)

2.3.4 - **Opportunities for improvement from the case studies**

This section reports the opportunities for improvement resulting from the case studies. Relevant literature to support the studies has been integrated where appropriate.

2.3.4.1 - Human requirements specification

The challenging cases seemed to suffer from poor specification of human requirements. Missing, incomplete, generic or vaguely specified human operator requirements (e.g., the "*system shall have a usable interface*") are known HFI flaws. They lead to the inability to assess whether a system or function is ready or fit for operational use, and that some aspects will not be tested. Also, human requirements shall be defined for the target implementation site.
Supporting LL: 01

Human requirements for the relevant human operators for the target implementation site shall be specified. This shall apply through the phases of development, procurement, adaptation, validation, and transition.

In addition to this, human requirements shall also be specified relevant to the change considering both different use modes (normal, degraded, contingency) and different relevant operational scenarios (normal ops, during OJT, high workload or over delivery, during sector/splitting process, under severe weather, deviations and the like).

2.3.4.2 - Assumption verification

Lack or poor specification of human requirements results from a development team taking decisions based on unchecked assumptions about the consequences that their decisions may have on operations. This is a known flaw, which was observed in at least four of the challenging case studies (see Table 3). It may be the result of overconfidence of the development team on own solution, or from the simplistic assumption that the change will bring no impact on the end user, either because it is a minor system or a technical system. Early verification of assumptions about human roles decreases the chance of building wrong assumptions about end user requirements.
Supporting LLs: 01, 02

It shall be ensured that assumptions about the (neutral, positive) impact of the change on human performance should be constantly verified, through the collection of relevant human operator data/human factors assessment.

This shall apply through the phases of development, procurement, adaptation, validation, and transition.

This applies even if the solution is expected to bring a positive impact on human performance, or to bring no impact at all.

Also, mechanisms shall be in place to permit that personnel (not involved in the change) that believe they will be impacted by the change to report their concerns to the leading team. (These mechanisms could be an extension of existing reporting schemes within the safety management systems in use.)

2.3.4.3 - Iterative development

Adequate time should be built in the programme schedule to clarify and mature the concept, based on end user data collected during iterative evaluations. The setup of a simulation environment to test, validate and train with the new solution supports this. However, note that iterative evaluations should start as soon as possible in the design process through low fidelity prototype, such as review of relevant use cases, paper prototypes, static prototypes, and in a wider change management context, trials of the solution with front end operators with the possibility to adapt the solution based on the results of these initial trails.

This approach will make it possible to increase gradually the complexity of the concept, fix design defects between iterations, and identify timely dead ends before significant time and money are spent on the final solution[39].

Supporting LLs: 08, 11

It shall be ensured that the change schedule allows enough time to clarify and mature the concept, also based on iterative evaluations with end users.

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[39] *EUROCONTROL (2019). Human Factors Integration in ATM system design. White paper.*

A simulation environment to permit testing, validation and training with end users shall be established.

It shall be ensured that operational resources are available to participate in the specification and validation processes.

Early evaluations of the solution with end users through the use of low fidelity prototypes shall be executed.

Lesson learnt and human requirements from these simulations/trials/evaluations should be used to update the solution.

2.3.4.4 - Roles to be considered in the change

When human operator requirements are considered in modernisation processes, the focus is often on ATCOs and Pilots. However, safe and effective ATM operations depends on successful performance of all ATM staff involved in the provision of ATM services. Therefore, it is important that the requirements of any ATM role that can be affected by the change are considered. Besides the case concerning the ATSEP, this aspects was also identified in a previous EGHD Paper[40]. Note that system engineers will also have to be considered in future change as their decisions will have potentially a greater impact on operations, given the trend towards increased automation levels.
Supporting LLs: 03

The consideration of all human needs of all potential roles affected by the change shall be ensured. These include:

- **Air Traffic Controllers (ATCOs)**
- **Air Traffic Safety Electronics Personnel (ATSEP)**
- **Air Traffic Control (ATC) Supervisors**
- **ATCO & ATSEP OJT instructors**
- **ATM Flow Managers**
- **Aeronautical Information Service (AIS) / Aeronautical Information Management (AIM) personnel**
- **Flight Data operators**
- **Flight Information Service Officers (FISOs and AFISOs)**
- **System Engineers**

2.3.4.5 - Human operator involvement

A theme highlighted across the cases was the limited or lack of involvement of human operators in the ATM change. Indeed, end user involvement is an essential enabler of successful HFI, and lack or limited end user involvement is a known HFI flaw[41].
Supporting LLs: 07

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[40] *EGHD (2018) Optimising ATM staff working stations in the Joint Human Machine System.*

[41] *Cardosi, K. (1998). Human factors lessons learned in the design and implementation of air traffic control systems.*

It shall be ensured that relevant human operators are involved in the ATM change, in planning, operational concept development, procurement, validation, transition, and operation.

Lessons learnt from previous FAA implementation programs[42] suggest that there are effective and less effective ways to involve human operators. In particular, for successful change management, front line operators should have a well-defined role in the modernisation programme, and their task should be clearly specified[43] (e.g., as study participant during a prototype evaluation, as an expert contributor during a workshop on future concept development, as operational expert involved in the decision making process etc.).

Front line operators shall have a well-defined role in the ATM change, and their task should be clearly specified[44] (e.g., as study participant during a prototype evaluation, as an expert contributor during a workshop on future concept development, as an operational expert involved in the decision making process etc.).

Staffing is one of the main challenges associated to meeting the requirements discussed in this section. This is further discussed in section. 2.3.1.9

2.3.4.6 - Training

The target staff population shall be adequately trained prior to the introduction of the solution. Lack of human operator training increases the potential for surprises and catastrophic, design-induced error. The members supported this point by referring to the example of the Boeing 737 MAX programme crisis, which involved two aviation disasters occurring five months apart and resulting in a total 346 casualties. In this case the pilot population was not trained on the use of a new functionality, the MCAS.

This kind of scenario is undesirable because it means that the concerned staff will not have the knowledge and working methods needed to effectively operate the system and deal with potential malfunctions. On the other hand, training should cover potential systems limitations that may occur during operations as well as transition phases, when hybrid system configurations may be in use.

Supporting LLs: 04

Adequate training shall be provided to the staff population affected by the change, so as to permit an efficient and safe use, and reduce the potential for surprise and human error in both normal and abnormal scenarios.

Such training shall include:

- **clear explanations of the reasons for the change;**

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[42] *Cardosi, K. (1998). Human factors lessons learned in the design and implementation of air traffic control systems.*

[43] *Cardosi, K. (1998). Human factors lessons learned in the design and implementation of air traffic control systems.*

[44] *Cardosi, K. (1998). Human factors lessons learned in the design and implementation of air traffic control systems.*

- **system limitations, including limitations that may occur during transition periods, when hybrid solutions may be in use, and working methods needed to cope with system limitations.**

Training for new solutions is better integrated/embraced if delivered in person and triggers an exchange of views between the operators affected by the change.

2.3.4.7 - Human Factors expert involvement

Members have expressed the idea that while human operators have an intimate knowledge of current operations and how they could be affected by the change, they are not always effective at explaining/formalising this knowledge. Thus, HF Expertise is needed to analyse and translate this knowledge into valid data that can be used to inform the process of change. Qualified Human Factors experts can support this process by relying on a variety of theories and models (e.g., Resilience Engineering, Human Information Processing, Naturalistic Decision Making, etc.) and methodologies (e.g., cognitive task analysis, user journeys, naturalistic observations, human error analysis, etc.) relevant for the analysis and the improvement of human work in complex settings, and the derivation of human requirements based on data—not opinions. It is a significant part of the role of HF to assist end users in understanding human error and other issues related to a change alongside other disciplines (e.g., safety, engineering).

Human Factors experts shall be involved in the analysis of the work of human operators, in HF assessment and the specification of human needs.

2.3.4.8 - Learning from ATM change

Learning from past/present experiences of ATM changes is important to derive relevant lessons learnt at ANSP level regarding how human requirements can be better integrated in future programmes/projects. Investigation can be conducted at local level following the realisation that the proposed solution was not fit for purpose (as shown in case 5).

Mechanisms shall be established at ANSP level to maximise the identification and retention of lessons learnt from previous change projects. This can happen through return of experience workshops and full retrospective investigation of change programmes. End users and HF experts should be involved in such workshops.

Supporting LLs: 04

2.3.4.9 - Staffing levels

It is recommended that at the start of the change ANSP's consider the needed front line resources to be involved in the change (see also § 2.3.1.5). This will have an impact on planning and realising staffing levels. In particular, planning must assure what type of expertise (operational, maintenance, or others) is needed and when. In turn this can then be forwarded to the relevant teams/manager accordingly so that they can fit the rosters.

Adequate staffing levels shall be allocated through the change, including the transition phase.

Supporting LLs: 06

2.4 - Additional opportunities for improvement

2.4.1 - Joint human machine system

The focus of the ATM change shall be on the overall *joint human machine system*, i.e., the unified system composed by the humans and the technology working synergistically. The focus on Joint Cognitive System (JCS) avoids a focus on the development of the technology in isolation first followed by the consideration of human requirements later. Such approach is dysfunctional because it leads to situations where human requirements (i) are not considered or (ii) are only partly considered when many design decisions have been taken already (see also cost scenarios A and B in §2.1.2 -). On the other hand, human aspects shall be considered together with technological aspects from the start of the change lifecycle. This is essential if we want to obtain systems that combine the strength of the humans and the technology, i.e., system where the technology and the human work synergistically and amplify each other's performances.

Human requirements and technology aspects shall be considered in an integrated way from the start of the change, to obtain systems that combine the strength of the humans and the technology, i.e., system where the technology and the human work synergistically and amplify each other's performance.

Situations where the technology is developed first, and then the human is fitted to the solution shall be avoided.

It is recommended to establish a forum within which ATM system designers and front-line operators (including, inter alia, ATCOs/FISOs, ATSEPs, AIS/AIM operators, ATM flow managers) can exchange directly in presence of ANSPs to find ways to smoothen the process of HFI in the development of new ATM systems.

2.4.2 - Generational gap

New generations of ATM staff have different needs compared to the current and previous ATM staff generations. This difference arises for instance due to a faster adoption rate and consumption of technology (such as social media). This difference, and the associated challenges and opportunities for change management, should be further investigated.

2.4.3 - Monitoring and reporting of change

No public repository of data on ATM change programmes was found in the literature. Yet, historic data on ATM change is needed if the industry wants to learn from present and past cases of change. As of today ATM cases of changes—like the ones reported in the previous section—usually remain known to the staff involved or affected by the change, but are not necessarily documented nor shared in the industry.

It is recommended that EASA/ICAO consider the definition of a reporting scheme for harmonised and consistent reporting of ATM change/modernisation programme that have been cancelled, halted, or delayed due to human performance issues. The scheme can also include positive changes, to favour the transfer of best practices. The template in appendix 1 of this paper provides an example of relevant categories to be traced for success and failure cases.

2.4.4 - Scientific studies of ATM change

The improvement of the consideration of human requirements in ATM change management should be based also on scientific studies of actual experiences of local, ANSP changes. However, while change is a widely discussed topic, a relatively limited number of this kind of scientific articles in ATM[45, 46, 47, 48, 49, 50] has been retrieved. The majority of these kind of studies have been developed in the healthcare domain, where different scholars have looked into actual implementations of healthcare solutions, ranging from electronic patient records, to drug dispensers, computerised physician order entry and alarms, and the like, with a focus on both the effect on the user as well as the organisational and managerial preconditions[51]. Triggered by the failure of past healthcare modernisation programmes[52], limited rate of adoption of healthcare innovations[53], and the importance of avoiding unintended consequences[54] on end users and patient safety, these studies provide management and decision makers with evidence based frameworks and guidance[55, 56]. Indeed these kind of studies are also needed in ATM, not only to look at cases of failure, but also at cases of success, so as to promote the identification and transfer of best practices.

It is recommended that the EC considers funding research investigating the best practices, barriers and enabling conditions, to successful integration of human requirements in the ATM change.

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[45] *EUROCONTROL (2006) A Safe Approach to Transition : Key elements to transition success. ECC report 405.*

[46] *Rozzi, S., Amaldi, P., & Kirwan, B. (2010). IT innovation and its organisational conditions in safety critical domains: The case of the Minimum Safe Altitude Warning system.*

[47] *Amaldi, P., & Rozzi, S. (2012). Inter-Organisational Safety Debate: The Case of an Alarm System from the Air Traffic Control Domain.* International Journal of Sociotechnology and Knowledge Development (IJSKD), 4*(1), 30-47.*

[48] *Rozzi, S., & Amaldi, P. (2012, May). Organisational and inter-organisational precursors to problematic automation in safety critical domains. In* Proceedings of the 2nd International Conference on Application and Theory of Automation in Command and Control Systems *(pp. 98-106).*

[49] *Cook, A., & Tanner, G. (2008). Managing the Acceptance of Change in ATM.* Air Traffic Control Quarterly, 16*(3), 235-254.*

[50] *Bolic, T., & Hansen, M. (2005, June). User request evaluation tool (URET) adoption and adaptation, three center case study. In* Proceedings of the 6th Air Traffic Management RD Seminar, Baltimore, MD.

[51] *Zheng, K., Abraham, J., Novak, L. L., Reynolds, T. L., & Gettinger, A. (2016). A survey of the literature on unintended consequences associated with health information technology: 2014–2015. Yearbook of medical informatics, 25(01), 13-29*

[52] *Justinia, T. (2017). The UK's National Programme for IT: Why was it dismantled?.* Health services management research, 30*(1), 2-9.*

[53] *Asthana, S., Jones, R., & Sheaff, R. (2019). Why does the NHS struggle to adopt eHealth innovations? A review of macro, meso and micro factors. BMC health services research, 19(1), 1-7.*

[54] *Jones, S. S., Koppel, R., Ridgely, M. S., Palen, T. E., & Wu, S. Y. (2015). Guide to Reducing Unintended Consequences of Electronic Health Records. 2011.* Agency for Healthcare Research and Quality.

[55] *Callen, J. L., Braithwaite, J., & Westbrook, J. I. (2008). Contextual implementation model: a framework for assisting clinical information system implementations. Journal of the American Medical Informatics Association, 15(2), 255-262.*

[56] *Sittig, D. F., & Singh, H. (2015). A new socio-technical model for studying health information technology in complex adaptive healthcare systems. In Cognitive informatics for biomedicine (pp. 59-80). Springer, Cham.*

3 - RECOMMENDATIONS FOR IMPROVEMENT

A total of 15 opportunities for improvement have been identified from the analysis summarised in Section 2, including EGHD member case studies and a review of the state of the art and relevant regulations.

These have been grouped into a set of six recommendations (including a set of 14 minimum Human Factors Integration requirements):

3.1 - HFI Awareness, Emphasis and Competency

Recommendation EGHD_2022_2_1: The EC or other stakeholders should promote awareness and emphasis of HFI in change management at ANSP level.

At least the following should be clarified:

- **basic definitions of Human Performance, Human Factors and Human Factors Integration;**
- **cost benefit of HFI in ATM change.**

Implementation methods might include:

- **sponsor relevant initiatives (research, white paper, programme reviews, etc.);**
- **sponsoring the development of a methodology to cost justify HF investments in the planning phase of the ATM change**
- **an oversight activity around HFI in change management to check the implementation of the principles set in the Change Management in the ATM industry Principles and Process document[57].**
- **increasing the visibility of HFI and ATM change in existing industry newsletters and publications (e.g., EUROCONTROL NETALERT, CANSO Newsletters, IFATCA, ICAO), through the publication of industry experience of change and implementation of human factors integration programmes. A dedicated newsletter could be created, focusing on HFI in aviation, or in transport domains.**

Recommendation EGHD_2022_2_2: The EC should develop a *Human Factors Integration* competency scheme for relevant staff based on industry best practice. This should include at least:

- **ATM executives;**
- **ATM project/programme leaders;**
- **ATM non-HF staff involved in projects, at least:**
  - **ATM safety practitioners,**
  - **ATM experts,**
  - **analysts**
  - **investigators**

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[57] *http://www.etf-atm.org/2018/11/1113/*

Other relevant roles may be identified, notably also depending on the results of the oversight activity around the Change Management in the ATM industry Principles and Process document[58].

3.2 - Promotion of HFI

Recommendation EGHD_2022_2_3: The EC and EASA should take appropriate steps to promote:

1. **Human Factors Integration (HFI) in ATM change at ANSP level, this should start from the consideration of the minimum HFI requirements delivered by this paper (see the table below) and be managed either through an update of EU Reg. 2017/373, or through the development of an associated EASA executive decision in consultation with EGHD members;**
2. **A positive communication of the change towards ATM staff;**
3. **Communication and mutual understanding between ATM system designers and frontline operators involving ANSPs, this can be achieved by establishing a focused group funded by the EC enabling this dialogue in a context wider than the usual one of a tender.**

Minimum HFI requirements to be addressed at ANSP level:

- Human requirements for the relevant human operators and for the target implementation site shall be specified. This shall apply through the phases of development, procurement, adaptation, validation, and transition.

- Human requirements shall also be specified relevant to the change considering both different use modes (normal, degraded, contingency) and different relevant operational scenarios (normal ops, during OJT, high workload or over delivery, during sector/splitting process, under severe weather, deviations and the like).

- It shall be ensured that assumptions about the (neutral, positive) impact of the change on human performance should be constantly verified, through the collection of relevant human operator data/human factors assessment.
    - This shall apply through the phases of development, procurement, adaptation, validation, and transition.
    - This applies even if the solution is expected to bring a positive impact on human performance, or to bring no impact at all.
    - Mechanisms shall be in place to permit that personnel (not involved in the change) that believe they will be impacted by the change to report their concerns to the leading team. (These mechanisms could be an extension of existing reporting schemes within the safety management systems in use.)

- It shall be ensured that the change schedule allows enough time to clarify and mature the concept, also based on iterative evaluations with end users.

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[58] *ATCEUC, CANSO, ETF (2018) Change Management in the ATM Industry: Principles and process. http://www.etf-atm.org/2018/11/1113/*

- A simulation environment to permit testing, validation and training with end users shall be established.

- It shall be ensured that operational resources are available to participate in the specification and validation processes.

- Early evaluations of the solution with end users through the use of low fidelity prototypes shall be executed.

- Lessons learnt and human requirements from these simulations/trials/evaluations should be used to update the solution.

- It shall be ensured that relevant human operators are involved in the ATM change, in planning, operational concept development, procurement, validation, transition, and operation.

- The consideration of all human requirements of all potential roles affected by the change shall be ensured. This include:
    - Air Traffic Controllers (ATCOs)
    - Air Traffic Safety Electronics Personnel (ATSEP)
    - Air Traffic Control (ATC) Supervisors
    - ATCO & ATSEP OJT instructors
    - ATM Flow Managers
    - Aeronautical Information Service (AIS) / Aeronautical Information Management (AIM) personnel
    - Flight Data operators
    - Flight Information Service Officers (FISOs and AFISOs)
    - System Engineers

- Front line operators shall have a well-defined role in the ATM change, and their task should be clearly specified[59] (e.g., as a study participant during a prototype evaluation, as an expert contributor during a workshop on future concept development, as an operational expert involved in the decision making process etc.).

- Adequate training shall be provided to the staff population affected by the change, so as to permit an efficient and safe use of the solution, and reduce the potential for surprise and human error, in both normal and abnormal scenarios.

- Such training shall include:
    - clear explanations of the reasons for the change;
    - system limitations, including limitations that may occur during transition periods, when hybrid solutions may be in use, and working methods needed to cope with system limitations;

- Training for new solutions is better integrated/embraced if delivered in person and triggers an exchange of views between the operators affected by the change.

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[59] *Cardosi, K. (1998). Human factors lessons learned in the design and implementation of air traffic control systems.*

- Human Factors experts shall be involved in the analysis of the work of human operators, in HF assessment and the specification of human requirements.

- Mechanisms shall be established at ANSP level to maximise the identification and retention of lessons learnt from change projects. This can happen through return of experience workshops and full retrospective investigation of change programmes. End users and HF experts should be involved in such workshops.

- Adequate staffing levels shall be allocated through the change, including the transition phase.

- Human requirements and technology aspects shall be considered in an integrated way from the start of the change, to obtain systems that combine the strength of the humans and the technology, i.e., system where the technology and the human work synergistically and amplify each other performances. Situations where the technology is developed first, and then the human is fitted to the solution shall be avoided.

- It is recommended to establish a forum within which ATM system designers and front-line operators (including, inter alia, ATCOs/FISOs, ATSEPs, AIS/AIM operators, ATM flow managers) can exchange directly in presence of ANSPs to find ways to smoothen the process of HFI in the development of new ATM systems.

Recommendation EGHD_2022_2_4: EASA should encourage and promote the effective and uniform implementation of EU Reg. 2017/373 across EASA Member States.

3.3 - Continuous HFI Improvement

Recommendation EGHD_2022_2_5: The EC should fund research initiatives investigating the barriers and enabling conditions for successful integration of human requirements in ATM change.

Recommendation EGHD_2022_2_6: EASA and/or ICAO should consider the definition of a reporting scheme for harmonised and consistent reporting of ATM change or modernisation programmes that have been cancelled, halted, or delayed due to human performance issues. This scheme should also include positive changes, to favour the transfer of best practices. The template in the appendix 1 of this paper provides an example of relevant categories to be traced for success and failure cases.

4 - APPENDIX 1: EGHD MEMBER CASE STUDIES

The present section reports the use case used in the development of the present position paper. The cases have been anonymised, hence the original names of ANSPs, sites, airports have been removed.

4.1 - Success stories

4.1.1 - Case study 01 – Datalink ATC Clearance delivery the target benefit

Context of the change	A Datalink ATC Clearance was integrated into Collaborative Decision Making tool, the tool used to sequence start-ups by ATCOs.
Year	2015
ANSP	E (ANSP anonymised name)
Impact on the user	The CDM enhancement effectively supports the clearance delivery ATCO, by saving the time and effort associated to the delivery of voice instructions (especially the long and complex ones) and readback. This gain contributed to reduce fatigue, as the CLD task was considered as stressful and exhausting, especially in peak hours. Note that the change lead to the new task of monitoring that the system is giving the right SID according to the different situations or in non-standard situations (change of RWY in use, non-preferred configuration, or not preferred dep's, etc.)
Impact on ATM KPI (safety, capacity, cost efficiency, delays, etc.)	*Not reported*
Success enabler(s)	*Not reported*
Lesson(s) Learnt	*Not reported*

4.1.2 - Case study 02 – Flight plan submission via internet app improving performance compared to previous method (telephone)

Context of the change	A designated internet application (eARO) was introduced for flight plan submission
Year	2017 (ANSP anonymised name)
ANSP / Organisation	
Impact on the user	Flight plan submission was made easier and faster for the end users compared to previously prevailing method (by telephone). There is less chance for errors due to poor hearing conditions or language skills. AIM specialists are able to process more flight plans in given time, therefore shortening waiting times for the end users.
Impact on ATM KPI (safety, capacity,	Safety improvement, due to higher accuracy in flight plan input as enabled by digital communication.

cost efficiency, delays, etc.)	Higher capacity and cost efficiency: the shorter processing time for each flight plan means higher capacity with same number of staff and therefore higher cost efficiency.
Success enabler(s)	*Not reported*
Lesson(s) Learnt	*Not reported*

4.1.3 - Case study 03 – Functional centralisation of AROs resulting in more evenly distributed workload and quicker response time

Context of the change	Aeronautical Reporting Office (ARO) units on different geographical locations were centralised to work as one system.
Year	2017 (ANSP anonymised name)
ANSP / Organisation	
Impact on the user	Previously there were big differences is terms of workload between different units, causing longer waiting times for end users at units with more traffic. Now AIM/AIS operator workload is evenly distributed which shortens response times. One phone number for all units is also a simpler and more user-friendly solution.
Impact on ATM KPI (safety, capacity, cost efficiency, delays, etc.)	- Centralised workload distribution increases capacity and cost efficiency. - Reduced work pressure for most active units means less errors and improved safety. - Increased workforce satisfaction: With no need for physical centralisation, employees can work on offices closer to home.
Success enabler(s)	*Not reported*
Lesson(s) Learnt	*Not reported*

4.1.4 - Case Study 04 – Introduction of maintenance monitoring tool

Context of the change	A new concept is introduced with significant impact on the SMC ATSEP working position. In this concept each monitored system is connected to a central monitoring system, used for alerting the ATSEP when something is wrong and a KVM matrix system to connect all monitoring clients and display them to the ATSEP on demand.
Year	2022 (ANSP anonymised name)
ANSP / Organisation	H
Impact on the user	The new ATSEP Working Position for SMC concept reduces the number of screens and input devices available to the ATSEP, by integrating all necessary functionality into a single working position. Where in the traditional concept there is a monitoring client for each individual system physically located at the SMC desk, displaying system status and alerting the ATSEP in case of a problem, the new concept introduces a central monitoring system, and a new HMI for reaching all monitoring clients. Changes for the user:

	• System monitoring clients are 'out of view'. ATSEP rely on the central monitoring system for alerting. • A new HMI for selecting individual monitoring clients
Impact on ATM KPI (safety, capacity, cost efficiency, delays, etc.)	CNS&ATM systems and services availability and continuity are transversal enablers for all ATM KPIs currently not directly and specifically addressed, included or measured by the current Performance* scheme. However, following a proposal by IFATSEA to JCSP this has been favourably received by stakeholders and is being considered for inclusion.
Success enabler	• Heavy involvement of SMC ATSEP in the concept development and validation. • Proof of Concept sessions in a representative offline environment which involved the entire SMC team • Ideas and suggestions from the PoC sessions were evaluated and implemented when deemed appropriate • Explanations were given for ideas and suggestions that were not implemented • Clear indications to the SMC team of the steps needed to implement the new concept into the operational environment • Clear indications to the SMC team of disadvantages of a hybrid situation during transition • Room for adjustments while implementing the concept
Lessons Learnt	• Involvement of end users in concept development, validation and implementation highly increases acceptance, even when a transition period entails increased workload, changes in working methods or other temporary disadvantages • Clear explanation of the reasons for a change and the benefits to the end user increases acceptance and triggers ideas for improvement • Taking the time to process feedback improves the concept and increases acceptance • An offline environment to validate and train the new concept increases end user confidence in the concept and its implementation

4.2 - Challenging case studies

4.2.1 - Case study 05 – Remote Tower solution not implemented due to vision system unfit for remote ATC services

Context of the change	The availability of AFIS staff for MI (site anonymised name) was an issue and remote tower was seen as an opportunity to use the controller in SP (site anonymised name) to provide ATC services to MI. The manufacturer, offered an economic camera system to view MI from SP. The new camera was installed on the existing tower
Year	2017

ANSP / Organisation	D (ANSP anonymised name)
Impact on the user	The remote visual presentation was inadequate for the provision of ATC services. • Remote ATCOs could not see the opposite runway threshold. • Network capacity limitations did not permit a reliable video image in St Pierre. • Frost on the cameras was also observed. • No operating method was possible with proposed setup and missions to accomplish
Corrective action(s)	The project was suspended. The ANSP in question has conducted an internal investigation into the project in order to derive relevant lessons learnt. (this is currently under completion.
Impact on business KPI (safety, capacity, cost efficiency, delays, etc.)	• Lack of benefit realisation • Corrective costs
Root Cause(s)	Lack of definition of operational needs specific for the target implementation site Lack of the staff needed to adequately manage the complexity of the change. Note that these (due to be shared with unions during Q1/2022)
Lesson(s) Learnt	Define operational needs specific for the target implementation site Define operational needs prior to procure a new system Staff the change with personnel able to manage it.

4.2.2 - **Case study 06 – STCA inadvertently impaired as a result of radar modernisation**

Context of the change	Radars were modernised to introduced Mode S standard. It was time to upgrade the radar tracking systems to minimise the use of different mode A codes as per a EU-wide plan. This inferred that all aircraft would use squawk code 1000 as a mode A. However in the centred concerned the short term conflict alarm (STCA) was set to ignore conflicting aircraft with the above mode A squawk code, to avoid to trigger false alarms in cases of garbling. It is only when TCAS entered into operations that the issue was identified and it took 3 months to correct.
Year	2013
ANSP / Organisation	D (ANSP anonymised name)

Impact on the user	• In the short term, ATCOs were not aware that their STCA did not detect aircraft squawking 1000. True conflicts involving these aircraft were not detected. • When ATCOs discover the STCA limitation, they lost trust in the system. • Concern on pilot side—a pilot organisation demanded clarifications to the ANSP involved.
Corrective action(s)	*Not reported.*
Impact on ATM KPI (safety, capacity, cost efficiency, delays, etc.)	• Degraded safety, due to the loss of/degradation of the STCA protective layer • Organisational costs needed to address pilot concerns
Root Cause(s)	Lack of a Total System Approach, i.e., failure to envisage/mitigate, at the time of the change, the negative consequences that a modification on a back end component (i.e., the radar tracking system) could have on the STCA. This was probably due to little awareness by the team involved of the STCA parameters. Organisational insulation may have favoured this.
Lesson(s) Learnt	Improved information sharing across department. Personnel that believe they will be impacted by the change have the possibility to report their concern to the team leading the change. It is important to anticipate the potential negative consequences that even a modification on a back end component (i.e., the radar tracking system) could have on an operational system (STCA case)

4.2.3 - Case study 07 – CDM enhancement (implementation of De-icing request and approval) inadvertently leading to performance degradation (instead of enhancement)

Context of the change	Implementation of De-icing request and approval in the Collaborative Decision Making (CDM) tool, a tool available for Airport ATCOs. The expected benefit was to provide a more reliable calculation of the Start Up time. This enhancement was expected to be particularly beneficial in winter time.
Year	2021
ANSP / Organisation	E (ANSP anonymised name)
Impact on the user	The system delivered unreliable start up information (as it did not consider when de-icing is requested by the company and approved, so it doesn't calculate the taxi times accordingly) The lack of reliability led to an increase in workload for the clearance controller, due to the need to double check every flight plan with airport operations, and "manually" calculate the right time..

	As a result, ATCOs prefer to work to dismiss the CDM and work manually during the morning rush hour. Traffic restriction (-40%) were issued by supervisor during peak hours to permit the ATCO to operate manually
Impact on ATM KPI (safety, capacity, cost efficiency, delays, etc.)	• Loss of benefit realisation, a tool that was introduced to increase capacity, in fact had a negative impact; • Loss of capacity (-40%) during peak hours, due to traffic restrictions • Loss of cost-efficiency: too early start up time result on extra fuel spent on ground • Increased Delays, in case of delayed start up time. • Corrective costs to fix the tool.
Corrective action(s)	The automated tool was switched off. The ANSP concerned is currently working on an improved version of the same tool.
Root Cause(s)	- The new functionality was developed (only) by one team without checking or collaborating with the developers of the CDM system in which it was going to be patched or the rest of the airport stakeholders and tools collaborating in the CDM (companies, Flight info, ATM, etc); - It is likely that the project had a strong pressure to meet a deadline and that end user testing was omitted;
Lesson(s) Learnt	*Not reported*

4.2.4 - Case study 08 – Change in Tower staffing levels leading to increased fatigue risk

Context of the change	A busy tower (32 movements per hour) was normally staffed with 4/5 ATCOs during a 12hrs day shift, and 3/4 during night shift. That involved 7/9 ATCOs during a 24hr shift. Staffing levels permitted to have 2 ATCOs on holiday. This organisation was considered effective. The Management of the concerned organisation decided to have 3 shifts (Morning, Afternoon, Night) with a "stand by" ATCO for each. As the minimum staff to have 2 frequencies open is 3, that supposes 3 (+1 stand by) x 3 = 12 ATCO's each 24 hrs. The main driver for the change was cost reduction (33% reduction in staffing levels).
Year	2010
ANSP / Organisation	E (ANSP anonymised name)
Impact on the user	The 33% reduction in staffing level resulted in longer shift hours, which translated into ATCO's overload and extreme stress. Mid-term effect included: illness, depression, car accidents due to fatigue, family issues because of reduced family time.
Corrective action(s)	6 extra controllers from a nearby centre were introduced until the service was privatised 2 years after. This solution turned out to be very expensive.
Impact on ATM KPIs (safety, capacity, cost	• Negative impact on safety levels, as increased fatigue levels equal increased potential for unsafe acts;

efficiency, delays, etc.)	• Corrective costs related to the need to bring in ATCOs from another centre.
Root Cause(s)	Lack of/Poor integration of evidences about the potential impact on ATCOs' performance (i.e., fatigue risk) in the decision making process. Apparently, there was no consultation, assessment, or preparation prior to the introduction of the change.
Lesson(s) Learnt	Assess the potential impact that the change may have on operations early in the change process. When assuming that the change will have no impact on human performance, this assumption should be verified.

4.2.5 - Case study 09 – Implementation of a new ATC system encountering a 5yrs delay due to lack of ATCO' acceptance

Context of the change	Implementation of a new ATC system and opening of a new OPS room
Year	End of 1990s
ANSP / Organisation	MU (ANSP anonymised name)
Impact on the user	Lack of trust and acceptance by the end user. ATCOs didn't accept working with the new system due to several bugs in the human machine interface, and the extra effort in terms of workaround required to cope with them. This realisation came as a surprise to the development team ("*The engineers couldn't believe it. They thought that they had created the best system in the world and now, stop.*")
Corrective action(s)	Set up of a team composed of ATCOs and engineer to analyse the situation and improve
Impact on ATM KPIs (safety, capacity, cost efficiency, delays, etc.)	Corrective costs, Programme suspension and delay (5yrs) (*"After this disaster…the project was put on hold, and the inauguration postponed. The inauguration finally took place something like 5 years later.*")
Root Cause(s)	No involvement of ATCOs (end users) in requirements and testing activities. Overconfidence of engineers on the fit for purpose of the new system.
Lesson(s) Learnt	It is important to have operational experts integrated into the change. The foundation of a group of engineers and ATCOs (this group is still in place) to find viable solutions to the numerous problems. Today this group is used as well for ATCO requests for additional features which will be discussed, prioritized and implemented.

4.2.6 - Case study 10 – Closure of regional ATS reporting office

Context of the change	Centralisation of all regional ATS reporting offices to BO (site name anonymised). Change involved staff relocation (to different services),

	adapting all technical systems and procedures to living without a regional ATS reporting office next door.
Year	2012
ANSP / Organisation	D (ANSP anonymised name)
Impact on the user	The ability to get the appropriate flight plan information for the ATC services near LI (site name anonymised) and BO (site name anonymised) was not ensured. During 15 months the service was greatly degraded due to the plans for staff relocation and lack of availability of operational data to the relevant stakeholders (ATS reporting office was closed at night without the Bordeaux centre to have the data). For VFR pilots, at times (roughly every night for 12 full months), ATS services were unable to monitor closure of flight plan on time to trigger alerting services if needed.
Corrective action(s)	*Not reported*
Impact on ATM KPIs (safety, capacity, cost efficiency, delays, etc.)	Negative impact on safety levels, as VFR flight plans were not able to trigger alerting
Root Cause (s)	Lack of understanding of the total ATM system. Overconfidence in a change which was seen as a simplification.
Lesson(s) Learnt	No formal return on experience was issued.

4.2.7 - Case study 11 – Lack of consideration of maintenance requirements in system update

Context of the change	Teams or suppliers developing system releases, be it hardware or software, are often not aware of the requirement to maintaining the system once it is has entered operation. Projects are focused on functionality, budgets and deadlines, while maintainability has a lower priority and is likely to be compromised when time runs out or a budget is exceeded.
Year	Approx. 2015
ANSP / Organisation	H (ANSP anonymised name)
Impact on the user	When a system release doesn't meet the maintainability criteria and a technical problem occurs, the maintenance organisation (ATSEP) need a lot of extra time and effort to solve a problem, which leads to increased operational impact. Frustration in ATSEP when a technical problem takes longer to solve because technical documentation and procedures are missing, incomplete or obsolete, or training has been insufficient.
Corrective actions	A handover form was introduced, which includes maintainability requirements like ATSEP proficiency documentation, technical training,

	hard and software component registration. This form has to be used at the start of each system release or project, to ensure awareness of maintenance requirements and to include those during the entire release cycle or system development.
Impact on ATM KPIs (safety, capacity, cost efficiency, delays, etc.)	Increased system downtime which results in capacity reduction and delays
Potential Root Cause	• Unfamiliarity with maintenance requirements at suppliers or development teams • Focus in projects on deadlines and budget, which could compromise maintainability. • Insufficient understanding of the impact of unmet maintenance requirements • Maintainability is taken for granted by system developers
Lessons Learnt	• By introducing maintenance requirements in an early stage of a release cycle or system development, the development team knows what is expected and can plan activities to meet the requirements, instead of discovering the actions needed to hand over the release close to deployment; • Management commitment to uphold the maintenance requirements is paramount; • Involving ATSEP in release cycles and system development from an early stage enhances maintainability, which in turn reduces system downtime in case of a technical problem.

5 - APPENDIX 2 : SUMMARY OF TERMS

5.1 - Acronyms

Abbreviation	Full Term
AIM	Aeronautical Information Management
AIS	Aeronautical Information Service
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATSEP	Air Traffic Safety Electronics Personnel
ATM	Air Traffic Management
ATSU	Air Traffic Service Units
CISM	Critical Incident Stress Management
EASA	European Union Aviation Safety Agency
EC	European Commission
EU	European Union
ECTL	EUROCONTROL
EGHD	Expert Group on Human Dimension
FDP	Flight Data Processing
(A)FISO	(Aerodrome) Flight Information Service Officer
FMP	Flow Management Position
FRM	Fatigue Risk Management
HF	Human Factors
HFI	Human Factors Integration
HP	Human Performance
KPI	Key Performance Indicator
MET	Meteorological (information)
OJT	On the Job Training
OJTI	On the Job Training Instructor
SES	Single European Skies
SESAR	Single European Skies ATM Research
TRM	Team Resource Management

5.2 - Glossary

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ADSP	An ATM Data Service Provider is an entity that will manage some or all of the data processing and associated support services needed by one or several Air Traffic Service Units (ATSUs) to deliver air traffic services to airspace users. In this way, the ATM Data Service Provider concept encompasses the decoupling of ATM data service provision from other air traffic services. An ADSP service can be provided to a given ATSU in several ways, for example: 1. The ATSU could have a single ADSP providing all real-time ATM data needed for it to deliver ATS services;

	2. Different data services including flight data processing, surveillance or meteorological data could be provided by different ADSPs. This might also involve some exchange of data between those ADSPs. Because it can be geographically remote from the ATSU, the ADSP is enabler for the Virtual Centre. ADSP concepts enable separation of the various ATM functions, responsible for operational data and associated technical services, while ATSU remain focussed on the core business of air traffic management and control. An ADSP could exist in joint ownership or close partnership with an ATSU, as may be the case for many existing ANSPs, or it might exist as a certified external entity providing a service under market conditions. (*Source: SESAR JU, Airspace Architecture Study, March 2019; EGIS*)
AIS/AIM personnel	Personnel directly involved in the provision of Aeronautical Information Services (AIS) and management (AIM) a service established within the defined area of coverage responsible for the provision of aeronautical data and aeronautical information necessary for the safety, regularity and efficiency of air navigation. An AIS shall ensure that aeronautical data and aeronautical information necessary for the safety, regularity or efficiency of air navigation are made available in a form suitable for the operational requirements of the air traffic management (ATM) community (involved in flight operations and air traffic services, including pre-flight, see DOC 9854). ICAO Annex 15 specifies that each Contracting State must provide an aeronautical information service (AIS) or delegate this to an appropriate non-governmental agency. An AIS shall receive, collate or assemble, edit, format, publish/store and distribute aeronautical data and aeronautical information concerning the entire territory of the State as well as those areas over the high seas in which the State is responsible for the provision of air traffic services. Aeronautical data and aeronautical information shall be provided as Aeronautical Information Products. The service shall be available during the whole period an aircraft is in flight in the area of responsibility of AIS, plus a period of at least two hours before and after such a period. Service shall also be available at such other time as may be requested by an appropriate ground organisation. An AIS shall, in addition, obtain aeronautical data and aeronautical information to enable it to provide pre-flight information service and to meet the need for in-flight information (from the AIS of other States or other compliant sources) (*Source: ICAO Annex 15*)
ANSP	An Air Navigation Service Provider (ANSP) is a public or a private legal entity providing Air Navigation Services, which supports the management of air traffic on behalf of a company, region or country. Depending on the specific mandate, an ANSP either directly or indirectly provides one or more of the following services to airspace users: • Air Traffic Management (ATM)

	• Communication navigation and surveillance systems (CNS) • Meteorological service for air navigation (MET) • Search and rescue (SAR) • Aeronautical information services/aeronautical information management (AIS/AIM). These services may be provided to air traffic during all phases of operations (approach, aerodrome and en-route). *(Source: European Commission, December 2020)*
Air Traffic Services Operations Specialist (ATOS)	ATOS is the overall definition for different roles in ATS, which are not ATCO, ATSEP, MET. ATOS is part of ATS. Roles within ATOS can include one or multiples of the following roles: FDA, FDS, FDP, AIS, ARO, NOTAM-Office, FMP, Flow Coordinator, Data Assistant, FISO and AFISO, Clearance Delivery, Apron Control. ▪ **Flight data specialist (FDS), Flight Data Assistant (FDA), Flight Data Processing (FDP), Data Assistant:** FDS monitor the flight plans of all controlled flights within their area of responsibility. They relay, change and process information regarding flight plans ensuring that air traffic controllers have the most accurate and up-to-date information to work with. This includes information pertaining to flight plans, relevant information within the area of responsibility (SIGMET, AIRMET, MIL exercises, etc.) and coordination or forwarding of relevant information to adjacent units. ▪ **Flow Management Position, Flow Coordinator:** Flow Management Position (FMP) is responsible for ensuring the local promulgation, by the appropriate means (national NOTAM, AIP, ATM operational instruction, etc.) of procedures which affect ATC Units or operators within the FMP's area. FMPs shall monitor the effectiveness of such procedures. The FMP's role is, in partnership with the Network Manager, to provide the most effective ATFCM service to ATC and AOs. The FMP shall be the local ATFCM partner for the ACC(s), other ATS units (military and civil) within the FMP area of responsibility and local Aircraft Operators. (Source: EUROCONTROL ATFCM Operating Procedures For Flow Management Position (Edition N°: 18.1.1)). ▪ **FISO – Flight Information Service Officer:** Flight Information as 'a service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights' (ICAO Annex 11: Air Traffic Services, 15th edition, 2018). Flight information service officers shall provide service to all aircraft which are likely to be affected by the information. Flight information service (FIS) is intended to supplement and update flight information on weather, status of navigation aids and other pertinent matters (military exercises, airspace restrictions, etc.). Flight information service shall ensure the provision of flight information service and alerting service within a flight information region (FIR) – unless specified otherwise locally. (ICAO DOC 4444 PANS ATM (16th edition 2016), chapter 4.2). ▪ **AFISO – Aerodrome Flight Information Service Officer:** For aerodromes that are busy enough to justify Air Traffic Service, but do not require air traffic control, Aerodrome Flight Information Service (AFIS)

	can be provided to ensure the appropriate safety levels. Contrary to Enroute FIS, two-way radio contact is usually mandatory at AFIS-aerodromes and the surrounding airspace (ATZ). ICAO DOC 4444 (PANS ATM). ▪ **Clearance Delivery Position – FDA in Tower/APRON Control:** Clearance delivery is the position that issues route clearances to aircraft, typically before they commence taxiing. These clearances contain details of the route that the aircraft is expected to fly after departure. Clearance delivery or, at busy airports, Ground Movement Planner (GMP) or Traffic Management Coordinator (TMC) will, if necessary, coordinate with the relevant radar center or flow control unit to obtain releases for aircraft. Flight data (which is routinely combined with clearance delivery) is the position that is responsible for ensuring that both controllers and pilots have the most current information: pertinent weather changes, outages, airport ground delays/ground stops, runway closures, etc. Flight data may inform the pilots using a recorded continuous loop on a specific frequency known as the automatic terminal information service (ATIS).
ATM human operators	Includes ATCOs, FMP staff, ATSEP, AIS/AIM staff, FISO, FDA, pilots, MET officers, Network Manager staff.
Air Traffic Services Operations Specialist (ATOS)	ATOS is the overall definition for different roles in ATS, which are not ATCO, ATSEP, MET. ATOS is part of ATS. Roles within ATOS can include one or multiples of the following roles: FDA, FDS, FDP, AIS, ARO, NOTAM-Office, FMP, Flow Coordinator, Data Assistant, FISO and AFISO, Clearance Delivery, Apron Control. ▪ **Flight data specialist (FDS), Flight Data Assistant (FDA), Flight Data Processing (FDP), Data Assistant:** FDS monitor the flight plans of all controlled flights within their area of responsibility. They relay, change and process information regarding flight plans ensuring that air traffic controllers have the most accurate and up-to-date information to work with. This includes information pertaining to flight plans, relevant information within the area of responsibility (SIGMET, AIRMET, MIL exercises, etc.) and coordination or forwarding of relevant information to adjacent units. ▪ **Flow Management Position, Flow Coordinator:** Flow Management Position (FMP) is responsible for ensuring the local promulgation, by the appropriate means (national NOTAM, AIP, ATM operational instruction, etc.) of procedures which affect ATC Units or operators within the FMP's area. FMPs shall monitor the effectiveness of such procedures. The FMP's role is, in partnership with the Network Manager, to provide the most effective ATFCM service to ATC and AOs. The FMP shall be the local ATFCM partner for the ACC(s), other ATS units (military and civil) within the FMP area of responsibility and local Aircraft Operators. (Source: EUROCONTROL ATFCM Operating Procedures For Flow Management Position (Edition N°: 18.1.1)). ▪ **FISO – Flight Information Service Officer:** Flight Information as 'a service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights' (ICAO Annex 11: Air Traffic Services, 15th edition, 2018). Flight information service officers shall provide service to all aircraft which are likely to be affected by the

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ATSEP	Air Traffic Safety Electronic Personnel (ATSEP) describe those technical specialists authorised to work to provide and support the electronics and software which enable ATS systems to function. ATSEP comprise engineers, technicians, and computer hardware and software specialists who are responsible for the specification, procurement, installation, calibration, maintenance, testing and certification of ground electronic systems used to help control aircraft movements. ATSEP have a basic level of initial training in the electronics and engineering domains followed by specific system/equipment ratings in four disciplines Communication, Navigation, Surveillance and Data Processing. At a time of increasing complexity of the air traffic system, ATSEPs have an increasingly important role in the safety chain. **APPLICABLE RULES** There is currently no provision in ICAO Annex 1, Personnel Licensing, for ATSEP to be issued with, or to hold, individual documents such as licences, but guidelines regarding skills of such personnel can be found in: - ICAO Annex 10 and guidance material in ICAO Doc 7192 - AN/857 Part E2 - Training Manual for Air Traffic Safety Electronics Personnel (ATSEP); - EUROCONTROL SAFETY REGULATORY REQUIREMENT (ESARR) related to ATM SERVICES' PERSONNEL, *ESARR 5*, Section3 - Requirements for

	Engineering and Technical Personnel Undertaking Operational Safety Related Tasks - Commission Implementing Regulation (EU) 2017/373 of 1 March 2017, laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight. Including annex XIII where are set "Requirements for service providers concerning personnel training and competence assessment. These requirements transpose the equivalent requirements of ESARR 5 into European Community law. *(Source: ECTRL, European Commission, SKYBRARY, January 2022)*
ATSU	Air Traffic Service Units (ATSUs) are specially designated to provide an air traffic service (ATS). The objectives of air traffic service as stated in ICAO Annex 11 are to: • prevent collisions between aircraft; • prevent collisions between aircraft on the manoeuvring area and obstructions on that area; note that this objective does not include the apron and ATS in general is not intended to prevent collision with terrain. • expedite and maintain an orderly flow of air traffic; • provide advice and information useful for the safe and efficient conduct of flights; • notify appropriate organisations regarding aircraft in need of search and rescue aid, and assist such organisations as required. An ATSU may provide more than one of these types of services. For example, an air traffic control unit may provide a flight information and alerting service, in addition to air traffic control. *(Source: ICAO Annex 11)*

D

Data accuracy	A degree of conformance between the estimated or measured value and the true value. *(Source: ICAO Annex 15)*
Data completeness	The degree of confidence that all of the data needed to support the intended use is provided. *(Source: ICAO Annex 15)*
Data format	A structure of data elements, records and files arranged to meet standards, specifications or data quality requirements. *(Source: ICAO Annex 15)*
Data integrity (assurance level)	A degree of assurance that aeronautical data and its value has not been lost or altered since the origination or authorized amendment. (*Source: ICAO Annex 15*)
Data product	Data set or data set series that conforms to a data product specification (ISO 19131). *(Source: ICAO Annex 15)*
Data product specification	Detailed description of a data set or data set series together with additional information that will enable it to be created, supplied to and used by another party (ISO 19131). Note.— A data product specification provides a description of the universe of discourse and a specification for mapping the universe of

	discourse to a data set. It may be used for production, sales, end-use or other purpose. *(Source: ICAO Annex 15)*
Data quality	A degree or level of confidence that the data provided meet the requirements of the data user in terms of accuracy, resolution, integrity (or equivalent assurance level), traceability, timeliness, completeness and format. *(Source: ICAO Annex 15)*
Data resolution	A number of units or digits to which a measured or calculated value is expressed and used. *(Source: ICAO Annex 15)*
Data set	Identifiable collection of data (ISO 19101). *(Source: ICAO Annex 15)*
Data set series	Collection of data sets sharing the same product specification (ISO 19115). *(Source: ICAO Annex 15)*
Data timeliness	The degree of confidence that the data is applicable to the period of its intended use. *(Source: ICAO Annex 15)*
Data traceability	The degree that a system or a data product can provide a record of the changes made to that product and thereby enable an audit trail to be followed from the end-user to the originator. *(Source: ICAO Annex 15)*

H

Human Factors (HF)	Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people. (Source: International Ergonomics Association)
Human Performance (HP)	Human Performance (HP) represents the human contribution to system performance and refers to how people perform their work. Throughout the aviation system, people are both the source of some of the risks and an integral part of identifying and managing all risks. (Source: *Doc10151- Manual on Human Performance (HP) for Regulators*)

J

Joint Human Machine System	Human and machine complement each other to achieve system goals. A humanistic design that allows humans to recover from the rare high-risk Scenarios. (Source: *IFATCA*)

V

Virtual Centre	A Virtual Centre is composed of one or more air traffic service units (ATSUs), using data provided by ATM data service providers (ADSPs). It may provide Air Traffic Services to one or more ACCs or aerodrome towers, which may or may not be geographically adjacent. In some cases therefore, a Virtual Tower may be an example of a Virtual Centre. Each ATSU may use ATM data services from multiple providers, just as a data provider may serve multiple ATSUs. Enabled by the ADSP concept, the Virtual Centre concept refers to the decoupling of air traffic management (ATM) data services from the physical controller working position (CWP). This enables the geographical, and ultimately the organisational, decoupling of ATM data service providers from ATSUs. It

	requires standardised data formats to manage information, processes, resources and infrastructure. Data involved might include for example flight data, radar data and weather information. The services required by the Virtual Centre concept are listed below. These services can be provided independently from one another by different service providers. - **Air traffic services (ATS)**, consuming ATM data services, is the core service that maintains separation between aircraft, expedites and maintains an orderly flow of air traffic. - **ATM data services**, consuming integration services, provide the data required to provide ATS. - **Integration services**, integrating information from different regions of geo-fixed services and/or different data providers, overcoming geographic constraints. - **Geographically-fixed services**, in support of CNS, these are services that have a fixed relationship with a geographical location. They include the provision of navigation signals, weather and surveillance sensors and the provision of air-ground antennae. - **Transversal services**, security and communications. (*Source: SESAR JU, Airspace Architecture Study, March 2019*)

6 - APPENDIX 3: REFERENCES

ATCEUC, CANSO, ETF (2018) Change Management in the ATM Industry: Principles and process. *http://www.etf-atm.org/2018/11/1113/*

Amaldi, P., & Rozzi, S. (2012). Inter-Organisational Safety Debate: The Case of an Alarm System from the Air Traffic Control Domain. International Journal of Socio-technology and Knowledge Development (IJSKD), 4(1), 30-47.

Anthony M. & Boardman, M. (no date) Human Factors Integration (HFI) : The Means of Considering the Human Component of Capability within Acquisition. Presentation.

Asthana, S., Jones, R., & Sheaff, R. (2019). Why does the NHS struggle to adopt eHealth innovations? A review of macro, meso and micro factors. BMC health services research, 19(1), 1-7.

Biede, S. (2017). Effectiveness of the application of the Human Performance Assessment Process in SESAR 1 Sharing Lessons Learnt. ATM system seminar.

Bias, R. G., & Mayhew, D. J. (Eds.). (2005). Cost-justifying usability: An update for the Internet age. Elsevier.

Bolic, T., & Hansen, M. (2005, June). User request evaluation tool (URET) adoption and adaptation, three center case study. In Proceedings of the 6th Air Traffic Management RD Seminar, Baltimore, MD.

Booher, H. R., & Minninger, J. (2003). Human systems integration in army systems acquisition. Handbook of human systems integration, 663-698.

Callen, J. L., Braithwaite, J., & Westbrook, J. I. (2008). Contextual implementation model: a framework for assisting clinical information system implementations. Journal of the American Medical Informatics Association, 15(2), 255-262.

CANSO (2019). Standard of Excellence in Human Performance Management. *https://canso.org/publication/canso-standard-of-excellence-in-human-performance-management/*

Chapanis, A., Garner, W. R., & Morgan, C. T. (1949). Applied experimental psychology: Human factors in engineering design.

Cook, A., & Tanner, G. (2008). Managing the Acceptance of Change in ATM. Air Traffic Control Quarterly, 16(3), 235-254.

FAA (No date). Value of HF. *https://hf.tc.faa.gov/value-of-hf/*. Accessed on: 09/03/2022.

European Commission (2017). Commission Implementing Regulation (EU) 2017/373.

Gilbert, C. (2020). What Is the Place of Human and Organisational Factors in Safety? In Human and Organisational Factors (pp. 1-4). Springer, Cham.

Greenley, Mike, Scipione, Andrea, Brooks, Jeremy, et al. The development and validation of a human systems integration (HSI) program for the Canadian Department of National Defence (DND). CAE PROFESSIONAL SERVICES KANATA (ONTARIO), 2008.

ICAO Doc 10151: Manual on Human Performance (HP) for Regulators.

Jones, S. S., Koppel, R., Ridgely, M. S., Palen, T. E., & Wu, S. Y. (2015). Guide to Reducing Unintended Consequences of Electronic Health Records. 2011. Agency for Healthcare Research and Quality.

Josias, L., Demagalski, J., Donovan, S. (2018). Real World Strategies to Achieve Human Factors Integration. Proceedings of the Human Factors and Ergonomics Society Annual Meeting 61 (1) :460-464.

Justinia, T. (2017). The UK's National Programme for IT: Why was it dismantled?. Health services management research, 30(1), 2-9.

Krois, P., Farrow, D., Johnson, W., & Bair, D. (2007). Panel: Advancing the Human Factors Business Case. In 2007 International Symposium on Aviation Psychology (p. 346).

Krois, P., Armenis, D., Joly, R., Kirwan, B., Marrison, C., May, N., Piccione, D., & Schwarz, M. (2015). Toward a Human Performance Standard of Excellence in Air Traffic Management. 18th International Symposium on Aviation Psychology, 90-95.

EGHD (2018) Optimising ATM staff working stations in the Joint Human Machine System.

EUROCONTROL (1999). A Business Case for Human Factors Investment. HUM.ET1.ST13.4000-REP-02.

EUROCONTROL (2019). Human Factors Integration in ATM system design. White paper

EUROCONTROL (2000). Human Factors Integration in Future ATM systems – Design Concepts and Philosophies. Technical Report n. HRS/HSP-003-REP-01.

EUROCONTROL (2004). The Human Factors Case : Guidance for Human Factors Integration.

EUROCONTROL (2007). Guidance for Human Factors Integration.

EUROCONTROL (2011). Support material for Human Factors case application.

Pelchen-Medwed R. et al. (2021). The Evolution towards a common Air/Ground Framework for Human Performance Assessment in ATM. In I.V. Koglbauer & S. Biede-Straussberger (Eds.), Aviation Psychology: Applied Methods and Techniques.

Rozzi, S., Amaldi, P., & Kirwan, B. (2010). IT innovation and its organisational conditions in safety critical domains: The case of the Minimum Safe Altitude Warning system.

SESAR (2018) Human Performance Assessment Process V1 to V3-including VLDs.

Sirett, P., & Sutcliffe, J. (2010, April). Barriers to successful human factors integration within the military domain. In Contemporary ergonomics and human factors 2010: Proceedings of the International Conference on Contemporary Ergonomics and Human Factors (pp. 183-191).

Sittig, D. F., & Singh, H. (2015). A new socio-technical model for studying health information technology in complex adaptive healthcare systems. In Cognitive informatics for biomedicine (pp. 59-80). Springer, Cham.

US Airforce (2009) Air Force Human Systems Integration Handbook. Planning and Execution of Human Systems Integration. Directorate of Human Performance Integration. Human Performance Optimisation Division.

Zheng, K., Abraham, J., Novak, L. L., Reynolds, T. L., & Gettinger, A. (2016). A survey of the literature on unintended consequences associated with health information technology: 2014–2015. Yearbook of medical informatics, 25(01), 13-29.