Human AI teaming Knowledge and Understanding for aviation safety

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, taking into account the inputs provided by T8.1, T8.3 and the HAIKU Use Cases #1 and #2, namely the *Startling and surprising events in the cockpit* and the *Flight deck route planning/replanning*. 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

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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, the two use cases "**startling and surprising events in the cockpit**" (*UC#1*) and "**flight deck route planning/replanning**" (*UC#2*) were used as anchors to define the required future skills and the training methods to fill the future skills gap. The document will describe the sequential approach used to explore pilot interactions 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 interview held with a commercial airline flight instructor. The document is currently focusing on the role of pilots, and, as part of Task 8.4 the same methodology will be extended to the role of air traffic controllers as well as the envisaged future role of UAM coordinators.

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 pilots may require lower extraversion and higher openness to experience to adapt to social isolation and AI integration, as SPIC and SPO configurations in the future will necessarily result in less or no human interaction in the cockpit
- **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 future pilots 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 & Takehuchi, 1995). With the introduction of AI as a teammate in the cockpit 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 flight 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 remarkably impact future roles by 2035. This document describes the potential transformation of the role of pilots 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 trainings are suggested. Finally, as future changes will likely result in the accumulation of new knowledge, procedures and know-how, a proactive strategy to collect, manages, store, and share knowledge within 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.

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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 pilots' 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 and 2, focusing on the role of pilots.

HAIKU took a sequential approach in data collection:

- During a workshop with relevant stakeholders (representatives of the use cases; pilots), participants were asked to systematically reflect on the interactions and practices that pilots need to engage in today and in the future of 2035.
- Based on this 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.)

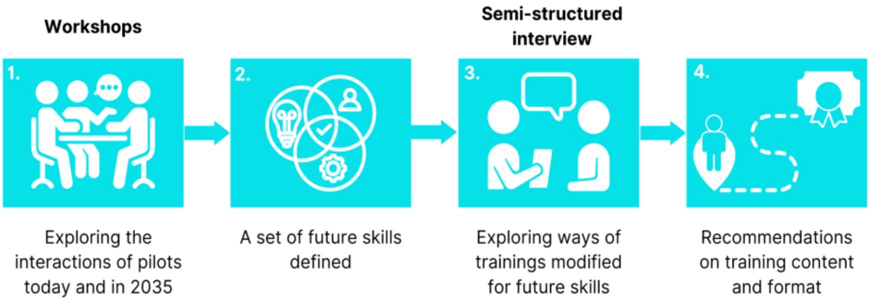

Figure 1: Sequential approach in data collection

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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.

2.2. Workshops

As the first step, two workshops for the two Use Cases 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 the two Use Cases 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):

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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.

2.3. Semi-structured interview

Next, a semi-structured interview with a flight instructor from a commercial airline was conducted to deep dive into the key aspects of the 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 session was 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?

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.

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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 pilots 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 pilots' 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 pilots 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 pilots' personality traits and their working environment 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 pilots 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. 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 pilots and the teams they are to form. On the other hand, pilots 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) should be modified and systematically extended in order to cover aspects of collaboration with an AI-based system. Therefore, we recommend the development and use of a new framework, called "AI CRM".

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 pilots
- What to train? - new skills for the future and the concept of AI-CRM
- How to train? - recommendations on training and knowledge sharing

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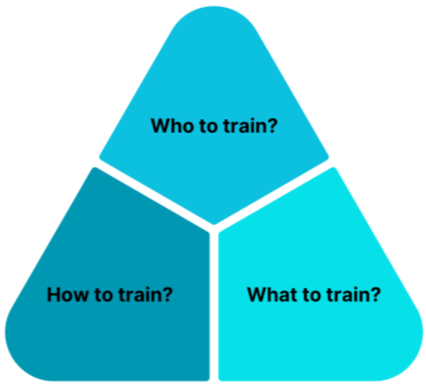

Figure 2: Areas of recommendations on future skills & training

3.2. Who to train: personality traits of future pilots

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). 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.

The most commonly used personality index in assessing pilots' 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.

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- **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.

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Factors of the FFM	Individuals scoring high on this dimension tend to…	Individuals scoring low on this dimension tend to…
Openness to experience	● 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	● be more unimaginative ● be more resistant-to-change ● be more conforming
Conscientiousness	● be more thorough and careful ● be more ambitious and hardworking ● be more self-disciplined and responsible	● be careless ● be more disorganised ● be more weak-willed
Extraversion	● be more energetic and outgoing ● be warm and talkative ● seek the company of others ● need more external stimulation	● feel more comfortable being alone ● need quiet to concentrate ● prefer working alone rather than in group ● get quickly overwhelmed by social stimulation
Agreeableness	● be more cooperative and flexible ● be more tolerant towards others ● be more friendly and prosocial ● build trust easily	● be more sceptic ● be more uncooperative ● be more indifferent in their social environment
Neuroticism	● feel more insecure ● be psychologically unstable ● give strong reaction to perceived threats ● have trouble dealing with stress ● have negative thoughts and feelings	● 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)

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3.2.1. Pilots" personality traits today

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 amount 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.

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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.

An inevitable supplemental process to reconsider is the **recruitment of future pilots to be trained**. The anticipated changes in future aviation will certainly require a revision on to whom, through which channels and how the future role of pilots 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 cockpit, recruitment processes should consider techniques that offer a **comprehensive introduction to this future role**, 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 role of pilots requires 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.**

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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

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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, 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.

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Interaction type: Pilot (Liveware) with…	Changes	Risks, challenges	Important skills
Liveware	• SPO • No observation of PF • Less resources spent on human-human coordination, communication.	• Losing spontaneous communication • Losing non-verbal communication (biophysical data instead) • Need, willingness for verbal interactions (chat GPT), social isolation • Trust issues	• Stress management - biofeedback, emotion regulation, the physiology of stress • Technical knowledge on AI • Coordination, communication with AI (human-AI teaming)
Software	• No CRM in the cockpit • No cross check on actions • New procedures, new CRM with IA • Specific procedure for SPO	• Self-double check: no one to challenge the pilot, no other mental repr. - looking for cues to reassure his own view.	• Decision making: false mechanisms to reassure oneself • Self-critical thinking
Hardware	• Biofeedback data • Broadened spectrum of sight • Interaction initiated by IA (can be controlled manually) • Situation awareness score	• Passive communication and interaction from the pilot • "Look but not see" • Information exposure - catch attention but avoid cognitive overload • Explainability • Responsibility in the cockpit	• 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. 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**

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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)	• 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?	• 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)	• 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	• Prioritizing intentions with IA • Procedure of performance calculation (IA will take over) • Evaluate the system's suggestions	• Trust or overreliance • Learning new procedures involving IA • Algorithmical trustworthiness	• Ability to take over control on calculations • Actively evaluate and prioritize options suggested by IA
Hardware	• COMBI assistant • Performance calculation (EFB now, COMBI in the future)	• Explainability - to take over control	• Ability to take over control if needed

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

3.3.2. AI-CRM

Considering the two use cases 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-

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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 5.):

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Figure 5. 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,

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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**

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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:

- **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

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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 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 phraseology and procedures with humans and AI, accordingly 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
Leadership & Teamwork	Demonstrates effective leadership and team working	**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;

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		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;
		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 the aircraft and aircrew
Problem Solving & Decision Making	Accurately identifies risks and resolves problems. Uses the appropriate decision-making processes	**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
		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
Situation Awareness	Perceives and comprehends all of the relevant information available	**Current elements:** Identifies and assesses accurately the state of the aircraft and

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	and anticipates what could happen that may affect the operation	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;
		Additional elements: 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;
Stress & Workload Management	Managing available resources efficiently to prioritise and perform tasks in a timely manner under all circumstances	**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;
		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.

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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 pilots that is mostly based on formal training. On the other hand, the **subjective experiences, know-how, perceptions, and attitudes** of professional pilots represent an important **and valuable form of knowledge**. As required technical skills and procedures might slightly differ among airlines, the related know-how and experiences of pilots also represent a collection of tacit knowledge being unique to each airline. If **collected and shared effectively**, this knowledge could be an important additional asset in training future pilots 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 6.). 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.

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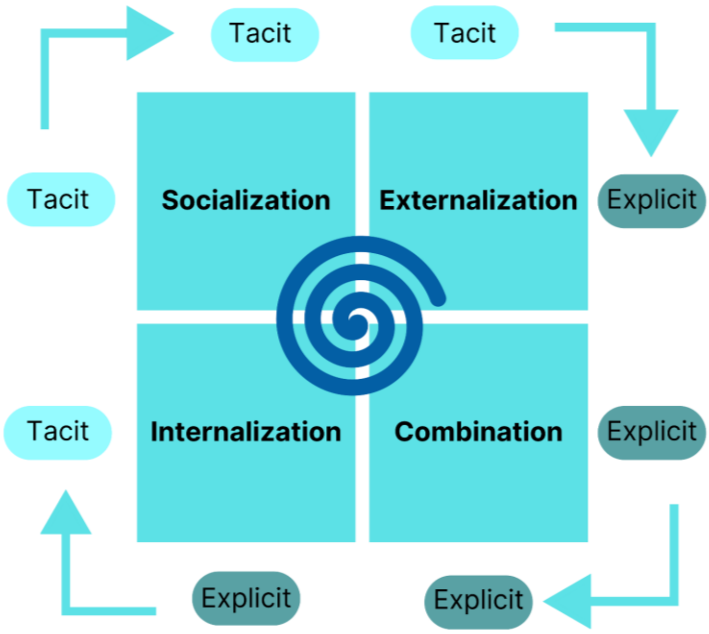

Figure 6: "SECI" model of knowledge management, the "knowledge management spiral" (Nonaka & Takeuchi, 1995)

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, controllessness 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

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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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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**. Lessons learned collected in this chapter are also considered as the **key take away messages of the document:**

Table 3: Lessons learned

I. Who to train		
1. Selection	LL_I_1_01	A revision of future pilot personality profiles is recommended: individuals with higher Emotional stability, Openness to experience, Agreeableness and with lower Extraversion may be favoured 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 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 role 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	SPIC and SPO configurations in the future will require a wider variety of stress management and emotion regulation techniques.
	LL_II_1_02	SPIC and SPO configurations in the future will require pilots to acquire enhanced skills on self-assessment (cognitive, physiological, psychological state).
	LL_II_1_03	In order to avoid information overload after startle effect, AI is suggested to support pilots through different modalities (visual & auditory).
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 *indeed* regained after startle (to avoid "look but not see" effect).

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	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 AIs will be the key in supporting pilots 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 future pilots' key tasks 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	SPO configuration will result in pilots losing the chance to be cross-checked by co-pilots. Critical thinking and the ability to question oneself and the system will be crucial in successful decision making.
5. Communicatio n & teamwork	LL_II_5_01	Losing spontaneous and non-verbal communication in the cockpit will call for the reframing of communication procedures. Future pilots 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 training	LL_III_1_01	Future training should incorporate formal group 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.

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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 flight instructors will be needed to understand and keep up with the changes in technical and non-technical skills they will train future pilots.
	LL_III_3_02	Flight instructors 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 flight instructors in order to maintain efficiency of future training.

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5. Conclusions

This document shows the results of the outcomes of HAIKU T8.4. related to the detailed understanding of the transformation of pilots' skills and related training 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 IAs are also envisaged as full-fledged, active, and key actor in the cockpit. 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 pilots 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 the role of pilots 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 pilots will most likely require a personality profile with more openness and trust to collaborate with new technologies and less need for social stimulation and human interactions. A potential revision of the personality profile of future pilots 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 to become a pilot 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 concept of AI-CRM has been introduced in this deliverable, as a framework that leverages on the already explored areas of non-technical skills, but takes 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.

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Lastly, the envisaged transformation is also expected to be a challenge for flight instructors, therefore formal supervision and "train the trainer" sessions were recommended as new ways of supporting flight instructors along the envisaged transformation process.

Future changes in aviation of course do not only affect the role of pilots. How will the transition to an AI-based working environment affect the competences and related training paths for tower ATCO-s? How is the new role of UAM coordinators expected to be built up in terms of required knowledge, skills, and abilities? These are the questions HAIKU project seeks to explore as the next steps of the research in T8.4.

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7. Annex

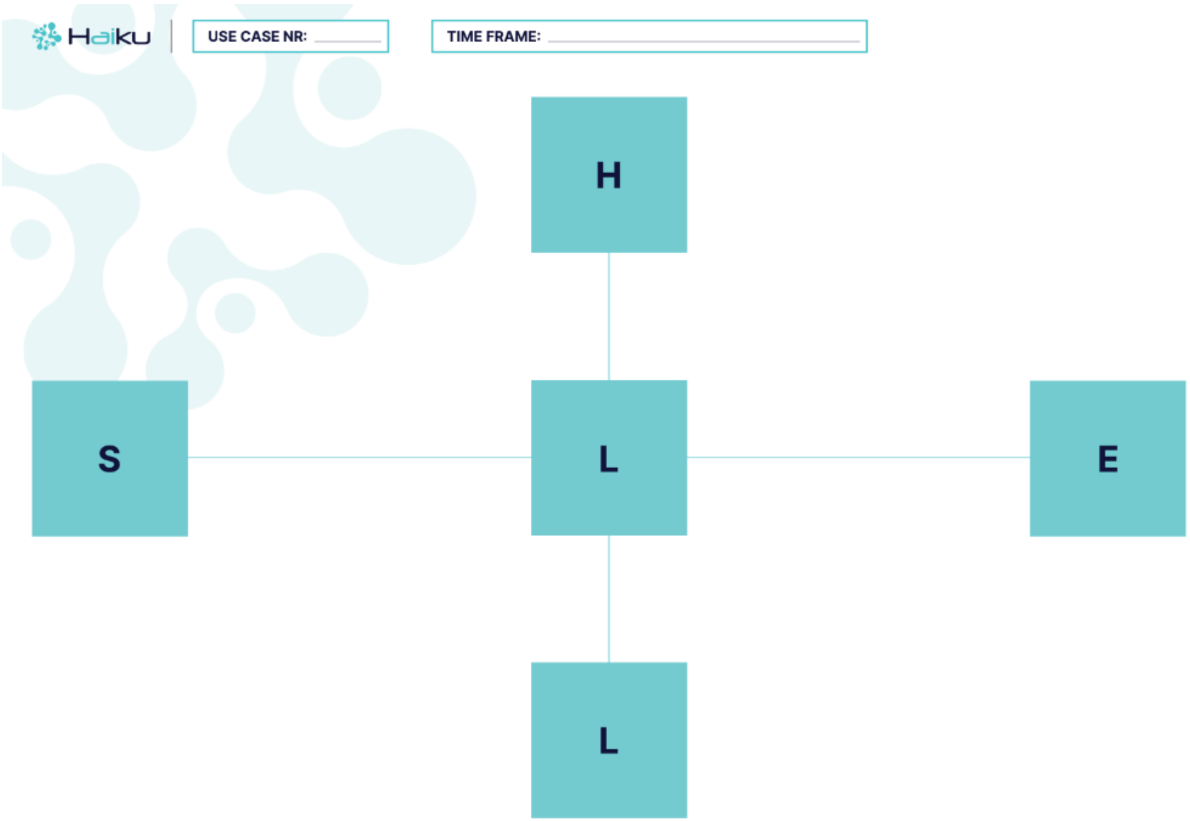

Figure 7: SHELL board template applied during the workshops

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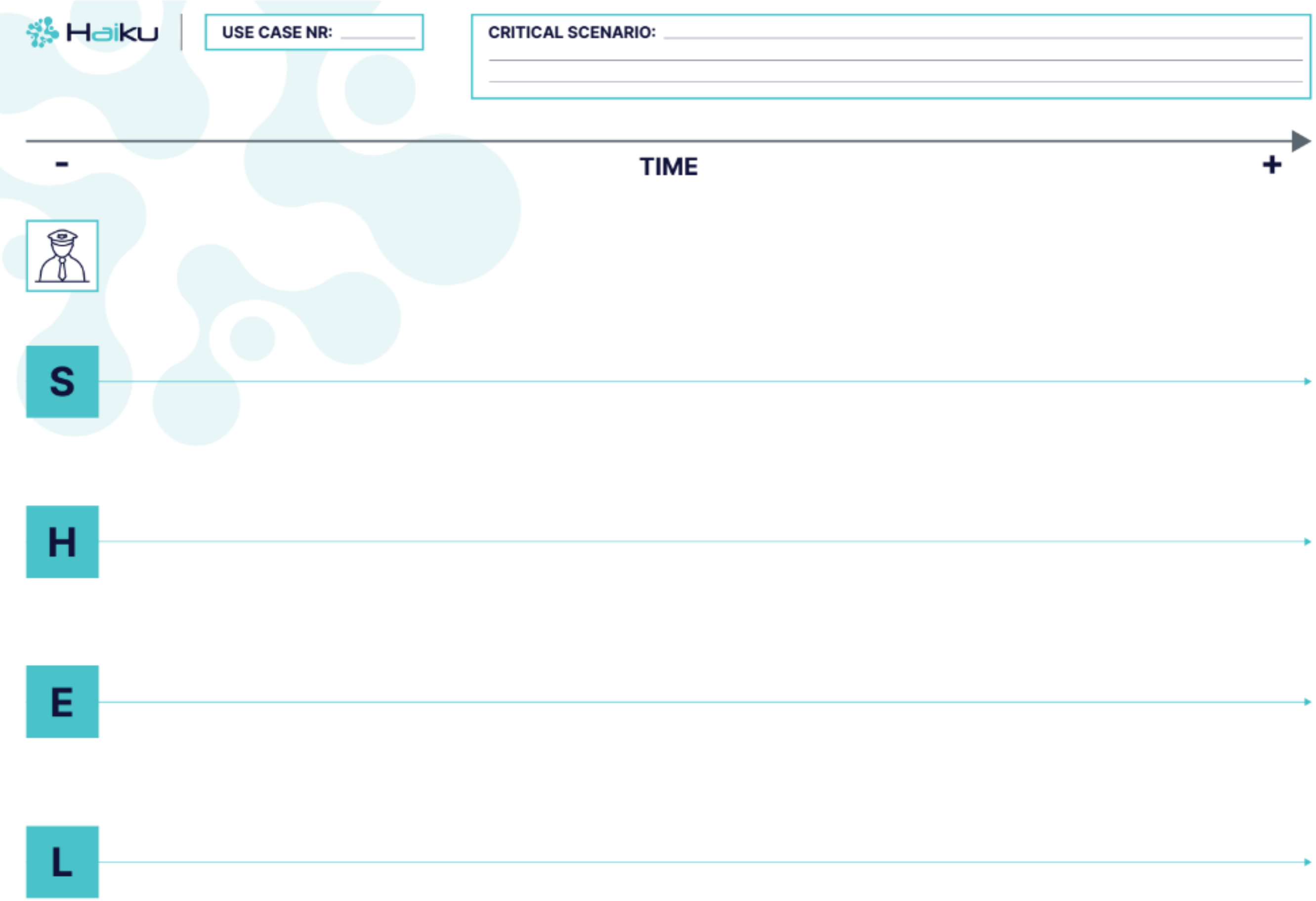

Figure 8: Timeline board template applied during the workshops

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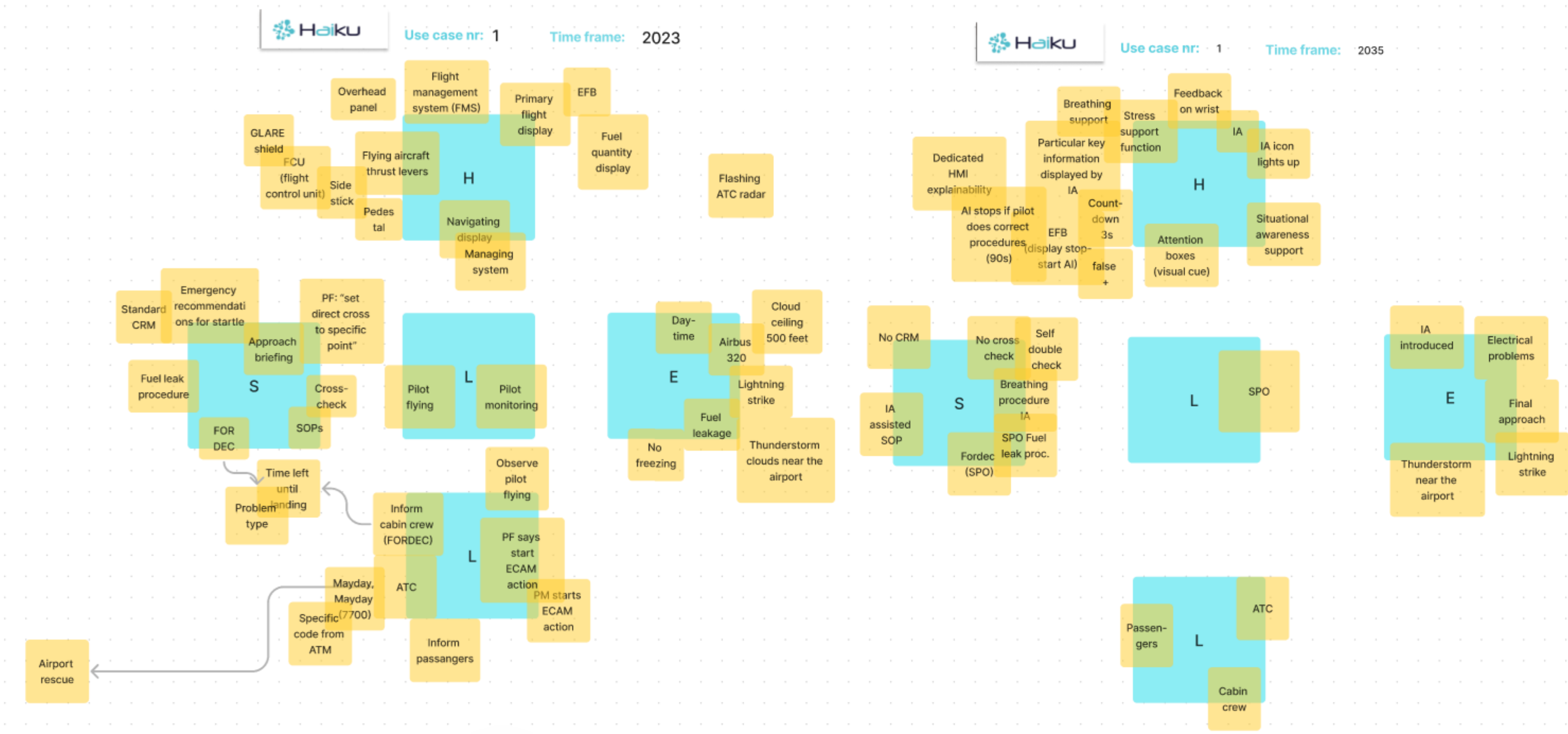

Figure 9 : Example of how the SHELL board was filled in the workshop (UC#1; left SHELL: today, right SHELL: 2035)

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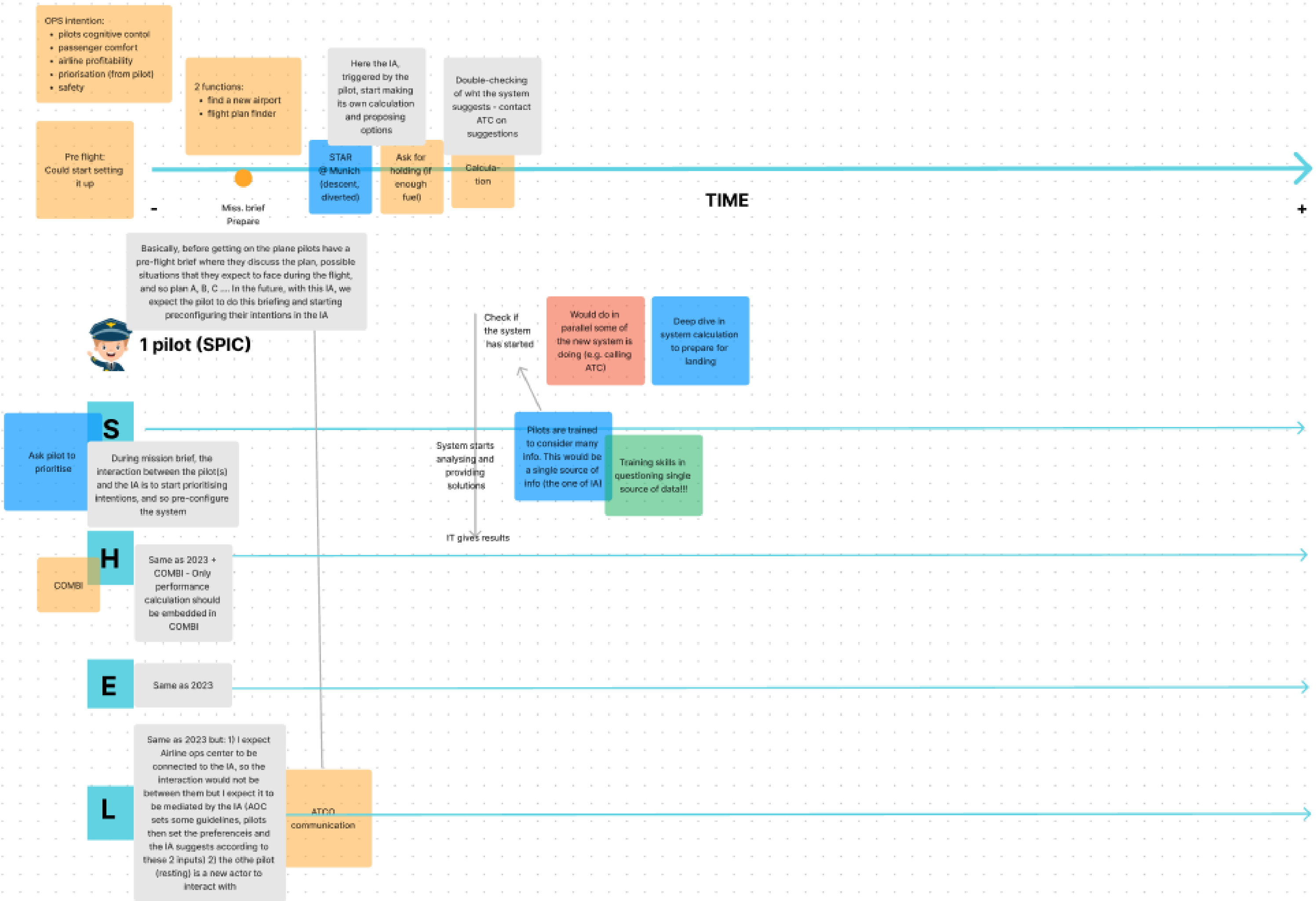

Figure 10 : Example of how the timeline board was filled in the workshop (UC#2)

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Table 4: 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;*	*Not required (covered under CRM training required by Part-ORO)*

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Leadership, cooperation, synergy, delegation, decision-making, actions; Resilience development; Surprise and startle effect; Cultural differences; Identification and management of passenger human factors: crowd control, passenger stress, conflict management, medical factors.	
Specifics related to aircraft types narrow-/wide-bodied, single-/multi-deck), flight crew and cabin crew composition and number of passengers	
Relevant to the operator and the organization (principles)	
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.	*Not required (covered under CRM training required by Part-ORO)*
Case studies	

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