



Deliverable 8.2.

The transformation map

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Abstract:

This deliverable 8.2 documents the activities and the results achieved within HAIKU Task 8.4 *“Support skilling/upskilling/reskilling processes: the transformation map”*. It presents the definition of possible training paths, with the aim of “bridging the gap” between the baseline competence/skills profile of the user and the required competencies and skill set of the specific professional profile, considering the inputs provided by T8.1, T8.3 and the HAIKU Use Cases #1, #2, #3 and #4. The following document provides a description of the main components of the future training pathways towards highly automated and AI-based systems, answering the three fundamental questions of *Who to train?*, *What to train?* and *How to train?*.

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List of Acronyms

Acronym	Definition
AI	Artificial Intelligence
ATM	Air Traffic Management
CRM	Crew Resource Management
DX.x	Deliverable X.x
EASA	European Aviation Safety Agency
FFM	Five-factor-model
HAT	Human-AI-teaming
IA	Intelligent Assistant
RJP	Realistic Job Preview
SHELL	Software Hardware Environment Liveware Liveware
SPIC	Single pilot in cruise
SPO	Single pilot operation
TX.x	Task X.x

Executive summary

Deliverable 8.2. reports on the work performed in Task 8.4 of the HAIKU project, focusing on the **training pathways** towards a future where **AI-based Intelligent Assistants** will be in place in the cockpit. To achieve this, four use cases (UC#1: "startling and surprising events in the cockpit"; UC#2: "flight deck route planning/replanning"; UC#3: "urban air mobility"; UC#4: "digital and remote towers") were investigated to define the required future skills and the training methods for Pilots, Air Traffic Controllers and the envisaged new role of UAM coordinators. The document will describe the sequential approach used to explore the interactions of these roles from current times projected to 2035, presenting the results of both the workshops on the future skills within the use cases and the semi-structured interviews held with instructors.

The main findings will be presented in three macro areas:

- **Who to train?** Regarding the Big Five personality traits, in addition to emotional stability and conscientiousness, future professionals within aviation may require lower extraversion and higher openness to experience to adapt to social isolation and AI integration, as teaming up with AI-based intelligent assistants will necessarily result in less human interaction in everyday work.
- **What to train?** An updated Crew Resource Management (AI-CRM) training programme is recommended, incorporating aspects of interaction with AI-based intelligent assistants. AI CRM training would address skill gaps and provide targeted training for the aforementioned future roles on transversal skills related to the interaction and management of humans and Intelligent Assistants (IAs). Essential skills include stress management, coordination, decision-making, technical knowledge on AI, and manual control proficiency.
- **How to train?** The envisaged future scenarios will not only require modifications on the content of future training, but also the way these skills can be best trained. As an unexploited potential, we emphasise the importance of learning by sharing knowledge and know-how through facilitated group sessions, following the Socialization, Externalization, Combination, and Internalization (SECI) model (Nonaka & Takeuchi, 1995). With the introduction of AI as a teammate in aviation domain a great amount of new know-how is expected to be accumulated which - if managed effectively- could have important added value to the content of training in the future. Finally, recommendations on supervising training instructors are provided to further improve training efficiency.

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1. Introduction

The main purpose of this document is to present the activities and results achieved within HAIKU Tasks 8.4. "Support skilling/upskilling/reskilling processes: the transformation map".

Introducing Artificial Intelligence (AI) into commercial air transport operation is expected to remarkably impact future roles by 2035. This document describes the potential transformation of the role of pilots, air traffic controllers and UAM coordinators in terms of personality traits and skill set needed today and in the future, as well as it provides recommendations on recruitment techniques to ensure a sufficient pool of candidates for selection. Based on the results of the research conducted within T8.4. modifications related to the content of CRM training are also suggested. Finally, as future changes will likely result in the accumulation of new knowledge, procedures and know-how, a proactive strategy to collect, manage, store, and share knowledge within the aviation industry is recommended.

The document is structured as follows:

- Section 1 introduces the document.
- Section 2 shows the methodology adopted to achieve Task 8.4.
- Section 3 deals with the results gathered from the workshops and interview.
- Section 4 addresses the key takeaways and the lessons learned from the task.
- Finally, section 5 presents the conclusions from the researchers involved in the task.

2. Introduction to methodology

To go beyond the empirical results introduced in D.8.1, the current methodological approach placed a special importance on the specificity of the contexts in which future skills and competences were explored. To reach this goal:

- only the shorter time interval of 2023 to 2035 was considered.
- envisioned tasks and activities were specifically tailored to HAIKU Use Cases 1, 2, 3 and 4.

HAIKU took a sequential approach in data collection:

- During a workshop with relevant stakeholders (representatives of the use cases, pilots, air traffic controllers and other subject matter experts), participants were asked to systematically reflect on the interactions and practices that pilots, air traffic controllers and UAM coordinators need to engage in today and/or in the future of 2035.
- Based on this, in cases of pilots and air traffic controllers, a gap analysis was performed reflecting on the discrepancies between the skill set for today's and the future's scenario, resulting in a modified set of competences for the future.
- Finally, potential training paths were identified according to the future skill set, and recommendations were provided on the content and format of future training. (see Figure 1.)

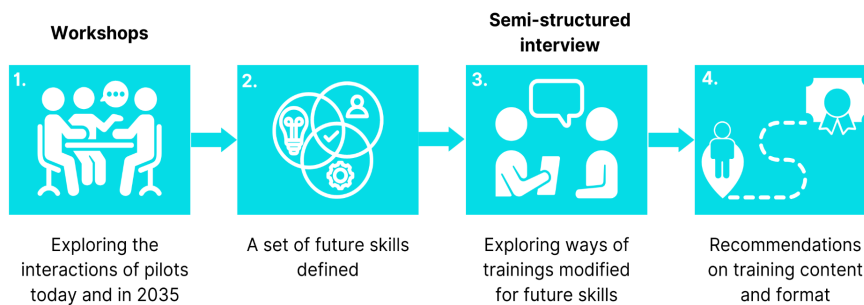


Figure 1: Sequential approach in data collection

2.1. Future scenarios

UC#1: The FOCUS (“Flight Operations Companion for Unexpected Situations”) AI-based assistant aims to support pilots during ***startling and surprising events in the cockpit***. These events sometimes provoke “freeze” reactions, delay in response time or inappropriate cockpit inputs and can lead to accidents. Startle refers to a stress response to a sudden intense stimulus, whereas surprise is a cognitive and emotional reaction that results from the mismatch between pilot’s expectations and reality. As they have an interactive negative effect on performance, they may seriously impair a pilot’s ability of troubleshooting and immediate procedural actions (Piras et al., 2023). To tackle this, FOCUS will offer real-time assistance to commercial pilots, detecting startle events, helping them regain emotional stability and situation awareness.

UC#2: The IA aims to assist pilots in ***route planning/replanning (“Flight deck route planning/replanning”)***. Replanned routes result from new constraints and different hazards, such as weather changes that prevent pilots from landing at their originally targeted airport. Re-planning a route, although made on the basis of previously defined alternative routes, requires pilots to adapt to changing circumstances and take decisions in a timely and effective manner. The IA developed in UC#2 will support pilots during the flight by providing the means of translating pilots’ high-level intentions to technical parameters of the IA. Similarly, the information feedback from the system is presented in a manner that allows the pilot to understand the system’s response (haikuproject.eu), thus enabling a shared understanding of the mission.

UC#3: The ***Digital Assistant for UAM Coordinator (DUC)*** monitors UAM operations, ground events, and city social life. In high complexity socio-technical systems emergency events may evolve very quickly with potentially serious consequences. Therefore, the adaptation of human operators to complex traffic or even emergency situations in an effective and timely manner will be one key to operational safety. The digital assistant (DUC) is envisaged to support the Human UAM Coordinator in day-to-day operations (both planning and execution), handling standard tasks and providing assistance during emergencies like in-flight medical incidents. With real-time capabilities, the DUC reduces the workload of the Human UAM Coordinator, enabling them to focus on high-level strategic decision-making. This collaboration optimises operational efficiency, enhances safety, and ensures effective oversight of UAM activities. By streamlining operations and freeing up valuable time, DUC significantly contributes to the smooth coordination of UAM operations in the urban environment.

UC#4: ***ISA (“Intelligent Sequence Assistant”)*** aims to support and enhance decision-making for Air Traffic Controllers. ISA optimises runway utilisation in

single-runway airports, providing real-time sequence suggestions for arriving and departing aircraft. The real-time assistance provided by ISA ensures timely and accurate forecast updates, allowing Tower ATCOs to manage traffic flow more effectively. The expected benefits would be improved decision-making, enhanced runway utilisation, increased operational efficiency, and a safer and more streamlined air traffic management system. Similarly to Use Case #1 and Use Case #2, the SHELL methodology was applied to understand the likely changes in the future skills of air traffic controllers, and to reason on personality traits and training paths.

2.2. Workshops

As the first step, two workshops for **Use Case 1 and 2** were conducted (Toulouse, France, December 4th, 2023) to explore interactions **pilots** need to engage in for specific scenarios (startle/surprise; route planning/re-planning), both today (2023) and in 2035. Interaction here was defined as a reciprocal action between on the one hand, the pilot and other hand, other human actors, rules, procedures and regulations, the technical system, and the physical requirement. The SHELL model (Edwards, 1972; Hawkins, 1993) was used to systematically define all possible interactions between pilots and their environment.

Workshops for UC#1 and UC#2 were running parallel, with 4 participants involved in each session. Participants were, on the one hand, representatives of the Use Cases, on the other hand, professional pilots of European commercial airlines. The duration of the workshops was 2,5 hours. To ensure that all the important inputs were registered, each session was managed by two facilitators, and key conversations were audio recorded. Based on the SHELL framework, potential elements of interactions were explored between (see in Annex, Figure 7 and 9):

The pilot (L) and Liveware (L): e.g. cockpit crew, cabin crew, ground crew, management, and administration personnel.

The pilot (L) and Software (S): laws, rules, regulations, instructions, policies, orders, SOPs, safety procedures.

The pilot and Hardware (H): physical elements of the system (e.g. controls, surfaces, displays of the aircraft; operator equipment, tools, materials, buildings, vehicles, computers, etc.).

The pilot and Environment (E): the context in which humans operate the system (e.g. cabin/cockpit temperature, air pressure, humidity, noise, vibration and ambient light levels, weather conditions, visibility, turbulence, etc.). This aspect was defined by the participants of the workshop.

Participants were first asked to identify today's elements of interactions, then they were asked to perform the same procedure with the same scenario, but referring to 2035, once IA is in operation. By using sticky notes, participants were invited to write each

identified interaction element on a sticky note and place it on a sheet (printed in A0) that depicted the SHELL framework (Figure 8.). They were then asked to place the same interaction elements on a timeline too (see in Annex Figure 10.), in order to visualise the chronology and relatedness of interactions. Based on the two SHELL boards (Figure 9.), a gap analysis was performed, identifying areas of major changes in interactions in the future. Having these major changes in mind, a set of new skills that would be required by pilots to successfully engage in those future interactions was defined.

For **UC#3**, a workshop was held on the 20th of May 2024 in Linköping, Sweden, to identify the most important characteristics and related competences of the future role of **UAM coordinator**. The intelligent assistant "DUC" ("Digital assistant for UAM Coordinator") required a distinct workshop methodology to reflect the unique nature of Urban Air Mobility (UAM) operations. Unlike Use Cases 1 and 2 (which focus on adapting existing commercial aviation roles to evolving ones due to the introduction of AI-powered tools) Use Case 3 focuses on defining the entirely new role of a UAM Coordinator. This role, assisted by the AI-powered Intelligent Assistant known as DUC, involves monitoring and managing UAM operations that have no direct historical precedent. Given this context, a dedicated methodology was developed to explore and define the future skill requirements for the DUC role and its coordination with human operators.

The workshop methodology combined a foresight-driven, human-centred approach to uncover and shape the skills needed over the next decade. Participants engaged in structured, scenario-based exercises - low-traffic and high-traffic situations - designed to reveal critical competencies and interactions between the UAS/UAM operator and the DUC. Each group mapped operational actions on a timeline to visualize the coordination and communication flows essential for responding to emergent situations. This exercise involved detailing task distribution, actor roles, and the specific collaboration mechanisms between the operator and the DUC in both scenarios.

In the Low Traffic Scenario, participants worked through a series of incidents starting at 9:00, including the unexpected closure of a vertiport and a missing air taxi requiring no-fly zones to be established. By 9:30, an operator requested diversion due to worsening weather conditions, prompting discussions around DUC's support in emergency decision-making. In the High Traffic Scenario, which began at 10:30, complex demands quickly escalated: diversions, flight plan adjustments, and an airspace restriction due to a fire in Slussen led to capacity limits being exceeded by 11:00. Each scenario underscored unique operational dynamics, focusing on task allocation, situational awareness, and rapid decision-making skills essential to UAM contexts.

Following these scenario exercises, participants analysed current Air Traffic Control skills applicable to UAM coordination and identified emerging competencies necessary for effective human-AI teamwork with the DUC. This two-part workshop approach highlighted the operational, technical, and communication skills foundational to

successful UAM coordination, providing a framework for future training and skill development specific to this groundbreaking role.

Finally, for UC#4, there was a workshop held in Madrid, Spain, on the 19th of June 2024, to explore the future role of **air traffic controllers** in an envisioned future scenario where ISA is introduced in real operation and used in its full capacity to reduce workload, support decision making and enhance operational safety. The objectives, content as well as the structure of this workshop was identical to the workshop for UC#1 and UC#2): participants were asked to reflect on the interactions between ATCOs (L) and other elements of their task (Environment, Software and Liveware) focusing on today, and repeat the same activity by focusing on an envisioned future of 2035 and onwards. Participants were introduced to the following hypothetical scenario:

"We are at Alicante Airport on a busy summer day, with 413 flights scheduled from across Europe. In the next 15 minutes, 19 arrivals and departures are expected to use the runway. After 5 minutes of regular but busy sequencing, an incoming aircraft (BAW412) suddenly accelerates while on final approach. The Tower ATCO is forced to rethink the original sequence to accommodate this unexpected scenario."

Based on the differences between the interactions of today and the future, a gap analysis was performed and changes in future required competences were identified.

2.3. Semi-structured interview

As a supplemental step for UC#1, UC#2 and UC#4, semi-structured interviews were conducted to deep dive into the key aspects of the SHELL workshop results, as well as to reflect on required modifications in training content and format, in order to align with the envisaged future changes. The interview sessions were built around the following main questions:

Having a vision of how the tasks related to this role will change by 2035, how do you envision key skills and competencies to change accordingly?

- *What kind of new skills are likely to emerge?*
- *What kind of skills are likely to become less relevant?*
- *How will the already existing skills be modified in terms of meaning/content (e.g. communication skills - with human/with AI)?*

How do you think current training should be changed in order to cover this modified set of skills and competencies?

How do you think recruitment strategy would change? To whom do you think the future role of teaming up with AI will be attractive? What kind of future trends (challenges, opportunities) do you foresee in recruitment strategy?

How do you think the requirements and key criteria related to future personnel selection should change according to the results of your gap analysis and the introduction of the intelligent assistant?

How do you think the general knowledge management will be impacted by the introduction of the intelligent assistant? How is the knowledge required by pilots/ATCOs is collected, stored and shared today? How do you think the new knowledge that is generated could be best collected, stored and shared in the future? How (in what way, through what means and channels, what format) do pilots/ATCOs acquire their core competences today? How do you think it will change in the future?

Finally, combining the results of the interview with the outcomes of the previous steps, recommendations on the targets, the content and the format of future training were formulated.

3. Results

3.1. Introduction to the main results

Although approached with a sequential research design, results of the data collection were defined and summarised iteratively. Based on our data synthesis, the following topics were recurrently addressed, thus seeming to be playing a key role when considering future skills in aviation.

First, **personal characteristics** of future professionals appear to be an important topic to be addressed. As technical and social aspects of the future work environment are anticipated to change, some personality traits that prove to be important predictors of standard performance today might not be so significant in the future. Some might even impair human performance in an environment where an IA operates, while other aspects of personality may become more relevant in the future than they are today. Defining the required characteristics of future roles could effectively support the aviation industry in building a successful recruitment strategy, increase success rate in selecting students, thus saving costs by decreasing their drop-out-rate. Most importantly, a correct match between personality traits and the working environment (Person-Job Fit) would contribute to human performance and therefore, operation safety in a remarkable way.

As envisaged future changes focus on the introduction of AI in operation, once selected effectively, future professionals in the aviation sector are expected to acquire a variety of **new technical and non-technical skills** related to collaborating with AI-based assistants. In the anticipated future, AI is no longer expected to be solely a decision aid but a full-fledged team member in the cockpit as well as on the ground. Human-AI Teaming will likely take a form where all actors will need to adapt to the needs and characteristics of their teammate. AI on the one hand, will be expected to adapt to human members of the teams they are to form. On the other hand, human team members will likely need to learn or adapt their soft and hard skills by adjusting them to the dynamics of a team in which humans and automated systems collaborate in an active and efficient manner. As a reference framework, traditional Crew Resource Management (CRM) and Team Resource Management (TRM) could be modified and systematically extended in order to cover aspects of collaboration with an AI-based system.

Finally, **future training** on technical and non-technical skills are expected to be re-considered in order to maximise training transfer efficiency and the successful application of the acquired skills in actual operation. Training of the future would not only be modified in content: new forms of learning and specific support for instructors are envisaged to be introduced in order to keep up with the requirements of the changes.

Based on the above-mentioned recurrent topics discovered, results of the data collection are grouped and built around three major questions regarding the future (Figure 2), namely:

- Who to train? - personality traits of future professionals
- What to train? - new skills for the future and the concept of AI-CRM/TRM
- How to train? - recommendations on training and knowledge sharing

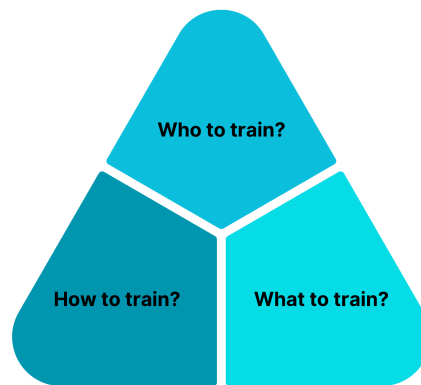


Figure 2: Areas of recommendations on future skills & training

3.2. Who to train: personality traits today and in the future

Personality is defined as a unique set of predispositions for a person to respond in particular ways. Personality permits a prediction of what a person will most likely do in a given situation. These trait characteristics, being relatively stable over time, lead people to behave in more or less distinctive and consistent ways across situations. As personality plays a key role in how individuals react to different situations, the personality of an aviator is very likely to have its own impact on how a pilot approaches different scenarios, including more demanding ones (Fitzgibbons et al., 2004; Ganesh & Joseph, 2005).

The most commonly used personality index in assessing personality is the **Five-Factor-Model (FFM)** which consists of five major personality dimensions, often referred to as the “Big Five” of personality (McCrae, 2009). It includes the following factors: Openness to experience (O); Conscientiousness (C); Extraversion (E); Agreeableness (A); Neuroticism (N).

- **Openness to experience** is defined as the degree of receptivity to a range of internal/external sources of information and new inputs.

- **Conscientiousness** is defined as the amount of persistence, organisation, and motivation in goal-directed behaviours.
- **Extroversion** refers to the amount of energy someone directs outwards to the external environment.
- **Agreeableness** is considered as the quality of one's interpersonal interactions along a continuum from compassion to hostility.
- **Neuroticism** is defined as the one's propensity to experience negative emotions, such as anxiety or depression (Fitzgibbons et al., 2004; Chaparro et al., 2020).

The most relevant behavioural indicators related to each of the five factors are presented in Table 1.

Factors of the FFM	Individuals scoring high on this dimension tend to...	Individuals scoring low on this dimension tend to...
Openness to experience	<ul style="list-style-type: none"> • be more receptive to a range of new input and information. • seek and appreciate new experiences. • be original, imaginative, and curious. • be more interested in learning 	<ul style="list-style-type: none"> • be more unimaginative • be more resistant-to-change • be more conforming
Conscientiousness	<ul style="list-style-type: none"> • be more thorough and careful • be more ambitious and hardworking • be more self-disciplined and responsible 	<ul style="list-style-type: none"> • be careless • be more disorganised • be more weak-willed
Extraversion	<ul style="list-style-type: none"> • be more energetic and outgoing • be warm and talkative • seek the company of others • need more external stimulation 	<ul style="list-style-type: none"> • feel more comfortable being alone • need quiet to concentrate • prefer working alone rather than in group • get quickly overwhelmed by social stimulation
Agreeableness	<ul style="list-style-type: none"> • be more cooperative and flexible • be more tolerant towards others • be more friendly and prosocial • build trust easily 	<ul style="list-style-type: none"> • be more sceptic • be more uncooperative • be more indifferent in their social environment
Neuroticism	<ul style="list-style-type: none"> • feel more insecure • be psychologically unstable • give strong reaction to perceived threats • have trouble dealing with stress • have negative thoughts and feelings 	<ul style="list-style-type: none"> • be more rational • be able to stay calm • be more optimistic • manage stress easily • be resilient • be less likely to give strong reaction to stress

Table 1: Behavioural indicators of factors in the Five-Factor-Model (FFM) (Fitzgibbons et al., 2004; Breuer et al., 2023; Chaparro et al., 2020)

3.2.1. Pilots' personality traits today

While psychomotor skills and cognitive abilities have long been commonly employed in pilot selection, personality assessment as a means of predicting one's aptitude has gained incremental validity more recently (Breuer et al., 2023). Although there is an ongoing controversy of whether there is a unique combination of characteristics that make up the "ideal pilot", **certain personality traits such as being emotionally stable, conscientious, agreeable, and extroverted have been identified as crucial** for training success and later job performance.

When it comes to assessing these personality traits in aviation, the majority of studies show that pilots, compared to the general population, score lower on *Neuroticism*, indicating a profile with more balance and emotional stability. This could be due to the need to be less reactive to stress in an industry which is by nature a high stakes/high stress environment. With respect to *Extraversion*, empirical data suggests that the pilot population has higher levels of *Extraversion* compared to the general population. Sociability is typically an important characteristic in commercial aviation, where pilots perform their tasks in a team context. Apart from communicating over the radio, they need to socialise with their fellow pilot and cabin crew (for passenger aircraft) with whom they can be confined for several hours during operations. *Openness to experience* is a personality trait that does not seem to differentiate between pilots and general population, as both tend to score equivalent on this scale. A possible explanation lies in the nature of the aviation industry: as the job of pilots is highly procedural, there may be less need for a pilot to be creative, adaptive, and receptive to changes. With respect to *Agreeableness*, pilots in general tend to be less agreeable than the general population, however, in the case of commercial pilots, results are mixed (compared to military pilots and pilots-in-training). This again might result from their higher need to effectively work in a team context where the ability to build trust quickly in a constantly changing crew is crucial. In the case of *Conscientiousness*, the pilot population appears to trend somewhat higher than the general population, however, this tends to be less of a pattern in case of pilots-in-training, presumably due to their age, compared to professional pilots in commercial aviation or in the military (Chaparro, et al., 2020). While in comparison with professional pilots, pilots-in-training seemed to score somewhat lower on *Conscientiousness*, a meta-analysis found this personality trait to be a significant positive predictor of training success, along with low levels of *Neuroticism*. In other words, student pilots, reporting high levels of *Conscientiousness* and low levels of *Neuroticism* appeared to have slightly better chances of passing their flight training successfully (Breuer et al., 2023).

In summary, today's operational context in aviation may require pilots to be emotionally stable, extroverted, agreeable, and conscientious with less importance given to being open to experience.

3.2.2. Pilots' personality traits in the future

Long-term changes in the aviation industry, on the other hand, are envisaged to bring significant changes in pilots' job context in terms of who they will team-up with in the cockpit. Pilots are foreseen to be gradually accompanied by AI, and this is a change that may redefine the typical personality traits of future pilots.

One important aspect of this anticipated change is related to the **social isolation of future pilots**, as already presented in D8.1. (HAIKU, D8.1.). Pilots are expected to have significantly fewer human interactions, exposing them to potential boredom and loneliness in the cockpit. The reduced number of social interactions may favour those who need less external and social stimulus, feel comfortable working alone and may be more indifferent to their direct social environment. In addition, being isolated in the cockpit may require future pilots to be even more stable emotionally, as direct social support in stress management will be reduced and pilots may need to have an even better ability to self-regulate their own emotions and anxiety.

Another important aspect of future change will be **pilots' willingness and efficiency to team up with AI**. General attitudes towards the use of AI may have a significant impact on the skilling, up-skilling and reskilling of professionals in the aviation industry. Therefore, it may be worthwhile to further investigate whether certain personality traits have the potential to predict these attitudes. As individuals who score high on *Openness to experience* tend to be more innovative and open to new experiences, pilots with higher scores on this scale may exhibit more positive attitudes and acceptance towards teaming up with AI and switching to new technologies, along with a willingness to enrol in new training that these changes require (Sindermann et al., 2022). Similarly, it might be reasonable to think that a higher level of *Agreeableness* could be linked to more positive attitudes towards the acceptance of AI. As empirical data shows, individuals who score higher on *Agreeableness* tend to be less sceptical and more tolerant towards the negative aspects of AI (Kaya et al., 2024).

All in all, envisaged changes in future operational context may require future pilots to possess a slightly different personality profile compared to the traits they tend to have today. ***In the future, an even higher emotional stability and lower level of Extraversion may be required from pilots to be able to cope with reduced human interactions and social isolation, while a higher level of Openness to experience and Agreeableness may be needed to develop positive attitudes towards the use of AI that might affect success in skilling, up-skilling and reskilling.***

Personality assessment will most probably continue to play a vital role when it comes to selecting pilots. Considering the high cost of dropouts and substandard performance, a valid and meticulously designed testing of personality traits that takes major future changes into consideration may be vital.

3.2.3. Air traffic controllers personality traits today

When it comes to the safe operation provided by air traffic controllers, non-cognitive skills, especially the ones related to personality seem to play a crucial part in their job

performance. Focusing specifically to the sample of students, air traffic controller trainees were found to express **more positive emotions** than the general population. Moreover, they were found to have a higher level of **Extroversion, Openness to experience** and **Conscientiousness** and **lower level of Neuroticism** compared to the general population (Schroeder et al., 1993). According to another study, students who were higher on anger and anxiety scores were significantly more likely to fail as professional controllers, indicating that **emotional stability and emotional regulation** are crucial for the successful operation of air traffic controllers (Nye, Collins, 2018).

The above-mentioned empirical results seem to be creating an image of air traffic controllers' personality profile that is in line with the ones of pilots. Since they work in a team environment, and **need to communicate frequently and efficiently**, a high level of Extroversion and Agreeableness can support and enable air traffic controllers to effectively interact with other actors of their working environments. In addition, similarly to the case of pilots, ATM is a technologically dominated field which requires air traffic controllers to have a **generally open and receptive mindset to changes and technological advancements** related to their job. Having a higher level of Openness to experience is therefore needed for them to have a more optimistic, positive attitude to anything new they might need to learn as a response to new technologies. Besides the need for openness, it is well-known fact that the profession of an ATC controller is entrusted with an **enormous amount of responsibility** where decisions affect the safety of pilots, crews and passengers (Suresh et al., 2012). Therefore, scoring high on the factor of Conscientiousness is a crucial pre-requisite of high job performance. Last but not least, air traffic controllers usually work under very high workload and time pressure, which requires them to be able to regulate their emotions, stay stable and composed in situations where there is high workload. Strongly related to that, it is important to underline that **stressful and high workload periods are not always predictable**. As one of the workshop participants expressed: *"you never know at the beginning of your shift if this day will be an easy or a difficult one."* Therefore, scoring high on Emotional stability is another important personality profile that ensures smooth and safe operation in ATM.

3.2.4. Air traffic controllers personality traits in the future

Similarly to what has been discussed in the case of pilots, air traffic controllers are also foreseen to be gradually accompanied by AI, and this is a change that may redefine their typical personality traits in the future. First of all, as ISA is envisaged to take over the majority of tasks related to communication, the frequency and need for being engaged in human-human interactions will drastically drop in the future. Therefore, the need for future professionals to score high in **Extroversion will most probably not be as crucial as it is today**. On the other hand, when it comes to emergency situations, human controllers and voice communication are still foreseen to play an important role. As emergency situations are characterized by high tension, stress and unpredictability for all the actors involved, being friendly, optimistic, tolerant and flexible are very important to effectively handle conflicts related to an emergency. Therefore, **future**

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ATCOs who score high on Agreeableness are anticipated to be more capable of handling future emergency situations than controllers who score lower on this scale. Furthermore, as the anticipated changes in the future will be based on ground-breaking technological developments and the introduction of an AI-based assistant in operation, future air traffic controllers will need to stay open, receptive and have generally positive attitudes towards change. Therefore, **Openness to experience is foreseen as a personality trait that will remain crucial in the future** personnel selection, job performance and potential re-skilling processes. When it comes to the Conscientiousness of future air traffic controllers, being fit for job and feeling responsible for one's day-do-day task is still envisioned to be crucial in the future, therefore, **scoring high on Conscientiousness is envisaged to be another important aspect of the future profile**. On the other hand, it inevitably raises the questions of liability related to artificial intelligence, and therefore, calls for precise clarification of future responsibilities within a human-Ai team. Last but not least, as introduced later in chapter 3.3.3., future air traffic controllers are foreseen to be relieved from the majority of workload by the introduction of the AI-based assistant, however, **new types of stressors are envisaged to emerge**. These will most likely be related to potential emergency situations, the collaboration with their AI-based teammate, the potential feeling of being kept out of the loop, and the potential fear related to AI complacency. Therefore, it is anticipated that **scoring high on Emotional stability** will stay a crucial part of future air traffic controllers personality profile.

3.2.5. UAM Coordinator: is a transition from ATC feasible?

The development of the DUC and the planning of a future human role to interface with it initially assumed a smooth transition from Air Traffic Controller (ATCO) to UAM Coordinator, reflecting the expectation that Urban Air Mobility (UAM) Traffic Management (UTM) could evolve naturally from traditional ATC roles. However, the workshop outcomes highlighted a greater skill gap between ATCOs and UAM Coordinators than anticipated, suggesting that a straightforward transition may not only be challenging but potentially counterproductive. Detailed analysis in section 3.3.1 explores this skill gap further, underscoring why transitioning ATCOs to UAM roles may require a more nuanced approach than originally envisioned.

The first key consideration builds up around the question: if this transition is proving more complex than expected, why not change it? Establishing the UAM Coordinator as an entirely new role could serve society better than repurposing the ATCO role, given that UAM coordination requires distinct skills, interactions, and decision-making processes. While both roles are grounded in situational awareness and traffic management, the methods, interactions, and broader implications differ substantially. Unlike ATCOs, who maintain situational awareness through systematic planning and replanning, UAM Coordinators operate in high-velocity contexts where they need to synthesize information, prioritize tasks, and communicate across diverse, often non-aviation-focused stakeholders. This way, a key component of the ATCOs' job, **planning**, will be set aside. The envisioned evolution of the ATCO role, as detailed in

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Deliverable 8.1, anticipated a natural progression toward these competencies, yet the findings suggest otherwise. Instead of reshaping ATCOs to fit UAM operations, a dedicated role might offer a clearer, more targeted path for recruiting and training individuals specifically suited to the demands of UAM coordination.

A second consideration is the possible future shortage of ATCOs, one of the motivators to be held into consideration when incorporating AI-powered Intelligent Assistants into operational contexts. Given the challenges associated with reskilling ATCOs for UAM roles and the workforce gaps in traditional ATC, insisting on a forced transition could enhance workforce issues. Introducing the UAM Coordinator as a distinct role could alleviate these pressures while making the position itself more attractive to new candidates who align with the unique skills and responsibilities required. Rather than attempting to “retrofit” ATCOs skills into a new framework, UAM Coordinator recruitment could focus on candidates with relevant competencies, personality traits, and interests from the outset. This tailored selection process might benefit both organizations and individuals: organizations can define precise job requirements, streamlining recruitment to match the demands of UAM operations, while candidates would engage in targeted skilling processes rather than undergoing extensive reskilling, making the role more accessible and reducing the strain of transitioning from a potentially mismatched skill set.

Following this logic, when it comes to assessing the required personality profile of UAM coordinators, the role of air traffic controllers may not be the correct starting point of reasoning. As introduced in detail in section 3.3.1., the most important characteristics of future UAM coordinators are related to their ability to coordinate and communicate in an effective manner in both routine and emergency situations. As this will require the successful conveyance of information coming from multiple simultaneous sources, these professionals will need to engage in a significant amount of social interactions during task execution. The importance of **scoring high on Extroversion** may therefore be a crucial characteristic of UAM coordinators, along with having **rather high scores on the Agreeableness** scale to possess a friendly, flexible and tolerant approach to various stakeholders with different professional backgrounds. At the same time, however, it would be important for these future professionals to keep their critical mindset in focus when assessing the correctness of information they receive, in order to avoid misunderstandings and the flow of controversial information due to the potentially divergent phraseology of the actors involved in the communication chain. Furthermore, as coordinating a potential emergency situation may impose a significant amount of stress and workload on UAM coordinators, **scoring high on Emotional stability** will be another crucial prerequisite for successfully taking this future role. Finally, similar to any other job type in complex socio-technical work environments, future professionals need to **score high on Conscientiousness** to make sure the job is taken by individuals who take full responsibility for the task they execute every day.

3.2.6. Realistic Job Preview: a key to a strong candidate pool

An inevitable supplemental process to reconsider is the **recruitment of future professionals (pilots, air traffic controllers, UAM coordinators) to be trained**. The anticipated changes in future aviation will certainly require a revision on to whom, through which channels and how these future roles should be promoted in order to ensure a sufficient pool of applicants in terms of both quantity and quality. As the envisaged future work environment might be even more difficult to fully imagine for applicants with no real experience in the aviation sector, recruitment processes should consider techniques that offer a **comprehensive introduction to these future roles**, with detailed explanations on the tasks, **as well as the pros and cons** related to the role. One recruitment technique to recommend based on its potential to provide a 360-degree picture on jobs could be a **Realistic Job Preview (RJP)**. This recruitment technique is often associated with the implicit process of self-selection, as it offers a realistic view on the job, thus **reducing the probability of mismatch between applicants' competences & needs and the characteristics of the job**. Formats may include brochures, testimonial videos of pilots, interactive digital work stimulations, videos, etc. While there is a reasonable motivation to attract top-level-candidates for training, **offering a realistic (not sugar-coated), tangible picture** of what a role will actually look like would support candidates in developing realistic expectations towards their job and career path (Morgan, 2023). To mitigate potential shortcomings on the number of future applicants, the aviation industry should prepare a **proactive strategy to anticipate and understand the needs of future generations** related to their job and career path as well as to build an **action plan on how these needs can be fulfilled in the envisaged, AI-based work environment**. The successful and realistic identification of what the future roles require and what it has to offer would contribute to a better match of candidates' profile and job requirements, thus **keeping potential dropouts at the lowest possible level**.

3.3. What to train

3.3.1. New skills for the future

UC#1: Focusing specifically on the future scenario of surprise/startle effect, the workshop identified the following major changes, related risks, challenges, and skills to consider (see Figure 3.):

Liveware: in the future of reference, a "single pilot operation" (SPO) configuration is envisaged, resulting in the pilot flying being in control of the aircraft. Although less resources would be spent on human coordination and communication, pilots would also **lose the monitoring ensured** by their co-pilot. As participants of the workshop highlighted, co-pilot's cross checking is an important means to ensure that situational awareness is correctly built, system data and parameters are correctly interpreted, and

crew members are on the same page during flights. The **anticipated lack of spontaneous communication**, along with the non-verbal communication channel is an important related challenge (although non-verbal communication will partly be replaced by biophysical data registered by the IA). Spontaneous, oral communication is an important means of reducing stress and providing social and emotional support under stress, as well as overcoming a potential startle effect. In addition, **social isolation** itself is a topic to be addressed when identifying future challenges related to SPO configuration. Pilots reportedly need to be able to talk to someone during flights, for which a Generative Pre-Trained Transformer (GPT) chatbot might be able to provide an alternative solution in the future. Furthermore, oral communication is found to be an important need of pilots in re-building their situational awareness, after a startle effect has taken place. **Trust issues** related to accepting the support of an AI-based assistant is another challenge to consider. Trust must be neither too high, to avoid overreliance, nor too low, to avoid an increased workload due to multiple evaluations of the AI outcomes. This might mean a challenge to cope with dispositional (i.e., general attitudes towards AI or, more in general, technology) and situational (i.e., trust towards the IA elicited from the context) trust towards technologies in the cockpit. More on the topic of trust can be found in D2.2 of the HAIKU Project. Therefore, pilots in the future might need to learn **additional stress management skills** (e.g. biofeedback techniques, breathing and relaxation techniques, mindfulness, etc.) in order to successfully **self-regulate their own emotions** during flights. **Detailed technical knowledge** on how the **AI-based IA** supports pilots during flight might also be important in order to address the issues related to trusting the new system. Finally, **communication and coordination skills** will most probably need to be modified or extended to include ways of effective collaboration **with an AI-based teammate**. More specifically, a new framework and systematic procedure is needed to support pilots in deciding when and how to call their AI-based teammate into action, what type of information or message to convey to their AI-based teammate and to their human co-actors (cabin crew, ground operation, etc) and how to build a shared understanding of the crew as a whole.

Software: As human teammates are envisaged to be absent from the cockpit in the future, pilots' decision making, adherence to procedures and the correct execution of these procedures will not be discussed and cross-checked by a team of humans who share the same physical location. Although the IA developed by Use Case #1 will support single pilots in regaining situation awareness by highlighting key parameters on the display, surprise and startle events can cause pilots to develop a tunnel-vision. Under this state, individuals tend to ignore certain cues in their environment. Therefore, future single pilots under high stress may develop a distorted decision making by only focusing on a limited number of parameters in the cockpit and/or by looking for parameters which reinforce their line of thinking. Therefore, they may need to develop enhanced skills in **self-critical thinking** and the **ability to question themselves** before making a decision. The envisaged human-AI teaming in the future will also require the **modification of the CRM procedures:** as traditional crew resource management techniques will continue to play a role in effectively collaborating with cabin crew,

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passengers and ATM, new procedures and practices will need to be developed to describe ways of **collaboration with the AI teammate**.

Hardware: During surprise and startle events, IA is expected to activate itself by certain biophysical parameters (e.g. gaze behaviour, heart rate, etc.) which indicate that the pilot is under startle. Though this can be controlled manually, the interaction between the two teammates is envisaged to be initiated by the IA, leaving the pilot in a **more passive and less spontaneous role** within the communication loop. This will require some **new principles of team communication** to effectively collaborate with different actors. For instance, future pilots will need to have a solid understanding on the communication needs of all the actors, being them human or AI-based ones, and appropriately select when, how and what to communicate to their human and AI-teammates. To recover from startle, pilots will be expected to breathe according to a signal on the display, flashing at a certain rhythm. To regain situational awareness, pilots will need to look at certain key parameters on the cockpit display, guided by signals. If the pilot is looking at these key parameters long enough, the IA will turn itself off, assuming that the pilot has regained situational awareness. Guiding signals on the display might be an efficient way to focus a pilot's attention in case of startle but may also potentially lead to **information overload** in a cognitive state in which pilots are already struggling to interpret cues from the environment. **Theoretical knowledge of the effects of stress on cognitive skills** (tunnel vision, cognitive overload, etc.) as well as **technical knowledge of the system** may help in overcoming this challenge. Furthermore, the application of auditory inputs (voice instructions) besides visual cues might decrease the chance of information overload, by **dividing information across modalities**. In addition, staring at the displays for an extended period of time does not guarantee enhanced situational awareness if these pieces of information are not actively elaborated ("look but not see" effect). Future knowledge of procedures and checklists to **actively assess one's level of situational awareness** may be an important additional support in regaining situation awareness during stressful events.

Interaction type: Pilot (Liveware) with...	Changes	Risks, challenges	Important skills
Liveware	<ul style="list-style-type: none"> • SPO • No observation of PF • Less resources spent on human-human coordination, communication. 	<ul style="list-style-type: none"> • Losing spontaneous communication • Losing non-verbal communication (biophysical data instead) • Need, willingness for verbal interactions (chat GPT), social isolation • Trust issues 	<ul style="list-style-type: none"> • Stress management - biofeedback, emotion regulation, the physiology of stress • Technical knowledge on AI • Coordination, communication with AI (human-AI teaming)
Software	<ul style="list-style-type: none"> • No CRM in the cockpit • No cross check on actions • New procedures, new CRM with IA • Specific procedure for SPO 	<ul style="list-style-type: none"> • Self-double check: no one to challenge the pilot, no other mental repr. - looking for cues to reassure his own view. 	<ul style="list-style-type: none"> • Decision making: false mechanisms to reassure oneself • Self-critical thinking
Hardware	<ul style="list-style-type: none"> • Biofeedback data • Broadened spectrum of sight • Interaction initiated by IA (can be controlled manually) • Situation awareness score 	<ul style="list-style-type: none"> • Passive communication and interaction from the pilot • "Look but not see" • Information exposure - catch attention but avoid cognitive overload • Explainability • Responsibility in the cockpit 	<ul style="list-style-type: none"> • Integration of data from multiple sources • Understanding redefined team roles and responsibilities (accurate and shared team mental model) • Awareness of legal issues

Figure 3: UC#1: major changes, related challenges and required skills

UC#2: Focusing specifically on the future scenario of **route planning/re-planning**, the workshop identified the following major changes, related risks, challenges, and skills to consider (see Figure 4.):

Liveware: in the future of reference, a "single pilot in cruise" (SPIC) configuration is envisaged: 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 8.1). Pilots flying will have an advanced support system in making their decision about alternative airports. IA is anticipated to integrate key technical parameters, preferences of different actors and suggest solutions accordingly. While pilots today are trained to integrate parameters from multiple sources and decide based on them, **decisions** on alternative routes in the future are expected to be **based on one single source of information:** the IA. Therefore, more **critical thinking**, the **ability to question the system** and advanced theoretical **knowledge about human decision making** may be needed in the future. Relying on AI in decision making will also require the **ability to understand and trust the system**. In addition, pilots in this future context will be required to self-assess their own cognitive comfort, including how comfortable they are with the suggestion of the IA. This will call for more advanced **self-assessment skills** of one's own subjective comfort in relation to the alternatives. The introduction of AI is also anticipated to impact the team dynamics of the two pilots. As the IA is expected to assist the pilot flying in the decision making, a challenging question will be when to call the other pilot into action, and how to brief them. The introduction of AI may result in a difference in how pilots resting rely on information coming from the pilot flying versus the information coming from the IA.

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Therefore, a deeper understanding of **team dynamics in human-AI teaming** may be needed. Finally, resting may have some side effects on the ability to **quickly build situational awareness**, especially if pilots are awakened from sleeping. Theoretical knowledge on the human **cognitive functioning after sleeping** may be needed in the future.

Software & Hardware: In the anticipated future of reference, the IA is expected to assist in prioritising intentions and taking over the procedure of performance calculation. Pilots, as a result, will be required to learn new procedures involving IA. As decision making is supposed to be based on one source of information, trust or overreliance in the system will be an important factor to consider. Even if suggestions will be proposed by the IA, pilots need to remain part of the process. This way, they will be able to **actively and critically evaluate** these alternatives as well as to **maintain situational awareness, anticipate future steps** (“being one step ahead of their aircraft”) and **take over control** from the IA on the procedure of performance calculation, whenever necessary. Therefore, understanding the hierarchy of the software will be crucial in the future.

Interaction type: Pilot (Liveware) with...	Changes	Risks, challenges	Important skills
Liveware (Pilot in cruise, pilot resting, IA)	<ul style="list-style-type: none"> SPIC Self assessment of ones skills and status - intermediate step, embedded in the system (cognitive comfort) - how comfortable are they with the suggestion of the IA? 	<ul style="list-style-type: none"> Side effects of resting (required knowledge on sleep cycle, sleep inertia) and develop skills for effective teamwork and safe operation with awareness to the side effects of sleeping. Questioning the truth of the system with only one centralised source of information. What is the difference between how the pilot resting relies on the information gained from the pilot flying vs. the information gained from the IA? (Trust Human-Human vs Human-AI) 	<ul style="list-style-type: none"> Resting pilot: being gradually involved in the situation but quickly build SA Assessment, evaluation of only one source - questioning it or overreliance Decision making, based on IA suggestion Issues of the design (explainability of IA): technical skills to understand IA operation Self management/ self assessment skills Adapting to new team dynamics (also understand when to call the other pilot)
Software	<ul style="list-style-type: none"> Prioritizing intentions with IA Procedure of performance calculation (IA will take over) Evaluate the system's suggestions 	<ul style="list-style-type: none"> Trust or overreliance Learning new procedures involving IA Algorithmical trustworthiness 	<ul style="list-style-type: none"> Ability to take over control on calculations Actively evaluate and prioritize options suggested by IA
Hardware	<ul style="list-style-type: none"> COMBI assistant Performance calculation (EFB now, COMBI in the future) 	<ul style="list-style-type: none"> Explainability - to take over control 	<ul style="list-style-type: none"> Ability to take over control if needed

Figure 4: UC#2: major changes, related challenges and required skills

UC#3: Focusing specifically on the future scenario of **Urban Air Mobility Traffic Management**, the workshop identified the following major changes, related risks, challenges, and skills to consider:

The workshop methodology supported critical insights into the evolving role of the UAM Coordinator, highlighting a notable shift from traditional Air Traffic Control (ATC) responsibilities to those needed in urban air mobility (UAM). The scenario-based

discussions provided a robust foundation to understand how UAM Coordinators, in collaboration with the DUC, would function dynamically, adapting to real-time changes and emerging situations.

In the low-traffic scenario of the first step, participants observed how the DUC systematically collected and prioritized data, providing essential updates and communicating pertinent information to facilitate efficient decision-making. The UAM Coordinator's role became prominent when **handling unforeseen situations** - such as locating a missing aircraft - demonstrating the need for their **proactive engagement**. Unlike ATCOs, who control all aspects of air traffic with a detailed, engineering-like precision, the UAM Coordinator **remains focused on keeping communication channels open with various stakeholders**, including emergency services, vertiport operators, and possibly affected businesses. This dual-layered management approach underscores the UAM Coordinator's responsibility for **interpreting the DUC's insights and maintaining a broader situational awareness, while also ensuring relevant parties are engaged and informed**, even during low-stakes operations.

Transitioning to the high-traffic scenario, in the first step the role of the **UAM Coordinator and DUC collaboration** was further emphasized. In a scenario marked by operational complexities, such as diversion requests, emergency airspace closures, and capacity constraints, the DUC's **ability to prioritize alerts and maintain constant information flow** proved essential. Participants highlighted the UAM Coordinator's role in **processing this influx of information**, as well as establishing **effective communication with non-aviation stakeholders**. Through this, they learned that while the DUC enables situational awareness by sorting and reporting data, the UAM Coordinator is responsible for **assessing the impact on each involved actor**, reflecting a key difference from traditional ATC.

In the second step, with a focus on skill translation and situational analysis, the low-traffic scenario revealed further distinctions between the traditional ATCO role and the new UAM Coordinator role. While ATCOs are accustomed to controlling and anticipating every operational detail, **UAM Coordinators will operate by making decisions based on limited data, synthesising various inputs, and responding to an evolving landscape**. This adaptive mindset, oriented toward ongoing **problem-solving** rather than predefined control, emerged as a core requirement. This approach suggests the need for training in **flexibility, rapid situational assessment, and scenario analysis** to help UAM Coordinators manage unpredictable UAM operations effectively.

The high-traffic scenario in the second step provided additional insights, particularly regarding the UAM Coordinator's **situational awareness and decision-making processes**. While ATCOs build Situational Awareness through preemptive planning and replanning, UAM Coordinators rely on DUC's planning support, focusing instead on the **readiness to act promptly when the situation changes unexpectedly**. Training to cultivate this rapid situational awareness might parallel established decision-making frameworks, like the FORDEC model, which enables high-stakes decision-making based on a trained cognitive process. This would allow UAM Coordinators to respond effectively to unexpected events, drawing on an agile and practiced response to cope with disruptive events inducing startled responses.

Further, the findings emphasized **the importance of communication training**. Unlike current aviation personnel, who are trained in a standardized communication style to minimize misunderstandings, the UAM Coordinator must **interact with a wide range of stakeholders, many of whom lack formalised communication training**. This includes emergency responders, police, hospitals, and other critical actors whose participation in UAM operations could affect safety outcomes. Participants concluded that UAM Coordinators would require specialized communication training to **effectively convey complex information, manage multi-party interactions, and ensure clarity under pressure**. This skill would be essential in maintaining operational effectiveness and safety, especially when **coordinating with stakeholders unaccustomed to aviation-specific phraseology**.

Finally, participants identified a need for UAM Coordinators to develop a solid **understanding of the business and economic implications of their decisions**. Unlike ATCOs, who primarily focus on safety and regulatory compliance, UAM Coordinators must consider the broader operational impact of their actions, particularly in high-traffic scenarios where decisions such as route diversions and priority landings may have significant commercial implications. Training in business acumen would enable UAM Coordinators to **balance operational priorities with the economic impact of their decisions**, fostering a **strategic approach to UAM operations that aligns with both safety and business objectives**.

Overall, the results underscored the complexity of the UAM Coordinator’s role, combining elements of real-time adaptability, rapid situational awareness, effective communication across sectors, and business-savvy decision-making. These insights serve as a foundation for developing a comprehensive training framework, equipping future UAM Coordinators with the multidisciplinary skills required to navigate the evolving landscape of AI-assisted urban air mobility.

	Future tasks	Risks, challenges	Important skills
UAM coordinator	<ul style="list-style-type: none"> • Handling unforeseen situations proactively • Remaining focused on effective communication • Managing communication with various (non-aviation) stakeholders • Interpreting the DUC’s insights and while maintaining a broader situational awareness • Keeping relevant parties engaged and informed • Prioritising alerts • Maintaining constant information flow • Processing the influx of information • Assessing the impact of actions on each involved actor • Making decisions based on limited, „indirect“ data • Synthesising inputs from various information source • Flexibly and effectively responding to an evolving landscape • Rapid situational assessment and scenario analysis • Balancing operational priorities and economic impact • Making decisions while considering interests of various actors • Strategic planning 	<ul style="list-style-type: none"> • Difficulty to communicate with various stakeholders of different professional background and no common standard phraseology • Challenge related to quick reaction to the unfolding emergency situation • Integration of information coming from various sources to create situational awareness • Conducting correct situational assessment based on data coming from indirect sources (other actors) • Understanding the big picture and business interests of all parties, acting in a suitable way to ensure safety while minimising economic impact 	<ul style="list-style-type: none"> • Technical knowledge and understanding of the AI-based assistant • Ability to quickly assess situations • Ability to integrate multiple information • Adaptability • Flexibility • Problem solving skills • Stress management • Vigilance • Strong communication skills • Business acumen • Strong coordination skills • Ability to prioritise • Multitasking • Decision making • Analytical thinking • Problem solving • Prioritising • Strategic planning • Knowledge of the territory and its key characteristics

Figure 5: UC#3 future tasks, risk, challenges and important skills

UC#4: Focusing specifically on the future scenario of re-sequencing, the workshop identified the following major changes, related risks, challenges, and skills to consider for air traffic controllers (see Figure 6.):

Environment: in the envisaged future of 2035 and onwards, environmental factors that would otherwise needed to be dealt with manually and separately would be integrated and coordinated by ISA, thus greatly **reducing the extent of multitasking and consequently, the workload** affecting air traffic controllers. For instance, CHMI (Collaboration Human-Machine Interface) would be integrated into ISA and feed all the arrival and departure data directly into the system, as well as it would coordinate with FMP (Flow Management Position) to reduce the rate of arrivals and departures according to the situation. To support a smooth air traffic management, ISA would be able to automatically adapt separation times of arrivals and based on data from the past, it would predict the probability of go-around and runway-change. In addition, ISA would be able to provide direct and more accurate meteorological predictions along with an indication of how they would affect the operation of the airport.

Liveware: compared to today, the introduction of ISA in real operation would most probably affect the necessity of live communication between key actors, as the intelligent assistant is envisaged to decrease the frequency of voice-to-voice communication by approximately 95%. First of all, there would be no anticipated communication between ground controllers and pilots: ISA would provide the whole sequence of aircrafts as well as the suggested route to the stands, and provide it to ground controllers as a suggested **decision plan for approval**, leaving ground controllers in a **supervisory role**. Once the suggestion has been approved, ISA would send the information directly to the pilots, **eliminating direct communication** between them and ground controllers. In addition, there would be no need for direct communication between ground controllers and tower ATCOs, as ISA would fully take over the so-called „silent communication“ (indirect, data-based communication, without the necessity of verbal information exchange) between the two actors. ISA would not only support the daily tasks of ground controllers: it would also represent the communication link between pilots and tower ATCOs, by receiving pilots' requests, translating them into decision plans and forwarding them to the controllers for approval. This would not only remarkably reduce the workload that tower ATCOs are exposed to, but also significantly **contribute to operational safety, by eliminating potential communication-related errors** resulting from misunderstandings, language barriers and pronunciation. Moreover, the indirect communication via ISA would reduce the room for additional pressure coming from the pilots to the tower controllers, related to their requested place in the operational sequence, as well as it could result in a greater acceptance of sequence-related decisions, having been done by a technical system instead of a human controller. By greatly reducing the workload of both the ground controllers and tower controllers, in the envisaged future **there would be no need for delivery**, as this task could be executed by the ground controller due to their reduced workload. In addition to communication between pilots, ground controllers and tower

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controllers, ISA is envisaged to automatically coordinate with approach and the airport, as well as automatically suggest the use of marshallers, depending on the situation. In short, the greatest impact of the introduction of ISA into operation would certainly be related to direct voice communication of actors, as well as their role in becoming more of supervisors than task executors within the future scenario.

Software: by introducing ISA in real operation, procedures will radically change as well, requiring the development of a new operational manual which provides controllers with a specific and detailed guidance on **how to collaborate with the intelligent assistant**. This manual would not only specify the collaborative process between the human and the AI but would also provide a detailed description of **ISA's reasoning** behind certain suggestions, thus contributing to the **explainability** of the system. Most importantly, the operational manual would entail a comprehensive, detailed, step-by-step **contingency plan** in case ISA failed, stopped working or showed signs of false operation. Regarding the collaboration of ISA and controllers in emergency situations, ISA is envisaged to handle certain emergencies if taught to do so, based on data from past emergency events. Most probably, however, in these cases, ISA would **take over certain simple, executive tasks** from the human, by explicitly being called to do so (e.g. "ISA, stop departures"). This would **allow controllers to handle the emergency** situation with more cognitive resources and less workload.

Hardware: an important development of the envisaged future scenario would be a central system (screen) to provide **integrated information** coming from multiple different sources, sensors and devices and feed it into the main HMI of ISA. A central interface like this would greatly reduce the workload of controllers and would help them integrate information and **gain understanding of the situation in a quicker and more effective manner**. As mentioned earlier, the majority of information exchange and communication would be conducted via this technical system, leaving only direct frequencies and push-to-talk lines for handling emergency situations. The most important anticipated challenge related to an integrated interface like this is related to the explainability of the system. The interface will have to provide easy-to-understand information and be designed in a way that ISA's reasoning behind certain decision plans would be clear. Nevertheless, another challenge of this future interface will be related to its ability to provide all the integrated information via one interface without causing cognitive overload for controllers.

To summarize the results of the envisaged future scenario, the three most important changes that participants of the workshop have anticipated were: **1) Communication:** the majority of communication processes will be taken over by ISA, translating future communication into an indirect, digitised procedure where human controllers and voice communication will only play a role in emergency situations. This envisaged support on the one hand is expected to significantly reduce the workload that results from the very high frequency of multiple simultaneous communication between the actors in case of a resequencing is necessary. The assistant is also expected to reduce the probability of

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communication-related errors resulting from the characteristics of voice-to-voice communication. On the other hand, being involved in indirect communication where messages are normally transferred and exchanged between digital systems will certainly challenge human controllers' abilities to have an overall and comprehensive understanding of the situation and continuously stay in the loop. Future tower controllers are therefore required to develop the theoretical knowledge and practical skills on how to team up and collaborate with an AI-based assistant. **2) Sequencing:** the sequencing task will change remarkably by the existence of a global sequence in each airport, instead of how it is spread out today between ground and tower controllers. Moreover, controllers are envisaged to be receiving information via an interface which provides all the aggregated data that is necessary to task execution. Such interface is expected to greatly reduce their workload and the necessity of being able to integrate and interpret data from different sources. On the other hand, it will certainly contribute to the challenge of **building a situation awareness** that is based on the direct cues and signals coming from the environment. Instead, future controllers' situation awareness will almost exclusively be built on a **reality that is mediated by ISA**, which most probably will raise the issue of controllers' **trust in or overreliance on the system**. Therefore, future controllers will be required to have **advanced critical thinking skills to be able to question the operation** of the system, as well as an even more advanced **digital literacy** to interpret all the data coming from ISA's interface. In addition, ISA is expected to automatically coordinate among the relevant actors and develop ready-made suggestions and decision plans to be approved by the controllers. This envisaged activity of the system will significantly change the task profile of the controllers, by leaving them in a more **supervisory role in the future**. While contributing to a smooth and safe operation, it would represent a challenge of **keeping human controllers in the loop** as well as a need for even **more advanced decision-making skills**. **3) Management of abnormal situations and contingencies:** ISA would support controllers in handling abnormal situations (e.g. bird strike or medical emergencies), by taking over executive, simple tasks and thus reducing controllers' workload in handling the emergency scenario. On the other hand, this particular aspect of the expected changes in the future has been mentioned as the most challenging one. By the introduction of ISA in real operation, a new cluster of potential emergency situation is to be taken into consideration: the **emergency due to ISA's failure**, requiring controllers to very quickly gain understanding over the situation and **handle everything manually**. This emergency scenario is expected to be particularly challenging based on the aforementioned process of building a situation awareness on direct cues of the environment instead of the integrated data provided by ISA. A situation like this will certainly require a **very high level of adaptability and flexibility** from the controllers, along with advanced **stress management skills**. Moreover, they would not only be required to have **advanced analytical and problem-solving skills**, but also the ability **to integrate data coming from multiple sources under significant time pressure**.

Interaction type: Pilot (Liveware) with...	Changes	Risks, challenges	Important skills
Liveware	<ul style="list-style-type: none"> • 95% less communication compared to today. • No direct communication between ground controllers and pilots (ISA will provide the whole sequence of aircrafts and suggested route to the stands, and send it directly to the pilots). Ground controllers in supervisory role. • Silent communication between tower ATCOs and ground controllers are taken over by ISA • Communication mediated between tower ATCOs and pilots. Tower ATCOs in supervisory role. • Tower ATCOs communication with the airport only in case of emergency. • ISA will automatically coordinate with approach, too. • By reducing the workload of ground controllers, the role of delivery is not necessary anymore. • Marshalls are automatically suggested by ISA (depending on whether the situation might need inspection) 	<ul style="list-style-type: none"> • Passive communication • Trust issues or overreliance • Indirect way of building situation awareness – all environmental cues are presented by the system • Keeping human in the loop • Challenge to question ISA's suggestions 	<ul style="list-style-type: none"> • Stress management • Vigilance • Technical knowledge on AI • Coordination, communication with AI (human-AI teaming) • Situation awareness • Critical thinking • Decision making
Software	<ul style="list-style-type: none"> • Prediction and suggestion of potential runway change • Operational Manual: detailed information about how ISA works and how to collaborate with it, explanation of ISA's reasoning (explainability) and a detailed contingency plan if ISA fails. • ISA could handle certain emergency situations (if taught with past data) or take over simpler executive tasks while the controller handles the emergency situation, 	<ul style="list-style-type: none"> • Automation complacency • Explainability of the AI based assistant • Difficulty to switch to manual operation • Difficulty to oversee the big picture 	<ul style="list-style-type: none"> • Technical knowledge and understanding of the AI based system • Ability to quickly see through situation • Adaptability • Flexibility • Problem solving skills
Hardware	<ul style="list-style-type: none"> • A central system (screen), which provided integrated information coming from different sensors and devices. It aggregates all the data and feeds it into the main ISA HMI. • ISA as a communication bridge between the actors (with direct frequency remaining available) • Routine communication taken over by ISA, emergency communication handled by human controllers 	<ul style="list-style-type: none"> • Trust or overreliance on the system • "Look but not see" • Information exposure - catch attention but avoid cognitive overload • Explainability 	<ul style="list-style-type: none"> • Computer literacy • Problem solving skills • Decision making
Environment	<ul style="list-style-type: none"> • CHMI integrated within the ISA and feeds all arrival and departure data into the system • Direct and more accurate meteorological predictions and how they will affect operation • Coordinate with FMP to reduce the rate of arrivals and departures according to the situation • Adapt separation times of arrivals, automatically coordinate with approach and separation. • Predictions of the probability of go-around and runway change. 	<ul style="list-style-type: none"> • Trust vs. Overreliance • Challenge to question ISA's suggestions • Explainability 	<ul style="list-style-type: none"> • Analytical skills • Attention to detail • Critical thinking

Figure 6: UC#4 major changes, related challenges and required skills

3.3.2. AI-CRM: The future of Crew Resource Management for Pilots

Considering the two use cases (UC#1 and UC#2) developed within the HAIKU Project as a starting point, we assumed that, in the landscape of **2035 operations**, the performing abilities of AI will match the **safety** and **technical standards** required in Air Transport, thus transforming it into something more than a sophisticated decision support. With better **computational abilities** and by being able to **handle more data** at the same time, AI will have to be considered as a **member of the team**, actively **cooperating** with humans, not only supporting them. In this regard, **EASA** references **cooperation** and **collaboration** as the main components of **Level 2 AI**, the Human-AI **teaming** (EASA, 2023).

Traditional **Crew Resource Management (CRM)** has revolutionised cockpit safety by emphasising **communication**, **teamwork**, and **decision-making** skills. However, interviewing an airline evidence-based trainer, some limitations emerged, including a **focus on flight deck ambience** and compliance rather than fostering genuine collaboration, calling for an update. Integrating AI assistants as full-fledged "teammates" within an AI-CRM framework might present a promising next step in this evolution.

From the interview emerged also that current CRM often relies on "faking good" behaviours that do not translate to real-world situations. Additionally, its isolation from

other crew training and the tick-box mentality in which it is often addressed may reduce its effectiveness.

Finally, **future changes in the crew composition**, more specifically the envisaged future human-AI teams (HAIKU Project, 2023), will require an update of existing CRM from a **procedural** and **applicative** point of view.

Combining these assumptions with the findings presented in section 3.3.1, we argue that the most appropriate **training pathway** to follow towards 2035 could be a CRM update, considering **AI as an effective operative member** of the aircrew in managing startle and surprise events and flight deck route planning/replanning. By treating AI assistants as teammates, not merely as decision aids, this framework fosters a deeper collaboration, which is continuously leveraging on AI's strengths in data analysis and risk assessment while ensuring that **human judgement and skills remain central**.

Current CRM, mandated by EASA Regulation 1178/2011 (EASA, 2011, Annex V, Appendix I) as basic and recurrent training, equips commercial pilots with a broad range of skills covering **human factors, error management, and teamwork**. While this foundation remains crucial, the introduction of AI teammates as "crew members" necessitates a more nuanced approach to these topics.

The existing CRM framework, encompassing areas like **communication, leadership, and situational awareness**, was designed for **human-centric interactions**. As highlighted by the HAIKU Project Use Cases, scenarios dealing with startle events or dynamic route planning demand **additional competencies** if they happen in an environment where humans have to collaborate with AI-based Intelligent Assistants.

As presented in section 3.3.1, effectively **delegating tasks** to AI, critically **evaluating its outputs**, and **maintaining trust calibration** become essential components in Human-AI Teaming environments. Moreover, skills like **self-critique, assertiveness, and decision-making** require specific training considering the unique dynamics of **human-AI collaboration and cooperation**.

Therefore, considering the CRM Training Table of the EASA Regulation 1178/2011 (see Annex, Table 4.), we defined the following areas as the backbones of a potential future AI-based crew resource management (Figure 7.):

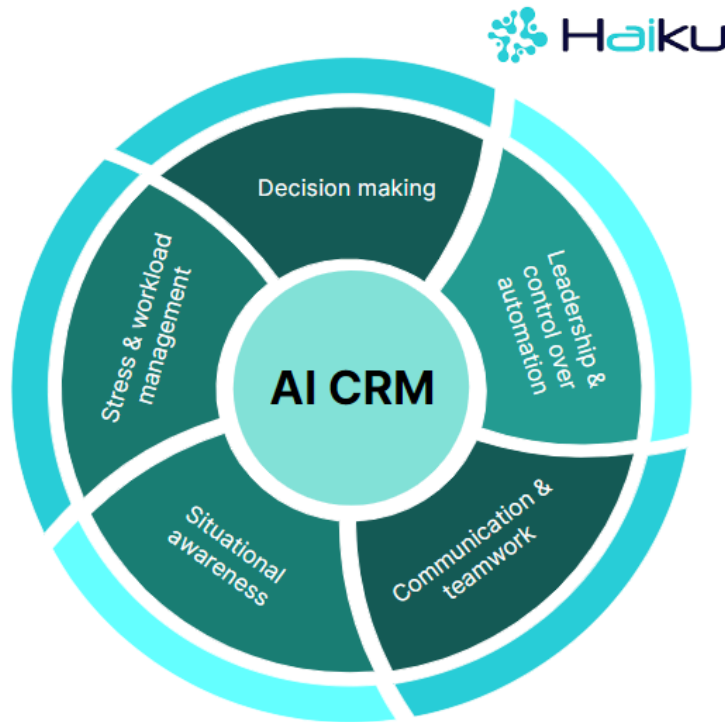


Figure 7. AI-CRM addressed topics

- **Stress & Workload Management:** while AI could take on tedious tasks, thus reducing overall workload, managing trust dynamics and potential over-reliance on automation would become crucial. CRM training would need to address concerns about **automation bias** and equip pilots to effectively **delegate and monitor** AI performance, potentially mitigating new sources of stress. Integrating AI adds another layer of complexity to the cockpit environment. Pilots might experience stress by managing the AI system, understanding its outputs, and ensuring its proper functioning, feeling underwhelmed when facing critical situations. Balancing **trust** in automation while maintaining **situational awareness** can be **mentally demanding**. CRM should address the paradox of receiving more support in a shorter period of time, generating more pressure to have good data-driven performance in new critical scenarios. In particular, for SPOs, future trainings should provide advanced skills of **emotion regulation** techniques, a deeper and more detailed understanding of both **psychological and physiological aspects of stress**, such as the **impact on situational awareness** (i.e., startle effect; tunnel-vision, losing chance to anticipate future steps), and how to act on them both with short- and long-term strategies, and with an **advanced skill-set** to assess one's **cognitive, physiological and emotional state** during flight.
- **Situational Awareness:** if pilots become overly reliant on AI for information processing and decision support, they might lose critical situational awareness skills developed through traditional CRM training failing in perceiving all the

necessary aspects of the surrounding environment (breakdown in step 1 – perception), without exploring them actively, failing in understanding them (step 2 – comprehension), or failing in projecting them into the future (step 3) (Endsley, 1995), bringing to agreeing with incorrect recommendations (Buçinca, Malaya, & Gajos, 2021), changing their mind to match AI recommendations (Kim, Yang, & Zhang, 2021), or weighting too much the AI recommendation (Logg, Minson, & Moore, 2019). This could hinder their ability to **independently assess situations** and make **informed decisions**, especially in unexpected circumstances. CRM of the future should therefore cope with this challenge by training pilots on how to collaborate with **AI on data processing to significantly enhance situational awareness** by providing comprehensive analysis and real-time updates. A modification of CRM training may be required in the future in order to leverage AI's strengths while ensuring that pilots maintain a holistic understanding beyond just AI-generated information. In particular, regarding situational awareness, CRM of the future should address the skill of **gaining and re-gaining control and information** quickly in nominal operations, after sleeping and in startle events. From a technical perspective, the interaction with explainable AI-based IAs will be a key factor in enabling pilots to recover from a **mismatch between what is expected and what is experienced** (Situational Awareness first level - Perception) and to **anticipate** future steps (Situational Awareness third level - Projection to future) (Endsley, 1995). On this topic, future CRM could also address the **psychology of sleep**.

- **Communication & Teamwork:** clear and concise communication would remain fundamental, but the focus might shift towards effectively conveying human **intent** and **goals** to the AI teammate, and vice-versa. Sperber & Wilson (1995), following the studies of Grice (1957), define communication as the **expression and recognition of intentions**. While AI can process and generate information efficiently, its **lack of human-like expressiveness** can hinder communication flow. Therefore, differences in **communication styles** and **information processing** between humans and AI could lead to **misunderstandings**. Pilots and crew might misinterpret AI outputs or struggle to convey their intent and goals effectively, potentially hindering **teamwork** and **decision-making**. From a technical perspective, **explainability** might be a factor **mediating** the different **communication styles**: CRM training would need to address potential **communication barriers** and **communication hazards** due to differing processing styles and ensure that all team members (human and AI) have a **shared mental model**. Therefore, the communication with AI could be addressed by deepening the concepts of **on-demand communication** (i.e., non-spontaneous), without **clues** usually used by **humans** to **increase consistency** in communications (i.e., absence of non-verbal modalities). Finally, the **cognitive cost of communication** should be addressed, providing the pilots with both the correct **procedure** and **cognitive tools** to understand when

prioritising communications or actions, possibly based on the future shared platform realised to reduce workload.

- **Leadership & Control over automation:** excessive **trust** in AI recommendations could lead to **complacency** and reduce the pilot's ability to make **independent decisions**, thus potentially creating **dangerous situations** when manual intervention is needed. Moreover, managing a crew with human (e.g. cabin crew, ground operation) and AI-based actors, adjusting communication practices, content and style to the needs of the different actors may be challenging. The CRM should therefore address these challenges aiming to develop a **leadership** model that encompasses the **management of human-AI teams**, fosters **trust**, and ensures **clear communication** and **delegation of tasks** and considers both a human communication model and a data-driven approach. To foster an effective **control over automation**, deep knowledge of both generic motoric skills to prevent skill loss (e.g., eye-hand coordination), transversally applicable and technical skills to understand AI behaviour will be required. Training these skills will increase the human ability to take over control whenever needed.
- **Problem Solving & Decision Making:** implementing **AI as a teammate** in an aircrew may be helpful to pilots in various aspects: first, it provides support in analysing **vast amounts of data** and present pilots with **insights** and **recommendations** on how to enhance human capabilities. It also allows pilots to **free up cognitive resources** by taking over tedious tasks. Finally, it could play a key role in **overcoming human biases** such as **overconfidence** and **anchoring**, by presenting different perspectives. At the same time, **blind reliance** on AI recommendations can lead to **automation bias**, where pilots neglect crucial information, and if AI decision-making lacks transparency or explanation. This overreliance may result in a "black box" effect, hindering trust and making it difficult for pilots to critically evaluate recommendations and potentially leading to flawed decisions. Finally, complex ethical issues may arise in flight decision-making. Pilots need frameworks and support to navigate these situations with responsible and transparent decision-making, even when they are influenced by AI. A specific recurrent training aiming to enhance basic digital literacy of pilots could also support the development of a decision-making process which considers the different AI communication and processing style, limiting biases such as data misinterpretation or failures in coordination between humans and AI. To foster an effective future decision-making, other skills such as critical thinking will need to be enhanced to mitigate false positive and false negative solutions provided by the AI-based assistant, having the right situational awareness to correctly question the received support.

By strategically addressing these key areas, AI-CRM goes beyond simply training pilots to operate alongside AI. It empowers them to **truly collaborate with their AI teammates, leveraging on the combined strengths of human judgement and AI capabilities**. This shift requires comprehensive training that equips pilots to:

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- **Critically evaluate AI outputs:** Pilots must remain the ultimate decision-makers, understanding and questioning AI recommendations to avoid automation bias.
- **Communicate effectively with AI:** Clear and concise communication, tailored to AI's processing style and to human needs, is crucial for seamless collaboration.
- **Maintain situational awareness:** Overreliance on AI should not interfere with pilots' ability to independently assess the situation and take manual control when necessary.
- **Addressing ethical dilemmas** arising from AI's involvement in decision making is also critical. Establishing clear ethical frameworks and fostering a culture of transparency will ensure responsible and trustworthy human-AI collaboration.

The new AI-CRM goes beyond technical training for specific assistants. It aims to address the more **transversal** and **soft-skill** aspects of **human-AI** and **human-human coordination**. Assuming a more holistic perspective, AI-CRM should improve the understanding of AI processes through digital and data literacy. This would smooth human-machine communication and coordination, ultimately increasing the agency of human actors towards informed decision-making. To achieve this effective enhancement of human capabilities, AI-based IA must be considered as integral members of the team and the crew, fostering genuine collaboration and a shared mental model within the cockpit.

In Table 2., an example of updated behavioural indicators for Pilots' Evidence Based Training after the introduction of AI-based assistants is provided.

Table 2: Example of Evidence Based AI-CRM, based on a personal resource provided by an Airline Evidence-Based Trainer

Competency	Competency description	Behavioural indicators
Communication	Demonstrates effective oral, non- verbal and written communications, in normal and non-normal situations	Current elements: Ensures the recipient is ready and able to receive the information; Conveys messages clearly, accurately, and concisely Confirms that the recipient correctly understands important information; Listens actively and demonstrates understanding when receiving information; Accurately reads and interprets required company and flight documentation; Correctly interprets non-verbal communication; Uses eye contact, body movement and gestures that are consistent with and support verbal messages;
		Additional elements: Adheres to standard radio communication

		<p>phraseology and procedures with humans and AI, according to the receiver of the communications; Selects appropriately what message to communicate; Selects appropriately when to communicate a message; Selects appropriately how to communicate a message (communication channels, style, language); Selects appropriately the recipients of the message (humans or AI-based assistants); Effectively prompts commands to the AI teammate; Accurately reads and interprets AI outcomes.</p>
<p>Leadership & Teamwork</p>	<p>Demonstrates effective leadership and team working</p>	<p>Current elements: Understands and agrees with the crew's roles and objectives; Creates an atmosphere of open communication and encourages team participation; Uses initiative and gives directions when required; Admits mistakes and takes responsibility; Anticipates and responds appropriately to other crew members' needs; Carries out instructions when directed; Communicates relevant concerns and intentions; Gives and receives feedback constructively; Confidently intervenes when important for safety; Demonstrates empathy and shows respect and tolerance for other people; Engages others in planning and allocates activities fairly and appropriately according to abilities; Addresses and resolves conflicts and disagreements in a constructive manner; Projects self-control in all situations;</p> <p>Additional elements: Identifies and manages over reliance and mistrust towards AI of the crew; Correctly delegates tasks balancing humans and AI; Effectively defines roles and responsibilities within the team; Makes sure the crew has a shared understanding of task allocation; Adapts to crew strategy and reallocates tasks according to unexpected events; Effectively makes decisions based on the inputs provided by the humans and AI teammates; Understands and takes responsibility in controlling</p>

		<p>the aircraft and aircrew; Has a clear understanding of the principles, challenges and requirements when collaborating with an AI system (as compared to collaborating with a human team member). Makes sure the strategy and approach is shared within the whole team, including both human and AI team members.</p>
<p>Problem Solving & Decision Making</p>	<p>Accurately identifies risks and resolves problems. Uses the appropriate decision-making processes</p>	<p>Current elements: Seeks accurate and adequate information from appropriate sources; Identifies and verifies what and why things have gone wrong; Employ(s) proper problem-solving strategies Perseveres in working through problems without reducing safety; Uses appropriate and timely decision-making processes; Sets priorities appropriately; Identifies and considers options effectively; Monitors, reviews, and adapts decisions as required; Identifies and manages risks effectively; Improvises when faced with unforeseeable circumstances to achieve the safest outcome</p> <hr/> <p>Additional elements: Considers critically IA's predictions; Effectively recognises and avoids automation bias; Compares eventual different human and AI solutions with a safety-driven approach; Adheres to procedures of the Intelligent Assistants</p>
<p>Situation Awareness</p>	<p>Perceives and comprehends all of the relevant information available and anticipates what could happen that may affect the operation</p>	<p>Current elements: Identifies and assesses accurately the state of the aircraft and its systems; Identifies and assesses accurately the general environment as it may affect the operation; Keeps track of time and fuel; Anticipates accurately what could happen, plans, and stays ahead of the situation; Develops effective contingency plans based upon potential threats; Identifies and manages threats to the safety of the aircraft and people; Recognizes and effectively responds to indications of reduced situation awareness;</p> <hr/> <p>Additional elements:</p>

		<p>Understands in real-time the AI information; Understands the AI data processing; Understands and assesses the overall system hierarchy and possible provided support according to the situations; Recognises contradictions in the system; Recognises biases in AI data processing; Identifies and assesses accurately the aircraft's vertical and lateral position, and its anticipated and predicted flight path; Maintains awareness of the people and Intelligent Assistants involved in or affected by the operation and their capacity to perform as expected;</p>
<p>Stress & Workload Management</p>	<p>Managing available resources efficiently to prioritise and perform tasks in a timely manner under all circumstances.</p>	<p>Current elements: Maintains self-control in all situations; Plans, prioritises, and schedules tasks effectively; Manages time efficiently when carrying out tasks; Offers and accepts assistance, delegates when necessary and asks for help early; Reviews, monitors, and cross-checks actions conscientiously; Verifies that tasks are completed to the expected outcome; Manages and recovers from interruptions, distractions, variations, and failures effectively;</p> <p>Additional elements: Is able to perform a variety of stress management techniques when needed; Has a deep understanding of his/her emotional state; Effectively performs emotion regulation techniques; Is aware of the mental health issues that may arise due to the lack of human interactions; Notices when mental support is needed.</p>

3.3.3. The future of Team Resource Management for Air Traffic Controllers

Similarly to the concept that has been introduced for Pilots, a modified training program, the AI-TRM (AI-Team Resource Management) for air traffic controllers is envisaged and recommended for the future. The modified version of the training would specifically target to improve aspects of soft skills that are particularly important in successfully teaming up with an AI-based intelligent assistant. In the following section the behavioural indicators related to the previously introduced five soft skills (Communication, Leadership and Teamwork, Problem solving and decision making, Situation awareness, Stress and workload management) are introduced.

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- **Stress and workload management:** while one of the most important objectives of ISA would be to reduce tower controllers' workload by taking over tasks and provide suggestions based on the available data, the introduction of an AI-based assistant might generate a **different form of stress** that does not result from the extremely high workload. Instead, controllers might feel anxious **due to a perceived decrease in their control over the process**, as well as they could feel challenged to **develop a detailed understanding** of the different technical parameters isolated from each other. **Trusting the AI-based system** could be an additional source of controllers' stress along with a potential anxiety related to the **potential failure of ISA**. Last but not least, it is important to point out that while an intelligent assistant would inevitably support the workload management of controllers' in periods of high peak, using the assistant during low peak periods of the day could potentially cause **cognitive underload** and therefore increased stress among controllers.
- **Situation awareness:** by the introduction of the intelligent assistant, air traffic controllers are no longer expected to be the executors of the majority of tasks. Instead, they are envisioned to take on a **supervisory role**, in which they are **provided with suggestions** of decision plans -based on automatically integrated data- and asked for approving the plan and monitoring the execution. While contributing to reducing control officers' workload, the envisioned intelligent assistant may represent a **challenge in the timely and accurate development of their situation awareness** in at least two ways. First, as all crucial data is envisaged to be integrated and provided by the system (instead of them being accessible via different interfaces) the intelligent assistant might contribute to a faster way of building situation awareness, however, this **situation awareness will be based on the representation of the intelligent assistant. In other words, if this representation is incorrect, the situation awareness of the controllers will equally be so.** On the other hand, taking on a rather supervisory role would also mean that **in case of emergency situations** as well as in case of ISA's breakdown, **controllers will be in charge to take back control** and manage the scenario as soon as possible. This, however, would require them to 1) perceive all the important environmental cues 2) interpret them correctly and 3) project this interpretation to the near future to anticipate what to do next. It is therefore vital that **air traffic controllers are kept in the loop of events** and stay engaged and up to date with the most important parameters of the system. This will on the one hand require an interface of **the assistant that not only provides mere data, but also the reasoning behind certain suggestions**, thus making sure that the **human and the machine are sharing the very same mental model of the task**. On the other hand, this will **require adaptability from the controllers** to be able to react quickly and smoothly to an unexpected situation, as well as they would need to have **advanced critical thinking skills to be able to recognize if the parameters provided by the system do not match the reality**. Last but not

least, understanding how ISA works would require controllers to have a very **comprehensive and detailed theoretical knowledge of the system.**

- **Communication:** as ISA is expected to reduce future interactions of air traffic controllers by approximately 95%, communication will certainly be **the most impacted area of the job of future controllers.** ISA is envisaged to act as a central communicator between the actors by receiving, forwarding and providing information to the humans and other systems involved in air traffic management, thus greatly reducing the risk of miscommunication that is by its nature, inherent part of voice communication. This, on the other hand, will also mean that the behavioural indicators of communication as a skill, in their current form will be less applicable to future situations. While **controllers will need to retain their skills related to voice communication for the sake of emergencies,** they will also need to learn **how to interpret the "communication" of their AI-based teammate as well as how to communicate with it and with other humans via the system.** As intrateam communication is also considered as one of the crucial factors in building a shared mental model among team members, future controllers will need to have a very **detailed understanding of the content of information to communicate with a human and with an AI-based assistant** in order to support them **to be on the same page.**
- **Leadership, control over automation and teamwork:** Similar to the case of pilots, TRM should aim to develop a **training** model that encompasses the **collaboration of human-AI teams,** fosters **trust,** ensures **clear communication** and **delegation of tasks** and considers both a human communication model and a data-driven approach. To effectively manage a team that is composed of humans and AI-based assistants, one must have a **clear overview and firm strategy related to roles, tasks, responsibilities as well as the links between actors.** On the other hand, to foster an effective **control over automation,** theoretical knowledge and practical skills related to the manual execution of the task are inevitable, making the **prevention of skill loss** as one of the most important aspects of future training. To support humans in taking over control when needed, **operation manuals** should be also extended by not only describing the step-by-step description of how to collaborate with ISA, but also a detailed and **comprehensive contingency plan** for the case when ISA stops functioning, and an urgent need occurs to take over the tasks. Last but not least, **adaptability** to these kinds of unexpected emergencies will be the key for air traffic controllers to **quickly shift their mindset to manual operation.**
- **Problem solving & Decision making:** In order to overcome human biases resulting from the overreliance on or lack of trust in the AI-based assistant, future air traffic controllers will need to be provided with a transparent interface to oversee and understand the reasoning of the system and the logic behind certain decision plans. In addition, skills related to **critical and analytical thinking, problem solving** and **building situation awareness** will be crucial to gain **understanding** of the problem as well as **the consequences of decisions.**

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One of the most important prerequisites of advanced decision making in the future will be the ability to **correctly interpret data provided by the ISA**, as well as to **correctly perceive and identify signs of potential system breakdown**.

In Table 3., an example of updated behavioural indicators for air traffic controllers' Evidence Based Training after the introduction of AI-based (TRM) assistants is provided.

Table 3: Example of Evidence Based AI-TRM (current elements are taken from "Easy Access Rules for Air Traffic Controllers' Licensing and Certification – Revision from March 2024", issued by the European Union Aviation Safety Agency)

Competency	Competency description	Behavioural indicators
<p>Communication</p>	<p>The ability to communicate effectively across all operational situations.</p>	<p>Current elements: Speaks clearly, accurately and concisely Uses standard radiotelephony phraseology, when prescribed Verifies accuracy of read backs and if necessary, corrects Selects communication mode (e.g. radio, telephone) that takes into account the requirements of the situation, including speed, accuracy and level of detail of the communication Uses plain language when standardised phraseology does not exist or the situation warrants it Adjusts verbal communication techniques to suit the situation (e.g. rate of speech, use of phonetic alphabet for clarity, words twice, separating instructions)</p>
		<p>Additional elements: Uses correct phraseology and procedures with humans and AI, according to the receiver of the communications; Selects appropriately what message to communicate to which actor; Selects appropriately when to communicate a message; Selects appropriately how to communicate a message (communication channels, style, language); Selects appropriately the recipients of the message (humans or AI-based assistants); Effectively prompts commands to the AI teammate; Accurately reads and interprets AI outcomes.</p>
<p>Teamwork and</p>	<p>The ability to effectively</p>	<p>Current elements:</p>

<p>leadership</p>	<p>collaborate with others in reaching shared goals and manage task- and team related aspects of the task environment.</p>	<p>Demonstrates consideration of and tolerance for other people, if necessary Ensures that actions and duties are carried out in a manner that fosters a team environment Responds appropriately to the needs of others</p>
	<p>Additional elements: Identifies and manages overreliance and mistrust towards AI of the crew; Has a clear vision of tasks and responsibilities of humans and AI-based assistants. Effectively collaborates with others, with respect to the characteristics of a human and an AI-based teammate; Communicates with other actors to foster shared understanding of task allocation; Adapts to unexpected situations by effectively taking over control over the system; Makes necessary adjustments in task approach in line with the occurring changes. Effectively makes decisions based on the inputs provided by their humans and AI teammates; Has a clear understanding of the actions of their AI-based assistant and the logic behind its actions; Has a comprehensive knowledge of the operation manual and the contingency plan related to system breakdown. Identifies and reports malfunctioning of the AI-based system. Has a clear understanding of the principles, challenges and requirements when collaborating with an AI system (as compared to collaborating with a human team member). Makes sure the strategy and approach is shared within the whole team, including both human and AI team members.</p>	
<p>Problem Solving & Decision Making</p>	<p>The ability to make informed decisions and having a clear strategy to approach problematic situations.</p>	<p>Current elements: Uses appropriate tools to assist in determining possible solutions to a problem Ensures safe and efficient solution to a problem Prioritises actions in an appropriate order Applies an appropriate mitigation strategy for the threats and/or errors identified (e.g. increased vertical separation in case of CAT, go around if RWY is blocked, etc.)</p> <p>Additional elements:</p>

		<p>Considers critically the IAs predictions; Effectively recognises and avoids automation bias; Compares eventual different human and AI solutions with a safety-driven approach; Adheres to procedures of the Intelligent Assistants; Has a clear understanding of the actions of their AI-based assistant and the logic behind its actions; Is capable of understanding potential malfunctioning by correctly interpreting system's inputs. Analyses the situation correctly by breaking it down to sub elements and understanding the links between them. Correctly identifies signs of potential AI-based system breakdown.</p>
<p>Situational Awareness</p>	<p>The ability to perceive and comprehend the current operational situation and anticipate future events accordingly.</p>	<p>Current elements: Monitors traffic in own area of responsibility and adjacent area(s) e.g. adjacent sectors, apron. Monitors the meteorological conditions that impact on own area of responsibility and adjacent area(s) Acquires information from available sources (e.g. surveillance and flight data systems, meteorological data, electronic data displays, verbal request) Analyses the actual situation based on information acquired from monitoring and scanning Identifies potential threats and errors Verifies that information is accurate and corrects when doubt exists, if necessary Checks and uses available tools to scan and comprehend operational situations Processes the information acquired from monitoring and scanning to maintain situational awareness</p> <p>Additional elements: Understands in real-time the assistant's information; Understands the assistant's data processing; Understands and assesses the overall system hierarchy and possible provided support according to the situations; Recognises contradictions in the system; Recognises biases in AI data processing; Maintains awareness of the people and Intelligent Assistants involved in or affected by the operation and their capacity to perform as expected; Correctly interprets the inputs coming from the assistant and anticipates future steps accordingly.</p>
<p>Stress &</p>	<p>The ability to manage</p>	<p>Current elements:</p>

Workload Management	available resources efficiently and to prioritise and perform tasks in a timely manner.	<p>Maintains self-control in changing and/or adverse situations</p> <p>Manages tasks effectively in response to current and future workload</p> <p>Manages interruptions and distractions effectively</p> <p>Delegates tasks to reduce workload, if necessary</p> <p>Integrates assistance if necessary, to reduce workload, if offered or requested</p> <p>Adjusts the pace of work according to workload</p> <p>Uses ATS equipment to perform tasks in an efficient and timely manner (e.g. strip marking, updating radar labels, use of automated functionalities)</p>
		<p>Additional elements:</p> <p>Stays comfortable and confident when the assistant is in operation, be “letting the system work”;</p> <p>Remains composed when there is an urgent necessity to take control over automation;</p> <p>Adjusts their pace of work and priorities when there is a sudden need to take over control;</p> <p>Stays focused and vigilant in periods of low workload.</p>

3.3.4. Future training for UAM coordinators

Similarly to the concept that has been introduced for Pilots and Air Traffic Controllers, the training approach of AI-CRM and AI-TRM could be applied in the case of UAM coordinators, by following the previously introduced five soft skills (Communication, Leadership and Teamwork, Problem solving and decision making, Situation awareness, Stress and workload management) and matching them with the envisaged key future behavioural indicators. In this section a possible future list of these indicators is introduced for the role of UAM coordinators.

- **Stress and workload management:** As the UAM coordinators’ role becomes pertinent when handling unforeseen situations, it is essential to stay calm, composed and focused even during a quickly unfolding emergency situation. This requires them to maintain their emotional stability and quickly regain balance while effectively communicating with actors of multiple backgrounds. Effective workload management skills will be expected when UAM coordinators need to collect, synthesise and interpret information from various sources along with constant and effective communication, coordination and planning of immediate actions.
- **Situational awareness:** One of the key challenges related to the future role of UAM coordinators is their responsibility to interpret insights of the intelligent assistant, combining it with the information received from multiple actors, and based on them build and accurate and updated situational awareness, by

bearing the characteristics of the broader operational context in mind. In the envisaged scenario, key information for decision-making will arrive from multiple parallel sources, sometimes including actors who may lack familiarity with aviation phraseology and lack the same mental model of the UAM coordinators. It is therefore essential for safe operation that the professionals of this future role possess a quite advanced critical thinking to be able to assess the correctness of the information received. Strongly linked to this, the ability to change perspectives and understand the situation from another actor's point of view may be crucial for a future UAM coordinator to receive the right information in a timely manner, thus building a situational awareness that is aligned with the real scenario.

- **Communication:** Probably one of the most important skills of future UAM coordinators will be their ability to effectively communicate with all the relevant actors of a potential emergency situation. This entails their capacity to maintain constant information flow, as well as to understand the needs of the other actors in terms of content and style of communication. As communication may often entail information exchange with non-aviation stakeholders, the ability to use the right communication style, to ask for information and to deliver the right information will be crucial in avoiding information overflow and thus a significant cognitive overload. This includes one's capability to adapt their language to the characteristics and knowledge of the receiver.
- **Leadership, control over automation and teamwork:** As envisaged central actors of a future air traffic, UAM coordinators will be expected to have excellent coordination skills. This involves -as mentioned before- their ability to effectively engage actors in the communication chain, to make sure that key information is received and delivered in an effective and timely manner, as well as to assess the impact of contribution of each actor on the envisaged future situation. As coordinators of a potential emergency scenario, they may need to make decisions based on limited data previously synthesised from previous sources, including AI-based assistants. As highlighted earlier, understanding the business and economic implications of their decisions will be the key for balanced priorities. This will require them to have a broad overview and understanding of the wider operational context as well as a strategic approach that aligns with both safety and business objectives.
- **Problem solving & decision making:** As UAM coordinators are envisaged to handle not only low-traffic routine situations, but also intensive, quickly unfolding emergency scenarios, their ability to make effective decisions will be an essential skill in the future. As these decisions may be based on limited data, UAM coordinators must have excellent problem-solving skills as well as great flexibility to quickly adapt themselves and their strategy according to the situational requirements. Strongly linked to their decisions, they need to be able to understand the possible impact and consequences of these decisions on all the involved actors in the procedure. While managing high traffic scenarios, UAM

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coordinators may also need the ability to prioritise alerts and create the sequence of planned actions accordingly.

In Table 4., an example of future behavioural indicators for UAM coordinators is provided.

Table 4: Example of future behavioural indicators for UAM coordinators

Competency	Competency description	Future behavioural indicators
Communication	The ability to communicate effectively across all operational situations.	<ul style="list-style-type: none"> Conveys information and in a timely, clear and concise manner; Uses appropriate vocabulary and communication mode to convey information depending on the situational requirements; Understands the informational needs of other actors with various professional backgrounds. Shares the right amount of information, in order to stay informative but avoid information overflow. Engages in active listening to understand message content and intent of other(s); Confirms that the recipient correctly understands important information (e.g. verifying accuracy of readbacks); Uses correct phraseology and procedures with humans and AI, according to the receiver of the communications; Selects appropriately what message to communicate to which actor; Selects appropriately the timing of communication (when to communicate a message); Selects appropriately how to communicate a message (communication channels, style, language); Effectively prompts commands to the AI teammate; Accurately reads and interprets AI outcomes.
Teamwork & leadership	The ability to effectively collaborate with others in reaching shared goals and manage task- and team related aspects of the task environment.	<ul style="list-style-type: none"> Interacts with others in a respectful and professional manner; Applies a strategic, holistic approach when planning his/her actions, considering short-term, mid-term and long-term impacts. Effectively involves actors in the communication chain; Correctly assesses the impact of the contribution of each actor in the task execution; Understands and keeps in mind the business and economic implications of decisions; Effectively balances between safety, business and economic impacts of planned actions;

		<p>Seeks actively the input and involvement of others; Ensures that correct and complete information is given to every respective actor; Admits own mistakes and takes corrective action; Gives and receives feedback professionally; Works through interpersonal conflicts to ensure smooth collaboration among actors. Quickly and flexibly adapts strategy to unforeseen situational requirements. Has a clear vision of tasks and responsibilities of humans and AI-based assistants. Effectively collaborates with others, with respect to the characteristics of a human and an AI-based teammate.</p>
<p>Problem solving & decision making</p>	<p>The ability to make informed decisions and having a clear strategy to approach problematic situations.</p>	<p>Gathers information and other's input when making decision. Effectively collects and synthesises inputs coming from various stakeholders. Effectively applies critical thinking when assessing the content of communication received by different actors. Identifies and analyses the critical elements of a situation and sees connections, patterns and trends even when not obviously related (analytical thinking). Actively engages in collaborative decision-making to find solutions to complex problems; Anticipates potential obstacles and considers the short and long-term implications of a decision/possible solution to a problem. Understands and considers the business impact of actions when making decisions and planning strategy. Makes decisions effectively even in quickly unfolding situations. Prioritises among tasks in an efficient manner and creates a correct sequence of planned actions accordingly. Compares eventual different human and AI solutions with a safety-driven approach; Adheres to procedures of the Intelligent Assistants; Has a clear understanding of the actions of their AI-based assistant and the logic behind its actions; Analyses the situation correctly by breaking it down to sub elements and understanding the links between them; Correctly identifies signs of potential AI-based system breakdown.</p>

<p>Situation awareness</p>	<p>The ability to perceive and comprehend the current operational situation and anticipate future events accordingly.</p>	<p>Gathers the correct information from various actors to build understanding of the situation. Actively and regularly seeks information coming from human and AI-based actors to ensure an updates situational model. Monitors the status updates of different actors in the information chain. Monitors the operational circumstances and forms predictions of the near future accordingly. Keeps a clear overview of the traffic situation by scanning regularly, extrapolates traffic progression and anticipates future events; Identifies potentially hazardous situations; Understands in real-time the assistant's information; Understands the assistant's data processing; Understands and assesses the overall system hierarchy and possible provided support according to the situations; Recognises contradictions in the system; Recognises biases in AI data processing; Maintains awareness of the people and Intelligent Assistants involved in or affected by the operation and their capacity to perform as expected; Correctly interprets the inputs coming from the assistant and anticipates future steps accordingly.</p>
<p>Stress & workload management</p>	<p>The ability to manage available resources efficiently and to prioritise and perform tasks in a timely manner.</p>	<p>Plans, prioritises and schedules tasks effectively in response to the current workload; Maintains concentration and manages interruptions and distractions effectively; Maintains focus while addressing multiple tasks and priorities; Quickly shifts attention between competing work activities and demands, based on operational requirements; Adjusts the pace of work according to workload; Manages own workload in emergency situations so that he/she remains in control and is not overwhelmed by competing tasks. Stays focused and vigilant in periods of low workload.</p>

3.4. How to train: recommendations on training and knowledge sharing

In addition to the anticipated changes in what skills and knowledge will be crucial to address during training, another important question will be **how to teach them in the future**. The format of training may have a key impact on whether and how effectively these new skills are acquired and applied in real-life situations. Continuous technological developments in the aviation sector require an increasing number of new technical skills, resulting in an education path for employees that is mostly based on formal training. On the other hand, the **subjective experiences, know-how, perceptions, and attitudes** of professionals represent an important **and valuable form of knowledge**. As required technical skills and procedures might slightly differ among organizations, the related know-how and experiences of future pilots, air traffic controllers and UAM coordinators also represent a collection of tacit knowledge being unique to their organization. If **collected and shared effectively**, this knowledge could be an important additional asset in training future professionals as well as overcoming the initial difficulties of teaming up with AI.

Nonaka and Takeuchi's "SECI" model (1995) of knowledge management represents a practical approach to how knowledge within a company is created and re-created, as different forms of explicit and tacit knowledge are continuously transforming into one another (see Figure 8.). According to the model, the four forms of knowledge creation are:

- **Socialisation (tacit to tacit):** a form of knowledge sharing that is based on physical proximity. During socialisation, knowledge is shared and captured by direct observation, imitation and/or practise through apprenticeship.
- **Externalization (tacit to explicit):** the other form of knowledge sharing, during which tacit knowledge becomes explicit, crystallised, and shared with others, thus becoming the basis of new knowledge. This way, personal tacit knowledge becomes useful for others in an explicit, understandable, and interpretable form (e.g. concepts, documents, images).
- **Combination (explicit to explicit):** it involves the organisation and integration of knowledge, whereby different forms of explicit knowledge are merged, and finally a new form of explicit knowledge is created. Examples of combinations involve writing a report or building a prototype.
- **Internalisation (explicit to tacit):** the receiving and application of explicit knowledge by an individual. Explicit knowledge becomes part of an individual's knowledge base, typically by the act of learning-by-doing.

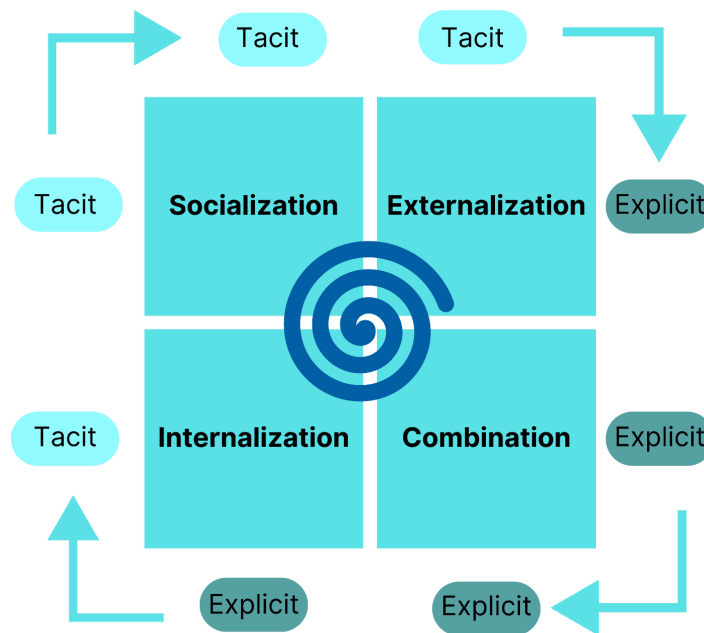


Figure 8: “SECI” model of knowledge management, the “knowledge management spiral” (Nonaka & Takeuchi, 1995)

Knowledge management of pilots

As it has been highlighted during the semi-structured interview, **pilots-in-training today acquire knowledge** mostly through the process of **internalisation and socialisation**. By acquiring **theoretical knowledge on aviation** and by practising technical and non-technical skills on a **simulator (learning-by-doing)** they internalise explicit knowledge that is required to become a pilot. This internalised knowledge is then expanded and **fine-grained by observing the other pilot** during flights, in other words, a form of socialisation takes place. **Externalization as a** knowledge sharing form, however, is often present in a **less formal and therefore ad-hoc form**, resulting in valuable subjective experiences and best practices remaining unshared.

On the other hand, unexpected events or other stressful, high workload situations often provoke intensive subjective feelings and emotions, like frustration, insecurity, lack of control or even fear. These subjective experiences may activate very diverse individual reactions, from which some prove to be successful, thus turning into a recurrent coping skill, in other words, a best practice of the individual. These **subjective feelings and related coping mechanisms** are, however, **prone to remain unshared**, even though they could be important knowledge accumulated and shared within the company. This is mostly due to the **prevailing masculine organisational culture** within aviation (Gorlin, Bridges, 2021) where - as pinpointed during the semi-structured interview - talking openly about **emotions and personal weaknesses is still a challenging area**. A potential mitigation strategy could be the application of formally organised focus group

sessions, facilitated by psychologists. These sessions would provide an opportunity to share individual best practices and make them explicit. Based on that, the collection, organisation and sharing of this knowledge would ensure that it becomes part of the knowledge management spiral, and thus, part of the organisation's collective knowledge. The presence of a facilitator, on the other hand, would give a guarantee that a psychologically safe atmosphere is provided for pilots to talk about their subjective experiences openly and freely.

Anticipated changes in the future related to AI will also result in a major transformation of airlines' existing knowledge base. A considerable amount of explicit and tacit knowledge will likely become outdated and irrelevant, as technology and the related procedures, regulations and policies will transform radically. On the other hand, **new forms of explicit knowledge will be required**, and along with that, a remarkable amount of **new know-how will be accumulated** in the form of tacit knowledge. This knowledge, if shared and organised efficiently, **could be channelled into the future training of pilots**, thus **accelerating successful human-AI teaming**. Organisations in the aviation sector are therefore highly encouraged to build a proactive strategy on how to consciously manage organisational knowledge in the future, when AI will become an important actor in the cockpit. One challenging aspect of this transformation would be to **discover how an AI-teammate could be involved in the organisation's knowledge management spiral**. A potential area in which AI could play a key role in the future is the process of Combination, during which AI-teammates would create new forms of explicit knowledge by merging different sources of already existing explicit knowledge. AI will most likely also be crucial in the storage, organisation and provision of explicit knowledge when needed in the cockpit.

Changes in the future do not only call for new forms of training among pilots: **flight instructors are also expected to be up-skilled to develop new knowledge and a detailed understanding of the systems** on which they train their students, as well as the related technical and non-technical skills. In addition, flight instructors in the future will likely face the **challenge of the different training requirements related to the skilling and reskilling of pilots**. In other words, a detailed understanding will be needed on what and how to train students with no previous knowledge in aviation and professional pilots who need to overwrite already existing knowledge. Moreover, some instructors may be expected to experience **difficulties in training due to potential negative attitudes or initial resistance towards learning and re-learning a system** where AI acts as full-fledged teammate in the cockpit. Therefore, it could be important that flight instructors receive **regular feedback and supervision** from a number of different professionals (flight instructors, psychologists, pedagogues) on the way they train in forms of **"train the trainer"** sessions. This guided feedback would support them in the future to maximise the effectiveness of training, as well as enable them to provide personalised forms of education to students, be they new cadets or re-skilled professional pilots.

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Knowledge management for air traffic controllers

After passing tests that assess one's medical and psychological eligibility, applicants first go through an **"initial training course"** to gain theoretical knowledge and practical skills related to air traffic management. The initial training course lasts about 5-6 months, during which students' skills related to communication, adaptability to uncertain situations, stress management, multitasking, situation awareness and procedure compliance are all practiced and assessed. Besides the formal, theoretical, formal knowledge sharing, students are also engaged in different exercises on the simulator and gain knowledge based on the principle of "learning by doing". It can therefore be concluded that during the initial training course, the knowledge sharing, and management is mostly formal by ensuring time and space for students to internalise explicit formal knowledge related to ATM ("Internalisation"). After the initial training, students participate in a **"unit training"** where they acquire all the specific information and knowledge that is crucial to be able to operate effectively as an air traffic controller at one specific airport. From the knowledge management spiral point of view, unit training is the part of the formal process, where students get the opportunity to gain knowledge by "Socialisation" and "Externalisation". During these months, they are provided with implicit knowledge, best practices and specific know-hows by observing controllers doing their daily tasks ("Socialisation"), as well as by senior colleagues sharing useful information and knowledge with them ("Externalisation"). As underlined during the interview session, the **most important changes in future trainings** will certainly be related to the fact that **air traffic controllers will not be problem solvers** at first place anymore, **but rather supervisors of a complex system**. **For the initial training course**, this will require the extension of the training material by not only covering competences related to manual operation but addressing the knowledge acquisition needed to team up with the AI-based intelligent assistant, as well as the practical skills to collaborate with it. The training therefore should **specifically address the challenge of how to keep human controllers in the loop to prevent the loss of skills and to ensure that situation awareness is maintained**. A potential future initial training course could therefore first address how to operate without ISA, and **once competences related to manual operation are mastered, it could address how to operate and collaborate with ISA**. After the initial training course is completed, specific unit training should address how ISA is implemented at specific airports and whether there are certain best practices, know-hows that are explicitly related to the collaboration with the intelligent assistant. As highlighted during the interview, one potential mitigation of skill loss could be to apply **both manual and AI-assisted operation in the future, with respect to the daily peaks of workload at airports**: during high-peak hours, ISA could operate as a full-fledged team member in operation, thus decreasing tower controllers' workload, while during less intense periods (e.g. night shifts), controllers could operate manually,

without the aid of an AI-based assistant. Furthermore, **periodic training on simulators addressing the refreshment of competences related to manual operation** will be crucial to ensure human's adaptability to an emergency situation.

Knowledge management for UAM coordinators

When creating the knowledge baseline for the new role of UAM coordinators, the most important starting point in the knowledge management spiral will likely be the one of **"Combination"**: taking the already existing roles (e.g. ATCOs) as the points of entry, a clear and written characterisation of this role will be required, including a thorough job analysis, the necessary technical knowledge, required operational rules and procedures, related training, and competency profile. By combining the already existing knowledge and expertise, the new role will secure its distinct place within the future aviation industry. The newly generated knowledge will then form the basis for new entrants to be trained to become UAM coordinators, in other words, this knowledge will be **"internalised"** by future professionals. It is important to highlight that, compared to the role of pilots and air traffic controllers, the role of **"Socialisation"** (learning-by-doing) will not be a significant source of knowledge sharing for the first generation of UAM coordinators, as this will be a role that has not existed before, therefore, the direct observation of how it is being done will not be available for the first students. On the other hand, their direct experience in this position, and how the formal description of required knowledge may be distinct on how things can be done in real operation will be a crucial source of knowledge for the second generation of UAM coordinators, and by **"Externalising"** their know-how and experience in the position, the previously created knowledge can be further improved and fine-tuned. Similarly, they will play a key role in the **Socialisation** of UAM coordinators at a later stage, as live examples of how this job type is done.

4. What to take away: Lessons Learned

In this section, the main findings of T8.4. are summarised as lessons learned to **provide recommendations for future actions**. Coded lessons learned will serve as **anchors to look back at when developing future training programs for pilots, air traffic controllers and UAM coordinators**. Lessons learned collected in this chapter are also considered as the **key take away messages of the document**:

Table 5: Lessons learned

I. Who to train		
1. Selection	LL_I_1_01	A revision of future personality profiles is recommended: in the case of pilots and ATCOs individuals with higher Emotional stability, Openness to experience, Agreeableness and with lower Extraversion may be favoured in selection. In the case of UAM coordinators individuals with higher Extroversion, Agreeableness, Conscientiousness and Emotional stability will likely be preferable in selection.
2. Recruitment	LL_I_2_01	A revision of recruitment strategy is needed: understanding future generations' needs and matching them with what the future role of pilots, air traffic controllers and UAM coordinators has to offer will be key in successful recruitment.
	LL_I_2_02	A revision of recruitment strategy is needed: a clear introduction of all aspects of the future roles will support candidates to build realistic expectations and thus minimise dropouts and turnover.
II. What to train		
1. Stress & workload mgmt.	LL_II_1_01	Working environments with a reduced human interaction in the future will require a wider variety of stress management and emotion regulation techniques.
	LL_II_1_02	Working environments with a reduced human interaction will require pilots to acquire enhanced skills on self-assessment (cognitive, physiological, psychological state).
2. Situation awareness	LL_II_2_01	Besides the visual support provided by the IA, the use of a checklist is recommended to make sure,

		situational awareness is <i>indeed</i> regained after startle (to avoid "look but not see" effect).
	LL_II_2_02	A deeper understanding is needed on the process of building situational awareness after shorter or longer phases of resting/sleeping.
	LL_II_2_03	The explainability of the AI-based intelligent assistants will be the key in supporting future professionals to reach and maintain their situational awareness on the highest level (anticipation, projection to future, "being ahead of the aircraft").
3. Leadership & control over automation	LL_II_3_01	Prevention of motoric skill degradation will be crucial in keeping the ability to take over control over the automated system (e.g. eye-hand coordination).
	LL_II_3_02	One of the key aspects of future roles related to leadership will be the understanding and correct delegation of tasks and responsibilities across human and AI-based team members, in a way that is clear to everyone.
4. Problem solving & decision making	LL_II_4_01	Working environments with a reduced human interaction will lower the chance to be cross-checked by human team members. Critical thinking and the ability to question oneself and the system will be crucial in successful decision making.
5. Communication & teamwork	LL_II_5_01	Losing spontaneous and non-verbal communication in the future will call for the reframing of communication procedures. Future professionals will need to understand when and how to communicate with human and AI-teammates and how to build a shared mental model involving human and AI-teammates.
	LL_II_5_02	The revised framework on team communication must take into account the cognitive cost of communication and strive to keep it on the minimum level.
	LL_II_5_03	Training on future teamwork must incorporate the dynamics of trust within the team: human crew members might rely differently on information received by humans or by AI teammates.
III. How to train		
1. Format of the	LL_III_1_01	Future training should incorporate formal group

training		sessions where individual feelings, experiences and coping mechanisms are shared ("Externalization").
	LL_III_1_02	Suggested formal group sessions are recommended to be facilitated by psychologists to make sure that a psychologically safe environment is created.
2. Knowledge management	LL_III_2_01	A well-planned, proactive organisational strategy is called for to collect and organise accumulated new knowledge related to HAT in the cockpit.
	LL_III_2_02	A strategy is called for to find ways to incorporate AI-based teammates in the knowledge management cycle.
3. The role of instructors	LL_III_3_01	An up-skilling of trainers will be needed to understand and keep up with the changes in technical and non-technical skills they will train future professionals.
	LL_III_3_02	Future trainers will be required to apply different, customised solutions in training depending on whether they train new students (skilling) or professional pilots (re-skilling).
	LL_III_3_03	Regular feedback and supervision are recommended to provide with trainers in order to maintain efficiency of future training.

5. Conclusions

This document shows the results of the outcomes of HAIKU T8.4. related to the detailed understanding of the transformation of skills and related training for pilots, air traffic controllers and UAM coordinators in the mid-term future once AI will be introduced in live operation.

AI, as a promising future direction in aviation is undoubtedly expected to require a novel approach in how humans operate successfully within this industry. In addition to being a supporting tool for pilots in finding optimal solutions or priorities, future intelligent assistants are also envisaged as full-fledged, active, and key actors in any teamwork. Therefore, to anticipate the requirements and prepare for a potential future where humans team up with AI is crucial.

- This process should start with systematically revising recruitment strategies and the key principles based on which future professionals are selected for training. The radical change in the working environment may result in current recruitment trends becoming outdated, as the main employee benefits will most likely change, too. In other words, the aspects that make these roles appealing today will not be the same in the future. As new generations will gradually enter the aviation industry, understanding their career needs and matching them with what the envisaged future work environment has to offer will become a priority in human resource management.
- Similarly, personal characteristics that likely predict a high job performance today may change consistently, as future professionals will most likely require a personality profile with more openness and trust to collaborate with new technologies and a high level of emotional stability. A potential revision of the personality profile of future roles could save important resources for companies in terms of time and costs, as the successful selection of pilots may minimise the risk of dropouts and attrition in later career stages.
- The required technical and non-technical skills will need to be modified and extended by the aspects of collaboration with an AI-based teammate. By developing a detailed understanding of future skills and by breaking them down into tangible behavioural indicators would not only support smooth human-machine interaction: behavioural indicators would also serve as new anchors of selection and performance appraisal thus ensuring a valid process of aptitude testing. In order to provide a systematic framework for the new skill set, the concepts of AI-CRM/AI-TRM for the three roles have been introduced in this deliverable, as frameworks that leverage on the already explored areas of non-technical skills, but take the potential to extend them according to the requirements of the collaboration with an AI-teammate.

- Finally, the way this modified skill set will be trained seems to be another interesting area to revolutionise in the future. As the transformation of the work environment, the ways of working as well as the requirements on technical and non-technical skills will necessarily result in the accumulation of new explicit knowledge and implicit know-how, defining effective ways of knowledge management and training formats in which these new knowledge and know-how can be successfully acquired will be a key in maintaining human performance and aviation safety. Lastly, the envisaged transformation is also expected to be a challenge for instructors, therefore formal supervision and “train the trainer” sessions were recommended as new ways of supporting instructors along the envisaged transformation process.

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7. Annex

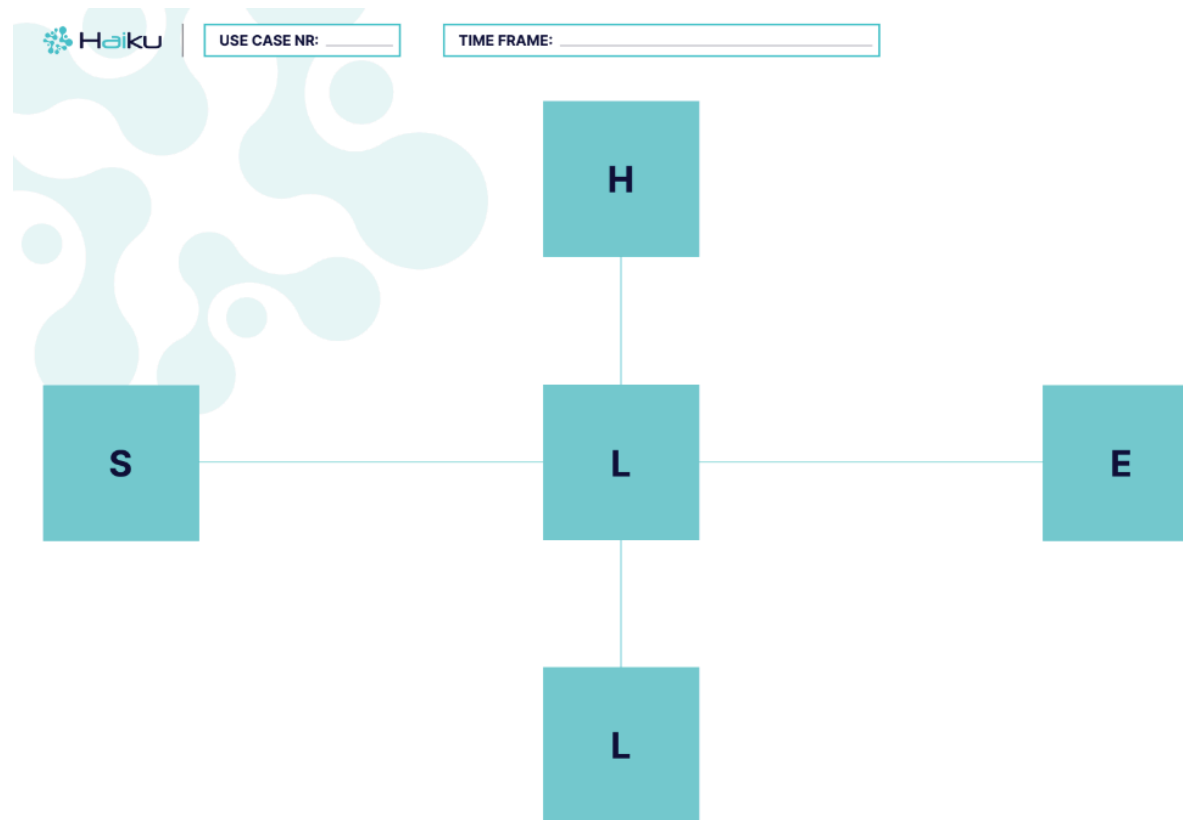


Figure 7: SHELL board template applied during the workshops for UC#1; UC#2 and UC#4

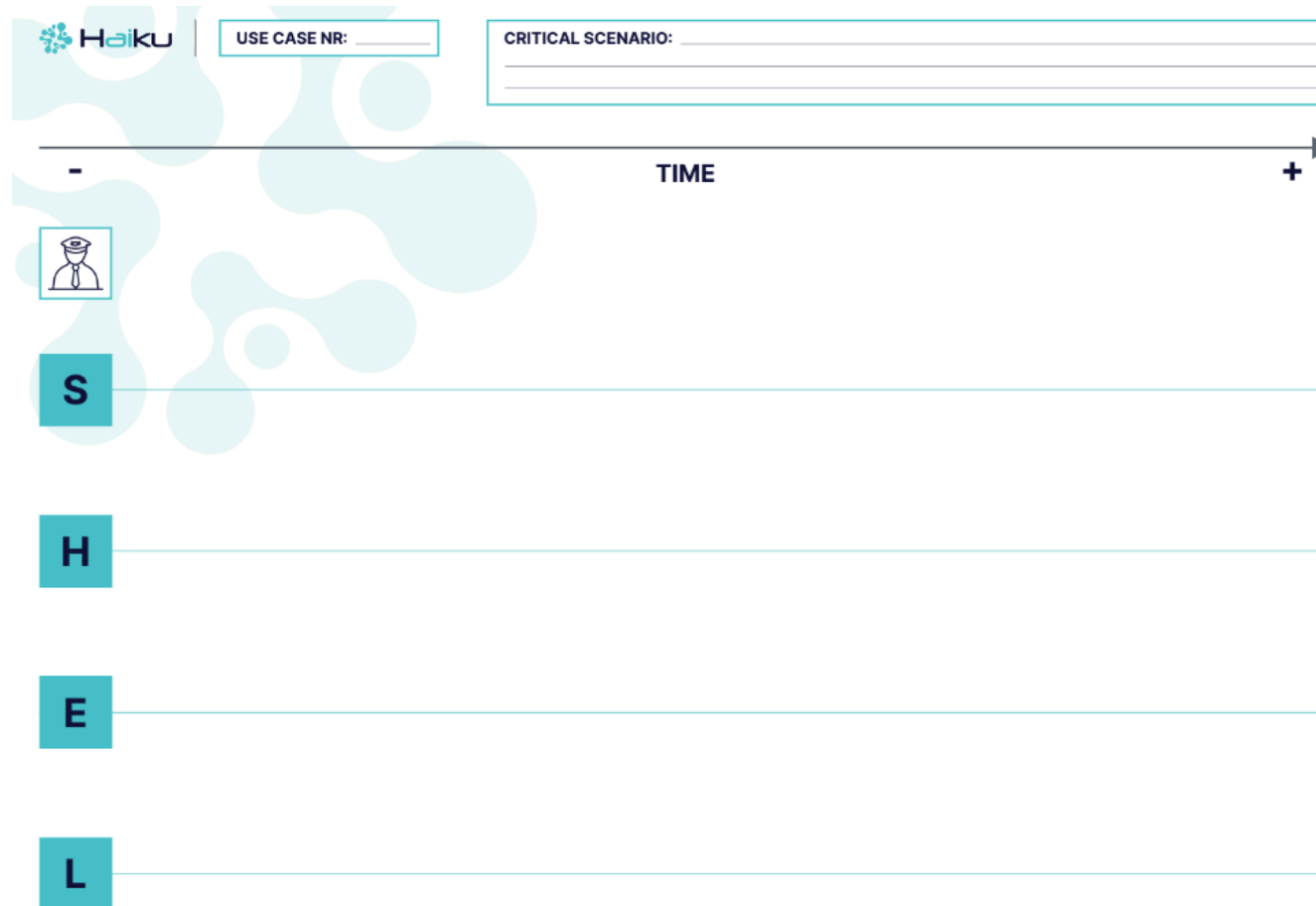


Figure 8: Timeline board template applied during the workshops for UC#1; UC#2 and UC#4

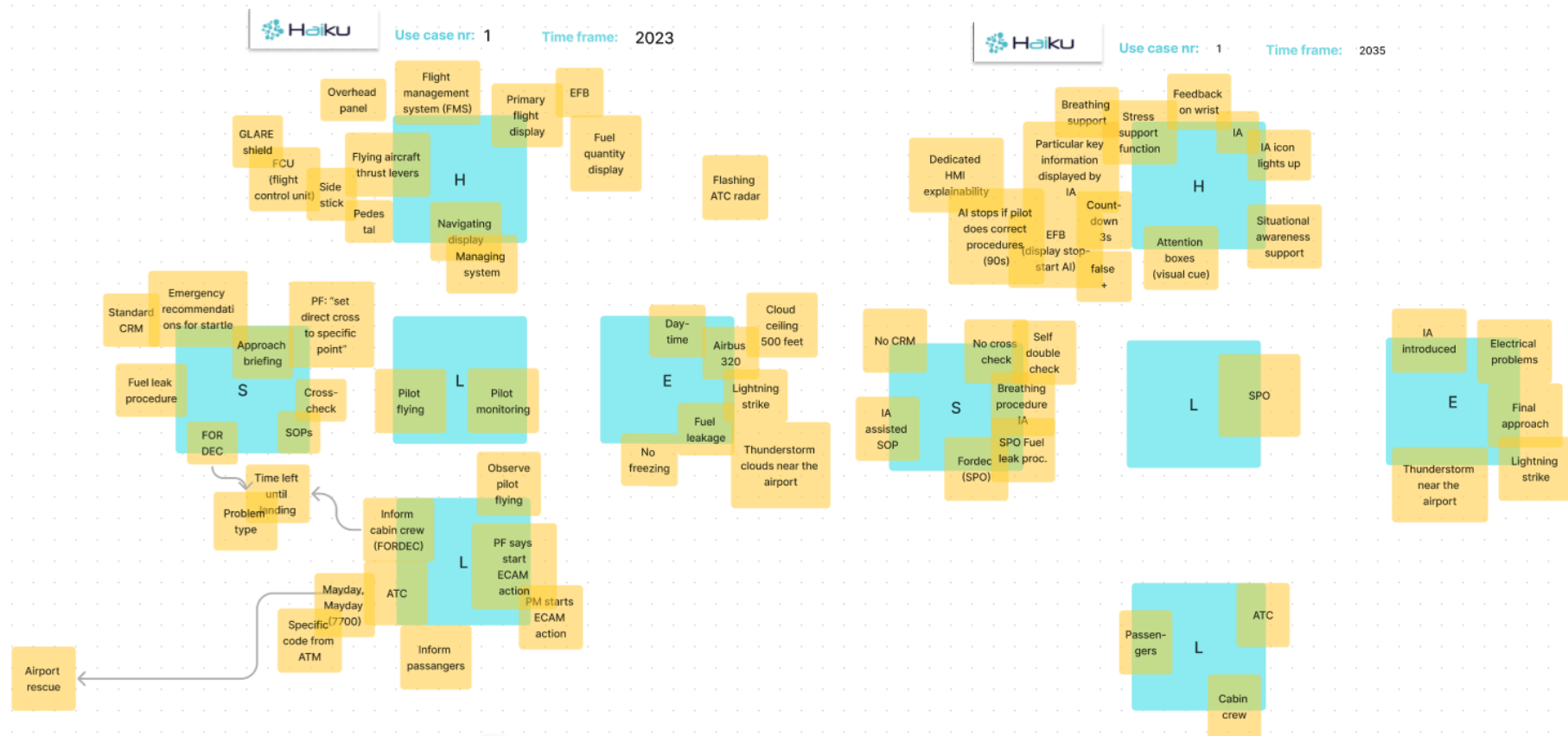


Figure 9: Example of how the SHELL board was filled in the workshop (UC#1; left SHELL: today, right SHELL: 2035)

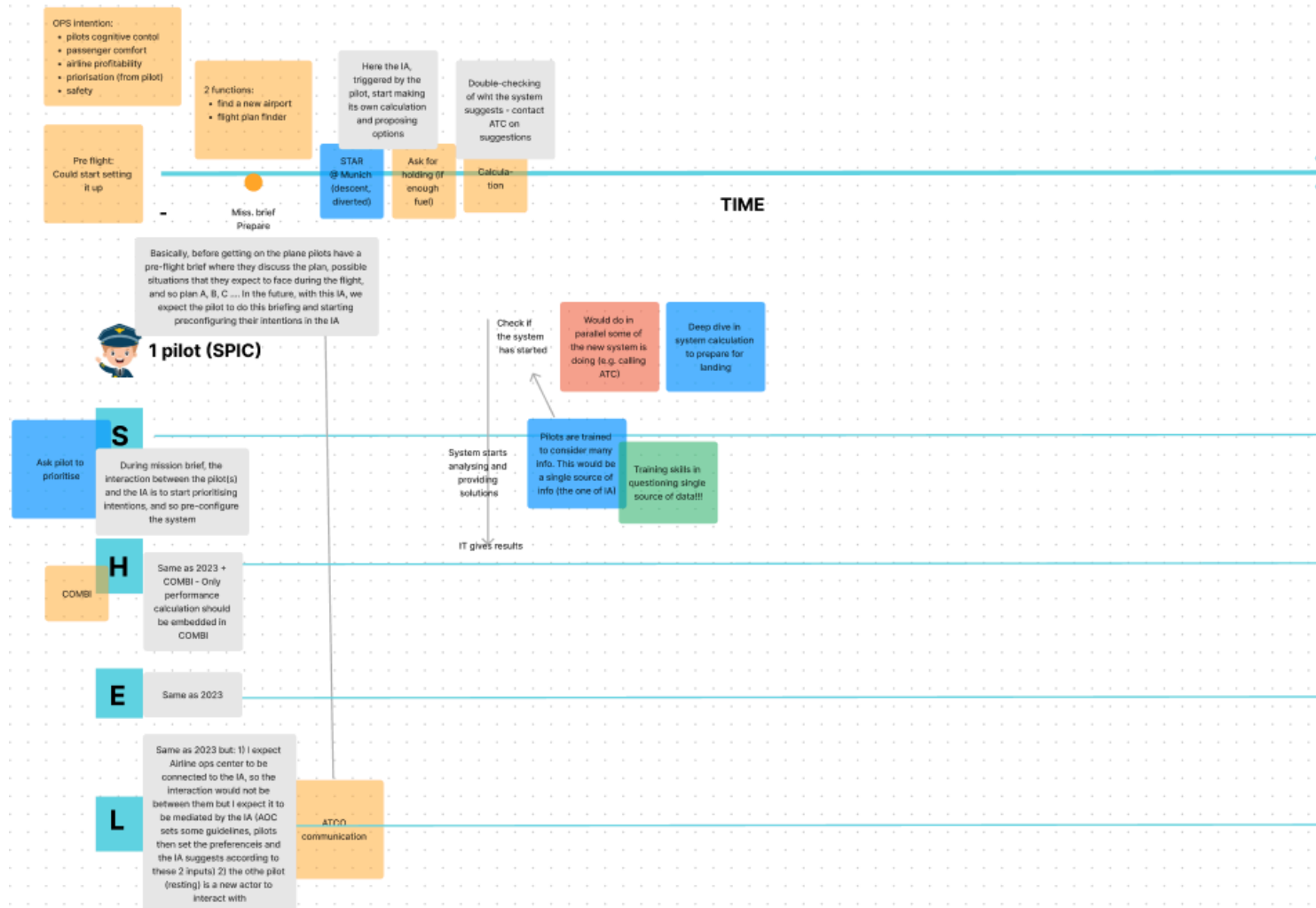


Figure 10: Example of how the timeline board was filled in the workshop (UC#2)

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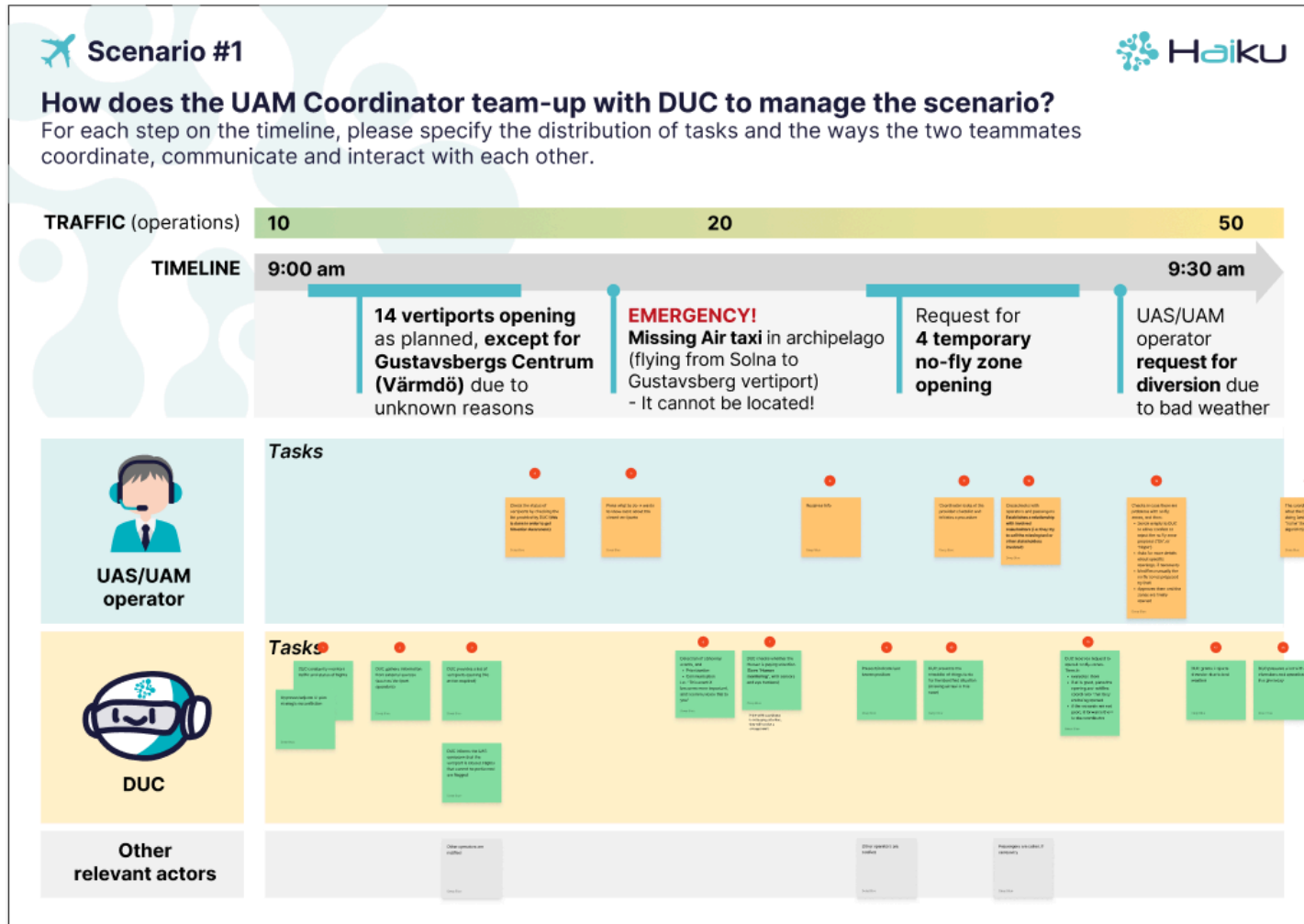
Table 6: CRM Training Table from EASA Regulation 1178/2011

CRM TRAINING TABLE	Introductory course on CRM
Training elements	
General principles	
Human factors in aviation General instructions on CRM principles and objectives Human performance and limitations Threat and error management	in-depth
Relevant to the individual cabin crew member	
Personality awareness, human error and reliability, attitudes and behaviours, self-assessment and self-critique, stress and stress management, fatigue and vigilance, assertiveness, situation awareness, information acquisition and processing	in-depth
Relevant to the entire aircraft crew	
Shared situation awareness, shared information acquisition and processing; Workload management; Effective communication and coordination between all crew members including the flight crew as well as inexperienced cabin crew members; Leadership, cooperation, synergy, delegation, decision-making, actions;	Not required (covered under CRM training required by Part-ORO)

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<p><i>Resilience development; Surprise and startle effect; Cultural differences; Identification and management of passenger human factors: crowd control, passenger stress, conflict management, medical factors.</i></p>	
<p><i>Specifics related to aircraft types narrow-/wide-bodied, single-/multi-deck), flight crew and cabin crew composition and number of passengers</i></p>	
<p><i>Relevant to the operator and the organization (principles)</i></p>	
<p><i>Operator's safety culture and company culture, standard operating procedures (SOPs), organizational factors, factors linked to the type of operations; Effective communication and coordination with other operational personnel and ground services; Participation in cabin safety incident and accident reporting.</i></p>	<p><i>Not required (covered under CRM training required by Part-ORO)</i></p>
<p><i>Case studies</i></p>	



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