Haiku
Human AI teaming Knowledge and Understanding for aviation safety

Deliverable N.8.1

The Human Role in Future Aviation

Authors:
Arrigoni V., Cavagnetto N. (DBL)

Main contributors:
Josefsson B., Boonsong S., Meyer L. (LFV)

Reviewed by:
Pozzi S. (DBL), Kirwan B. (ECTL)

Abstract:

This deliverable documents the activities and the results achieved within HAIKU Tasks 8.1 "*Review the State of the Art in aviation selection and aptitude testing, training and licensing*" and 8.3 "*Understand the evolution of the human role*". It presents the envisaged impact of the introduction of AI systems into aviation operations on human roles, skill-set and competencies.It provides a high level analysis of how pilots and controllers are selected and trained today, highlighting trends for the near future and suggesting necessary actions and changes to support the shift towards a human-AI teaming working environment.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Information Table

Deliverable Number	8.1
Deliverable Title	The Human Role in Future Aviation
Version	1.0
Status	Final version
Responsible Partner	DBL
Contributors	LFV
Contractual Date of Delivery	August 31st, 2023
Actual Date of Delivery	August 31st, 2023
Dissemination Level	PU

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Document History

Vers.	Date	Status	Author	Description
0.1	Jul. 3rd, 2023	Draft	Arrigoni V. (DBL)	TOC
0.2	Jul. 14th, 2023	Draft	Cavagnetto N. (DBL)	Draft added: Chapters 1 and 2
0.3	Jul. 28th, 2023	Draft	Cavagnetto N. (DBL)	Draft added: Paragraphs 4.2, 4.3, 5.2, 5.3, 6 + Annex
0.4	Aug. 9th, 2023	Draft	Arrigoni V. (DBL)	Review of the existing paragraphs with changes Draft added: Chapter 3, Paragraphs 4.1 and 5.1, Conclusions Introduction of visualisations
0.5	Aug. 21st, 2023	Draft	Boonsong S. (LFV) Josefsson B. (LFV) Kirwan B. (ECTL) Pozzi S. (DBL) Venditti R. (DBL)	Review with comments
1.0	Aug. 30th, 2023	Final	Arrigoni V. (DBL) Cavagnetto N. (DBL)	Comment addressed Final version

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

List of Acronyms

Acronym	Definition
AGL	Airfield Ground Lighting
AI	Artificial Intelligence
AOC	Airport Operations Center
AR	Augmented Reality
a-VDOS	AI-powered Advanced Visual Docking Guidance Systems
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
CAVs	Connected Autonomous Vehicles
CNS	Communication-Navigation-Surveillance
CPDLC	Controller Pilot Data Link Communications
CRM	Crew Resource Management
EASA	European Union Aviation Safety Agency
EC	European Commission
EU	European Union
FEAST	First European Air Traffic Controllers Selection Test
FL	Flight Level
GPWS	Ground Proximity Warning System
GSE	Ground Support Equipment
HAIKU	Human-AI teaming Knowledge and Understanding for aviation safety
KAAT	Knowledge Alliance in Air Transport
IA	Intelligent Assistant

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Acronym	Definition
PIREPs	Pilot Reports
RPAS	Remotely Piloted Aircraft System
RWY	Runway
SME	Subject Matter Expert
SPIC	Single Pilot In Cruise
SPO	Single Pilot Operations
TMA	Terminal Manoeuvring Area
UAS	Unmanned Aircraft System
UTM	Unmanned Aircraft System Traffic Management
UATM	Urban Air Traffic Management
VLOS	Visual Line of Sight

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Executive summary

Deliverable 8.1 describes the envisaged **impact of the introduction of Artificial Intelligence** (AI) into commercial air transport operations on **human roles**, **skill-set** and **competencies (Task 8.3).** It provides a high level analysis of how pilots and controllers are **selected** and **trained** today, highlighting trends for the near future and suggesting necessary actions and changes to support the shift towards a **safe and attractive human-AI teaming working environment** (Task 8.1).

Chapters 1 and 2 define the scope of the document and explain the **methodologies** used to assess the human roles evolution from a present-to-future perspective - through desk research, 3 workshops and a round of interviews, involving **33 Subject Matter Experts** from 7 different countries.

Overall, by 2050, AI is envisaged to gradually become a full-fledged team member in the cockpit, ops rooms and airports. The envisaged **high-level roadmap of the introduction of AI into commercial air transport operations** is shown in *Chapter 3,* highlighting a possible evolution of the human role and related Human-AI teaming concept from 2025 to 2050.

A more detailed and analytical view on selected human roles expected to be significantly impacted by automation and AI in coming years is provided in the following *Chapters 4* (ATM and UTM), *5* (Flight Operations) and *6* (Airport).
Overall, the technological trend seems to lead to a scenario where tech systems and AI would be able to gradually take on the more operative and executive tasks currently mostly done by humans, leaving under operators' responsibility the more **strategic**, **managerial**, and **monitoring** ones. Furthermore, the **human contribution in emergencies and non-nominal situations** is still expected to be key. A variety of existing and potential new roles (see Table 1) are discussed in these chapters, showing their likely evolution from 2025 to 2050.

Table 1: Overview on analysed human roles, highlighting the level of impact

SEGMENT	ROLE	EXISTING	NEW	IMPACT ON ROLE (by 2050)[1]
ATM	En-route Air Traffic Controller	✔		High
ATM	Approach Air Traffic Controller	✔		High

[1] This column shows the envisaged level of impact - with 2050 as a time frame of reference - on the different human roles where *Low* = the role is expected to remain somehow the same as it is now/when it is expected to be introduced / *Medium* = the role may remain the same but with some changes in tasks, responsibilities and required skills / *High* = the role is expected to change significantly.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

SEGMENT	ROLE	EXISTING	NEW	IMPACT ON ROLE (by 2050)[1]
ATM	Network Manager	✔		High
ATM & UTM	Air Traffic Manager		✔	Low
ATM	Multi-Sector Planner		✔	High
ATM	Tower Air Traffic Controller	✔		High
ATM	Tower Ops Manager		✔	Low
UTM	Drone Pilot	✔		High
UTM	Site Inspector		✔	Low
UTM	Drone Fleet Manager	✔		Medium
ATM & UTM	Airspace Manager		✔	High
Flight OPS	Pilot Flying (Captain)	✔		Medium
Flight OPS	Pilot Flying (First Officer)	✔		High
Flight OPS	Flight Dispatcher	✔		Medium
Flight OPS	Flight Ops Ground Monitor		✔	Low
Airport	Regulatory & Compliance Manager of Infrastructure	✔		High
Airport	Infrastructure Manager of Automation		✔	Low
Airport	Tech support	✔		Low
Airport	Data Analyst	✔		Low
Airport	AI Manager		✔	Low
Airport	Roving Handler	✔		High
Airport	Aircraft engineer	✔		Low
Airport	Marshalls, pushback staff & other roles involved in a/c turnaround and apron management	✔		High

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

SEGMENT	ROLE	EXISTING	NEW	IMPACT ON ROLE (by 2050)[1]
Airport	Security personnel	✔		Medium
Airport	Summer Operations Manager		✔	Low
Airport	Customer Relations Manager	✔		Low

Chapter 7 are the conclusions. It presents a reflection on the results captured in the previous chapters, focusing on the main skills and personality traits that may be needed to perform effectively in the future. Furthermore, it identifies **two major challenges and concerns** that should be carefully addressed to ensure a safe and attractive future for the aviation industry: the **workers mental health** and the **desirability of future jobs**.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Table of contents

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

1. Introduction

The main purpose of this document is to present the activities and results achieved within HAIKU Tasks 8.3 "*Understand the evolution of the human role*" and 8.1 "*Review the State of the Art in aviation selection and aptitude testing, training and licensing*".

By looking ahead to **2030** and going even further towards **2050**, it depicts the envisaged **impact of the introduction of Artificial Intelligence** (AI) into commercial air transport operations on **human roles**, **skill-set** and **competencies**. Furthermore, it provides a high level analysis of how pilots and controllers are **selected** and **trained** today, highlighting trends for the near future and suggesting necessary actions and changes to support the shift towards a **safe and attractive human-AI teaming working environment**.

The document is structured as follows:

- Chapter 2 explains the methodologies used to assess the evolution of human roles from a present-to-future perspective through desk research, workshops and interviews;
- Chapter 3 presents a high-level overview of the Commercial Air Transport Human-AI Teaming Roadmap towards 2050;
- Chapters 4, 5 and 6 present the main outcomes of the evolution of human role for ATM & UTM, Flight Operations and Airport domains;
- Chapter 7 presents the interim conclusions.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

2. Ways of working

To compile a comprehensive understanding of the potential impact of AI on the human roles, skills and competences, selection and training, and thus develop a vision of the future aviation workforce, HAIKU adopted a 3-steps approach:

1. **Step 1 - Desk review**: review of existing relevant literature, methodologies and frameworks, such as the KAAT competencies framework for the aviation sector (KAAT, 2018), the HAIKU Human-AI teaming framework (HAIKU, 2023), and the EASA level of impact of AI classification (EASA, 2023);
2. **Step 2 - Workshops**: three workshops with Subject Matter Experts (SME) to discuss and analyse the AI systems' introduction into operations, and identify the likely necessary changes in human roles, skill-set and competencies. The three workshops took place in Italy (Rome, May 17th, 2023), Sweden (Stockholm, June 13th, 2023), and Belgium (Brussels, June 28th, 2023) and involved 30 SME from 7 countries, covering all aviation segments:
    - 8 SMEs from the ATM segment;
    - 6 SMEs on UTM and UAM;
    - 12 SMEs from airlines;
    - 4 SMEs from airports.

    The workshops, employing a variety of brainstorming methodologies (backcasting, forecasting, lotus blossom, etc.) aimed at crafting the story of the human role's evolution from the present day to 2050, based on 2050 scenarios developed earlier within the HAIKU project (HAIKU, 2023). More details on the workshop formats and materials are available in Annex A.
3. **Step 3 - Semi-structured interviews**: a set of semi-structured interviews to 'deep dive' on key aspects, mostly related to selection and training. The interview grid is available in Annex B. 5 SMEs were interviewed:
    - 2 ATM experts with relevant roles in selection and training;
    - 2 airline pilots and instructors;
    - 1 high-level expert from the UTM domain.

Thanks to this three-step approach and the valuable contributions of the involved SMEs, HAIKU offers its view on the future workforce. This view encompasses the workforce's envisaged developments in the short (2030), medium (2040), and long term (2050), along with a set of key milestones that should be reached to successful and safe shift towards a human-AI teaming working environment.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

3. Commercial Air Transport Human-AI Teaming Roadmap: from today towards 2050

Commercial air transport is envisaged to face a variety of challenges - as well as opportunities - in the coming years, related to the introduction of new technologies and more specifically AI, into operations. This section outlines a high-level roadmap, built on the basis of the experts' viewpoints, during the above-mentioned workshops and interviews.

By 2050, **AI** might gradually become a **full-fledged team member** in the cockpit, ops rooms and airports. Figure 1 shows the high-level roadmap of the AI introduction into commercial air transport operations, highlighting a possible evolution of the human role and related Human-AI teaming concept.

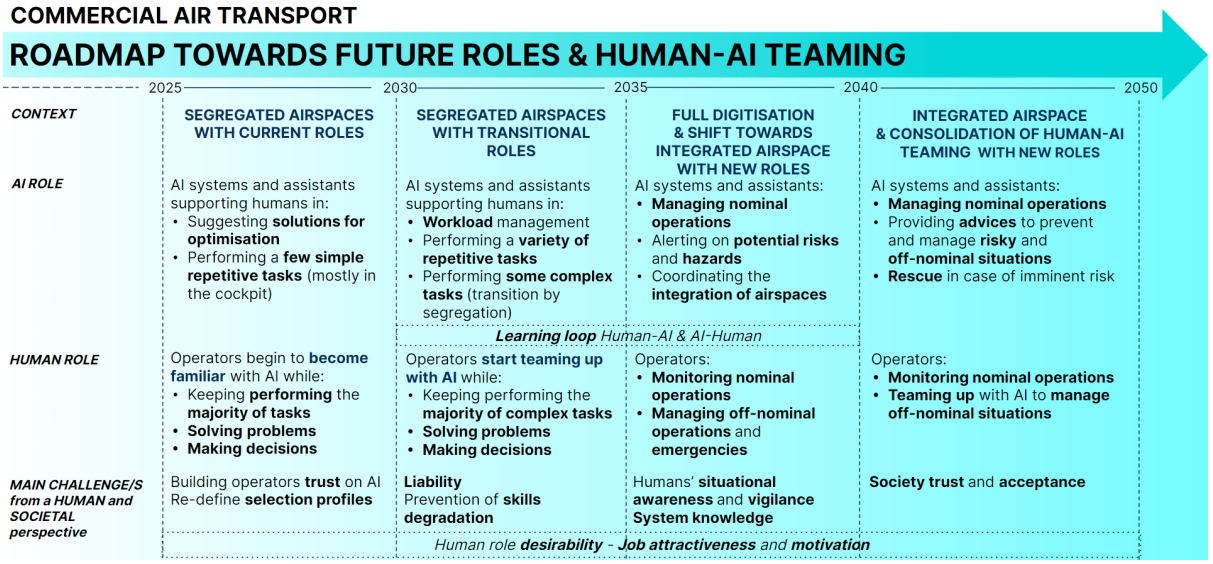

Figure 1: Human-AI Teaming roadmap for Commercial Air Transport

Between **2025** and **2030**, a time frame characterised by increased and heterogeneous air traffic managed in segregated airspaces (HAIKU, 2023), **AI** is expected to start supporting Commercial Air Transport operations by **assisting humans in identifying optimal solutions and priorities** (e.g. in case of medical emergencies on board the aircraft). Especially in the cockpit, a few initial simple and repetitive tasks (e.g. frequency management and taxiing) may be delegated to AI systems. The **human role** is **not expected to change much** from now to 2030. In fact, human operators are expected to still be in charge of the majority of tasks, problem solving and decision making. However, these 5 years are expected to be key to:

- Start **building a strong relationship of trust between humans and AI**, a critical success factor to allow the aviation industry to properly open the door and welcome AI into commercial air operations;

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

- **Re-design roles and job profiles** for the forthcoming years according to the technological evolution in the sector, to ensure having the right people, well-trained and equipped, ready to safely and securely operate in the following years.

The time frame **2030-2035** is envisaged to be a **critical transitional phase** characterised by higher operational complexity (still managed by segregation), increased role of AI systems, and consequent regulatory changes. Humans are indeed expected to be key to successfully leading and achieving this transition phase. Some existing roles may be revised and new temporary ones could be introduced, with a view to shifting the human values and contributions from operational positions to more managerial ones.
During these 5 years, **AI** is expected to **assist humans in workload management** and be in charge of **performing the majority of repetitive tasks** (e.g. voice communication) as well as some initial complex tasks for which a transition by segregation is foreseen (e.g. starting from off-peak and night-time slots). Humans are envisaged to remain responsible for the majority of complex tasks, problem solving and decision making, while starting to team up with AI.
The **quality of the human-AI interactions** may be a crucial success factor in this time frame. Indeed, this would be one of the key elements enabling the creation of an effective learning loop between humans and AI. Furthermore, when delegating tasks to AI, **preventing degradation skills** will be a must to maintain high safety standards.

The following 5 years are likely to be characterised by the consolidation of important changes from three areas:

- *Technological*, with the accomplishment of the digitisation process which opens the door to more and more AI applications;
- *Operational*, with the activation of the shift from segregated to integrated airspace;
- *Human*, with important changes in roles and responsibilities, and the introduction of new ones.

Between **2035** and **2040**, nominal situations are expected to be managed by technological and AI-based systems which will also alert humans to potential risky situations and hazards. AI would also be in charge of coordinating the integration of airspaces as well as harmonising and standardising systems across international actors. **Human operators** are expected to **monitor** and **intervene in case of non-nominal situations**.
Ensuring and sustaining human situational awareness, vigilance and system knowledge is expected to be the key challenge for this time frame.
A progressive **strengthening of the relationship between humans and AI** is expected to characterise the 2040-2050 decade. AI may extend its contribution to non-nominal situations, providing advice and directly intervening in case of imminent risks. Humans

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

are expected to mostly intervene, teaming up with AI, in case of non-nominal situations.
Societal trust and acceptance may be the major challenge during the 40s.

Looking at the whole picture, **ensuring desirability of the human role** and **retaining aviation job attractiveness** and **people's motivation** is expected to be one of the major challenges for the industry. People may be willing and happy to welcome AI in operations and teaming up with it, but only if important benefits are perceived not just from the economical and operational perspectives, but also from the safety and human ones.

The following chapters present a more detailed and analytical view on selected human roles (in ATM and UTM, Flight Operations, and Airport) that are expected to be significantly impacted by automation and AI in coming years.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

4. ATM & UTM

4.1. The evolution of human roles towards 2050

The technological evolution and, more specifically, the introduction of AI-based assistants are expected to significantly change the human role in ATM and UTM in the following years. During the above-mentioned workshops and interviews, a number of key existing human roles were selected, analysed and projected into the future. A possible evolutionary trend was outlined and a set of new potential future roles were identified. Figure 2 provides a consolidated and synthetic view of the results of this co-creation activity[2].

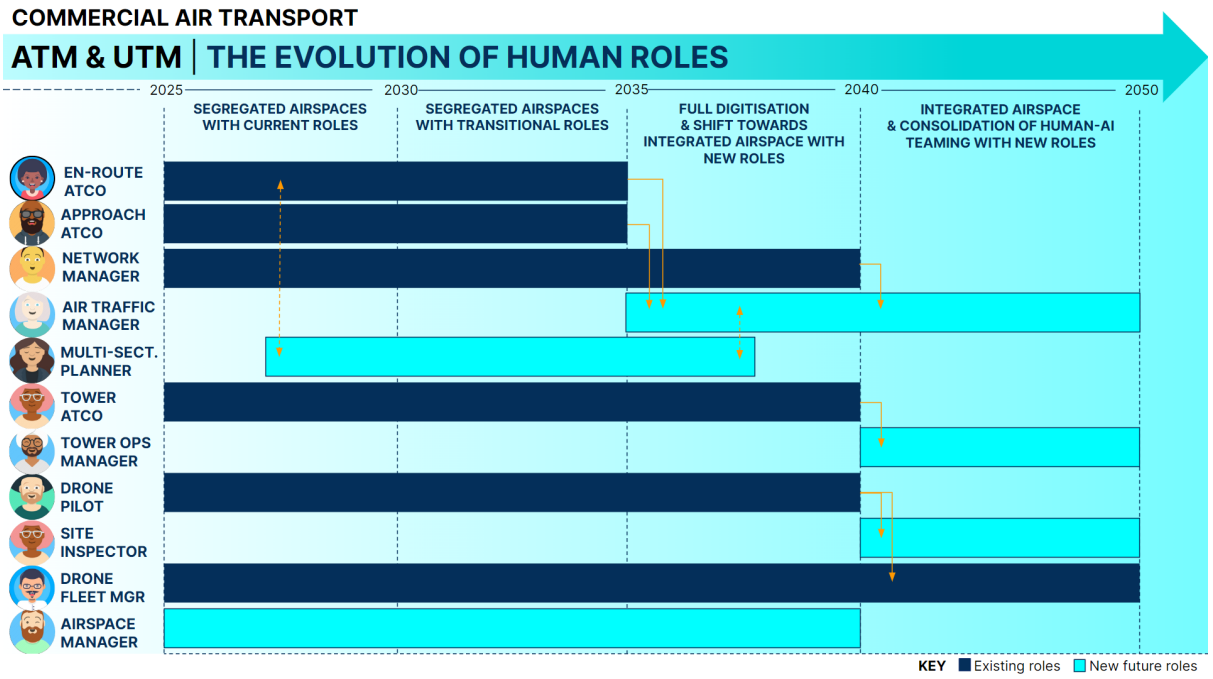

Figure 2: The evolution of human role in ATM & UTM

The **En-route** and **Approach ATCOs** (Air Traffic Controller) are envisaged to see their tasks and responsibilities mixed, gradually leaving them to a new emerging role named **Air Traffic Manager**. This change is expected to occur around 2035, following the integration of the two airspaces. During 2035-2040, the Air Traffic Manager should be in charge of monitoring nominal operations and manage non-nominal operations and emergencies for both ATM and UTM traffic, aided by AI in tactical and strategic de-confliction.

The **Network Manager** role is projected to significantly evolve, gradually shifting its tasks to both AI and the **Air Traffic Manager**. This transition is envisaged to be

[2] Co-creation is the practice of collaborating with other stakeholders to guide the design process (see here for more information about it).

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

accomplished in the early 2040s. In fact, in 2040-2050, the Air Traffic Manager is expected to assume a **more supervisory and strategic role**, focusing on high-level ATM and UTM operations and strategic planning in clusters of sectors, while being still in charge of managing non-nominal situations and emergencies. However, by that time, AI should be able to intervene in non-nominal operations and take proactive measures to prevent system degradation. It would monitor its own state, communicate system issues to the Air Traffic Manager within 30 seconds, and ensure Situation Awareness is promptly acquired.
This shift could be also supported by the **Multi-Sector Planner**, a role already researched by some SESAR projects, and expected to further evolve in the years 2025-2030. It may be a transitional role aimed to assist the En-route ATCOs first and then the Air Traffic Manager in overseeing multiple sectors. Its tasks are expected to be gradually absorbed by AI systems, making this role obsolete by 2035-2040.
Also, the **Tower ATCO** role may undergo a significant transformation. By 2030-2035, AI is expected to assist Tower ATCOs in performing repetitive tasks, such as communication instructions to pilots, and a few other more safety-critical tasks such as ensuring the required separation between aircraft in landing and take-off phases. During the 2040-2050 timeframe, similarly to the en-route ATCO, the Tower ATCO may transition into a new role with more supervisory and managerial responsibilities, named **Tower Ops Manager**. The Tower Ops Manager is envisaged to coordinate operations at a high level, make strategic planning, and intervene, supported by AI, in case of non-nominal situations and emergencies. AI is expected to be capable of issuing clearances, providing separations, handling communications through the Controller Pilot Data Link Communications (CPDLC), and detecting and solving conflicts. It would provide on-demand information to the Tower Ops Manager, attracting its attention to critical events and offering decision support.

Focusing on UTM operations, the **Drone Pilot** emerged to be one of the roles most likely to be impacted by the introduction of AI systems. During 2035-2040, AI would offer a 'traffic intelligent system', providing the essential information necessary for drone operations. In Visual Line of Sight (VLOS) operations, AI would provide situational awareness for the area of operations, offering details about the timing, position, and speed of crossing aircraft paths. By 2040, AI is expected to take on close to 95% of UAS operations, while the human drone pilot would primarily focus on specific site inspections - too specific in context and goals for AI to carry them out - and, therefore, be named **Site Inspector**.
The role of **Drone Fleet Manager** would evolve considerably, with increasing responsibilities assumed over time. During 2025-2030, the Drone Fleet Manager would primarily focus on obtaining flight authorizations. From 2035 onwards, the Drone Fleet Manager would gradually take over certain tasks previously performed by Drone Pilots, such as flight monitoring and managing non-nominal operations. The AI would play a crucial role as a planner, devising optimal trajectories, considering business and authorization perspectives. By 2040-2050, the Drone Fleet Manager would primarily

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

intervene during non-nominal operations, while the AI would promptly notify the manager of potential system failures.

Looking at ATM and UTM and their future integration, another new role, named **Airspace Manager**, is expected to be introduced very soon. The Airspace Manager would play a key role in managing the interface between the two segregated airspaces, and ultimately contributing to their integration. During 2025-2030, the Airspace Manager's primary responsibilities may involve coordination and emergency management between the two airspaces. The AI would serve as an information provider on users and their impact on operations, ensuring timely updates on take-off information, flight paths and routes. During 2035-2040, AI is envisaged to gradually take over the role of the Airspace Manager, with coordination and communication needs gradually disappearing as the two airspaces begin to integrate. Eventually, the role would disappear entirely following full airspace integration.

To conclude, below we list key steps and milestones of the transition from today to 2050.

- Timeframe 2025-2030: Standardisation of the Altitude Reference System for both the ATM and UTM.
- Timeframe 2030-2035: Gradual deployment of new AI systems and assistants based on a segregation approach (e.g. starting from off-peak and night-time slots);
- Timeframe 2035-2040: Integration of segregated airspaces and improvement of Airport Collaborative Decision-Making (A-CDM) Systems through full data digitalisation;
- Timeframe 2040-2050: Integration of Air and Ground systems would be realised, including the Communication-Navigation-Surveillance (CNS) systems, and full deployment of Remote Digital Towers, offering Air Traffic Management-as-a-Service.

Key accompanying actions from the human perspective are:

- Development and implementation of mitigation strategies to prevent skill degradation due to increased AI support. "Human-AI learning" would be initiated, allowing humans to learn new skills related to AI usage, while AI would learn from human operators to perform tasks as humans do.
- Defining role-based responsibilities between humans and AI systems, by establishing legal and regulatory frameworks.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

4.2. Future Personas

Selected roles have been further discussed during the workshops, in order to describe more detailed job profiles, called future personas[3] from now on. The goal was to better define the future working environments and human-AI teaming approaches, the envisaged responsibilities, main abilities and skills, as well as identifying the possible major challenges and concerns for each job profile in the context of advancing technology.
The future personas developed for the ATM & UTM segment are: Air Traffic Manager, Multi-sector Planner, Tower Ops Manager, and Drone Fleet Manager. These are presented below.

Air Traffic Manager

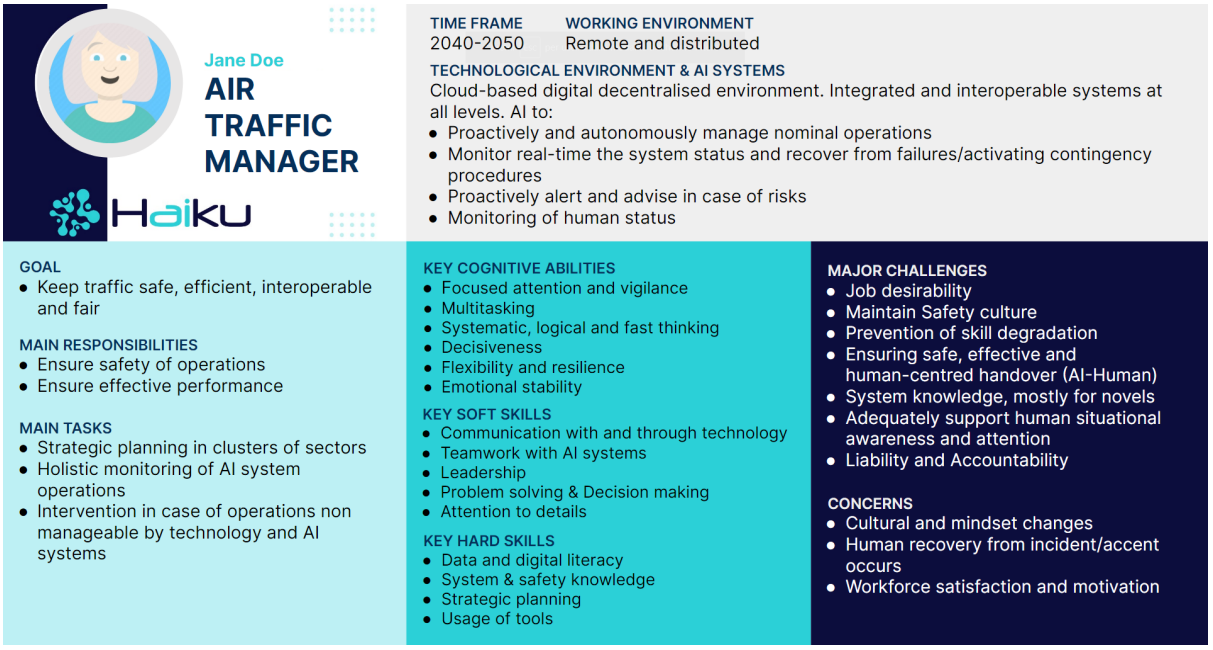

Figure 3: Air Traffic Manager Persona Canvas

The **Air Traffic Manager** is a role expected to be introduced by 2035 with the main goal of **ensuring safe, efficient, interoperable and fair operations**. As mentioned in the previous chapter, it is envisaged to gradually take on the En-route ATCO, Approach ATCO and Network Manager tasks that will not be managed by technology and AI systems.
In 2040-2050, the envisioned working environment for this role is a **cloud-based digital decentralised setup** with **integrated and interoperable systems** at all levels. The role is expected to be remote and distributed, operating as UATM-as-a-service. AI

[3] Personas are fictional characterization of users, a cornerstone of User Centred Design. Creating personas helps understand users' needs, experiences, behaviours and goals. They guide the ideation processes and help achieve the goal of creating good user experiences.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

is envisaged to proactively and autonomously manage nominal operations, monitor real-time the system status and recover from failures. It would also activate contingency procedures, as well as proactively alert and advise the Air Traffic Manager in case of potential risks and hazards to be managed. Additionally,advanced sensor technologies and AI are expected to constantly monitor human status.

Ensuring safe and effective operations are expected to be the core of the Air Traffic Manager's responsibilities. His/her main tasks would be to perform **strategic planning** in clusters of sectors, **monitoring of AI system operations** and **intervention in case of non-nominal operations**, or non manageable by technology and AI systems.

A variety of cognitive abilities are envisaged to be required for this role, such as **attention** and **vigilance**, **fast thinking**, **flexibility** and **resilience**. **Communication** and **teamwork** skills are expected to be more focused on the **interaction with technology and AI systems**. **Leadership**, **problem solving**, **decision-making** and **attention to detail** are envisaged to remain key skills. These soft skills would need to be combined with a set of hard skills, including **data and digital literacy**, **system & safety knowledge**, **strategic planning**, **separation techniques** and **usage of tools**. Finally, the Air Traffic Manager role may be less attractive for people who love social interactions, as this future role will mostly require interactions with technological systems rather than with human operators.

Job desirability, **Safety Culture**, **Skill degradation**, **effective and safe Human-AI interactions**, **vigilance** and **situational awareness**, and professional **liability** are foreseen as major challenges related to this role which go hand in hand with concerns related to **cultural changes** and **workforce satisfaction and motivation**.

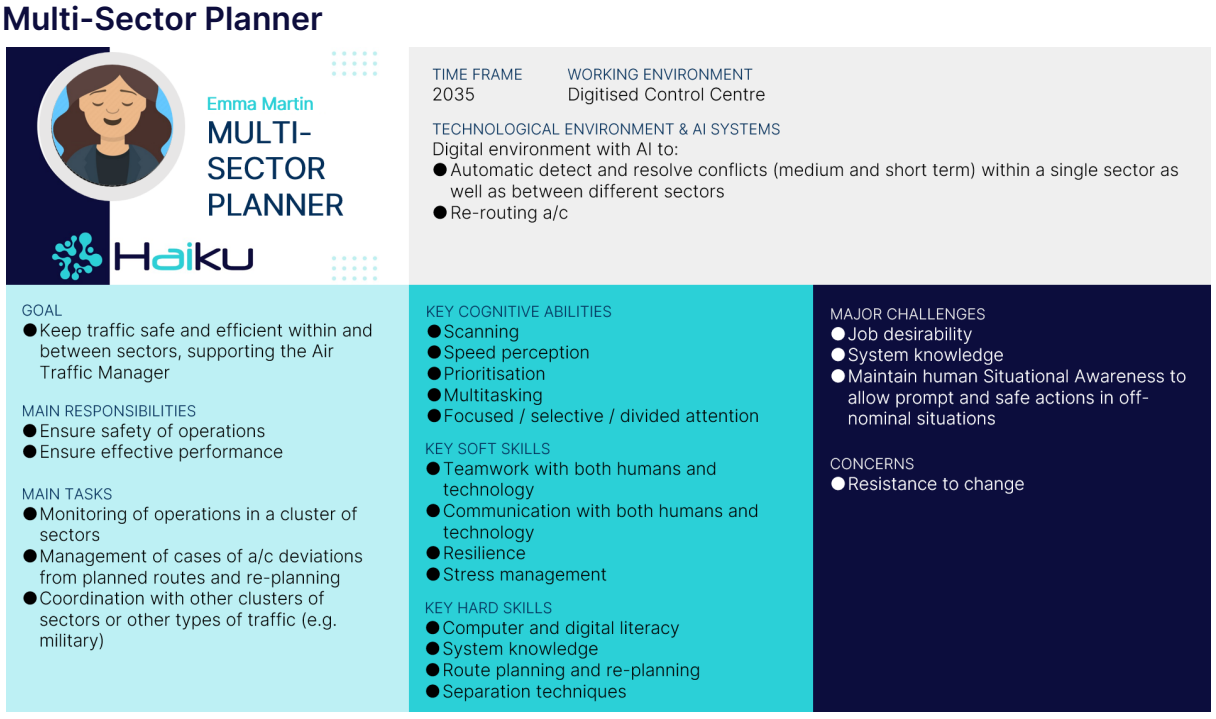

Figure 4: Multi-Sector Planner Persona Canvas

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

The **Multi-Sector Planner** is envisaged to be a transitional role aimed to **assist the En-route ATCOs first and then the Air Traffic Manager in overseeing multiple sectors** gathered in **clusters**. It is a role expected to be introduced during 2025-2030 and its tasks are expected to be gradually absorbed by AI systems, making this role obsolete by 2035-2040.

By the mid-30s, the envisioned working environment for this role is a **Digital Area Control Centre**, a cloud-based decentralised evolution of the current Area Control Centre. The actors working in Digital Control Centres, such as the Multi-Sector Planner, may most likely team up with AI systems in order to **ensure safety and efficiency within and between sectors**. AI is envisaged to automatically detect and resolve conflicts (medium and short term), within a single sector as well as between different sectors, and re-route traffic accordingly.

The main tasks are projected to be the **monitoring of operations in a cluster of sectors**, **management of cases of a/c deviations** from planned routes and re-planning, as well as **coordination with other clusters of sectors** or other types of traffic (e.g. military).

The main cognitive abilities that are envisaged to be required for this role are **scanning**, **speed perception**, **prioritisation**, **multitasking** and **attention**. **Team Working** and **communication** with both humans and technology are expected to be key soft skills for this role, together with **resilience** and **stress management** (especially if the AI support system fails). These would need to be combined with key hard skills, such as **computer and digital literacy**, **system knowledge**, route **planning** and **re-planning** and **separation** techniques.

Similar to Air Traffic Manager, **job desirability**, **system knowledge** and **situational awareness** are foreseen as major challenges and, since this role could have an impact on the size of the ATCO workforce, **resistance to change** is highlighted as a possible major concern. **Professional liability** may also be a concern with this role, as by its very nature it is taking on more responsibilities.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Tower Ops Manager

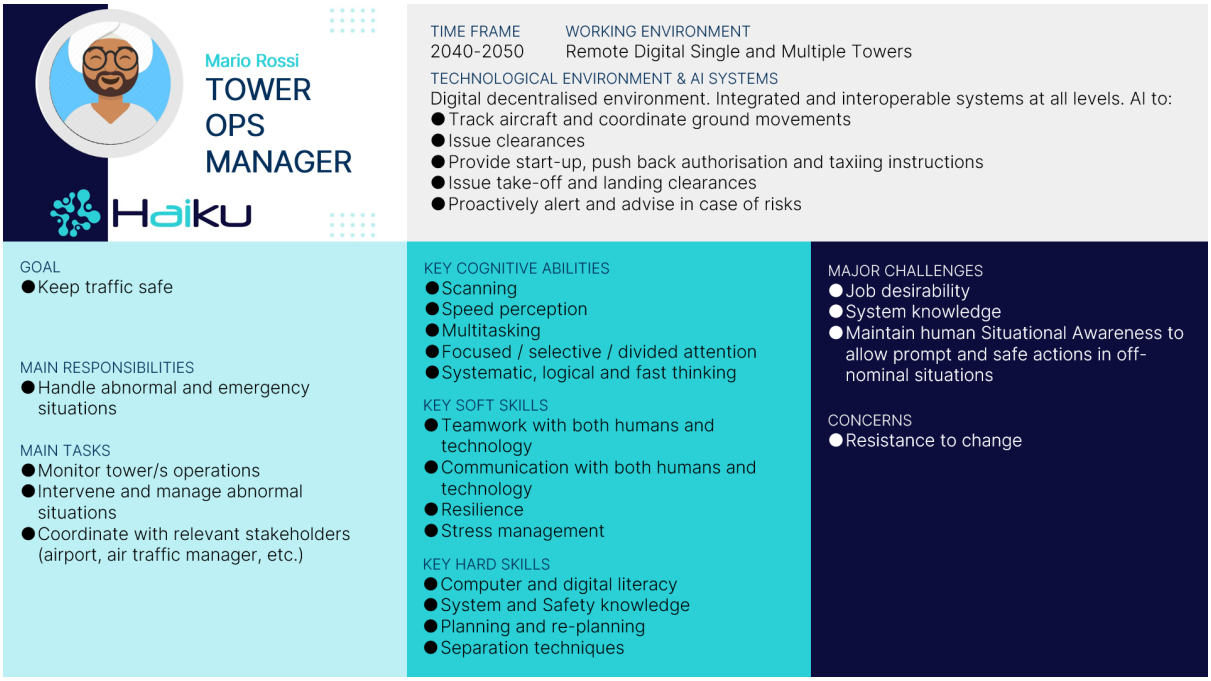

Figure 5: Tower Ops Manager Persona Canvas

The **Tower Ops Manager** is an evolution of the Tower ATCO role expected to be consolidated during the 2040s. Its main goal and responsibility would be to **safely coordinate tower/s operations** at a high level and **intervene**, supported by AI, in case of **non-nominal events and emergencies**. In these cases, **coordinating with relevant stakeholders** (such as airport, air traffic manager, drone fleet manager, emergency services …) would be also part of his/her tasks.

The envisioned working environment for this role is a **fully digitised and remote Tower** that could serve a **single** or **multiple airports**, with integrated and interoperable systems. The Tower Ops Manager is expected to be strongly supported by AI in a variety of tasks. In fact, AI may be capable of autonomously managing normal operations by tracking aircraft, coordinating ground movements, issuing clearances, providing authorisations and detecting and solving conflicts. In case of risks, it should proactively alert and advise the Tower Ops Manager offering decision support.

A variety of cognitive abilities are envisaged to be required for this role, such as **multitasking**, **attention**, and **fast thinking. Team Working** and **communication** with both humans and technology are expected to be key soft skills together with **resilience** and **stress management**. **Computer and digital literacy**, **system and safety knowledge**, **planning** and **re-planning** and **separation** techniques are hard skills that may be key for this role.

Similar to the previous roles, **job desirability**, **system knowledge** and **situational awareness** are foreseen as major challenges and **resistance to change** is highlighted as a possible major concern.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Drone Fleet Manager

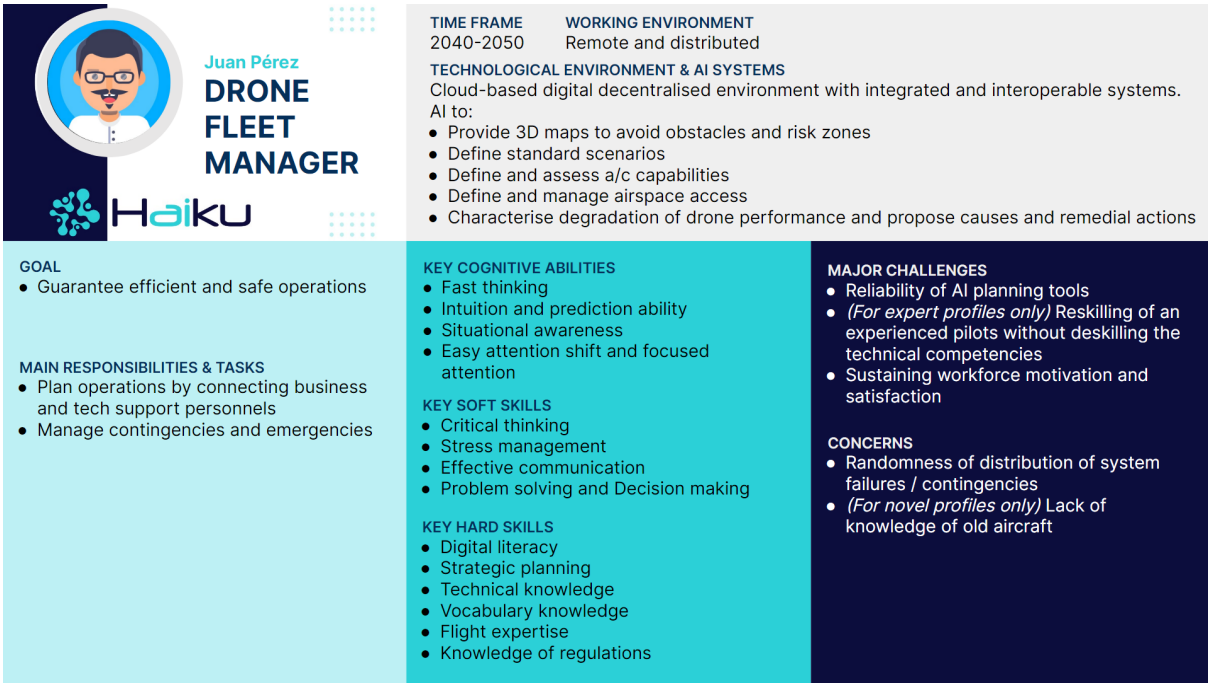

Figure 6: Drone Fleet Manager Persona Canvas

The **Drone Fleet Manager** is a role expected to evolve considerably over the next years and decades. By 2040-2050, the Drone Fleet Manager is envisaged to be the **main reference point between business and tech support personnel**, assuming a **strategic role in planning operations** and **guaranteeing business effectiveness** (including equity, flexibility and predictability for individual business users) and **safety**. Furthermore, s/he would primarily **intervene during non-nominal operations**, while the AI would promptly notify the manager of potential system failures. For these reasons, the Drone Fleet Manager is expected to be a former drone pilot capable of understanding operational aspects when intervening in non-nominal operations.

The 2040-50 envisioned working environment for this role is a **cloud-based digital decentralised setup** with **integrated and interoperable systems**. The role is expected to be **remote and distributed**. AI is envisaged to strongly support the Drone Fleet Manager by assisting in planning, providing 3D maps to avoid obstacles and risk-zones, defining standard scenarios, assessing aircraft capabilities, and managing airspace access.

The main cognitive abilities that may be required for this role are **fast thinking**, **situational awareness** and **attention**. **Intuition** is also envisaged to be fundamental as being able to understand autonomous drone behaviours and predict potential deviations or risks could be key to ensure safe and effective operations. **Critical thinking** and **stress management** may be important soft skills, especially to resist business pressures that may undermine safety. **Communication, Problem solving**, and **decision-making** are also expected to be fundamental. These abilities and soft skills would need to be combined with a set of hard skills, including: **digital literacy**,

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

strategic planning, **UAS flight expertise**, as well as **technical**, **vocabulary** and **regulatory knowledge**.
The major challenges revolve around **defining AI planning tool outputs' reliability**, **reskilling expert pilots** into business knowledge without deskilling technical competencies, as well as **keeping workforce motivation and satisfaction high**. Concerns involve **randomness in system failures** and **novice lack of knowledge** of old aircraft.

4.3. Selection and training: as is, gaps and potential changes

In the **ATC segment**, the regulations for **training** are well-established. The EU Regulation 2015/340 outlines the technical requirements for training, while EUROCONTROL specifies the contents to be included in the training programs. This ensures that aspiring ATCOs undergo comprehensive training to equip them with the necessary skills and knowledge.
The average time required for an individual to be trained and ready for operational duty as an ATCO ranges two to three years. This includes various stages of training, starting with an academy training at an ATC training centre, which covers the fundamental aspects of ATC operations and grants a student licence. The following phases involve training in the specific operational environment, such as airport, airspace and procedures, and culminate in the acquisition of an ATCO licence rated for a specific environment.
The situation is different when it comes to **selection** regulations, as there is no specific EU regulation. Various attempts have been made to standardise the selection process, but national regulations prevail. Despite the lack of centralised regulation, the **First European Air Traffic Controllers Selection Test (FEAST)** has emerged as a widely used evaluation tool, checking cognitive abilities, personality traits, and medical fitness. The FEAST test consists of four phases:

1. Phase 1: cognitive abilities tests;
2. Phase 2: two ATC work sample tests;
3. Phase 3: personality test;
4. Phase 4: medical examination.

The cognitive abilities tested include speed perception, attention, spatial abilities, working memory, planning ability, decision-making, and multitasking. Additionally, the personality test evaluates traits such as achievement drive, emotional stability, resilience and many other social and personal soft skills and personality traits. The exact contents of FEAST may still vary depending on the country adopting it.
Regarding general requirements for aspiring ATCOs, qualifications such as specific aviation degrees are rare, with most countries requiring at least a university entrance level qualification (e.g., "A" level). Candidates must also possess good English (i.e. ICAO English Proficiency Level 4 is a minimum operational level) and technical mother

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

tongue language skills of the Country the ATCO is expected to work in, be a national citizen, and fulfil an age requirement, typically not older than 27 years old. However, it is noted that the age limit may vary in different countries.

Looking ahead to 2030 and beyond, certain gaps in assessing and training certain abilities and skills are identified.
Nowadays, skills and competencies related to **digital literacy** and **human-AI interactions** are not explicitly tested during the selection process. As the industry progresses and human-AI interactions are expected to become more prevalent, these skills would need to be tested and acquired. Therefore, these would need to be incorporated into the selection criteria to ensure the right candidates are chosen. Overall, the selection process and requirements need to **adapt to the changing roles in this aviation segment**. For the envisaged future ATM roles, cognitive abilities may remain essential, but the emphasis will shift from giving instructions to becoming **information managers**, closely monitoring screens for critical information. **Spatial abilities** and **vectoring skills** may become less important as AI systems support these functions. Moreover, the profile of individuals interested in ATCO roles might change, with the profession becoming more attractive also for people with strong IT skills, and **less emphasis on extraversion and social skills**. Furthermore, in a scenario where the operators would be mostly responsible for managing non-nominal operations, **fast thinking** and the **ability to quickly shift from a mental pattern to a new one** are envisaged to be key.

From a training perspective, preparing for the AI-based future requires greater emphasis on digital literacy, human-AI interactions, and **understanding the role and limitations of automation and technology**, including how to verify or query its outputs if they don't look right.

Focusing on the **drones segment**, the EU Regulation 947/2019 covers drone pilots' training for the Open and Specific categories, but there is as yet no specific regulation for Certified category pilots. However, it is expected that this category will undergo an update based on the existing regulations for traditional aviation pilots. With EASA proposing amendments that are later approved and disseminated by the EC, the process aims to ensure standardised practices, although specific training details are often determined at the national level.
As for the training duration, it varies significantly depending on the category:

- Open category pilots can complete their training through online examinations. For drones weighing above 250g an online exam is required, followed by self-paced training that typically takes about a week.
- Specific category pilots must participate in in-person theoretical and practical courses lasting a few days for both VLOS and B-VLOS operations. With approximately 20 flights, pilots are expected to acquire the necessary skills before being subjected to theoretical and practical assessments. Despite the

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

lack of a standardised selection process, certain prerequisites, such as a Standard Scenarios certificate and a minimum age of 16 years for drones over 250g, are in place.

In terms of cognitive abilities, no specific regulations define the key skills required for drone pilots. However, experts consider a **strong sense of spatial orientation** critical for Open and Specific category pilots to avoid hazardous situations. For Certified category pilots, **maintaining focus / attention** during potentially monotonous tasks and increased **situational awareness** are emphasised as essential attributes.

The required skills and competencies for drone pilots are several and include **IT proficiency**, **theoretical knowledge of regulations and communication tools**, as well as practical skills such as **manual dexterity**. Additionally, a **strong safety culture** is considered imperative, particularly for Certified category pilots.

Nonetheless, the interviews also unveiled certain challenges and gaps in the current training and assessment procedures. Notably, the **lack of experienced instructors** for civil operations in the Certified category poses a significant challenge. Additionally, **assessing theoretical knowledge** comprehensively remains a complex task, and there is a pressing need to foster a more **encompassing aviation culture within training organisations**.

The introduction of automated systems is already transforming the role of drone pilots from traditional pilots to fleet managers. Looking ahead to the anticipated advancements in AI-based Intelligent Assistants (IA) by 2030/35, key changes in the selection process are foreseen. There will be a **reduced emphasis on practical skills**, with a **greater focus on assessing theoretical knowledge** and **fleet management abilities**. **Technical skills and abilities to use specific software for mission planning and detection** will also become increasingly important in the selection process.

From a training perspective, the same three changes must be addressed. Ensuring a balanced emphasis on theoretical knowledge, enhancing technical skills, and incorporating fleet management expertise will be crucial in preparing operators for an AI-driven future.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

5. Flight Operations

5.1. The evolution of roles towards 2050

The technological evolution and, more specifically, the introduction of AI-based assistants are expected to significantly change the human role also in Flight Operations in the following years.

During the above-mentioned workshops and interviews, a number of key existing human roles were selected, analysed and projected into the future. Figure 7 provides a consolidated and synthetic view of the results of this co-design activity.

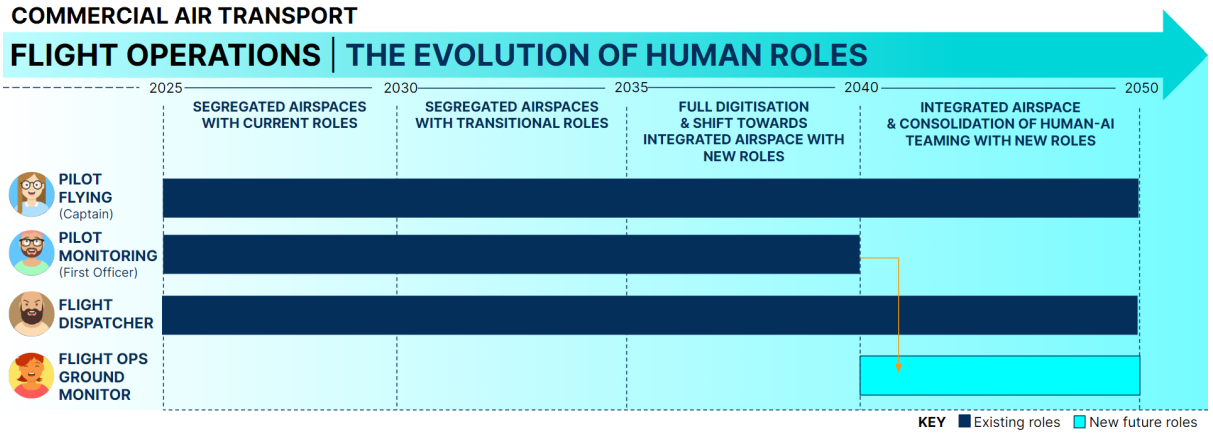

Figure 7: The evolution of human role in Flight Operations[4]

The 2050 reference scenario for Flight Operations foresees **Single Pilot Operations (SPO)** for both long-haul commercial and cargo flights, considering single pilots in the cockpit supported by on-board AI-based and powered IAs and automation, which would take care of the majority of the Pilot Flying and Pilot Monitoring tasks in nominal operations (HAIKU, 2023). In view of this technological and operational trend, during the 2040s the **Pilot Flying** is projected to progressively **absorb some of the Pilot Monitoring tasks**, while the **Pilot Monitoring** is envisaged to be moved outside the cockpit.

The **Pilot Flying**, when in a Single Pilot setting, is expected to assume a more **supervisory role** during nominal operations, while his/her contribution and competencies would be key in case of **non-nominal** and **emergency situations**. In these cases, s/he is expected to be supported by on-board AI systems as well as by remote human assistants. This new role, named **Flight Ops Ground Monitor**, can be considered as an example of evolution of the Pilot Monitoring. It is projected to **support SPO from the ground**, monitoring multiple flights at the same time and

[4] The Captain is analysed focusing on the Pilot Flying role, while the First Officer is seen from a Pilot Monitoring perspective. Therefore, this document refers to Pilot Flying and Pilot Monitoring.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

providing support when Single Pilots need assistance. In case of Single Pilot incapacitation, **on-board autonomous landing systems** would intervene.

The envisaged steps and milestones to enable a safe and effective shift towards this reference scenario are as follows:

- Timeframe 2025-2030: this first step is expected to be characterised by the **delegation of few simple repetitive tasks to AI-based IAs**, as well as by the development **AI-based Information Sharing Systems** between aircraft capable of filtering information for pilots, providing them only with what necessary to effectively perform avoiding cognitive overloads. More specifically:
    - Technology and AI are expected to assist pilots in:
        - Prioritising tasks and actions;
        - Providing alerts for turbulence and information on situational risks (e.g. thunderstorm warning in case of missed approach);
        - Suggesting solutions for optimisations;
        - Managing cases of emergency/engine failure by scanning permanently surrounding airports;
        - Automatically managing frequencies;
        - Automatically performing taxiing operations (taxiing as the first task to be fully delegated to AI);
        - Filtering the information to be presented to the pilot to optimise the information flow and sharing;

      The **AI Information Sharing System** between aircraft would allow sharing of information between aircraft, such as wind shear, turbulence, weather phenomena, traffic density, RWY conditions, etc.. It could also collect and analyse information on routes to advise on optimum Flight Level (FL) for fuel saving.
    - Pilots are expected to:
        - Analyse information and advice provided by AI systems and make plausibility checks;
        - Decide on the flight routes, taking into consideration the options proposed by AI-based assistants;
        - Keep performing all the other tasks related to aviate, navigate and communicate;

- Timeframe 2030-2035: a first important step toward SPO is expected to happen during the 30s: **Single Pilot in Cruise (SPIC)**. It refers to a reduction in the number of pilots required in the cockpit for a long-haul flight during the cruise phase: one pilot in command during the cruising phase while the second can rest and then take over, but both pilots are present for the preparation, taxiing, take-off, descent and landing phases (HAIKU, Deliverable 2.1).

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

This second step is envisaged to be characterised by the introduction of an **AI basic co-pilot**, leading to the **delegation of more and more tasks to AI systems**. A **strengthening of the human-AI teaming** is expected in this phase, where technology is envisaged to mostly **support humans in crew coordination**, **integration** and **workload management**. More specifically:

- Pilots are projected to be assisted by AI in:
  - Checking the correct execution of checklist and procedures;
  - Managing the flight path;
  - Supporting pilots in flying the aircraft during en-route phase and Terminal Manoeuvring Area (TMA) operations;
  - Supporting free flight and/or trajectory-based operations by coordinating with other aircraft AIs;
  - Constant monitoring and analysing the aircraft status and alerting in case of malfunctions or failures;
  - Constant monitoring of pilot status and alerting in case of incapacitation;
  - Automatic filing of Pilot Reports (PIREPs).
- Pilots are expected to:
  - Interact with AI-based assistants by voice commands;
  - Set boundaries to operations;
  - Fly the aircraft;
  - Communicate with ATC;
  - Gather information to assess alternate airports for ground support, infrastructure, and services for passengers;
  - Helping the AI co-pilot to learn how to perform operations.

- Timeframe 2035-2040: during this third phase, the **AI co-pilot** is expected to improve and continuously refine itself, becoming **more and more personalised**. AI is expected to extend its support to **decision-making**, **teamwork** and **leadership** functions, as well as to take on **more and more technical tasks**. More specifically:
  - Technology and AI are expected to assist pilots in:
    - Effectively managing the aircraft;
    - Managing ATC communications;
    - Autonomously performing go-arounds;
    - Avoiding terrain avoidance through an autonomous Ground Proximity Warning System (GPWS);
    - Avoiding bad weather in-cruise;
    - Performing landing autonomously;
    - Autonomously identifying airports for emergency landings;
    - Monitoring reduced performance and security threats;
    - Monitoring pilots' workload, status and well-being, recognising cases of extreme fatigue and mental exhaustion;

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

        - Assessing pilots' competence if missions and flight requirements are matched;

        - Providing pilots with the necessary information through a heuristic AI, adjusting the complexity of the information to their states and personality traits, ensuring situational awareness;
        - Providing on-the-job training to the cabin crew for cockpit tasks;
        - Automatically intervening in case of aircraft damage.
    - Pilots are envisaged to:
        - Supervise and monitor the system;
        - Aviate through inputs and prompts into the system, to remain engaged;
        - Intervene in non-nominal situations and emergencies;
        - Select airport and runway, based on the suggestions provided by AI, in case of emergency landing;
        - Communicate with the crew and with passengers;
        - Manage crew wellbeing;
        - Helping the AI co-pilot to understand and learn personal handling and communication strategies.

- Timeframe 2040-2050: this is the phase where the **SPO** concept is expected to come into operation (HAIKU, Deliverable 2.1). Pilots Flying are therefore projected to evolve into Single Pilots, thanks to improved and ready-to-perform on-board AI systems, while the Pilot Monitoring role would evolve into the **Flight Operations Ground Monitor**.
  Focusing on **Single pilots**:
    - Explainable AI-based assistants are expected to assist in:
        - Decision making, providing the necessary information and advice;
        - Autonomously handling startle responses on emerging risks by proactively analysing the ongoing occurrences;
        - Detecting potential runway excursions by predicting associated risks and providing effective solutions;
        - Detecting cases of single pilot incapacitation and taking full control of the aircraft;
        - Self-recognising cases of system inability to solve hazardous situations;
        - Transferring the needed information to the Flight Operations Ground Monitor, when needed.
    - Single Pilots are envisaged to
        - Mostly perform supervision of systems with the scope of ensuring safe operations and, thus, identifying hazardous situations;

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

- Contact the Flight Operations Ground Monitor whenever the situation requires additional support;
- Communicate with crew and manage crew wellbeing;
- Coordinate with relevant parties;
- Debrief and, when necessary, retrain AI systems.

The **Flight Operations Ground Monitor** is expected to monitor, from the ground, a number of aircraft and support Single Pilots when necessary. S/he would be supported by AI systems constantly monitoring flight operations, assessing and highlighting potential risks and hazards.

The **Flight Dispatcher** role is also envisaged to be impacted by this technological and operational trend. In fact, a progressive introduction of AI-based Intelligent Assistants to support Flight Dispatcher operations are expected:

- Timeframe 2025-2035: AI is expected to proactively gather real-time information and suggest options to planning optimised operations and handle medical emergencies;
- Timeframe 2035-2040: AI may autonomously plan and replan operations, handling the communications with the Network Manager;
- Timeframe 2040-2050: AI could perform most of the Flight Dispatcher tasks, sharing also the information between Airport Operations Center (AOC), pilots and ATC, leaving to the human actor only the collaborative decision-making, considering the pilots and the AOC perspectives.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

5.2. Future Personas

The **Single Pilot** role has been further discussed and a more detailed job profile (future persona) has been defined.

Single Pilot

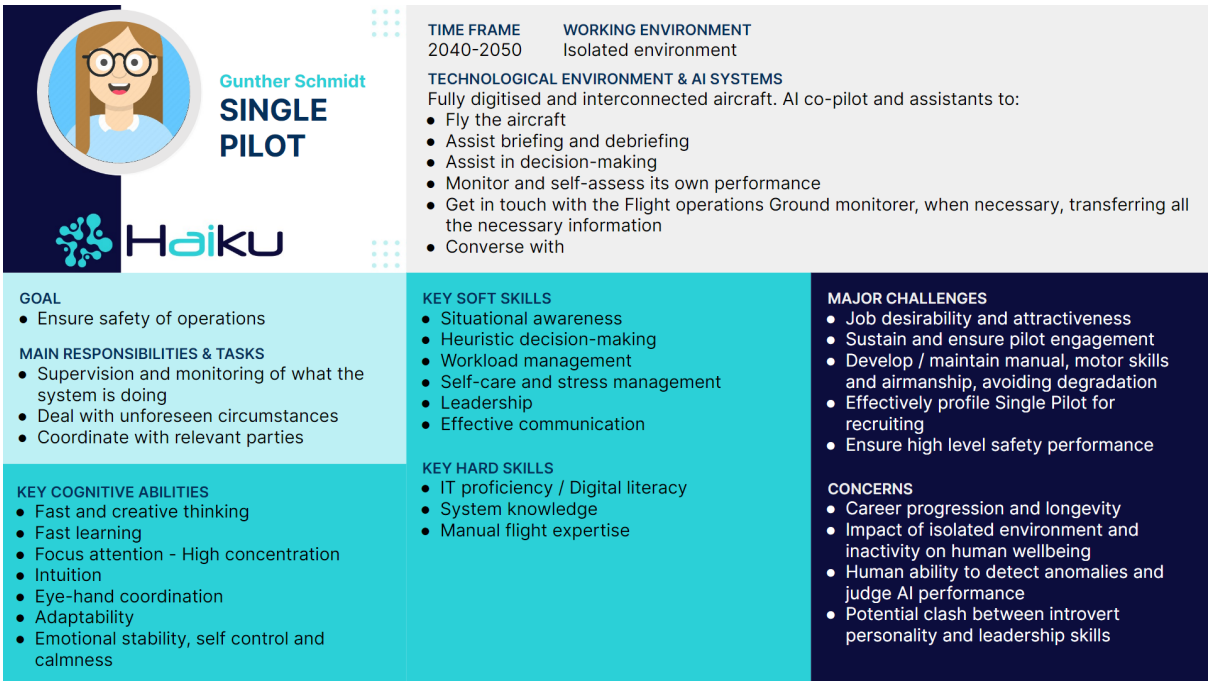

Figure 8: Single Pilot Future Persona Canvas

The **Single Pilot** is envisaged to be an evolution of the Captain Pilot Flying role. By 2040-2050, with the goal of **ensuring safe flight operations**, the Single Pilot is envisaged to work in an **isolated environment** (alone in the cockpit) operating **fully digitised and interconnected aircraft**. AI is envisaged to fly the aircraft, assist in briefing and debriefing, support decision-making, monitor and self-assess its own performance, get in touch with the Flight Operations Ground Monitor, when necessary, as well as a "digital companion" to converse with. His/her main in-flight responsibilities and tasks would be the **supervision and monitoring of what the system is doing**, **management of unforeseen circumstances** and **coordination and teaming with humans** (crew and Flight Operations Ground Monitor) and **AI systems**. The main cognitive abilities that may be required for this kind of profile are fast and **creative thinking** - to be able to think outside the box in case of failures, **fast learning**, **focused attention** and high concentration, **intuition**, **eye-hand coordination**, **adaptability**, **emotional stability** and **self-control and calmness**. Relevant soft skills could be **situational awareness**, **heuristic decision-making**, **workload management**, **self-care and stress management**, **leadership** and **effective and concise communication**. These would need to be complemented with a set of hard skills such as **IT proficiency**

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

/ digital literacy and **system knowledge**, as well as **manual flight skills** which are still expected to be key. Finally, as this future role will mostly require interactions with technological systems rather than with human operators, the Single Pilot job may be probably less attractive for people who love social interactions.
Due to the nature of the future single pilot's working environment - likely to be characterised by a sense of isolation and potential boredom, associated with long periods of monitoring and relative inactivity - challenges related to **job desirability and attractiveness** are expected, as well as concerns about **career progression** and **longevity** and **pilots' wellbeing**. As the role becomes less socially interactive, **selecting suitable personnel** becomes crucial, and **maintaining engagement** while avoiding performance degradation remains a key challenge. The introduction of new IAs to collaborate with could be a mitigation action to these challenges and concerns, for instance referring to briefing and debriefing assistants, AI-based CRM systems, "Ground pilot" avatar in the cockpit, AI assistants for communication and thought-sharing. Furthermore, Expert Single Pilots may also switch roles frequently, **alternating between Ground Monitor and Captain duties**, but only if this does not risk generating unintended effects on performance. In a similar way, rethinking IAs in a positive way - not only for crew reduction - could be instrumental to address the strong acceptance issues from pilots.
Developing and maintaining manual and motor skills as well as **airmanship** is also envisaged as a major challenge, mostly related to novices.

5.3. Selection and training: as is, gaps and potential changes

Nowadays, EASA does not provide specific requirements for commercial pilot selection but only general guidelines and prerequisites (**EASA regulation 1178/2011**). While this regulation sets the stage for becoming a pilot, the actual process of finding and selecting suitable candidates remains multifaceted and often subjective, depending on the airline, the need for hiring pilots and the people involved in the assessment of the candidate's skills and motivation. Moreover, the dynamic nature of aviation necessitates that EASA Regulation 1178/2011 is constantly updated to ensure it aligns with industry standards and needs.

Aspiring pilots undergo a **training** process that spans approximately **1.5/2 years**. The journey starts with initial training, including theoretical exams and acquiring the essential flight hours. Subsequently, once hired by the airline, further training lasting about 6 months follows, with the goal of honing the skills required for operational readiness. Once licensed, pilots must **renew their licence annually**, either through automatic renewal while working for an Airline or by undergoing a flight exam if operating independently or if unemployed. This constant renewal and reinforcement of skills ensure that pilots remain up-to-date and proficient.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Regarding pilot **selection**, the process varies from one airline to another. Some airlines heavily emphasise the Curriculum Vitae (CV), while others employ a more standardised approach. Notably, larger Airlines conduct a comprehensive assessment that includes **psycho-aptitude tests**, **interviews**, and **simulator tests**. This standardised selection profile aims to identify candidates who possess a blend of personality traits and technical skills conducive to successful piloting.
A range of attributes are sought in potential pilots. **Proficiency in English** is crucial, and a two-fold cluster of personality and knowledge factors is evaluated, including aspects such as **personal motivation** and willingness to become a pilot, and **technical knowledge** such as general aviation knowledge, aeronautical culture, basic manual flight, aircraft knowledge, physics knowledge such as aerodynamics, etc. The main personality traits required to join effectively the organisational culture are assessed mainly through the **16 Personality Factors** and the **Big Five Questionnaire** (Goldberg, 1992; Rothmann & Coetzer, 2003). The latter evaluates 5 main personality clusters such as Extraversion, Agreeableness, Conscientiousness, Neuroticism and Openness to experience. Nowadays, each cluster is important to perform effectively as a pilot, and there is no "optimal Big Five profile". Projecting to the future, these may require changes and adjustments to fit and be effective in the evolving working environment, to more effectively select in the *ideal pilot profiles*. Furthermore, cognitive abilities such as **motor coordination**, **situational awareness**, **spatial orientation**, **memory**, **concentration**, **focused attention** and **sustained attention** are fundamental.

Overall, the requested skills could be divided into two clusters:

- **Technical skills**, which include **flying the aircraft** both manually and supervising automation, **aircraft system** and **procedure knowledge**;
- **Non-technical skills**, which include **emotion regulation**, **effective communication**, **empathy**, **leadership**, **teamwork**, **workload management**, **problem solving** and **decision-making**.

It is noted that, nowadays, while technology and automation already play a significant role in modern aviation, the training and selection process **does not take into account digital literacy** per se. What is mostly requested is the **user capabilities to interact with digital systems** with the goal of having situational awareness of the aircraft state while automation is on.

Finally, **psychological well-being** is another relevant aspect that may become even more pressing in the future with pilots working alone in the cockpit. Nowadays, some airlines offer on-demand Peer-to-Peer Support Systems to sustain pilots' psychological well-being. However there are still cultural resistances, due to the prevailing stigma for psychological issues and the still present macho attitude. In fact, sharing personal and professional difficulties with the employer is not simple and inevitably comes with the fear of career repercussions. A key asset seems to be the **interaction with colleagues when flying**, where concerns, professional and personal

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

issues are shared and, sometimes, the peer-to-peer support is informally happening. Interactions in the cockpit are a key individual strategy for stress management, thus an important means to sustain pilots' psychological well-being. Projecting into the future, the shift toward SPO could mean removing an important and effective element for pilots' well-being. A special attention to this aspect should therefore be paid, also leveraging on the **AI potential for application as a tool for peer-to-peer support** or a **personal coach**.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

6. Airport

When looking at the workforce, airports are a very complex environment characterised by a large number of job roles. The technological evolution and, more specifically, the introduction of AI and more autonomous systems are expected to significantly change airports from both an operational and passenger experience perspective.

Figure 9 shows the 8 airport operational areas more likely to be impacted by technology by 2050 and highlights the human roles that are expected to be mostly affected by this change.

Figure 9: Airports' impact areas map

More details on the envisaged impact on all 8 areas are provided in the following paragraphs.

Impact area #1: Runway inspection & maintenance

Advanced technology and AI are expected to strongly impact the way operations concerning RWY, Pavement, AGL inspections and Maintenance are done. In particular:

- **Visual inspections may be conducted by autonomous drones under human supervision**: the AI-based system operating the UAS could be able to recognise any new defects and then report them filling in the Global Reporting Format;

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

- The **maintenance process**, meaning from the issue identification to the scheduling of the maintenance, may be **fully automated**;
- AI systems may be able to predict where on the runway the aircraft may land, in order to **increase the avoidance of runway incursions and excursions**, by seeking and identifying braking patterns.

In the view of this landscape, by 2050 the **Regulatory and Compliance Manager of Infrastructure** is expected to delegate some tasks to AI systems and absorb new functions, shifting more towards a more **general system and mechanical management of automation**. The evolved role would mostly be responsible for **overseeing AI operations** and **intervening when necessary overriding AI decisions and in emergency situations**. As the substance of work is expected to change, the job title may change as a result, proposing **Infrastructure Manager of Automation**.

Impact area #2: Airport Control Centre

Operation Control Centres are envisaged to be impacted by technology at different levels, shifting their core function more towards **supervision and coordination** by 2050. Projecting into an operational environment characterised by **integrated and interoperable systems** and **extensive human-AI teaming**, automatic data feed and AI supporting operational planning is envisaged, significantly reducing manual data input and enabling more accurate predictions and plans.

This would lead to the introduction of a new role: the **AI Operations Manager**. The AI Operations Manager would be responsible for effectively taking actionable data from AI systems, monitoring performance and making the final decisions, and would be supported by a revamped **Tech Support** and **Data analysts**. In this AI-powered work environment, tech support would be more focused on system improvement rather than fixing issues, whereas the Data analyst role, which is expected to massively grow going forward, would deal with the incoming data flowing into the airport systems. However, the final decision will be made by the AI Op managers, which will ensure that AI's suggestions are evaluated by a human before being implemented, so as to avoid any possibilities for airlines to game the system and exploit the AI's calculations to their advantage.

To this end, an extensive knowledge of AI systems from a technical perspective will be required and a significant change in the required skills and competencies is envisaged.

Impact area #3: Baggage Ops & Handling

The future of baggage operations and handling is foreseen to be significantly impacted by the new technologies, allowing to provide a more effective and accurate service to passengers. In fact, baggage handling, nowadays manually managed, will be **fully autonomous**. In particular:

- **Accurate baggage tracking systems** are envisaged to be in place by 2050, allowing for a significant reduction in lost and mishandled baggage;

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

- **Unmanned security digital checkpoints** and **facial recognition software** are expected to be in operation, enabling **personalised baggage delivery systems** through **Connected Autonomous Vehicles** (CAVs). This would ensure a more effective baggage collection, with a significant reduction in stolen baggage and the risk of confusing own luggage with similar ones.

The most impacted role would be the **Roving Handlers**, who will probably see some of their current tasks absorbed by Intelligent Assistants (IA) and automation.

Impact area #4: Aircraft turnaround & Apron Management

The Aircraft Turnaround and Apron Management area is one identified by the participants that could exploit an extensive usage of AI systems at all levels. In particular:

- **AI systems** are expected to **fully manage pushback operations and some turnaround operations**, such as embarkment and disembarkment, baggage load and offload. Fuelling, catering load, chocking, watering, fuelling, doors opening and closing and loosing load will still be managed by humans. Furthermore, **cleaning services** (in the airport and in the aircraft) are envisaged to be provided by **robots**. This would lead to a **consistent reduction in the ground teams members currently supporting the execution of turnaround operations**;
- **AI-powered Advanced Visual Docking Guidance Systems** (a-VDOS) are foreseen to be fully automated (Level 3B), rendering the **marshall** role unnecessary;
- **Full autonomous de-icing systems** could be in place, with an AI-powered IA aiming both at safety and sustainability of operations;
- **AI** could also support an **optimised allocation of Ground Support Equipment** (GSE).

These changes are foreseen to impact the **Aircraft Engineer** role which is expected to **strongly team up with AI** in **detecting anomalies**, **keeping humans in-the-loop** to have complementary visions and **catching what IAs may slip on**, such as minor changes to accommodate human needs (e.g., the Captain moving the seat to be more comfortable recognised by the AI as something different and, therefore, wrong).

Impact area #5: Security

With a view to improving the passengers' experience and offering a more effective, safe and security service, security checks are expected to be profoundly changed by 2050. In particular:

- **Passport control operations are envisaged to be fully automated** (Level 3B) thanks to an **improved profiling** of passengers through **biometrics**;
- Operations may be reorganised, meaning that **passport controls could be performed only at the departing airport**, such as in a “smart Schengen” scenario;

This project has received funding by the European Union’s Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

- Queues at the security checkpoints may disappear thanks to **AI-based body and baggage scanners** able to check the content of the passengers' bags before going through the gates area.

On the basis of this landscape, a **consistent reduction** in the **security staff** number together with changes in tasks and responsibilities is envisaged.

Impact area #6: Wildlife & Habitat Management

Sustainability and environmental safeguard are already key aspects for Airports. In fact, wildlife and habitat management aspects must be considered in designing the future of European Airports. For example:

- **AI** (Level 2), leveraging on **cameras**, could be able to autonomously **scan bird presence** in the Airport field;
- Connected and autonomous trimmers may be able to keep the desired level of vegetation and habitat just programming in advance the needed cycles.

This area may be under the responsibility of the already mentioned **Infrastructure Manager of Automation**, supported by an emerging role, named **Summer Operations Manager**, who will be in charge of managing summer operations, balancing demand and RWY movement with environmental targets.

Impact area #7: Customer Service

With the support of new technologies and AI, the Customer Service is expected to be strongly improved, enabling a much better customer experience. For example:

- **AI** may be used to **break down language barriers**, enabling smooth and effective communication and increasing the quality of customer service
- Each passenger may have a **personal IA** supporting his or her experience through the airport, for example, providing seamless journeys through **Augmented Reality** (AR);

This would mostly impact the **Customer Relations Manager** position, as its area of responsibility may focus on emergency situations only (e.g., first contact to help a passenger collapsing). This would be possible since most of the other current tasks performed by the Customer Relations Manager would be absorbed by AI.

Impact area #8: Cargo Handling

Cargo Operations are not envisaged to change much since training AI models for this kind of operations could be extremely challenging, due to a huge number of variables to consider (such as damaged goods, fragile goods, infinite numbers of dimensions, several different sizes and weights etc.). **Semi-automatic operations** can be envisaged by 2050 thanks to CAVs and robots performing the most boring, repetitive and laborious tasks, therefore leaving the more relevant tasks under human operator responsibility.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

7. Conclusions

This document shows the results of the outcomes of HAIKU work on future aviation workforce, highlighting the envisaged **impact of the introduction of AI systems into aviation operations on the human roles.**

Undoubtedly, new technologies and, more specifically, AI are powerful means to support aviation operators, allowing the industry to safely and effectively face the envisaged rise in traffic complexity, due to increased demand and heterogeneity in traffic (HAIKU, 2023). However, technological **evolution is expected to significantly change the human role**.
AI may gradually absorb human tasks, probably leading to a significant change in the workforce landscape in the next 30 years. In fact, some **roles** are expected to **change** (e.g. the Tower ATCO projected to evolve into the Tower Ops Manager), others to become **obsolete** (e.g. the Pilot Monitoring due to the shift towards SPO), and **new roles** may be introduced (e.g. The Air Traffic Manager, the Flight Ops Ground Monitor, and the Airport AI Operations Manager).
Overall, by 2050 the human contributions in aviation operations seem to be mostly needed for **supervising system performance and intervening in case of malfunctions, unexpected events and emergencies**, and (mostly for selected roles in the ATM&UTM domain) **strategic planning**.

In this scenario, **in-depth system and technological knowledge** and **strong and effective human-AI teaming** will be key. This leads to three main considerations:

- The future aviation workers are envisaged to work, team-up and coordinate with non-human assistants for most of their job. The human-human interface will remain, but most likely on high level coordination tasks and exceptional situations - i.e. when AI cannot find a solution. Social interactions in the workplace will happen as part of the human-AI teaming, with *less humans, more AI*. This workplace may become very attractive for people with a **strong passion for technology** and **personalities not strongly oriented towards social interactions**, similarly to the IT industry. **Leadership abilities** are envisaged to be still a key asset in future operations, especially to ensure safe and effective management of emergencies. These aspects may be relevant to define future profiling and selection criteria and requirements;
- System and technical competencies and knowledge are expected to be the core of future workforce job profiles, leading to the assumptions that the future roles would be mostly similar to nowadays **system controllers**;
- In a context in which humans are mostly expected to work on their own, the **proficiency level** to get into real operations may be definitely **higher than today**, requiring **deeper and stricter selection processes** and **methods**, as well as **more preparatory training**. For example, the shift towards SPO would

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

demand a re-evaluation of a key milestone: the transition from a First Officer to a Captain. This means that, in a Single Pilot scenario, the qualities to be an effective Captain must be shown from the beginning, and not acquired whilst performing as First Officer. Moreover, in a context in which humans are not expected to often apply their competencies and skills as technology is envisaged to perform the majority of tasks, **retaining operators' skills and competencies** at the necessary proficiency level may also require **longer**, **more extensive** and **recurring training**.

Looking at the above described future contexts through Human Factors lenses, **two major challenges and concerns** are identified. These are key aspects that should be carefully addressed to ensure a safe and attractive future for the aviation industry.

- **Workers' psychological well-being**: the 2050 workplace will be markedly different from today. Work may be carried out in increasing social isolation, due to physical separation of distributed teams and/or fewer interactions with humans and/or changes in job stability. It is also observed a tendency for jobs to become more and more complex, with more aspects to manage, in less time, with more constraints, etc... This may create **new stressors** and **problems in the detection of situations of psychological difficulty** - nowadays often identified and aided by colleagues - which should be promptly and adequately sustained and managed. Therefore, alternative solutions to ensure workers well-being and promptly detect and manage relevant cases shall be found. **Effective support programs** should be introduced, while improving **organisational cultures** to ensure people could feel free to speak up and report personal difficulties. Technology and, more specifically, AI may also help in sustaining workers' psychological well-being and detecting relevant cases.

- **Job desirability and motivation**: how do we retain the desirability of these new aviation jobs? This is a question that needs to be answered by:
    - **Understanding the main motivational drivers of new generations**: the passion for aviation no longer seems to be a key driver, while the passion for technology could be a dominant one. For instance, until a few years ago, the main motivational driver of becoming a pilot was the passion for flying, followed by financial incentives. Today, these motivational drivers seem to be changing: flying the biggest aircraft no longer seems to be an attractive driver for new generations, nor high salaries. The motivational drivers of new generations seem to be more intrinsic;
    - **Clearly identifying effective solutions to keep aviation jobs attractive and retain workforce motivation**: what could be offered to ensure attractiveness and motivation? More flexible conditions? More spare time? Would a personalised approach to staffing and people

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

management be an option? This is an important area to be further discussed and addressed by the industry.

To conclude, the potential of technology is somehow clear, while a lot of questions still need to be answered to have a clear view on the future human roles. This leads to an additional and final question: **how do we ensure that we get the right human role in this future scenario?**
HAIKU will keep working on this topic, aiming to shed some more light and provide additional insights and food for thought.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

8. References

Armstrong, J.S. (Ed.). (2001). Principles of Forecasting: A Handbook for Researchers and Practitioners. Springer US.

Belbin, R. M. (2010). Management Teams: Why They Succeed Or Fail. Butterworth-Heinemann.

EASA (2023). EASA Artificial Intelligence Roadmap 2.0: Human Centric Approach to AI in Aviation. ', European Union Aviation Safety Agency (EASA).

Goldberg, L. R. (1992). The development of markers for the Big-Five factor structure. Psychological Assessment, 4(1), 26–42. https://doi.org/10.1037/1040-3590.4.1.26

HAIKU (2023). D2.1: Vision and Scenarios.

HAIKU (2023). D3.1: Human-AI Teaming Framework and Design Document.

Holmberg, J., & Robèrt, K.-H. (2000). Backcasting - A framework for strategic planning. International Journal of Sustainable Development and World Ecology, 7, 291-308. 10.1080/13504500009470049

KAAT (2018). R1.1: Report on Occupational Analysis in Air Transport Industry.

Robinson, J. (2003). Future Subjunctive: Backcasting as Social Learning. Futures, 35, 839-856. 10.1016/S0016-3287(03)00039-9

Rothmann, S., & Coetzer, E. P. (2003, October 24). The big five personality dimensions and job performance. SA Journal of Industrial Psychology.

Tomasello, P., & Brambati, F. (2022). Bridging gaps between mental health assessment and support programs. International Conference of Aerospace Medicine Proceedings.

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Annex A - Workshop Formats and Materials

HAIKU performed 3 workshops to discuss and co-design the evolution of the human role in 2050 in ATM&UTM, Flight operations and Airport.

For **ATM&UTM and Flight operations**, the workshops followed a methodology designed to elicit valuable insights from the participants. The work was organised in two steps:

- Step 1: to co-design a comprehensive picture of the roles related to a given scenario, detailing the evolution of tasks performed by humans and AI over time for a set of roles selected by the participants (see Figure 10 for materials and scenarios);
- Step 2: starting from the roles discussed and developed in Step 1 and focusing on the picture as close as possible to the "to be", the participants were asked to further detail few of them in terms of working environment, the collaboration with new Intelligent Assistants, the goals of the evolved job role, key responsibilities, and the cognitive abilities, soft, and hard skills required to excel in the new environment. The result was what we call "future personas" (see Figure 11 for materials).

For **Airport** a different approach and methodology was applied:

- Step 1: to define the 2050 Airport workforce, highlighting the areas more likely to be impacted by the introduction of the AI (see Figure 12 for materials);
- Step 2: to further detail the level of impact (reference: EASA AI Roadmap 2.0) and highlight potential changes to the workforce (see Figure 13 for materials).

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

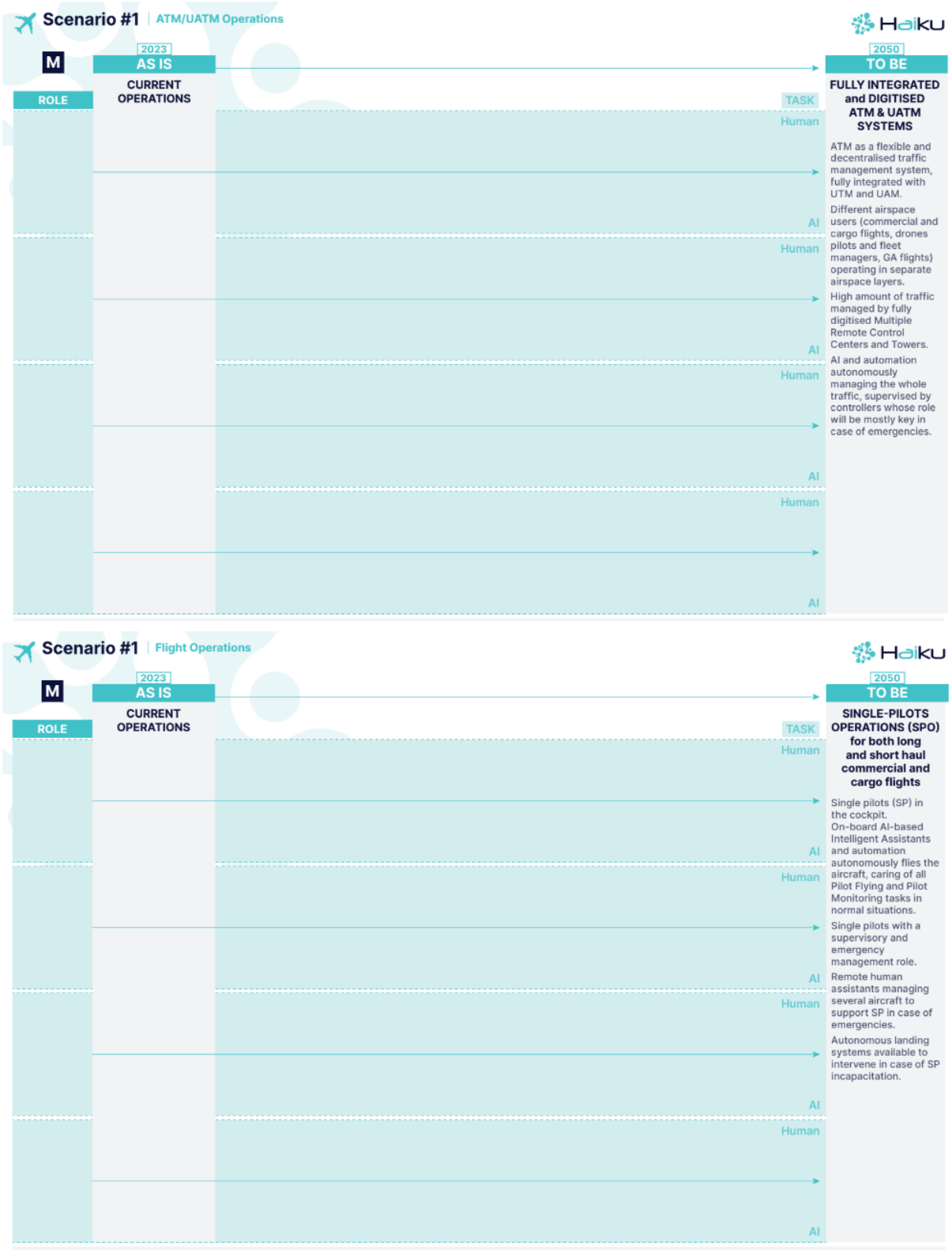

Figure 10: Step 1 Board for ATM&UTM and Flight Operations

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Figure 11: Step 2 Future personas canvas for ATM&UTM and Flight Operations

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

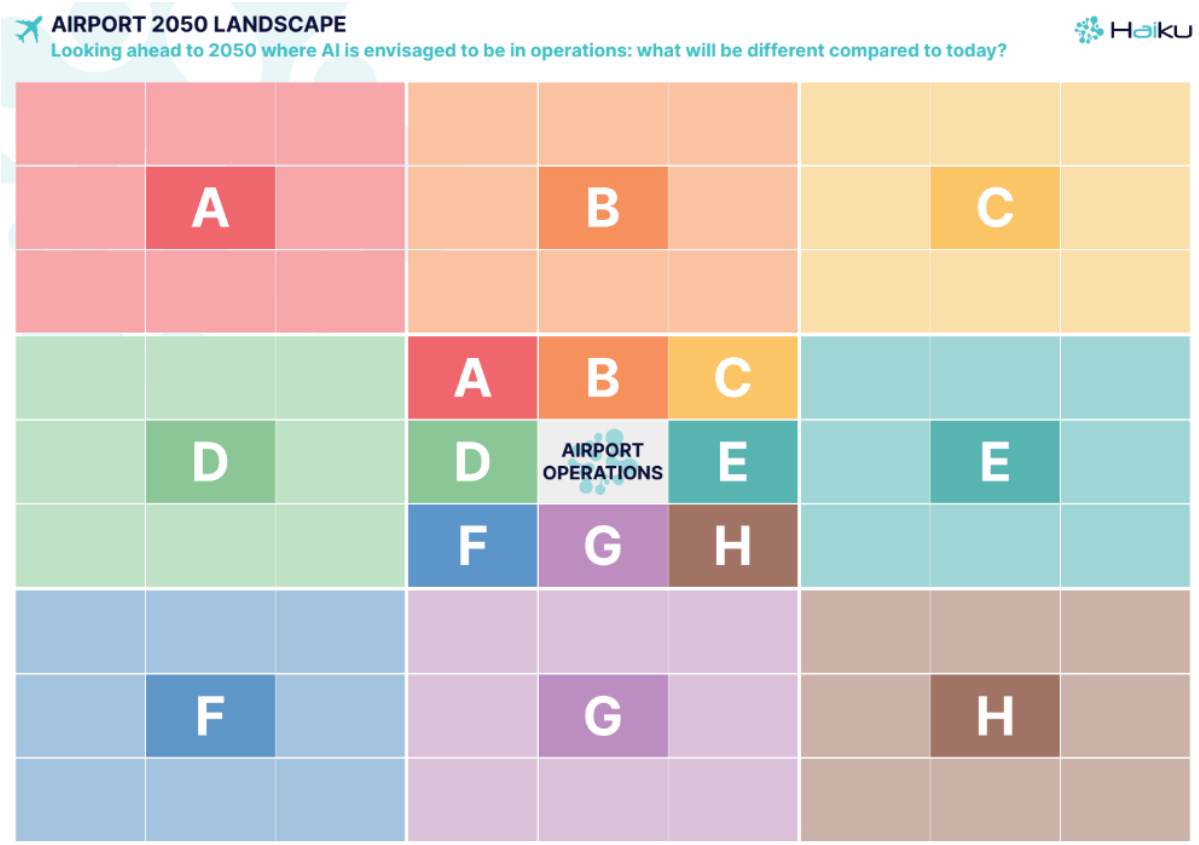

Figure 12: Step 1 Board for Airport

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

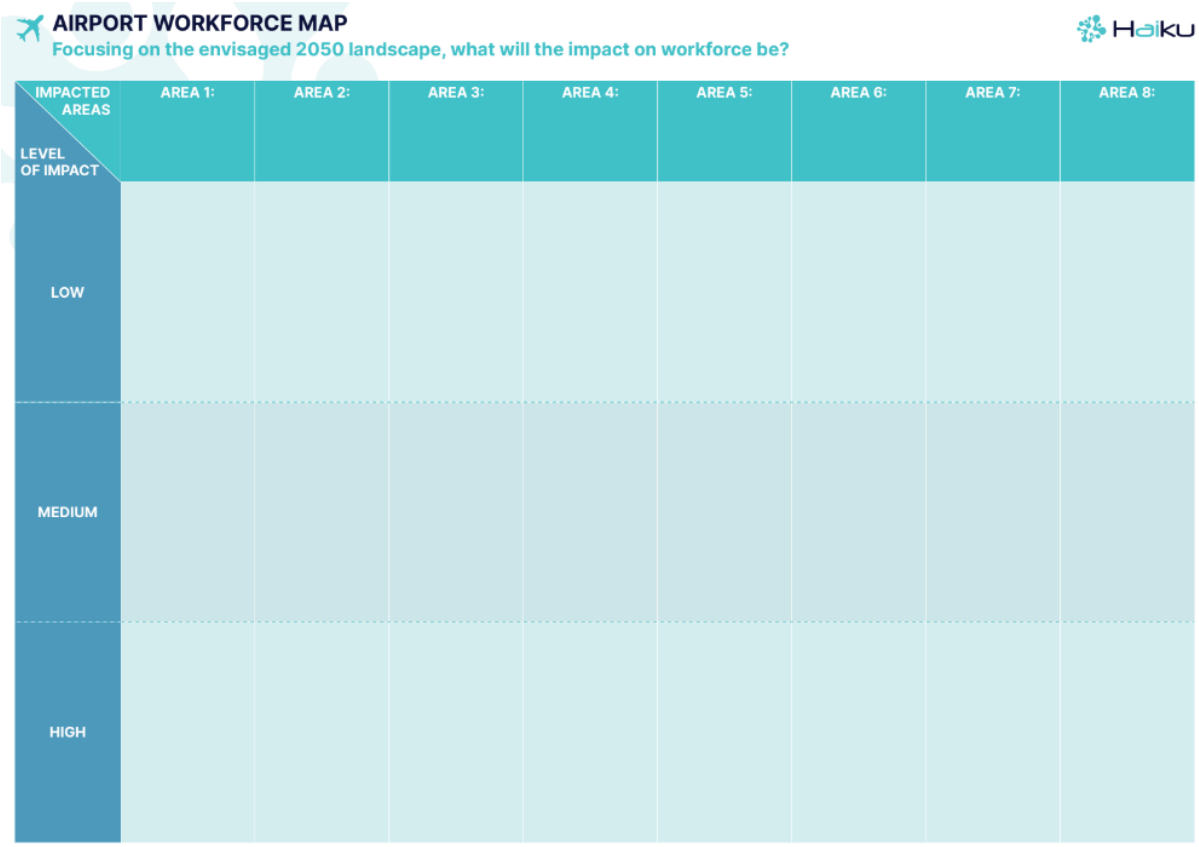

Figure 13: Step 2 Board for Airport

Figure 14: Example of Role Card used during the Future Workforce Workshop

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Annex B - Interviews Grid

Table 2: Selection and training interview grid

N.	Question
*Looking at **today...***	
Q1	What is/are the **regulation/s** of reference for ATCOs/Airline pilots/Drone pilots selection and training?
Q2	On average, **how long** does it take for a person to be trained as an ATCO/Airline pilot/Drone pilot and be ready for operations?
Q3	*Focusing on **selection**:*
	A - What are the required **tests** and **gates** to pass through?
	B - What are the requested **general requirements** (qualification, past experience, age, etc.)?
	C - Which are the **key cognitive abilities** of a good candidate? How are they assessed?
Q4	What are the **key skills** and **competencies** that are required, assessed and trained? How?
Q5	What skills and competences related to **digital literacy/human-AI interactions** are currently considered in the selection and part of curricula?
Q6	Comparing with the current operational needs, are there any **gaps/issues** in the abilities, skills and competences currently assessed and trained? Any ability, skill or competence that should be trained more?
*Looking at the **past 20 years** or so...*	
Q7	Has the selection process changed? Has the training approach of skills and competencies changed? If yes, could you please mention and explain the **3 main changes** that have been faced?
*Looking ahead to **2030/35** when we expect to have AI-based Intelligent Assistants in place...*	
Q8	From a **selection** perspective, what are the **3 main changes** that need to be faced to be ready for it?
Q9	From a **training** perspective, what are the **3 main changes** that need to be faced to be ready for it?

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Table 3: Integrative interview grid for the Future Workshop

N.	Question
High level ATM&UTM 2050 Landscape ***FULLY INTEGRATED AND DIGITISED ATM AND UTM SYSTEMS*** *ATM as a flexible and decentralised air traffic management system, fully integrated with UTM and UAM. Various airspace users (commercial and cargo flights, drone pilots and fleet managers, GA flights) operating in distinct layers of the airspace. A significant volume of traffic handled by fully digitised remote control centres and towers. Artificial intelligence and automation autonomously manage the entire traffic, overseen by controllers whose role will be crucial in case of emergencies.*	
Q1	What do you think of this **landscape**? Are there elements you would **modify** and/or **incorporate**?
Q2	Focusing on the **introduction of AI systems in operations** and the **impact** this will have on the **workforce**. In your opinion, in **which tasks** will AI provide support to **controllers**? What are the **benefits**, **challenges**, and **impact** on **roles** (existing / new)?
*During the "Future Workforce" workshop, the involved experts discussed a **Skill Degradation Point**, a point in the future where support will be so significant that novice air traffic controllers will experience a radical shift in their basic skill set. This could lead them to no longer be able to perform the operations currently carried out due to the expected increase in air traffic and the anticipated reduction in human personnel.*	
Q3	Regarding the **skill degradation point**, do you agree? In what areas and terms should action be taken to prevent or mitigate it?
Q4	Let's project ourselves into **2050** and envision the role of an Air Traffic Controller: what are the key **competences** and **skills** they should possess to perform **effectively and safely**?
Q5	To summarise what has been discussed so far, in your opinion, what are the **milestones** from now until 2050 that should mark this change?

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

Annex C - Description of the methodologies

Table 4: Methodologies used to explore the evolution of the human role

Methodology	Description
Backcasting	Backcasting is a strategic planning methodology that involves working backward from a desired future scenario to the present, identifying the necessary steps and actions required to reach that future state. It is not focused on predicting the future, but rather on designing a pathway to achieve a specific vision by determining the policies, measures, and interventions needed to realise the desired outcome (Robinson, 2003; Holmberg & Robèrt, 2000).
Forecasting	Forecasting is a method of projecting future values by analysing current trends. It begins with the present as a starting point and extrapolates future trajectories to attain a desired future outcome (Armstrong, 2001). In the context of the "Future Workforce Workshop" sessions, forecasting worked in tandem with backcasting, offering a holistic insight into both the existing state and potential future advancements.
KAAT Competencies Framework for the Aviation Sector	The KAAT project competencies framework in the aviation sector served as a unified foundation for recognizing and categorising essential competences, skills, and tasks across different roles within aviation. With a structure comprising eight distinct categories, this framework encompassed a range of both cross-cutting and occupation-specific proficiencies. Each category included multiple competences that were derived from occupation-driven demands and subsequently validated by stakeholders and project partners involved in the KAAT initiative (KAAT, 2018). Leveraging this framework, the HAIKU project effectively pinpointed novel skill requirements for the 2050 scenarios, which were utilized as aspirational benchmarks in both the backcasting and forecasting methodologies.
HAIKU Human-AI Teaming Framework	The HAIKU project employed the Human-AI Teaming framework, which was crafted in preceding stages of the project and drew inspiration from Belbin's team roles (Belbin, 2010). This framework was utilised in collaboration with domain experts through workshop sessions. Its primary objective was to delineate distinct profiles for AI-based Intelligent Assistants (IA) based on their specific capabilities – whether in terms of analysis,

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332

	management, on-demand actions, or proactive responses. This endeavour led to the establishment of six distinct IA profiles, namely Observers, Informers, Secretaries, Coordinators, Rescuers, and Executors. These profiles served as labels for forthcoming intelligent assistants, shedding light on the operational landscape that the future workforce would engage with.
EASA Level of Impact of AI	The EASA Level of Impact of AI played a pivotal role in comprehending the degrees of AI involvement in operational contexts. This framework was structured into three distinct categories, each delineating a specific role of AI within operations. At Level 1, AI primarily provided assistance to human operators. Level 2 marked the domain of human-AI teaming, signifying collaborative interactions. Meanwhile, Level 3 denoted advanced automation, where AI takes on more autonomous responsibilities (EASA, 2023).

This project has received funding by the European Union's Horizon Europe research and innovation programme HORIZON-CL5-2021-D6-01-13 under Grant Agreement no 101075332