Human AI teaming Knowledge and Understanding for aviation safety

Deliverable D6.1

First validation strategy and plan

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Abstract:
The HAIKU project aims to generate knowledge on intelligent assistants, and to develop AI-enabled prototypes for six aviation-related Use Cases (UCs):

- Use Case #1 – Flight Deck Startle Response
- Use Case #2 – Flight Deck Route Planning/Replanning
- Use Case #3 – Urban Air Mobility
- Use Case #4 – Digital and Remote Tower
- Use Case #5 – Airport Safety Watch
- Use Case #6 – Airport Spreading Virus Prevention

This document provides the first result from WP6 in the HAIKU project – D6.1: First validation strategy and plan - that shall serve as a guiding document for the upcoming prototype evaluations in VAL1. Based primarily on the European Operational Concept Validation Methodology (E-OCVM), the document provides use case descriptions, high-level and detailed validation objectives, requirements, corresponding indicators and metrics, for all use cases.

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1.0	01-09-2023	Final version	Victor Tuvesson, UC-Leaders, Magnus Bång	Includes contributions from all UCs and final DBL feedback

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List of Acronyms

Acronym	Definition
AI	Artificial Intelligence
AltMOC	Alternative Means of Compliance
AMC	Acceptable Means of Compliance
ATM	Air Traffic Management
DA	Digital Assistant
DUC	Digital Assistant for UAM Coordinator
EASA	European Union Aviation Safety Agency
HAIKU	Human AI Knowledge and Understanding
HAIT	Human AI Teaming
HAT	Human Autonomy Teaming
HF	Human Factors
HLR	High Level Requirements
HMI	Human Machine Interface
HPC	High-Performance Computing
IA	Intelligent Assistant
IR	Implementing Rules
KPA	Key Performance Area
KPI	Key performance Index
LACC	Levels-of-autonomy-in-cognitive-control
LACC-LOA	A matrix of LOA and LACC, for the identification of critical HAIT issues.
LLA	London Luton Airport
MbC	Management by Consent
MbE	Management by Exception
ML	Machine Learning
MOC	Means of Compliance
MoE	Measures of Effectiveness
MoP	Measures of Performance
R&D	Research and Development
SA	Situation Awareness
SOAR	State of the Art Report

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TEM	Threat and Error Management
UC	Use Case
UAM	Urban Air Mobility
UTM	Unmanned Aircraft System Traffic Management
VAL1	First Validation
VAL2	Second Validation
VTOL	Vertical Take-off and Landing
WP	Work Package

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Table of Contents

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

List of Tables

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

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

List of Figures

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

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Executive Summary

The HAIKU project aims to pave the way for human-centric Intelligent Assistants (IAs) in the aviation domain by developing AI enabled prototypes for six aviation-related Use Cases (UCs):

- Use Case #1 – Flight Deck Startle Response
- Use Case #2 – Flight Deck Route Planning/Replanning
- Use Case #3 – Urban Air Mobility
- Use Case #4 – Digital and Remote Tower
- Use Case #5 – Airport Safety Watch
- Use Case #6 – Airport Spreading Virus Prevention

The goal of WP6 is twofold: to assess whether the project and the Intelligent Assistant prototypes are proceeding in the right direction, and to assess the final Intelligent Assistant prototypes by providing empirical evidence on their operational benefits. D6.1 First validation strategy and plan supports these aims and provide use case descriptions as well as detailed plans and specifications for the upcoming prototype validations in iteration 1 (VAL1).

D6.1 is generally based on EUROCONTROL's European Operational Concept Validation Methodology (E-OCVM). However, the six use cases are diverse in terms of domains, needs, end users, implementations and level of automation. Consequently, the actual evaluation goals, methods, data collection techniques, and metrics etc vary according to the goals of each use case.

Based on insights from VAL1, the Intelligent Assistant prototypes will be refined. Hence, D6.1 is a living document that will be refined for the second iteration of the project to suit the evaluation requirements for VAL2.

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Introduction

1.1 Purpose of the document

This document provides the first validation strategy and plan of the six HAIKU use cases. The document includes high-level validation objectives, detailed objectives, corresponding indicators and metrics, and the work plan for the first validation.

1.2 Structure of the document

This document is structured in 9 sections:

Section 1: Executive summary

Section 2: Introduction

Section 3: Use Case #1 – Flight Deck Startle Response

Section 4: Use Case #2 – Flight Deck Route Planning/Replanning

Section 5: Use Case #3 – Urban Air Mobility

Section 6: Use Case #4 – Digital and Remote Tower

Section 7: Use Case #5 – Airport Safety Watch

Section 8: Use Case #6 – Airport Spreading Virus Prevention

Section 9: References

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1 Use Case #1 – Flight Deck Startle Response

1.1 UC#1 Background

In the cockpit, startling and surprising events can occur and trigger a "startle effect" among the crew. The startle effect can be defined as the first response to a sudden, intense stimulus. It triggers an involuntary physiological reflex, such as blinking of the eyes, an increased heart rate and an increased tension of the muscles (Koch, 1999). On the flight deck, the startle effect is often combined with a surprise that results from a disparity between a person's expectations and what is actually perceived (Horstmann, 2006). As the flight deck is the interface between highly automated complex systems and pilots, such disparity between the reality and crew members' expectations can have significant consequences on the safety of the flight. Startle and surprise reactions have played a key role in a significant number of accidents, including Loss-of-Control In-flight (LOC-I).

Strategies have been put in place to minimise the consequences of a startling and surprising event. Pilots are made aware and trained to this problem. Theoretical courses and simulator sessions on events that can trigger a startle effect are followed by student pilots. All along their career, line pilots also attend recurrent training sessions every 6 months. Most airlines identify three kinds of training to minimise the startle effect among pilots: (i) Crew resource management (CRM) to prevent surprise by building a good crew situation awareness through effective communication. (ii) Threat and error management (TEM), to prepare mitigation means in advance to react more easily to a startle. (iii) Basic flying skills and upset Prevention and Recovery training (UPRT) to recognize threatening aircraft state and recover from it with manual flying using core competencies.

Intelligent Assistants could play a key role in startle events by accompanying pilots in the application of their training, especially when pilots lose accurate situational awareness due to startle coupled with initial confusion over what is happening. The Intelligent Assistant could also act as an additional crew member in the case of single pilot operations and reduced crew situations, as well as occupying a key role in future Personal Planes and Sky Taxis, whose pilots will likely have far less training compared to commercial pilots.

1.2 UC#1 Context of the Validation (VAL1)

1.2.1 UC#1 Key R&D Needs

Problem Statement - what is the problem to address with the Intelligent Assistant?
The Intelligent Assistant could help pilots to recover from startle and surprise effect proposing a collaborative way to mitigate consequences in several steps:

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- A first level of assistance could consist in the digital assistant supporting the pilot in overcoming Startle and surprise thanks to an emotion regulation function. This function consists of Biofeedback techniques. Biofeedback is a mind-body technique [1] that involves using visual or auditory feedback to teach people to recognize the physical signs and symptoms of stress and anxiety, such as increased heart rate, body temperature, and muscle tension. The assistant will guide the pilot breath through haptic and visual feedback.

- To support the pilot in making sense of the situation after a startling and/or surprising stimulus, a second level of assistance could consist in maintaining and raising the Situation Awareness level of the pilot. Indeed, under startle and/or surprise, a loss of situation awareness is in some cases observed. After this initial phase, the assistant could accompany pilots in a structured decision-making process (i.e. FORDEC). During this phase, the assistant could for example assist the pilots in gathering all the necessary information, generate options and quickly assess risks and benefits

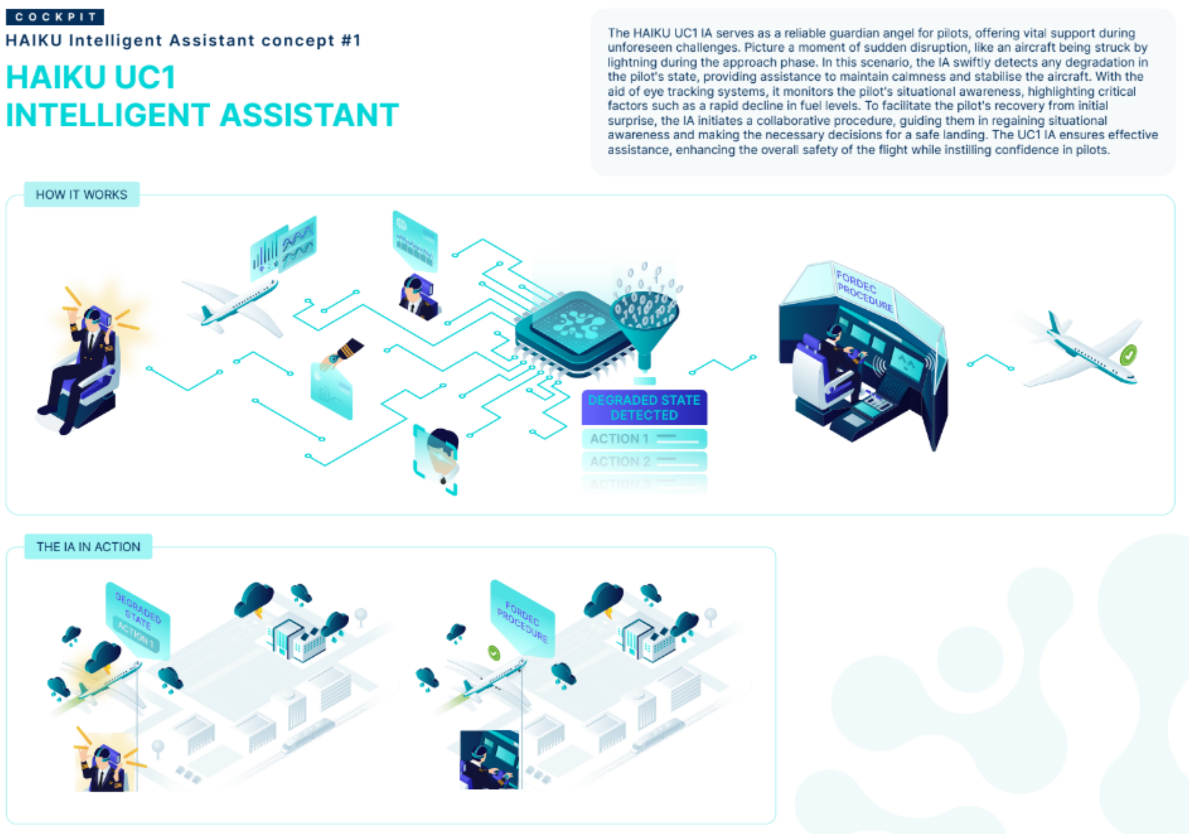

Figure 1: UC1 Intelligent Assistant Concept

A related research question is to what extent should the startle assistant be explainable or provide an explainable layer? An explainable layer in the Human-Machine-Interface (HMI) of the assistant itself may help pilots regain the situational awareness, but it can also overload pilots with additional information. The

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Use Case will explore this aspect, most likely using the explainable layer to tune the assistant during the development phase, eventually deciding to leave it or not in the final design.

Human Factors & Safety Risks – Potential risks and problems introduced by the Intelligent Assistant

Trust: How could a pilot trust and make the appropriate action while being under the effect of a startling event?

Overload: in these situations, the assistant may end up increasing the workload, by providing an additional source of information.

1.2.2 UC#1 Operational Concept Description

Figure 2 depicts an overview of the UC1 assistant operational concept. The concept provides operations to support the pilot as soon as the physiological and cognitive state degrade and until the pilot is back in control, “ahead of the aircraft”. For the scope of Use Case 1 single pilot operation apply.

The assistant monitors the pilot’s physiological data at all times. When the assistant detects an abnormal physiological state, the recovery procedure is launched. The pilot can cancel the procedure at any time. The first step of the procedure is to ensure that the plane is stabilised and flying properly. The assistant will provide guidelines to ensure the pilots can stabilise the aircraft if needed. Upon aircraft stabilisation, the assistant will support the pilot to unload emotional response and to bring the physiological state back to before the startle event. Finally, the assistant will support the pilots to reframe the situation and build a situation awareness that matches the actual flying situation.

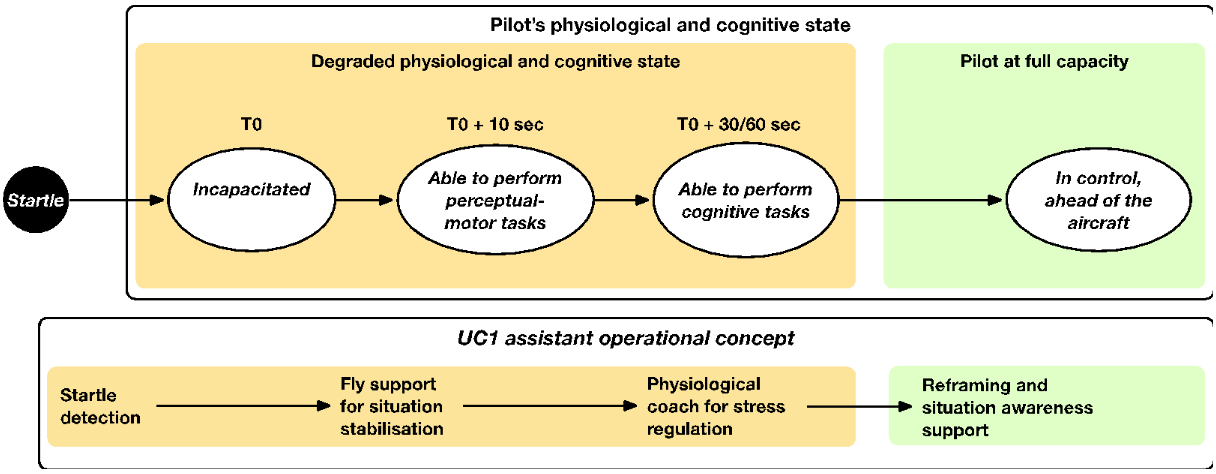

Figure 2: UC1 Assistant Operation Concept

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1.2.1 UC#1 Performance Targets

KPA	Category	KPI
Startle detection	MoE/MoP	Detection accuracy, detection rapidity
Surprise detection	MoE/MoP	Detection accuracy, detection rapidity
Pilot startle and/or surprise physiological recovery (partial incapacitation)	MoE/MoP	Recovery rapidity, recovery rate. Pilot acceptance, pilot performance on the operational task.
Pilot situation awareness sustainability/recovery	MoE/MoP	Subjective situation awareness assessment, pilot performance on the operational task. Rapidity to come back to a "normal" scan path. "Normal" scan path recovery rate.

Table 1: UC#1 Performance Targets

1.2.3 UC#1 Requirements

HL-REQ-ID	UC1-HLR-01
Requirement	The crew (AI and pilot) must handle the situation better than a single pilot crew without assistance.
Rationale	The objective of the assistant implementation is to make future single pilot flights safer than without the assistance.
KPA	Operational, Safety, Human Performance

Table 2: UC1-HLR-01

HL-REQ-ID	UC1-HLR-02
Requirement	The pilot must have authority over the digital assistant at all time.
Rationale	To reduce impact of potential AI errors and to guarantee responsibility to the pilot.
KPA	Operational, Safety

Table 3: UC1-HLR-02

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HL-REQ-ID	UC1-HLR-03
Requirement	The crew (AI and pilot) must be able to minimise the consequences of the startle and surprise effect.
Rationale	To handle an unexpected event in the cockpit, a key objective is to minimise the effect of startle and surprise for the pilot to be able to respond quickly and accordingly to the situation.
KPA	Safety, Human Performance

Table 4: UC1-HLR-03

HL-REQ-ID	UC1-HLR-04
Requirement	The pilot must be able to be assisted at different levels of support.
Rationale	To guarantee the right level of assistance and optimal HAT.
KPA	Safety, Human Performance

Table 5: UC1-HLR-04

1.2.4 UC#1 Key R&D Objectives

OBJ-ID	Validation Objective	Success Criteria ID	Success Criteria
UC1-OBJ-01	To assess the operational relevance of the solution from the CAT (Commercial Air Transport) pilots perspective in SPO (Single pilot Operations).	UC1-CTR-01	The solution is considered relevant by CAT pilots in SPO.
UC1-OBJ-02	To assess the acceptability of the solution from the CAT pilots perspective in SPO.	UC1-CTR-02	The solution is considered acceptable by CAT pilots in SPO.
UC1-OBJ-03	To assess the feasibility and integration of the solution in relevant operational environment.	UC1-CTR-03	The solution is considered feasible and can be integrated in relevant operational environments.
UC1-OBJ-04	To assess the effectiveness and efficiency of the assistant	UC1-CTR-04	The solution is considered effective and efficient in supporting CAT pilots to overcome the startle and

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	support in relevant operational environment.		surprise effect in relevant operational environment.
UC1-OBJ-05	To assess the generalisation of the solution to multiple different scenarios.	UC1-CTR-05	The solution is considered to be useful in different operational conditions by CAT pilots.

Table 6: UC#1 Key R&D Objectives

1.3 UC#1 First Validation Plan (VAL1)

1.3.1 UC#1 Approach – VAL1

Validation 1 (VAL1) will be a key step to get the first insights about the different key R&D objectives. It will be used to receive initial feedback from end users to enable a new design iteration to develop a complete prototype for Validation 2. Therefore, only parts of the assistant will be tested for VAL1. Specifically:

- **Startle and surprise detection module:** Detection of startle and surprise will be done in Wizard of OZ meaning that actual outputs of the detection module will be faked. Indeed, given the state of development of the detection module, the accuracy of the detection is not satisfactory enough to be used consistently in operational scenarios. However, the detection module will run anyway during validation 1 exercises to get results about the performance of the module in a live environment.

- **Physiological coach:** a first version of the solution will be tested live during validation 1 exercises to assess the usability of the solution as well as its acceptance. Specifically, the ability of the pilot to follow assistant breathing guidance and the effect of the guidance will be analysed.

- **Situation awareness augmentation functions:** A first version of the function will be tested live during validation 1 exercises to assess the usability of the solution as well as its acceptance. Specifically, the ability of the pilot to keep a good situation awareness all along the scenarios will be analysed to assess the assistant added value.

For validation 2 (VAL2), it is planned to use the feedback given by pilots as well as the results of the exercises of validation 1 to make a design iteration on existing functions. Moreover, it is planned to augment the situation awareness function with a second level of assistance which will consist in a FORDEC-like procedure done between the assistant and the pilot when the situation is stabilised. This second level of assistance will require a complete conception iteration with specific pilot interviews and design meetings.

For VAL2, it could be interesting to test the different exercises with and without the assistant to be able to assess the objective added value of the developed solution.

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1.3.2 UC#1 Exercise Description and Scope – VAL1

Exercise Description	Scope (What is being assessed)	Key R&D Objectives explored
Experiencing startle and surprise in relevant operational environments with the assistant support	The usability, acceptability and integration of the assistant	UC1-OBJ-01/02/03/04
Testing several levels of automation of the assistant	The usability, acceptability and integration of the assistant	UC1-OBJ-01/02/03/04
Testing the assistant's support in different operational conditions	The ability of the assistant to provide a relevant support in different flight phases	UC1-OBJ-05
Testing different HMI to provide an adapted level of explainability	The usability, acceptability and integration of the assistant	UC1-OBJ-01/02/03/04
Testing different HMI to assess the good integration of the assistant in the cockpit and its invasiveness	The usability, acceptability and integration of the assistant	UC1-OBJ-01/02/03/04

Table 7: UC1 Exercise Description and Scope

1.3.3 UC#1 Exercise Scenario(s) – VAL1

All scenarios will be played on ENAC A320 research simulator. They are based on scenarios used in scientific literature to trigger startle and surprise effects.

Lightning strike on final approach: On final approach, the aircraft is struck by lightning. As a result, a loud bang is heard, and an intense flash is triggered, provoking startle and surprise. Because of the lightning strike, electrical problems on board of the aircraft lead to the of automatisms disconnection.

Shifting cargo at take-off: Shortly after take-off, a cargo gets loose and a shift of centre of gravity occurs. As a result, a strong pitch up moment is observed and triggers a surprise. The pilot is forced to react quickly to control the aircraft and a rapid landing is necessary.

Overspeed upon Windshear occurrence in climb: In climb to FL140, a strong headwind provokes an overspeed disconnecting the Auto-Pilot, forcing a rapid manual recovery of the flight. This event should trigger a surprise by pilots.

1.2.1.1 UC#1 Reference Scenario(s) – VAL1

The same scenarios without the assistant could be used as references. However, this comparison to the reference scenario will be done only for VAL2.

1.3.4 UC#1 Platform / Tools & Technique – VAL1

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The VAL1 platform will be performed in the ENAC A320 Research simulator. Tobii glasses 2 will be used to track participants' gaze and a BITalino device will be used to gather participants' physiological data.

1.3.5 UC#1 Data Collection and Analysis Methods – VAL1

The qualitative data collection will be done through debriefings held after each scenario and at the end of the session. The over-the-shoulder observations will be performed by Human Factors and Operational experts. The quantitative data will be collected through the platform's logs and recordings.

Observations: This technique mainly allows to address topics related to Human Performance, with the purpose to provide detailed and reliable information on the way the activity is carried out by the user. Direct observation enables gathering a high amount of data, especially qualitative data which cannot be collected through other methods.
In the validation exercises, direct over-the-shoulder observation will be used to collect insights about the pilot's performance, including aspects related to experienced workload, situation awareness, usability, faced difficulties, recovery actions, safety related events, etc.

Questionnaires (standard and ad hoc): After each scenario, the pilots will be requested to fill in a questionnaire order to provide their feedback on aspects related to the assessment of Human-Machine Teaming, mental workload, situation awareness, trust, usability and safety.
The use of other dedicated (presumably custom designed) questionnaire might be considered to gather pilots' insight on other variables such as felt surprise or startle.

De-briefings: Debriefings, questionnaires and over-the-shoulders observations are interconnected techniques. This means that on the one hand, data collected through observations and questionnaires will be verified and discussed during the debriefings. On the other hand, insights extracted from the debriefings will be used to guide the following observations. This combination of techniques can complement and reinforce the quality of the quantitative data collected and contributes to achieving more reliable results.

Platform logs and participants physiological data: System quantitative data will be collected by the extraction of log files from the simulation platform. The data will be used as performance indicators and to further enrich the qualitative information collection (e.g. pilot input on the interface, reaction time, decision taken, etc.).

Moreover, participants' physiological data (e.g. heart rate, breathing rate, gaze behaviour, electro dermal response, muscles activity) will be gathered to assess the impact of the unexpected events and evaluate the support provided by the digital assistant.

1.3.6 UC#1 Planned Activities – VAL1

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Activity	Activity Description	General Information
VAL1	Validation 1 will be performed in the ENAC A320 research simulator in Toulouse, France. Simulation with the assistant on several scenarios will be performed.	Up to five CAT pilots will participate in the VAL1 Toulouse, France, Q3 2023
Workshops	Several workshops with pilots following the simulations could be organised to discuss specific points of design, particularly about HAT.	

Table 8: UC1 Planned Activities

1.3.7 UC#1 Use Case Relationships and Collaborations

No collaboration between the Use Case 1 and other use cases has been done for the validation 1. However, ideas to collaborate between use cases could be anticipated. For example, the Flight deck startle response assistant could be coupled with the Use Case 2 assistant. Indeed, upon a system failure generating a startle and/or surprise, the Use Case 1 assistant could support the pilot overcoming these effects. On pilot recovery, the Use Case 2 assistant could then support the pilots in his rerouting decision-making.

1.4 UC#1 Future work and Second Validation (VAL2)

1.4.1 UC#1 Expected R&D work

Several outputs of Validation 1 will be used for future R&D work leading to Validation 2:

First, pilots' physiological data gathered will be used to improve the model of startle and surprise detection. Thanks to these outputs, the assistant will be better trained to detect abnormal states of pilots in unexpected situations for Validation 2.

Second, qualitative data like the feedback of users will permit us to iterate on the design of the assistant, rejecting some design hypotheses while reinforcing some. Particularly, the level of automation of the assistant is seen to be a main discussion point with pilots.

Third, objective data like platform logs and pilots' physiological data will also be used to reject or confirm design hypotheses. It will indeed reflect their operational and personal performance and will permit us to evaluate the assistant's support efficiency.

1.4.2 UC#1 Validation Approach for the Second Validation

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For the Second Validation, we want to evaluate pilots on scenarios, with and without the assistant in Single Pilot Operations. At the time of validation 2, the prototype will have been consolidated by the feedback and results of the validation 1 and a new iteration of conception and development will have been organised during the first semester of 2024. To get statistically relevant results, 20 pilots are anticipated to participate in the validation 2 sessions.

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2 Use Case #2 – Flight Deck Route Planning/Replanning

2.1 UC#2 Background

During flights, pilots must manage complex situations involving numerous factors such as bad weather, complicated terrain, dense traffic, technical failures, human errors, etc. As human cognitive resources in the cockpit are limited, pilots can sometimes fail to correctly assess the optimisation of the flight path or the risks associated with such conditions, especially when several of them are combined. Weather-related rerouting, for example, can have a negative impact on aircraft fuel efficiency, pilot workload and the airline's economic revenues and expenses. A study showed that the presence of a weather threat can lead to a lack of efficient task allocation between crews and inadequate data management (Bayazitoğlu & Güngör, 2023) [2]. While increased training is usually the answer, it may not be sufficient or even feasible in the future, due to foreseeable and ongoing trends, like the expected rise of system complexity. Complex systems will rely on an amount of data that no single individual can fully grasp. With the advent of AI and ML, and access to open data sources (big data), this complexity will rise exponentially. A similar mission to one carried out today will include several intelligent systems that help reduce the number of operators (Single Pilot Operation, Single Pilot in Cruise, etc.). A more complex environment will not only increase the operator’s workload but also further distance them from the vital decision-making process. Complexity will also increase due to an increasing heterogeneity of traffic, e.g. unmanned aircrafts, remotely piloted ones, autonomous vehicles, and so on. The potential safety risk is the possible inefficiency of existing HMIs (Human Machine Interfaces) to help the crew manage such situations. This is the reason to introduce AI-based Digital Assistant to alleviate pilot cognitive resources involvement on secondary tasks. Genuine collaborative work (from a human point of view) between humans and intelligent systems will be a game changer for future operations whatever the environment: ground, sea, sky or space.

2.2 UC#2 Context of the First Validation (VAL1)

2.2.1 UC#2 Key R&D Needs

Problem Statement – what is the problem to address with the Intelligent Assistant? Technological evolution inevitably will lead towards more complex systems putting the operator out of the ability to grasp the whole working mechanisms. Thus, we need other ways to **facilitate the relationship between operators and new intelligent systems** to ensure collaborative efficiency while keeping the human in the loop. The ultimate goal is to reposition the operator as a strategic & tactical decision-maker and not as an engineer as is the case today. HAIKU’s proposal is to work on mission

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management using high-level Operational "Intentions" (e.g. green operations, quality of service, punctuality, fuel and global cost reduction, etc.). Intentions involve mental activities such as planning and forethought, they can be declared and clearly defined, while in other instances can be undeclared or masked, making them sometimes complex to identify (Bratman, 1987) [3]. These "intentions" in aeronautical operations have not yet been translated directly into technical automated functions. Operators implicitly follow these intentions when they decide on mission planning, avoidance of threats, greener ops, etc. The HAIKU project proposition is to use a "Bidirectional Communicator" named COMBI (Bidirectional Communicator) between humans and intelligent systems to facilitate their dialogue. COMBI is part of Thales Avionics background knowledge, and it has been demonstrated at TRL4. COMBI allows to determine the best mission / flight parameters that serve the operator's high level intention taking account the current mission/flight conditions. COMBI outputs will be presented at the same semantic level as the human intention, without forcing the operator to adapt from a technical expert point of view.

Human Factors & Safety Risks – Potential risks and problems introduced by the Intelligent Assistant

- Defining the Intelligent Assistant usage envelope, according to the AI/ML limitations with regards to situation variability.
- Use Experience of the Intelligent Assistant communication at the level of intentions. - Acceptability by pilots, including development of trust.

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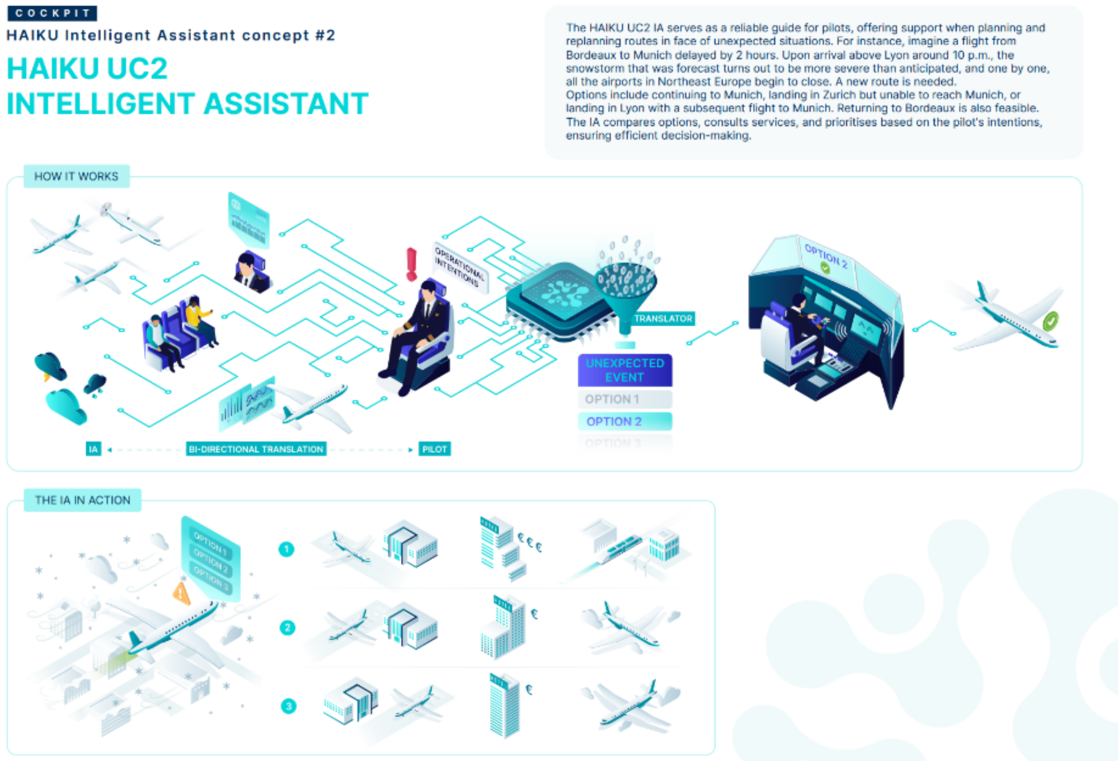

Figure 3: UC2 Intelligent Assistant Concept

2.2.2 UC#2 Operational Concept Description

According with the operational needs identified in the WP3, the main operational capabilities that should be considered for the HAT concept in the cockpit are (a selection or combination of these three options will be considered for the final demonstrators);

Pre-flight mission understanding: During the pre-flight, the team evaluates key aspects of the flight plan provided by the airline operations control centre, understands its rationale, and verifies adjustment needs, e.g. on the fuel margins or on the selection of alternate airports. The goal is to ensure that fuel margins are compatible with all identified threats and their assessed probability of occurrence, while maximising the outcomes related to the operational intentions established by the airline.

Diversion decision-making due to airport unavailability: During the flight, after receiving the information that the original arrival airport will be unavailable, the team evaluates relevant information on the airspace, weather, traffic, and alternate airports, assessing the suitability and impacts of the destination and re-route alternatives. The team selects new flight plan(s) associated with new destination(s), submits it/them to evaluation of relevant stakeholders (ATM, AOCC), and implements the final solution selected by the pilot in command. The goal is to assure safe flight termination, while minimising the impacts on the outcomes associated with operational intentions.

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Re-route/diversion decision making due to weather threat detected in flight: During the flight, in face of an unforeseen weather threat, the team evaluates relevant information on the weather, traffic, airspace, and/or alternate airports, assessing the impacts of the threat in the original flight plan. If required, the team selects new flight plan(s) to deviate from weather threat (re-routing to the original destination or selecting an alternate destination), submits it/them to evaluation of relevant stakeholders (ATM, AOCC), and implements the final solution selected by the pilot in command. The goal is again to assure safe flight termination, while minimising the impacts on the outcomes associated with operational intentions.

2.2.3 UC#2 Performance Targets

Key Performance Areas (KPAs) were identified related both to Measures of Effectiveness (MoEs) and Measures of Performance (MoPs) of the HAT concept. As the main purpose of the HAT concept is to manage and prioritise intentions related to different KPAs, according to the company policy and the defined context, some of the identified KPAs will not represent a MoE by themselves. The combination of those KPAs, weighted by their prioritisation score, will derive a global KPA that will be used as a MoE. The table below presents a brief description of the KPAs, their classification as MoEs or MoPs, and their associated KPIs. Their performance targets will be defined in relation to the reference scenarios (with a two-pilot team in the cockpit), which are yet to be characterised using these metrics.

KPA	Category	KPI
Mission Safety	MoE	Safety margin index [ ]. (prescribed activity) (ex.: fuel at destination)
Mission Commercial Performance	MoE	Operational impact index [function of cost efficiency, punctuality, passenger experience, ..., TBD with SME]
Decision Quality	MoP	Decision quality index (function of aspects taken into account, TBD with SMEs) Implementation Feasibility index (function of time to decide, time to implement, ATM considerations..., TBD with SMEs)
Regulatory Acceptance	MoE	Beyond 2030: Self evaluation against the SoA, and an acceptance

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		of SMEs from regulatory organisations.
Social Acceptance	MoE	Usage of the assistant due to perceived usefulness (reliability, trust, performance...)

Table 9: UC2 Performance Targets

2.2.4 UC#2 Requirements

HL-REQ-ID	UC2-HLR-01
Requirement	The crew must achieve a safe flight termination
Rationale	Flight safety is not negotiable, safe termination of flight is a constraint on all solutions
KPA	Mission Safety

Table 10: UC2-HLR-01

HL-REQ-ID	UC2-HLR-02
Requirement	The crew must minimise the impact of disturbance in company commercial operation.
Rationale	The initial flight plan represents the best solution from a commercial aspect. If an event will lead to a constrained context, the objective is to minimise the impact of the disturbance on the company.
KPA	Mission Commercial Performance

Table 11: UC2-HLR-02

HL-REQ-ID	UC2-HLR-03
Requirement	The crew decision quality must be equal or better than that of a two-pilot crew in the same situation.
Rationale	The team decision must be best-in-class. Different companies define different operational goals and their prioritisation. The team solution purpose is to achieve a good solution within the constraints imposed by the specific context where the decision must be made.

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	In pre-flight, e.g., decision on extra-fuel impacts A/C performance and cost. In diversion, re-route, many components must be traded off, making the decision context and company dependent.
KPA	Decision Quality

Table 12: UC2-HLR-03

HL-REQ-ID	UC2-HLR-04
Requirement	The crew decision must be implementable
Rationale	The decision must be provided with enough time to enable implementation (by human, by AI) after stakeholders validation (ATM and/or AOCC), when needed.
KPA	Implementation Feasibility

Table 13: UC2-HLR-04

HL-REQ-ID	UC2-HLR-05
Requirement	The crew solution must be considered as potentially regulatory acceptable against the latest concept paper about beyond 2030.
Rationale	Beyond 2030: self evaluation against the SoA, and an acceptance of SMEs from regulatory organisations.
KPA	Regulatory Acceptance

Table 14: UC2-HLR-05

HL-REQ-ID	UC2-HLR-06
Requirement	The crew solution must be considered as potentially acceptable by the SME regarding the use of the technology in the 2030 HAIKU landscape scenarios.
Rationale	Usage of the assistant due to perceived usefulness (reliability, trust, performance...)
KPA	Social Acceptance

Table 15: UC2-HLR-06

2.2.5 UC#2 Key R&D Objectives

OBJ-ID	Validation Objective	Success Criteria ID	Success Criteria

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UC2-OBJ-01	Combi enable effective and efficient high-level intentions communication in the team.	UC2-CRT-DT (Decision Time) UC2-CRT-RT (Reaction Time) UC2-CRT-PWL (Perceived Workload) UC2-CRT-UAC C (User Acceptance) UC2-CRT-RAC C (Rate of Acceptance)	Comparison against benchmark (e.g., SPO or 2P crew direct inputting technical parameters into solver without assistance). User Acceptance: Questionnaire validation (SUS, CSUQ, TAM3 …) [Rate of Acceptance: Acceptance and rejection rates for AI recommendations by the pilots (trust and why they don't use it (a way to improve HAT)].
UC2-OBJ-02	What are the key features for each type of assistance (decision support, cooperative, collaborative) that enable teamwork requirements assurance and effectiveness?	UC2-CTR-02	Functional analysis of key features and an evaluation of the capability of these features to reach a level of performance, safety, acceptance. Validation of identified features with SME. Draft proposal off design guidelines for building effective teaming
UC2-OBJ-03	Methods: HAT design methodology able to support HAT safety and effectivity assessments	UC2-CTR-03	Methodology is deemed adequate to provide MoC support according to IA based system EASA concept paper
UC2-OBJ-04	2A variant: HAT cooperative teaming improves decision making process for on air re-route situation vs. decision support assistance	UC2-CTR-04	Comparison against benchmark (SPO or 2P crew) and decision support assistance
UC2-OBJ-05	2B variant: HAT collaborative teaming improves decision making process for on air re-route situation vs. HAT cooperative teaming	UC2-CTR-05	Comparison against benchmark (SPO or 2P crew) and HAT cooperative teaming

Table 16: UC2 Key R&D Objectives

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2.3 UC#2 First Validation Plan (VAL1)

2.3.1 UC#2 Approach – VAL1

The objective of VAL1 is to address the objectives OBJ-02.02, OBJ-02.04 and OBJ-02.05 and create a training environment for VAL2. This VAL1 will make it possible to collect data to make AI learning more reliable. VAL1 is oriented to: Identify and prioritise the key features of three levels of HAT (assistive, cooperative and collaborative), evaluate the most suitable level for a specific situation and validate the proposed functions of IA managed by operational intentions.

2.3.2 UC#2 Exercise Description and Scope – VAL1

Three different low fidelity prototypes of HAT level will be developed: assistive, cooperative and collaborative.

Exercise Description	Scope (What is being assessed)	Key R&D Objectives explored
Walk-through for the selected phase without assistance	Baseline	UC2-OBJ-02 UC2-OBJ-04 UC2-OBJ-05
Walk-through for the selected phase with different design variants	Contribution of specific design features	UC2-OBJ-02 UC2-OBJ-04 UC2-OBJ-05

Table 17: UC2 Exercise Description and Scope

Design variants hypothesis (these design concept will be evaluated in terms of technical feasibility):

Design concept	Exercises description
2A variant: Automatic selection and implementation of route changes by the assistant in well-defined scenarios is accepted by end-users	Evaluate if the cooperative concept improves the acceptance of the IA
2A variant: Automatic selection and implementation of route changes by the assistant in well-defined scenarios is effective	Evaluate if the IA cooperative concept improves the operational effectiveness (compare to baseline - actual system) Comparison against benchmark variant - KPAs Assessment (TBD) - Pilot SA/Complacency evaluation (pilot cross-checks assistant actions) (TBD)
2B variant: Interface allowing the pilot to input/edit/remove context elements is effective	Comparison against benchmark variant - KPAs Assessment?

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	- Shared SA evaluation?
2B variant: Review of selection is effective	Comparison against benchmark variant - KPAs Assessment? - Trust/complacency evaluation?
2B variant: More fluid (and variable) interaction during options assessment is effective	Comparison against benchmark variant - Acceptance from end-users - KPAs Assessment? - Trust evaluation? - Training needs affected?
2B variant: Delegation of authority selected for negotiation in background with ATC is accepted by end-users.	Positive evaluation of design variant from end-users

Table 18: UC2 Design variants hypothesis

2.3.3 UC#2 Exercise Scenario(s) – VAL1

Derived from a multitude of sources, including EUROCONTROL and METAR analysis conducted at European airports (ATMAP scores), a flight has been developed. Within Europe, adverse weather conditions stand as the secondary predominant factor, attributing to 41.9% of delays. This trails behind air traffic control capacity and staffing limitations, encompassing occurrences such as strikes, which account for 44.5% of delays (Tuchhardt & Murphy, 2019 [4], Lui et al., 2022).

According to weather data and insights from Eurocontrol, the two periods of the year with the highest risk of rerouting are summer and winter. In summer, this particularly affects en-route traffic, while in winter, arrivals are impacted more significantly. The airports of Düsseldorf and Munich, in particular, experience the highest occurrences of hazardous meteorological phenomena and other freezing conditions or significant precipitation (EUROCONTROL, 2013 [5], Schultz et al., 2018 [6]). Delays in Europe are predominantly attributed to en-route facilities accounting for the majority at 52% in 2017 and to airport facilities at 48% (Liu et al., 2016 [7]).

Based on this information, a winter scenario was developed, involving a snowstorm and an en-route rerouting. The flight scenario is derived from actual flights between Milan (LIML) and Munich (EDDM) airports.

Context:

It's winter, a time when weather conditions can be particularly unpredictable and severe. The flight starts early in the morning (05:00) in the city of Milan. Munich is subject to harsh winter conditions, including strong winds and cold temperatures. The flight is operated by a regional airline. The passengers are primarily business travellers who value punctual and comfortable flights.

From/to: LIML/EDDM

Time of departure: 05:00 AM

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Flight duration: 45 min (less than 1 hour)

Operating aircraft: EMB 190

Initial flight plan:

The original flight plan entails a direct route from Milan airport to Munich airport. While relatively direct, this route crosses the Alps, notorious for their changeable and potentially hazardous winter weather conditions.

Flight Progression:

1. Takeoff: the flight commences smoothly from Milan-Linate Airport (LIML). The pilots are fully aware of the challenging winter conditions right from the beginning of the journey.

2. Climb and cruise: the aircraft climbs to a safe cruising altitude (FL280), and the pilots maintain close communication with air traffic control (ATC). Real-time meteorological updates are provided to the pilots via the System Wide Information Management (SWIM). This allows them to stay informed about the weather conditions during the flight, and to optimise fuel efficiency both en-route and upon arrival in Munich.

3. Change in weather conditions: as the aircraft approaches the mountainous region, the pilots receive an alarming weather report via the SWIM. A winter storm is rapidly forming in the area, bringing strong winds and reduced visibility due to snow and fog.

4. Route Change Planning: Confronted with the (extreme) weather conditions, the crew must make the decision to re-plan the flight to an alternative route and consider various possibilities provided by the IA, or to stick with the original route. The IA can generate routes based on the pilot's three high-level intentions. The pilot can prioritise these intentions through the IA interface, which will then generate routes accordingly.

The proposed routes might entail the need for a temporary U-turn before following a new course, extending the flight by approximately 30 minutes and/or involving a more complex approach to Munich airport. Among other options, the IA could propose routes with more favourable cruising winds, prioritise a higher altitude with a longer trajectory to avoid a low altitude holding pattern upon arrival due to high traffic.

The pilots could also choose to continue on the original route to Munich Airport, while adjusting altitude (lower FL and facing strong headwinds) to steer clear of significant turbulence areas. Due to potential turbulence and a slightly longer flight time, this approach might incur additional costs for the airline, such as maintenance expenses resulting from the potential impact on the aircraft.

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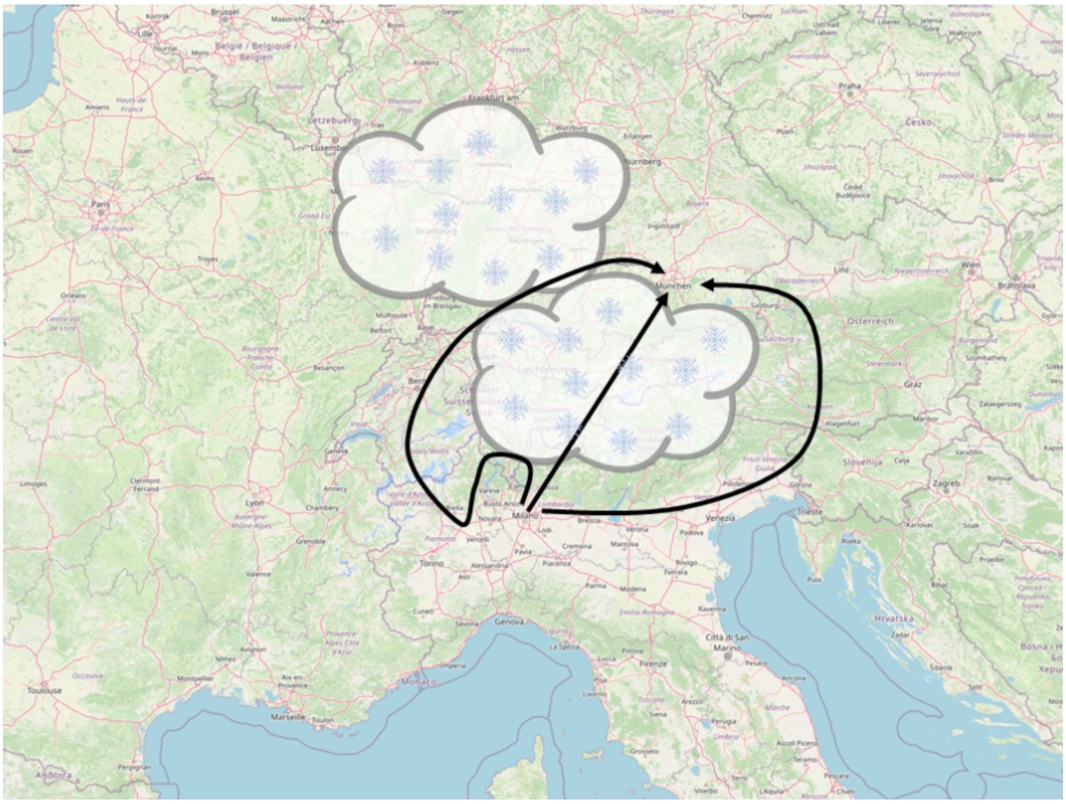

Figure 4: UC2 Initial flight plan and diversions available for HAT decision-making

1.2.1.2 UC#2 Reference Scenario(s) – VAL1

The reference scenario will be implemented in the Validation Phase according to the actual systems used by the pilot for decision-making.

2.3.4 UC#2 Platform / Tools & Technique – VAL1

An interactive simulation environment will be developed to simulate the 3 different levels of IA. It will be developed in a desk environment. Different types of support materials will be generated: scenario description to guide the walkthrough, interface mock-ups. The subjects of the experiment will be monitored using cameras to reconstruct their activity and gather their reactions to the system. The various information streams (video, logs, sound, interactions, physiological data) will be synchronised using RTMaps software.

2.3.5 UC#2 Data Collection and Analysis Methods – VAL1

Qualitative data will be collected directly during the different walkthroughs by Human Factors and Operational experts. Quantitative data will also be collected via questionnaires after the walkthroughs. These data will be used to make a statistical analysis that will compare the different level design concepts.

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- **Walkthroughs:** This methodology will provide a comprehensive means of comparing and better understanding the different levels of IA in the context of a predefined scenario. The aim is to determine how each level of AI can effectively assist, cooperate or collaborate with the pilot during the different phases and tasks of the scenario.

- **Questionnaires:** After the walkthroughs, the participants will respond to a questionnaire to evaluate the acceptance, perceived usefulness, perceived ease of use, usage intention of the IA. As the IA will be developed in a desk environment, the questionnaire will be adapted..

A specific data set of different situations, where decision making should be done, will be prepared. This data set will be evaluated by the pilots in terms of Operational Intentions. Thus, we will be able to train the system, based on the Bidirectional Communicator (COMBI), for the Second Validation.

2.3.6 UC#2 Planned Activities – VAL1

Activity	Activity Description	General Information
Scenario development workshops	This workshop will allow us to create variants in the scenarios so that we can test different experimental conditions.	Bordeaux, France Q2-Q3 2023
Digital assistant prototype development		Bordeaux, France Q3 2023
Validation of the experimental set-up	Technical validation of the test bench, checking communication between components and information gathering.	Bordeaux, France Q4 2023
VAL1	The subjects will go through 3 different types of AI to determine which will be the most suitable for their needs, depending on the tasks to be carried out.	Bordeaux, France Q1 2024

Table 19: UC2 Planned Activities

2.3.7 UC#2 Use Case Relationship and Collaborations

None at present.

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2.4 UC#2 Future work and Second Validation (VAL2)

2.4.1 UC#2 Expected R&D work

VAL1 will provide the final scope about what kind of assistant should be implemented in cockpit operations. Data collection in this validation will provide the training test for the Bidirectional Communicator that should be evaluated in VAL2. The R&D objectives not addressed in VAL1 will be addressed in VAL2.

2.4.2UC#2 Validation Approach for the Second Validation

The intelligent assistant concept will be integrated in a very representative simulation. For this purpose, Thales will provide a simulation environment that integrates real systems of a current cockpit. The Bidirectional Communication concept will be implemented in a specific user interface to evaluate the global concept of HAT based on operational intentions.

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3 Use Case #3 – Urban Air Mobility

3.1 UC#3 Background

The use of drones is envisioned to increase drastically within the next decades, necessitating some form of traffic regulation in urban areas. This new air transportation system of cargo and passengers, known as Urban Air Mobility (UAM), is expected to go live on a broader scale in cities already in 2025, initially in terms of piloted craft and then as autonomous or unmanned from 2030 (EASA, 2021) [8]. UAM promises applications of airborne manned and unmanned passenger transports, products delivery for consumers and for the industry, delivery of biomaterial (e.g. transplants) in healthcare, safety and security management (e.g. monitoring of road network during peak hours) and emergency services, including ambulance, police, and firefighting. The expected increase in drone traffic requires new solutions for dynamic and traffic management tied to real-time situational demands and the social life of the city (event planning). However, current practices in ATM are not directly transferable to unmanned traffic management (UTM) for high-density traffic. First, the amount of traffic is forecast to outnumber the most dense sectors in ATC. In ATC, there is a capacity limit tied to any volume of airspace and tied to the human operator. Similar limits may be needed in UTM (and at a high density of traffic unavoidable) but should not be referenced against current ATC capacity constraints. A question is therefore how to ascertain the safety of UAM reciprocal to that of ATM, as expected by society (EASA, 2021). This challenge has been addressed by stakeholders and regulators all levels of society, including national and international authorities (i.e. European Commission's "A Drone Strategy 2.0 for Europe, EC 2021), industry (e.g. EmbraerX, 2019) and research (e.g. DLR 2017, AURORA project1 , METROPOLIS project2). The latter proposes a density-based airspace management where UAM airspace users are initially integrated into uncontrolled airspace. EmbraerX envisions an Urban Air Traffic Management (UATM) solution, where essential components include optimised airspace usage, adaptable airspace structures, and shared situation awareness for all stakeholders. In the recently approved regulatory framework, U-space service providers are required to designate U-space airspace and provide services in terms of network identification services, geo-awareness services, flight authorisation, and traffic information.

To manage drones safely and efficiently in cities, it is evident that automation is needed to support the human operator. To address this, the use of AI and Intelligent Assistants in UTM is ideal for many reasons. The use of a Digital Assistant, supporting the human, can grant increased levels of traffic being managed, which also is of interest in ATM. Second, Digital Assistants can increase the safety of UTM by being able to (in parallel) monitor all traffic in the city airspace as well as monitoring ground events and city life with an impact on trajectory planning. To address the Human Factors challenge of UAM, HAIKU will perform a case study for UTM/UAM for two major European cities. The case study will build on previous UTM research conducted jointly by LIU and LFV, through the running platforms UTM CITY and SOMA-AI. Specifically, the case study aims to develop an advanced Digital Assistant for city

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UTM, allowing human operators to coordinate and monitor city drone traffic in conjunction with round events and the social life of the city.

3.2 UC#3 Context of the First Validation (VAL1)

Currently, in Sweden, the operational context does not yet exist – there are no large-scale drone operations, and consequently no operators or operations centre. There are however air operations currently in this future context that can be expected to continue also in the future. This means that we must approach the case differently, than if a change is to be made in an existing control context. The project will therefore build up a simulated context of operations, with which operators can get (limited) possibilities to engage and formulate (tentative) requirements.

Therefore, **all requirements formulated here are tentative**, reflecting **our current understanding** of the use case.

As the Intelligent Assistant prototype is built, and tested in simulated scenarios, this will change our understanding of both the operational context and of what support the digital assistant can and should provide.

3.2.1 UC#3 Key R&D Needs

The main R&D need that is met by this UC is to establish an operational concept that combines human operator work with automation (digital assistant) so that key urban air mobility operations become viable from an airspace and air traffic management perspective. The key airspace operations are represented by scenarios, and the automation is represented by a prototype that as closely as possible mimics that of a future intelligent assistant in operation. The operational context that is examined is that of the airspace manager, focussing our R&D effort more closely on the interface.

The current problem statement is based on having developed one traffic and operational scenario in detail in a simulator, for one city. Note that, we are not aiming at solving this particular problem, but at solving-reformulating-refining it. The final problem statement will be a major accomplishment – in combination with our solution concept.

Problem Statement – what is the problem to address with the Intelligent Assistant?
Our hypothesis is that the main problem that AI will address is the continuous monitoring and separation assurance of all drone traffic in the city airspace, considering the air situation as well as safety risks for ground activities. The AI can carry out many of the standardised, repetitive tasks involved in communicating with traffic operators, such as assigning clearances, instructions, setting constraints etc. as well as obtain and sustain a detailed overview of all air traffic and evolving ground situations. The Intelligent Assistant can attract operator attention when something of importance (according to set criteria) occurs. As such, the work of the human operator

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would in most cases not occur at the level of detail in monitoring or interaction with individual flights. Rather, the human operator would work with UTM at a higher level of abstraction, such as determining traffic separation objectives that the Intelligent Assistant would then implement, or establishing the hierarchy of priorities, for instance in case of emergencies. The human operator can also steer the assistant, e.g. by adjusting higher level parameters according to key performance measures.

Human Factors & Safety Risks – Potential risks and problems introduced by the Intelligent Assistant.

- To detect when AI is 'out of its depth' and human control needs to resume, for instance when a situation is too novel for AI to handle.
- Such a dynamic teaming between human and the Digital Assistant requires bidirectional communication, or the assistant can become difficult to understand. The Use Case will need to assess and establish the key aspects for explainability.
- Excessive reliance on AI and Digital Assistant, or on the contrary mistrust or distrust of AI.
- Ascertain that human operator workload is manageable, especially in case of sudden handover of control.

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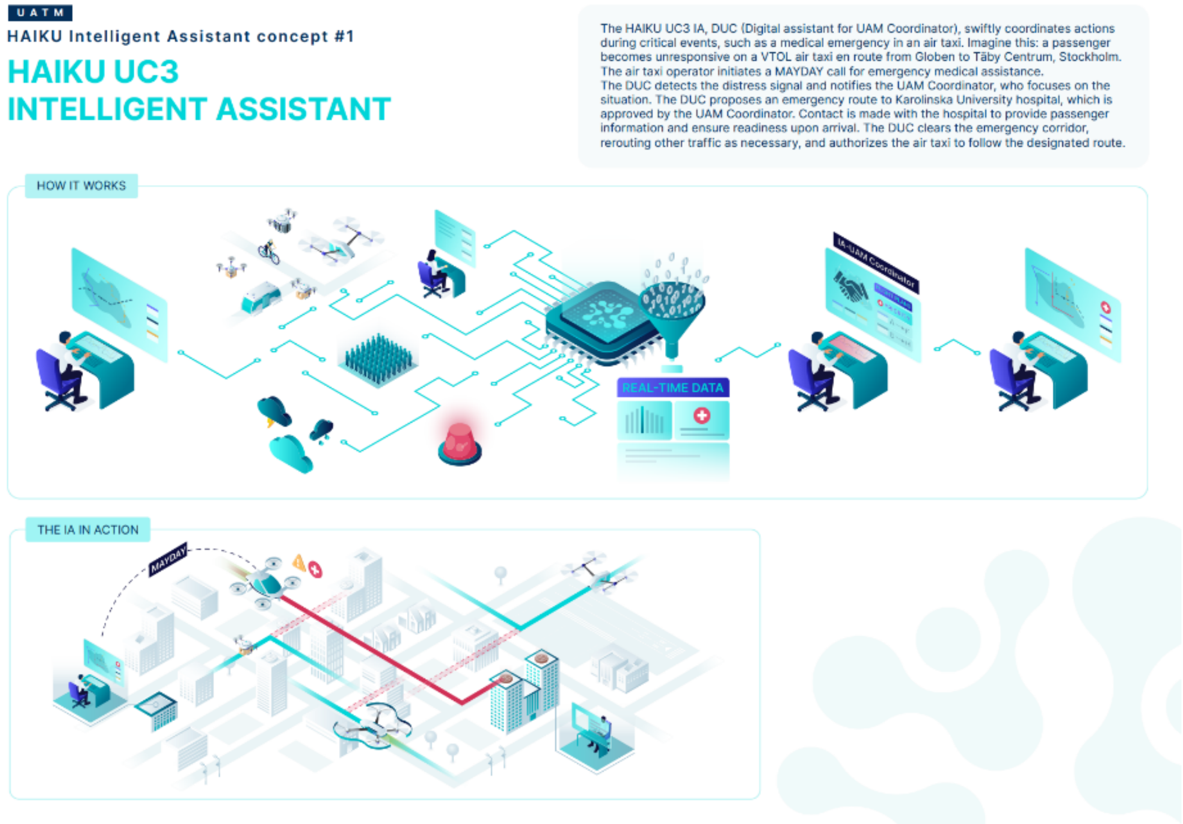

Figure 5: UC3 Intelligent Assistant Concept

3.2.2 UC#3 Operational Concept Description

The project has formulated an initial overarching vision, that is the starting point for our work.

The HAIKU UAM use case is based on the CORUS-XUAM project's [10] ConOps for UAM in the time window 2030-2050. In line with CORUS-XUAM, the UAM use case embraces the following key U-space (airspace overhead urban areas) services in *Z volume* airspace: Network Identification; Geo-awareness; Flight authorization; Traffic information; Weather information, and Conformance monitoring.

Thereto, new human roles as part of city U-Space Service Providers are required for safely managing and engaging with the UAM system to accommodate the link between ground and airborne activities. HAIKU envisions the **UAM Coordinator** as a key human role part of Urban Air Traffic Management (UATM) for a specific city, who provides real-time strategic and tactical U-space services to Unmanned Aircraft System (UAS) and UAM operators and stakeholders. In ascertaining the safety and efficiency in managing large traffic volumes and coordinating ground/airborne activities, the UAM Coordinator will be supported by intelligent assistants capable of monitoring all traffic

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in the city airspace as well as monitoring ground events and city life with an impact on trajectory planning.

The **Intelligent Assistant for UAM Coordinator (DUC)** will care for the majority of standard, repetitive, normal tasks (e.g., flight authorization, traffic monitoring, flight information, weather information). DUC is expected to reduce human task-/workload and allow the human to focus on high level strategic decision making in oversight of UAM operations. DUC will support the UAM Coordinator in day-to-day normal operations and emergency situations such as in-flight medical emergencies.

The UAM Coordinator is the end-user of the DUC. The UAM Coordinator and DUC form a team that works together to safely monitor the U-space and provide U-space services. One of the main activities is to coordinate ground and air activities and respond to emergency situations. The UAM coordinator has some resemblance to Air Traffic Controllers (ATCO) in that both provide a service to aircraft. A difference, however, is that operators in the U-space, in contrast to controlled airspace in ATM, are envisioned to operate more autonomously where typical ATC-problems such as route monitoring and Conflict Detection and Resolution (CD&R) is solved by automation without the need for human intervention. As such, a more suitable comparison is with road traffic management operators. In road traffic management, the cars operate autonomously. Instead, the road traffic management operators focus on flow management, managing constraints (e.g., closing roads), and reacting to emergency situations. Similarly, the role of the UAM Coordinator is envisioned as a requirement for managing the flow of aircraft, geo-fence provisions, reacting to emergency situations, and coordinating dependencies between ground-based activities and aircraft operations.

The DUC allows the UAM Coordinator to focus on high-level strategic decision making in oversight of UAM operations, where DUC cares for the majority of standard, repetitive, normal tasks (e.g., flight authorization, traffic monitoring, flight information, weather information). The DUC will direct the attention (e.g. visual cues in interface) of the UAM Coordinator to specific situations/events as needed. In emergency situations, DUC and the UAM Coordinator act to:

- Provide assistance to operator/pilot experiencing emergency (e.g., report, action proposal, contingency plans, emergency response plan)
- Inform and communicate with other stakeholders of emergency, such as other traffic and emergency response (on ground and in air)
- Adhere to emergency procedures (e.g., configure dynamic safety boundaries, change flight prioritisation, plan and coordinate emergency routings,
- Dynamically establish the priority criteria for the different types of flights.

Our validation activities start from these assumptions, and challenge them by testing our solution concept with operators.

3.2.3 UC#3 Performance Targets

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The following table presents metrics that can be used during evaluations, at different stages of development. Initially, we aim for a high-level assessment of the viability of the concept, with these KPI:s in mind.

KPA	Category	KPI
System Performance	MoP	Task completion time, task accuracy, system availability, timeliness, synchronisation, data exchange accuracy
Human Performance	MoP	Use Experience and Usability: Workload, situational awareness, operational method, acceptability, trust
Safety	MoE	Adherence to safety procedures, lateral/vertical separation, speed restrictions, airspace restrictions

Table 20: UC3 Performance Targets

3.2.4UC#3 Requirements

These requirements reflect our current understanding of the problem and the solution concept. Some of the requirements will be testable, whereas others may require tests at higher TRL, or more extensive tests. The initial tests will increase our understanding of the requirements, allowing us to revise some of them.

HL-REQ-ID	UC3-HLR-01
Requirement	The DUC shall provide relevant and real-time information to support the UAM Coordinator's high-level strategic decision-making, including traffic monitoring, flight information and emergency response plans.
Rationale	Providing relevant and real-time information to the UAM Coordinator supports their decision-making process. The DUC consolidates data from multiple sources, such as traffic monitoring and flight information, enabling the UAM Coordinator to make informed decisions based on accurate and up-to-date information.

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KPA	System Performance, Human Performance, Safety

Table 21: UC3-HLR-01

HL-REQ-ID	UC3-HLR-02
Requirement	The DUC shall effectively automate standard, repetitive tasks, reducing the time and effort required by the UAM Coordinator to perform routine operations.
Rationale	Automating standard, repetitive tasks through the DUC reduces the burden on the UAM Coordinator, allowing them to focus on higher-level decision making. By streamlining routine operations, the DUC enhances operational efficiency, improves productivity, and reduces the potential for human error.
KPA	System Performance, Human Performance, Safety

Table 22: UC3-HLR-02

HL-REQ-ID	UC3-HLR-03
Requirement	The Digital Assistant for UAM Coordinator (DUC) shall have an intuitive and user-friendly interface that allows the UAM Coordinator to easily interact with and understand the information visually provided and presented.
Rationale	The DUC should have an intuitive and user-friendly AI-based interface to ensure that the UAM Coordinator can quickly understand and interact with the system. This reduces the learning curve and minimises errors, enabling efficient task execution and effective utilisation of the system.
KPA	Human Performance

Table 23: UC3-HLR-03

HL-REQ-ID	UC3-HLR-04
Requirement	The DUC shall facilitate communication between the UAM Coordinator and other stakeholders, including UAS and UAM operators, emergency response teams, airspace users and other traffic participants.

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Rationale	Communication between the UAM Coordinator and stakeholders is crucial for effective coordination and collaboration in UAM operations. The DUC should facilitate timely and accurate information exchange, enabling the UAM Coordinator to communicate with UAS and UAM operators, emergency response teams, and other relevant parties.
KPA	System Performance, Human Performance, Safety

Table 24: UC3-HLR-04

3.2.5 UC#3 Key R&D Objectives

The main R&D need that is met by UC3 is to establish an operational concept that combines human operator work with automation (Intelligent Assistance) so that key urban air mobility operations become viable from an airspace and air traffic management perspective. The key airspace operations are represented by scenarios, and the automation is represented by a prototype that as closely as possible mimics that of a future intelligent assistant in operation. The operational context that is examined is that of the airspace manager, focussing our R&D effort more closely on the interface.

This approach toward our main objective means that we evaluate both achievement of more detailed success criteria and objectives, but also the relevance and content of the objectives per se. The following table reflects our understanding of objectives and criteria that we *at this stage of the project* believe are relevant to assess. Although these are objectives and criteria that we currently work on, practical considerations can also mean that some objectives and criteria cannot be evaluated during HAIKU; as our understanding of the case improves they will also be re-assessed.

OBJ-ID	Validation Objective	Success Criteria ID	Success Criteria
UC1-OBJ-01	To assess the operational feasibility and acceptability of the concept.	UC3-CTR-01	Positive feedback from the UAM Coordinator with respect to related tasks through cognitive walkthrough analysis. Acceptable quality of service, safety and workload. The DUC can manage the traffic inside the related airspace in an acceptable way. The HMI interface is user-friendly and provides the UAM Coordinator with necessary information.

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UC1-OBJ-02	To assess the tasks and operating methods of the UAM Coordinator.	UC3-CTR-02	The content of the operating methods has been determined to be clear and consistent by UAM Coordinator and experts.
UC1-OBJ-03	To assess the UAM Coordinator timeliness of actions, workload, situational awareness, trust and acceptability.	UC3-CTR-03	The UAM Coordinator can perform tasks in an accurate, efficient and timely manner. The UAM Coordinator workload is at an acceptable level. The UAM Coordinator can maintain an acceptable level of situational awareness. The UAM Coordinator has an acceptable level of trust and acceptability about the concept.
UC1-OBJ-04	To assess the effectiveness of the DUC in supporting the UAM Coordinator when a flight needs to deviate from its original route	UC3-CTR-04	The DUC should provide enough support to the UAM Coordinator to handle the deviation/emergency without compromising safety. The DUC should be able to provide information about the most suitable route, taking into account traffic, ground activity/availability, distance and airspace restrictions.
UC1-OBJ-05	To assess the DUC HMI interface and information requirements.	UC3-CTR-05	Positive feedback from the UAM Coordinator. Positive feedback from the UAM Coordinator on the information provision.

Table 25: UC3 Key R&D Objectives

3.3 UC#3 First Validation Plan (VAL1)

3.3.1 UC#3 Approach – VAL1

In the first validation (VAL1) UTM City has been selected as the simulation platform for the DUC concept and prototype. Because of its comprehensive capabilities in modelling urban airspace, simulating U-Space services, and facilitating coordination between ground and airborne activities makes it a suitable choice for validating the concept's functionalities and performance in a virtual environment at its current low level of maturity.

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Given the early stage of development, simulation-based testing using the UTM City software program provides a controlled and cost-effective approach to validate the DUC concept and prototype. It allows for iterative testing, refinement, and optimization of the concept's functionalities and performance within a simulated urban airspace. By collecting feedback from experts testing the UTM City platform, valuable insights can be gained, contributing to the further development of the concept.

The two exercise scenarios, one involving re-routing of an air taxi due to medical emergency (SS1) and the other involving the re-routing of a package delivery drone (SS2), contribute to cover the objectives of the HAIKU UAM Intelligent Assistant concept. By including these two scenarios, the HAIKU UAM Intelligent Assistant concept demonstrates its ability to address various operational aspects, ensure safety, integrate with existing systems, and prioritise user experience. The scenarios provide valuable insights and data to further develop and refine the concept and prototype, covering the objectives and progressing towards the target maturity level.

3.3.2 UC#3 Exercise Description and Scope – VAL1

Exercise Description	Scope (What is being assessed)	Key R&D Objectives explored
Stockholm Scenario 1: This scenario involves a single passenger air taxi transporting an unresponsive passenger from Globen to Karolinska University Hospital in Stockholm Sweden.	The scenario focuses on handling an emergency in real-time. The air taxi autonomously detects the passenger's health issue and initiates an emergency deviation. The DUC notifies the UAM Coordinator, proposes an emergency route and altitude change, and coordinates with relevant stakeholders such as the hospital and other traffic. The DUC dynamically establishes an emergency corridor, prioritises the flight, and guides the air taxi to a designated vertiport at the hospital.	UC3-OBJ-01/02/03/04/05
Stockholm Scenario 2: This scenario involves a delivery drone transporting a package from Västberga to Hässelby Strand in Stockholm Sweden.	The scenario focuses on handling a re-routing request in real-time. The delivery drone follows a predefined route but requests a change of destination. The DUC alerts the UAM Coordinator, calculates alternative routes, and presents options based on factors like distance and airspace	UC3-OBJ-01/02/03/04/05

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	constraints. The UAM Coordinator selects a route, coordinates with Air Traffic Control or the ATM system if needed, and the DUC sends the new route to the drone operator. The DUC ensures continued safe flight and landing, potentially vertiports, considering factors like battery usage and airspace restrictions.	

Table 26: UC3 Exercise Description

3.3.3 UC#3 Exercise Scenario(s) – VAL1

Stockholm scenario 1 – Re-routing of an air taxi due medical emergency: Single passenger air taxi transport in VTOL from Globen (A) to Täby Centrum (B) in Stockholm, Sweden. The flight plan and flight authorisation has been processed and approved automatically by the DUC. The UAM Coordinator is not aware of the specific details of the flight. The air taxi follows a predefined route, which is a direct route. In the vicinity of Hammarbyslussen (C), something happens with the passenger that requires an emergency deviation to acquire health services. The air taxi notices (autonomously through sensors, or by remote pilot supervising the air taxi operation) that the passenger is unresponsive. The air taxi operator calls MAYDAY and changes its ID code to an emergency. This changes the status of the flight and its priority in relation to other traffic. The DUC immediately detects the MAYDAY and informs the UAM Coordinator (e.g., by directing attention) to the air taxi on the UTM City interface. The UAM Coordinator's attention is shifted to the air taxi. The DUC proposes an emergency route and corridor to Karolinska University hospital (E) via Nybroviken (D) which is located along the planned route (see figure 1). It also proposes a change of altitude to a designated emergency altitude. The UAM Coordinator inspects and approves the proposed routing. The UAM Coordinator then contacts the hospital to relay information about the sick passenger and notify them of the inbound air taxi to ensure that it is met on arrival. The DUC takes action to clear the emergency corridor of other traffic (re-rerouting others as needed) and clears the air taxi to follow the emergency route. The emergency corridor is dynamically activated around the air taxi as it progresses toward the hospital. A larger than normal bubble around the air taxi represents a no-go zone, requiring an increase in separation to other traffic. The priority of the air taxi is automatically increased because of the emergency. Normally, there is a restricted no-fly zone around the hospital, for which the air taxi receives permission by the DUC to enter. The restricted zone around the hospital exists to accommodate traffic in emergency situations, or other prioritised traffic to and from the hospital. There is one or more vertiports at the hospital that can accept emergency traffic (e.g., the air taxi). The DUC coordinates the approval to land at one of the hospital vertiports. The air taxi lands at one of the vertiports and is received by hospital personnel who take care of the sick passenger.

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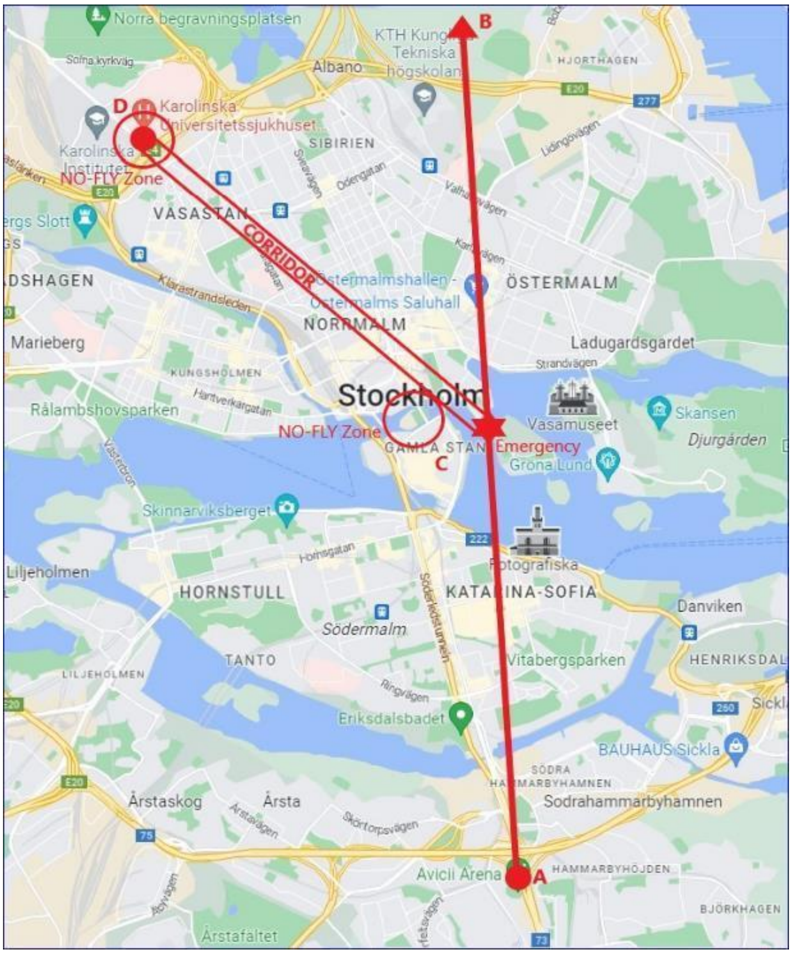

Figure 6: UC3 Stockholm scenario 1

Stockholm scenario 2 – Re-routing of a package delivery: A logistic company situated in Västberga (A) sends a delivery drone with a package to Hässelby strand (B) in Stockholm, Sweden. The flight plan and flight authorisation has been processed and approved automatically by the DUC. The UAM Coordinator is not aware of the specific details of the flight. At departure time, the delivery drone lifts off and follows a predefined route, which is a direct route. At approximately above Södra Ängby (C), the drone operator sends a request to change destination for the package delivery. New destination is Huvudsta (D). The DUC alerts the UAM Coordinator. At the same time, it processes the request and immediately calculates a route to the new destination. The DUC then presents different options, e.g. the shortest route, the fastest route or a route with minimum use of battery, to the UAM Coordinator. As illustrated in Figure 2 below, route 1 is presented as the shortest route. The delivery drone, however, could face a delay due to this routing takes it across the climb out area or approach path of manned aircraft at Stockholm Bromma airport (ESSB). This means the UAM Coordinator will need to contact the Air Traffic Controller or the ATM system to get permission for the delivery drone to enter and cross the controlled airspace. Another option, route 2, is also presented as the fastest route (longer distance but no delay). The delivery drone will fly via Tranebergsbron at lower level and over the water.

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Regardless of which route is chosen, the DUC should be capable of calculating continued safe flight and landing (CSFL) which may be vertiports in this scenario. The UAM Coordinator makes a decision based on the suggestions provided. The DUC then responds to the request and sends out a new route to the drone operator. It is worth noting that since this is a re-routing under normal situation, the delivery drone takes most of the delay and will not receive priority. This re-routing, therefore, does not have a big impact on other operations.

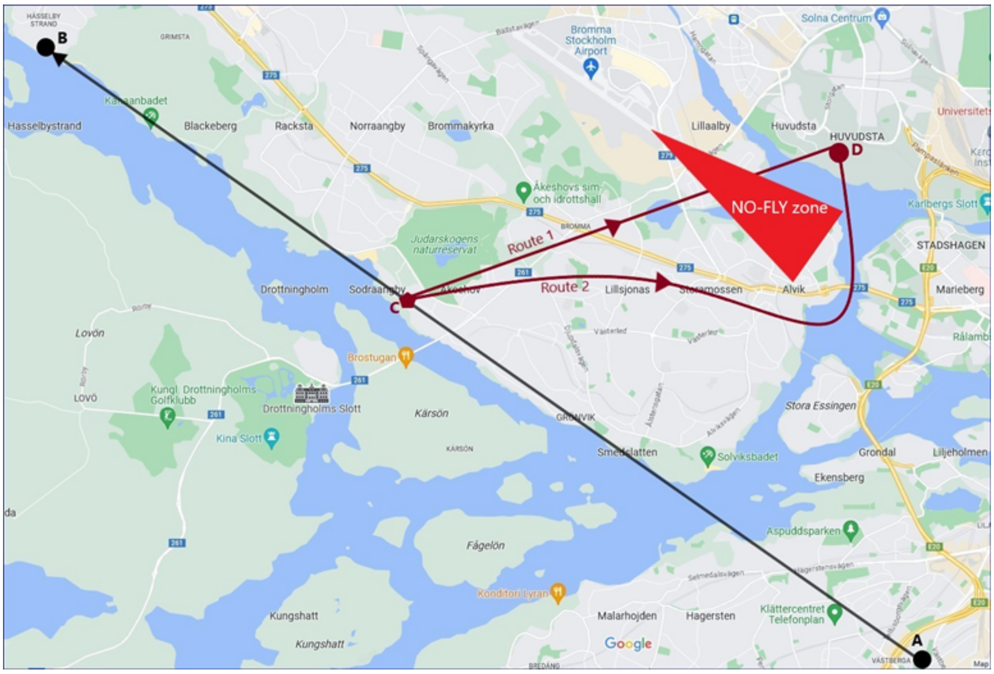

Figure 7: UC3 Stockholm scenario 2

1.2.1.3 UC#3 Reference Scenario(s) – VAL1

Creating a traditional reference scenario for the DUC concept presents challenges due to the unique nature of urban air mobility (UAM) and the limited existing infrastructure and procedures specifically designed for UAM operations. Unlike traditional aviation, which has well-established airports, air traffic control systems, and standardised procedures, the UAM ecosystem is still in its nascent stages.

Instead of relying solely on traditional reference scenarios, the development of the HAIKU UAM use case will involve the creation of tailored simulation scenarios that capture the essential aspects of UAM operations. These scenarios will incorporate elements such as urban airspace, U-space services, communication protocols, and interactions between UAS/UAM vehicles and ground infrastructure. By designing custom scenarios that reflect the future UAM landscape, the validation process can better assess the performance, safety, and effectiveness of the HAIKU Intelligent Assistant concept within the context of UAM operations.

3.3.4 UC#3 Platform / Tools & Technique – VAL1

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The following are the descriptions of the simulator and tools that we plan to use. The descriptions refer to the current characteristics and functions for VAL1, not considering the adaptations that might be performed for VAL2.

UTM City is an interactive visualisation that simulates drone traffic/services, external drones/data, and airspace restrictions/rules on a map with a dashboard. It has been chosen as the simulation platform to validate the HAIKU UAM Intelligent Assistant concept because of its comprehensive capabilities in modelling urban airspace, simulating U-Space services, and facilitating coordination between ground and airborne activities, making it a suitable platform for validating the concept's functionalities and performance in a virtual environment. Its robust features, user-friendly interface, and ability to incorporate realistic parameters enable accurate representation of the target cities (Stockholm and Lisbon), ensuring reliable assessment and iterative refinement of the concept at its current low level of maturity.

Figure 8: UC3 UTM City

SOMA-AI is a state-of-the-art software platform and infrastructure developed by LiU to analyse a large amount of heterogeneous streaming data in real time. Based on modern and open source distributed computing technologies, integration of machine learning and analytical algorithms is straightforward. Currently, the system is employed in a High-Performance Computing (HPC) cluster. The SOMA-AI platform contains historical flight data i.e. three years of recorded traffic. It can collect data, not just from the UTM City but also from open data sources on current traffic (e.g. aircraft, helicopters).

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JCF Editor is a tool developed at LIU to analyse human-automation/AI interactions. In this use case it is used to analyse the resolving of conflicts between different drone services. Below, is an example from the met threat case from another project partner.

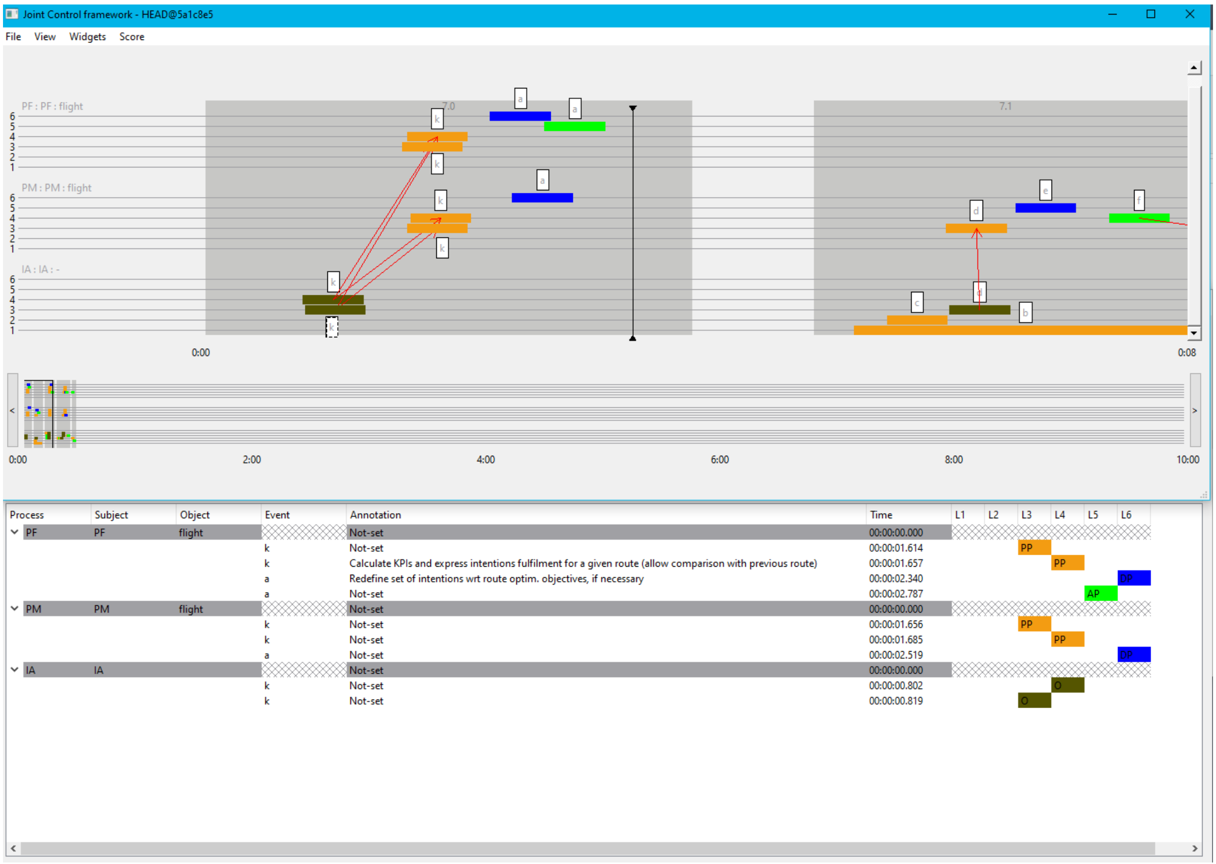

Figure 9: UC3 JCF Editor

The DUC prototype is being developed having capacity to exchange traffic data and drone plans between the UTM City and the SOMA-AI platform. In the figure below, we show our work-in-progress on the prototype. Note that this is an image/rendering of the interface on top of UTM CITY, used as guidance when we build the prototype.

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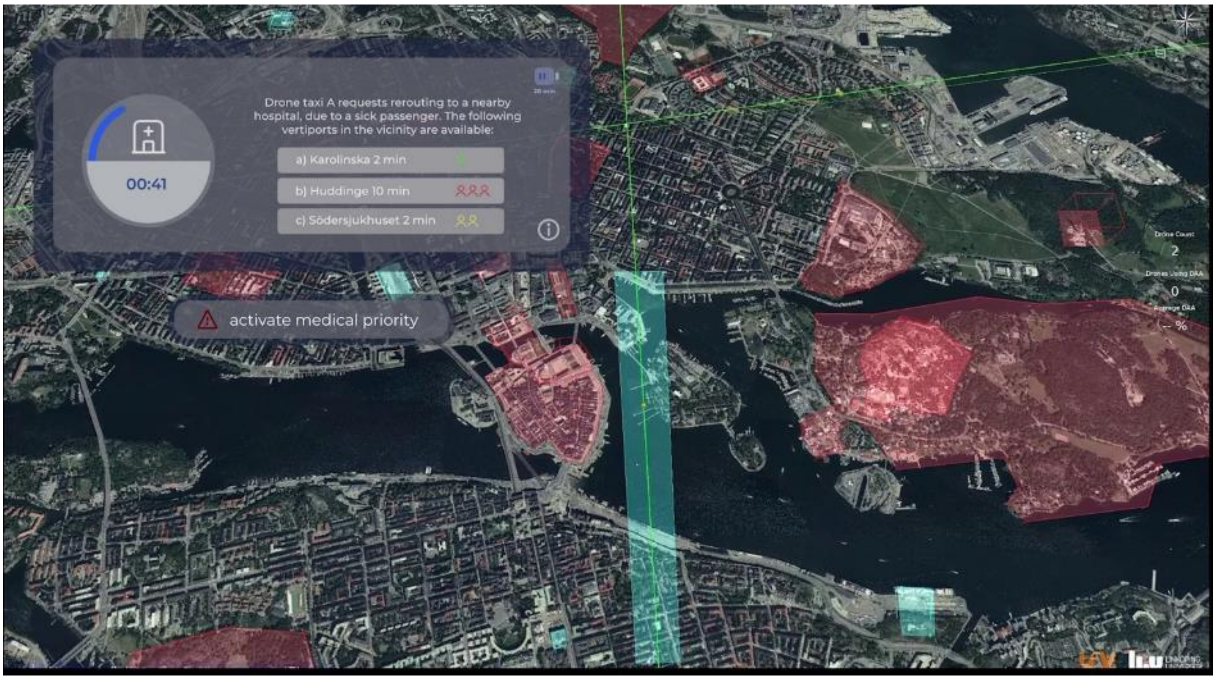

Figure 10: UC3 Intelligent Assistant Prototype

3.3.5 UC#3 Data Collection and Analysis Methods – VAL1

To prepare for the validation process, the UTM City simulation environment will be established to replicate the urban airspace and U-space services required for the HAIKU UAM concept. Additionally, a tailored HMI will be developed and integrated into the interface used by the UAM Coordinator, equipping them with the necessary tools and information to effectively monitor and manage UAM operations.

During the scenario simulations, the UAM Coordinator will engage with the integrated HMI, utilising its functionalities to carry out their tasks. This includes monitoring traffic, granting flight authorizations, receiving alerts, and responding to emergency situations. The simulations will assess the performance of both the HAIKU UAM concept and the HMI, focusing on the effectiveness of the HMI in supporting the UAM Coordinator's decision-making, workload management, and coordination with the DUC and other stakeholders.

To gather valuable insights, feedback will be collected from the UAM Coordinator and other participants involved in the simulations. This feedback will cover aspects such as technical feasibility and functionality of the system, and the end users' understanding, trust, acceptance, and experience of working with the AI as an Intelligent Assistant. The received feedback will be analysed to identify areas for improvement in the HMI design, functionality, and user experience.

During the VAL1 of the HAIKU UAM Intelligent Assistant concept, the following data collection methods will be used; observations, interviews, performance metrics and system logs. The use of questionnaires is being considered.

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3.3.6 UC#3 Planned Activities – VAL1

Activity	Activity Description	General Information
Scenario development workshops	Scenarios developed that encompass various operational aspects and challenges relevant to the HAIKU UAM Intelligent Assistant concept, such as traffic management and emergency situations.	Norrköping, Sweden Q2-Q3 2023
Intelligent assistant prototype development	Development of a prototype having capacity to exchange traffic data and drone plans between the UTM City and the SOMA-AI platform, and functionalities suitable for validations.	Norrköping, Sweden Q3 2023
System integration tests	Technical test(s) to ensure seamless integration and communication between the different components of the concept.	Norrköping, Sweden Q4 2023
VAL1	Validation exercises using UTM City simulations, incorporating the developed Intelligent Assistant prototype. Allowing the UAM Coordinator to interact with the HMI and perform their tasks.	Norrköping, Sweden Q1 2024

Table 27: UC3 Planned Activities

3.3.7 UC#3 Use Case Relationship and Collaborations

Collaborations with other use cases have been initiated regarding our analysis approach. Specifically, we have modelled the Met Threat case in the JCF Editor.

3.4 UC#3 Future work and Second Validation (VAL2)

3.4.1 UC#3 Expected R&D work

The outcomes of the VAL1 are expected to provide valuable insights and assessments regarding the DUC concept and prototype. Through the validation process, strengths, weaknesses, and opportunities for improvement will be identified, both in terms of user experience and system performance. We expect to modify the requirements list based

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on VAL1. The validation will also help validate the effectiveness of the Intelligent Assistant concept in achieving its objectives.

The VAL1 outcomes will serve as a foundation for the next phase of developing the concept. They will provide critical feedback and data to drive iterative design improvements and refinements in both the HAIKU UAM Intelligent Assistant concept and the prototype. Identified weaknesses and challenges can be addressed, while leveraging the strengths and successes to enhance the overall system.

Additionally, the VAL1 outcomes will contribute to building confidence in the concept and its technical feasibility and functionality of the system in collaborating with the human, including explainability and the user's ability to influence the Intelligent Assistant.

Ultimately, the VAL1 outcomes will guide the next phase of development, enabling the refinement and optimization of the HAIKU UAM Intelligent Assistant concept and the prototype, leading to an improved and more mature solution that is closer to practical implementation in urban air mobility systems.

3.4.2UC#3 Validation Approach for the Second Validation

The second validation (VAL2) is tentatively planned to take place between Q4 2024 and Q2 2025 and will aim at assessing the proposed concept for Digital Assistant at a higher TRL. The UAM use case aims to test Intelligent Assistants at TRL4 – 6 with target end users, which involves demonstrations of the prototype in the relevant operational environment (i.e. high fidelity simulator) where the scenarios (i.e. problem) will be designed as close as possible to the envisaged UAM traffic and operational environments. The activities will be the same as for VAL1, but the outputs such as experimental plans are expected to be more detailed as more measures can be applied in TRL4 – 6 validation trials. We plan to introduce a second city in VAL2, Lisbon, to broaden the generalizability of the use cases.

The validation process will focus on evaluating user experience, usability, system performance, and the effectiveness of the UAM concept in achieving its objectives. The validation results will be reported as parts of a deliverable due in Q2 2025.

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4 Use Case #4 – Digital and Remote Tower

4.1 UC#4 Background

The introduction of automated solutions and AI in the ATM domain is still marginal and mainly applied in the en-route or approach control, since the provision of separation in these cases is based on radar information, which is already digitised. Automation solutions in the aerodrome control service are rarely seen, mainly because the decisions and instructions provided by Tower controllers are primarily based on visual observation of aircraft under their control. Introducing automation in this environment is difficult since the information is not digitised and thus there is not an option to develop AI and ML based solutions.

However, with the dawn of digital towers - i.e. the provision of aerodromes service using the image of the airfield taken by a set of cameras situated at different locations in the airport - visual information used by Tower controllers becomes digital, which brings the opportunity to introduce Intelligent Assistants to the controller. More specifically, there is an opportunity to explore how an Intelligent Sequence Assistant (ISA) can support and enhance decision-making for Air Traffic Controllers, mostly focused on runway utilisation in single-runway airports, such as Alicante-Elche airport in Spain, providing real-time sequence suggestions for arriving and departing aircraft, as well as helping Ground controllers organise the traffic in the taxiways and apron. The real-time assistance provided by ISA should ensure timely and accurate forecast updates, allowing Air Traffic Controllers 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.

4.2 UC#4 Context of the First Validation (VAL1)

4.2.1 UC#4 Key R&D Needs

Problem Statement – what is the problem to address with the Intelligent Assistant? Intelligent Assistants would imply a significant increase of capacity and provision of new safety nets. Such assistants could be designed to aid air traffic controllers in a wide variety of tasks.

For instance, provision of air traffic control in single runway airports is challenging, since the same runway is used for both landings and take-offs. The capacity of such airports is normally limited by runway occupancy time, and thus to maximise capacity

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one needs to optimise runway throughput by optimising aircraft sequencing. A Intelligent Assistant that aided the controller in tasks such as vacating the runway and overflying the runway end would significantly reduce workload and ensure that the best possible sequence is designed by the tower controller, so as to maximise runway throughput.

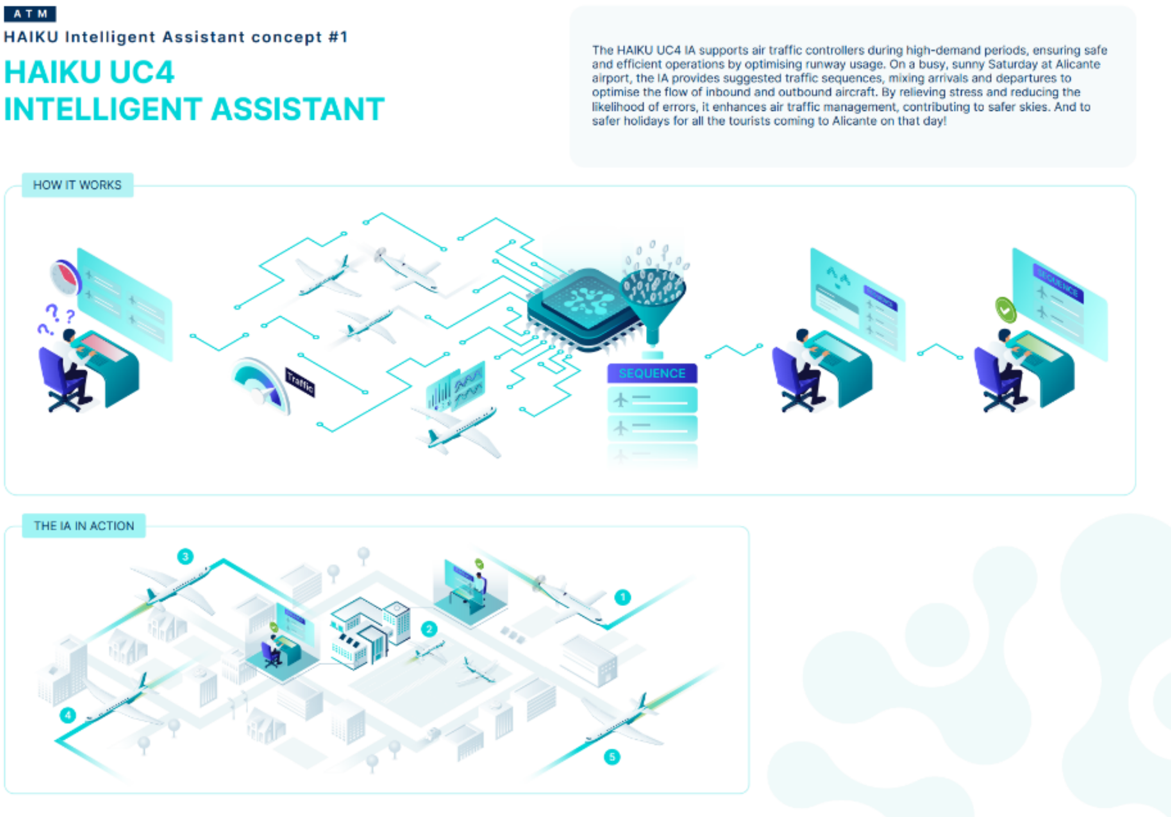

Figure 11: UC4 Intelligent Assistant Concept

4.2.2UC#4 Operational Concept Description

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 TWR 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. To do that, ISA will consider pre-set restrictions, rules of prioritisation and inputs from different events.

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4.2.3UC#4 UC#4 Performance Targets

KPA	Category	KPI
Operational, Traffic Management Efficiency	MoE	Number of arrivals and departures managed in an hour/X minutes
Safety	MoE	Number of safety events in an hour/X minutes (including “go around” manoeuvres, aborted take-off, etc.).
Human Performance	MoP	Comparison between “ideal” sequence vs. the sequence carried out by the ATCO

Table 28: UC4 Performance Targets

4.2.4UC#4 Requirements

HL-REQ-ID	UC4-HLR-01
Requirement	The team must always keep situational awareness of the traffic situation.
Rationale	The team must always keep situational awareness of the traffic situation.
KPA	Operational, Safety, Human Performance

Table 29: UC4-HLR-01

HL-REQ-ID	UC4-HLR-02
Requirement	The team must maximise company policy operational goals.
Rationale	The team must maximise company policy operational goals.
KPA	Operational, Safety, Human Performance

Table 30: UC4-HLR-02

HL-REQ-ID	UC4-HLR-03
Requirement	The team decision must represent a best trade-off of company goals and ATCO's feedback.
Rationale	The team decision must be based on efficiency (e.g. maximise the throughput of arrivals and departures in an hour) and

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	ATCO's feedback. Most efficient solution might not be feasible since it could mean assuming too much risk when managing a sequence of consecutive arrivals and departures. The ideal solution would be a system that can be tuned to offer a more aggressive or more conservative sequence, depending on the situation/ATCO in charge, and that could maximise the number of arrivals over departures (or the other way around).
KPA	Operational, Safety, Human Performance

Table 31: UC4-HLR-03

HL-REQ-ID	UC4-HLR-04
Requirement	The team must be able to keep situational awareness of safety events.
Rationale	The team must be able to keep situational awareness of safety events.
KPA	Safety

Table 32: UC4-HLR-04

HL-REQ-ID	UC4-HLR-05
Requirement	The team must be able to identify specific operational scenarios such as a runway change, the activation of low visibility procedures, bad weather conditions, etc.
Rationale	These specific scenarios usually mean higher workload for ATCOs and a higher risk of a safety incident.
KPA	Operational, Safety, Human Performance

Table 33: UC4-HLR-05

HL-REQ-ID	UC4-HLR-06
Requirement	The team must be able to reduce the workload.
Rationale	The assistant should help reduce ATCO's (subjective) workload (compared to the same scenario without any help from the IA).
KPA	Human Performance

Table 34: UC4-HLR-06

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HL-REQ-ID	UC4-HLR-07
Requirement	The team must achieve a "high trust factor".
Rationale	"High trust factor" means most ATCOs trust IA suggested sequence.
KPA	Human Performance

Table 35: UC4-HLR-07

4.2.5 UC#4 Key R&D Objectives

OBJ-ID	Validation Objective	Success Criteria ID	Success Criteria
UC4-OBJ-01	To assess the Operational Feasibility and Acceptability of the solution from the ATC perspective in nominal conditions.	UC4-CTR-01	The solution is considered Operationally Feasible and Acceptable by TWR ATCOs in nominal conditions (Medium Complexity scenario).
UC4-OBJ-02	To accept the solution Safety-wise from the ATC and Safety Team perspective in nominal conditions.	UC4-CTR-02	The number of Safety events and its severity is considered Acceptable by TWR ATCOs and the Safety Team and in nominal conditions (Medium Complexity scenario).
UC4-OBJ-03	To obtain a high "Trust factor" rating	UC4-CTR-03	The solution is considered Operationally Feasible and Acceptable by TWR ATCOs in nominal conditions (Medium Complexity scenario).

Table 36: UC4 Key R&D Objectives

4.3 UC#4 First Validation Plan (VAL1)

4.3.1 UC#4 Approach – VAL1

The validation approach consists of running several exercises in the simulator to compare the "ideal" sequence vs. the sequence carried out by the ATCO to understand their decisions and tune, if necessary, the assistant (e.g. is the sequence too aggressive?), using low-fi validation, video recording of SIM exercises and/or collecting ATCO feedback.

4.3.2 UC#4 Exercise Description and Scope – VAL1

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Exercise Description	Scope (What is being assessed)	Key R&D Objectives explored
Alicante Control Tower scenario	The exercise will be performed in a simulator that replicates the same conditions as in ALC Control Tower. The scope of the exercise is to assess the following; comparison between ideal sequence and ATCO sequence, number of safety events, workload, quality of AI resolutions and Human-AI teaming aspect.	UC4-OBJ-01/02/03

Table 37: UC4 Exercise Description and Scope

4.3.3 UC#4 Exercise Scenario(s) – VAL1

The scenario will be a simulator that replicates the same conditions as the Control Tower of Alicante Airport, where multiple exercises will be run and analysed. The scenario replicates a single-runway Airport (LEAL), with a main taxiway and 4 gates to get in & out to the apron:

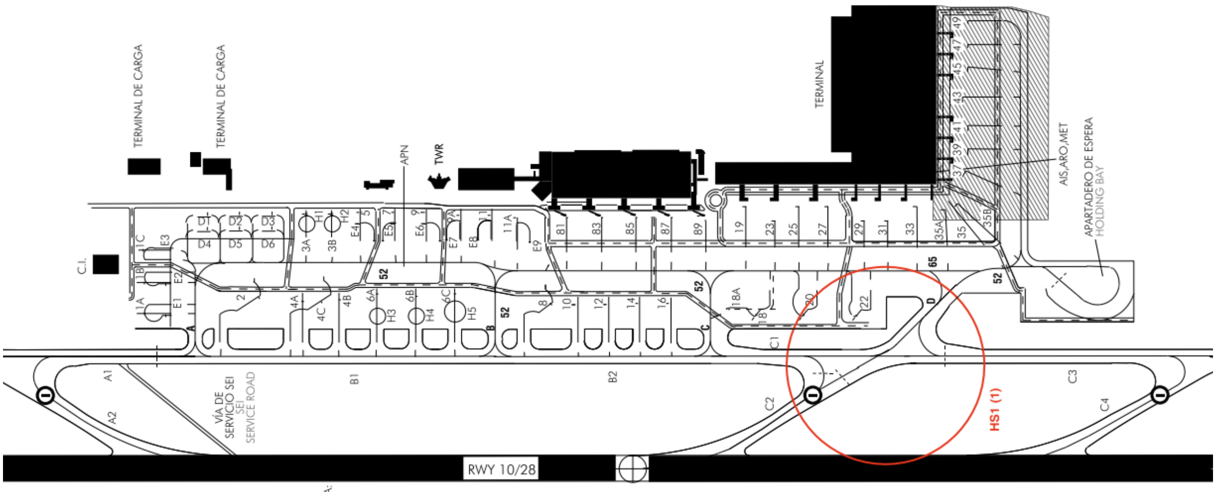

Figure 12: UC4 Alicante Airport

Different situations will be presented, including a variety of traffic density, unusual situations, emergencies, and contingencies. Pseudo pilots will act as real pilots as well as Airport staff (Ops Office, Firefighters, etc.) and Approach controllers, when needed.

1.2.1.4 UC#4 Reference Scenario(s) – VAL1

TBD. It is still too early to identify the ideal scenario in terms of efficiency and safety.

4.3.4 UC#4 Platform / Tools & Technique – VAL1

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The platform to be used for VAL1 will be a simulator that replicates the same conditions as the Control Tower of Alicante Airport. The whole setup includes several screens (for the scenario and operational information, such as weather conditions) and computers, and two working positions (LCL and GMC controller), as well as several working positions for pseudo pilots as well.

Figure 13: UC4 Simulator in Barcelona, Spain

4.3.5 UC#4 Data Collection and Analysis Methods – VAL1

The system must be able to feed real-time simulator data and process it accordingly. This data will possibly include:

Fixed parameters: Runway strip dimensions, volume/wingspan of the aircraft, separation between departures (LoA), ARP and dimensions of the controlled airspace.

Aircraft data: Position, velocity, CTOT (if applicable), EOBT, flight rules, type of flight, type of aircraft and wake turbulence.

Actions (triggered by pseudo pilots): clearance to enter the runway, clearance for take-off, clearance to land, clearance for touch and go, instruction to go around, clearance to overfly the runway and aborted take-off.

For the HF part, we will also conduct interviews and ask participants to fill questionnaires. We should be able to compare the initial sequence vs. the sequence carried out by the ATCO and, at the same time, compare the number of arrivals, departures and safety events that could have affected the final sequence. We will also gather feedback from ATCOs.

4.3.6 UC#4 Planned Activities – VAL1

Activity	Activity Description	General Information

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First technical approach and initial data model	Initial simulator tests performed in Barcelona, for the first technical approach, and to define an initial data model.	Barcelona, Spain, Q2 2023
Simulator installation	Installation of a new simulator in Madrid with new firmware and updates, which will be used for the VAL1.	In this simulator, we will have the latest firmware updates including any development required from Suite5 and DFKI in the future. We will use the first exercises run in this simulator to feed the IA (in order to be able to learn from them). Madrid, Spain, Q3 2023
VAL1	Simulator exercises performed in the simulator over several days with different ATCOs.	Each exercise about 60 min Madrid, Spain, Q1 2024

Table 38: UC4 Planned Activities

4.3.7 UC#4 Use Case Relationships and Collaborations

Not applicable at this time.

4.4 UC#4 Future work and Second Validation (VAL2)

4.4.1 UC#4 Expected R&D work

The outcome of the VAL1 is expected to provide valuable information. Strengths, weaknesses, and opportunities for improvement will be identified through the validation process, mostly focused on improving the sequence output suggested by the IA. The VAL1 results will serve as the basis for the next phase of development, which will include real-time data feeding to the Intelligent Assistant, to suggest a more accurate sequence. This will provide critical feedback and data to drive iterative design improvements. Identified weaknesses and challenges can be addressed, while leveraging the strengths and successes to enhance the overall system

4.4.2 UC#4 Validation Approach for the Second Validation

VAL2 will be focused on real-time suggestions from the Intelligent Assistant, based on live events. This suggested sequence will change according to the situation, and the validation approach will be specifically focused on improving this outcome.

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5 Use Case #5 – Airport Safety Watch

5.1 UC#5 Background

London Luton Airport (LLA: ICAO designation EGGW) is the fifth busiest airport in the UK, carrying over 18 million passengers in 2019 (pre-COVID), and is a major hub for EasyJet, Ryanair, TUI and WizzAir, as well as cargo and business jet traffic. Luton Airport benefitted from a previous EU project called Future Sky Safety (Kirwan et al., 2019; Ogica et al., 2020) [11] where it was the major test-site for the first airport-wide safety culture survey, leading to the creation of the Luton Safety Stack, which received an award from IATA for its ground-breaking safety efforts, and is seen by EASA and many others as demonstrating best practice in safety and safety culture, particularly for ground-handling, one of EASA's key risk areas. To that end LLA, and the Stack more generally, are interested in how AI can help learn from data collected across the airport, to understand where future hotspots or safety 'pinch-points' might arise, with a view to staying one step ahead on airport safety.

5.2 UC#5 Context of the First Validation (VAL1)

5.2.1 UC#5 Key R&D Needs

Problem Statement – what is the problem to address with the Intelligent Assistant? London Luton Airport is the duty-holder when it comes to safety, and as such it collects a vast amount of data from across the airport partners, creating over 50,000 entries to its safety management platform annually, all of which is categorised under its most relevant heading. The analysis of this data is undertaken manually. Right now, LLA cannot easily exploit all of this data, but with AI and Machine Learning there is the potential to identify which of our efforts produce the best results. For example, how does Near Miss Incorrect Parking of Vehicles and Equipment relate to actual collisions, and what safety promotion has been undertaken to raise awareness and what was its effect? LLA has experimented with different ways of visualising safety data, including Safety Dashboards as also developed in the EU project Future Sky Safety. The problem is that such manual analysis of data, much of which represents 'weak signals', is not always timely (the analysis 'lags' behind the actual events and evolving trends), and also sometimes it is difficult to see whether the data are 'noise', or are useful precursors to potentially more serious issues.

Human Factors & Safety Risks – Potential risks and problems introduced by AI. There should be no safety risks associated with use of the derived data analytics approach or learning tool, since it is analysing data and generating safety intelligence for the Stack, so any resultant recommendations would be evaluated by the Stack user group.

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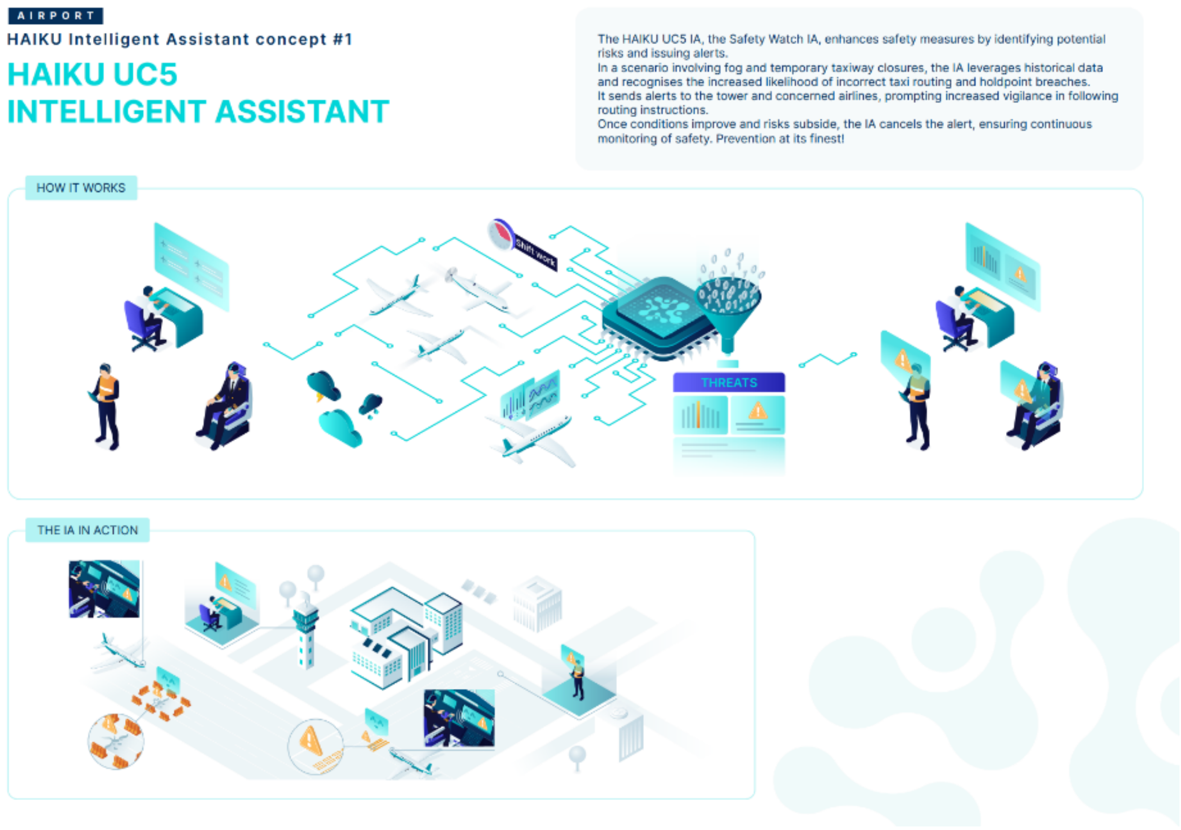

Figure 14: UC5 Intelligent Assistant Concept

5.2.2 UC#5 Operational Concept Description

The main aim of this Use Case is in transforming safety data into actionable and predictive safety intelligence for LLA safety staff, to inform safety of day-to-day operations.

LLA would expect the application of AI, informed by expert human users, to lead to better approaches to safety data collection, categorization, analysis and visualisation, so that they (and the entire Stack community) can better learn from it and team up with the AI for more accurate and fact-based decisions. LLA has over 150 stakeholders operating airside at London Luton Airport who also have vast amounts of data stored, much of which is reflected in LLA's data, so there would be clear benefits for those organisations. LLA is expecting outcomes that are at least TRL6 and are even likely to enter operational usage by the end of the project.

Additionally, such safety data are currently held within a system called OPSCOM, which is a tool used by more than sixty European airports to help them manage their data. In the longer term, there is therefore the chance to learn from a significantly larger data-set across Europe, and/or to export the airport safety watch concept, if

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successful, to other airports or to a multi-airport safety watch concept. The company that runs OPSCOM has already expressed interest in the HAIKU concept.

5.2.3 UC#5 UC#5 Performance Targets

KPA	Category	KPI
Safety Performance	MoP	Incident rate per quarter, for the following three types: Incorrect taxiway selection Holding Point bust Incorrect pushback
Safety Management	MoE/MoP	Concrete plans for incident rate reduction. Action Implementation Timescale
Safety Management	MoE/MoP	Changes to reporting practices to include new incident contributory factors
Stack Safety Collaboration	MoE	Engagement by the Stack on the insights from the tool, and collaborative efforts on risk reduction
Human-AI Teaming	MoE	Degree to which human and AI can collaborate to extract insights and warnings
Human-AI Teaming	MoP	Degree to which AI-produced warnings are heeded by operational partners in time to realise a risk reduction/mitigation.

Table 39: UC5 Performance Targets

5.2.4 UC#5 Requirements

HL-REQ-ID	UC5-HLR-01
Requirement	Sufficient data acquired from LLA & Airport Stack Partners to share with the technical partners (ENG/SUITE5)

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Rationale	For the airport safety watch concept to be viable, it needs sufficient quality data on all incident occurrences and situational data. In practice, this involves sharing data, at least of the last 7 years, such as pushback errors, selection of wrong taxiway and holdpoint busts, and additional data relating to the events as required.
KPA	Operational, Technical, Human performance, Safety. E.g. traffic movements, meteo, time of day, etc., Safety (near misses and incidents/accidents), Human Performance (errors, recoveries; time-on-shift; roster information (location in shift cycle); operational role (driver; flight crew, controller etc.)

Table 40: UC5-HLR-01

HL-REQ-ID	UC5-HLR-02
Requirement	Identification of new solutions for incidents: pushback errors, selection of wrong taxiway, holding point busts.
Rationale	Identifying new solutions or investigation of new avenues to decrease their occurrence rates of the incidents
KPA	Safety, Human performance, Operational

Table 41: UC5-HLR-02

HL-REQ-ID	UC5-HLR-03
Requirement	Deliverance of warnings of increased risk when certain conditions arise, such that incident avoidance actions can be taken in time by operational partners.
Rationale	This is the ambitious ideal endgame for the airport safety watch concept, the ability to analyse real-time operational data and give timely warnings when sufficient conditions are likely to align to give rise to one or more of the three incident types occurring.
KPA	Safety, Operational

Table 42: UC5-HLR-03

HL-REQ-ID	UC5-HLR-04
Requirement	Identification and implementation of changes to reporting processes to allow a richer

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	evidence database and more robust identification of weak signals that are contributing to the incident type occurrence.
Rationale	It may be that the full 'causal profile' for the incidents can be identified during the study, but the data collected since 2016 may not record all those details. If the reporting system is updated, this allows a new dataset to be generated, though it may take time to contain enough new data for AI / Data Science analysis purposes.
KPA	Safety, Human Performance, Operational, Technical

Table 43: UC5-HLR-04

5.2.5 UC#5 Key R&D Objectives

OBJ-ID	Validation Objective	Success Criteria ID	Success Criteria
UC5-OBJ-01	To assess the Operational Feasibility and Acceptability of the solution from the Airport perspective. An underlying R&D objective here is to see how, why and to what extent collaborative entities (companies) accept AI-derived safety intelligence.	UC1-CTR-01	A sufficient quorum of Stack members agree that the insight / solution has merit and are willing to explore its further exploration and/or implementation.
UC5-OBJ-02	To assess the ability of the system to 'see around the corner' and predict new events or when existing event types will have a higher likelihood of occurrence.	UC1-CTR-02	Stack partners take the intel seriously enough to increase monitoring during higher-risk periods and issue warnings to operational personnel, and/or consider operational mitigations during high-risk periods. Additionally, this results in lower incident rates.
UC5-OBJ-03	To assess the degree of new insight afforded by the AI support. The R&D objective relates directly to HAT, in that the AI may point out new ways of understanding the data,	UC1-CTR-03	The LLA Safety Team and related safety personnel in the Stack (e.g. airlines, NATS, Ground Handlers) agree the solution is novel or is framed in a new way not previously considered.

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	while the operational players interpret this and derive realistic solutions. The solution may therefore be truly dependent on Human AI Teaming, since neither party can fully solve the problem alone.		
UC5-OBJ-04	To see the degree to which the HAT interactions lead to new safety learning avenues, via changes to reporting and recording systems.	UC1-CTR-04	The interactions and analytic iterations on the 3 incident types lead to changes in reporting and recording systems, with a broader set of factors (e.g. on traffic parameters) or a higher granularity of factors (e.g. on human performance aspects).

Table 44: UC5 Key R&D Objectives

5.3 UC#5 First Validation Plan (VAL1)

5.3.1 UC#5 Approach – VAL1

Prior to validation there is verification of the AI data analytic process, as shown in the figure below. This is an iterative process in which the LTN Stack via LLA transmits data to the AI developers, who may then ask for more data or clarification of the datasets.

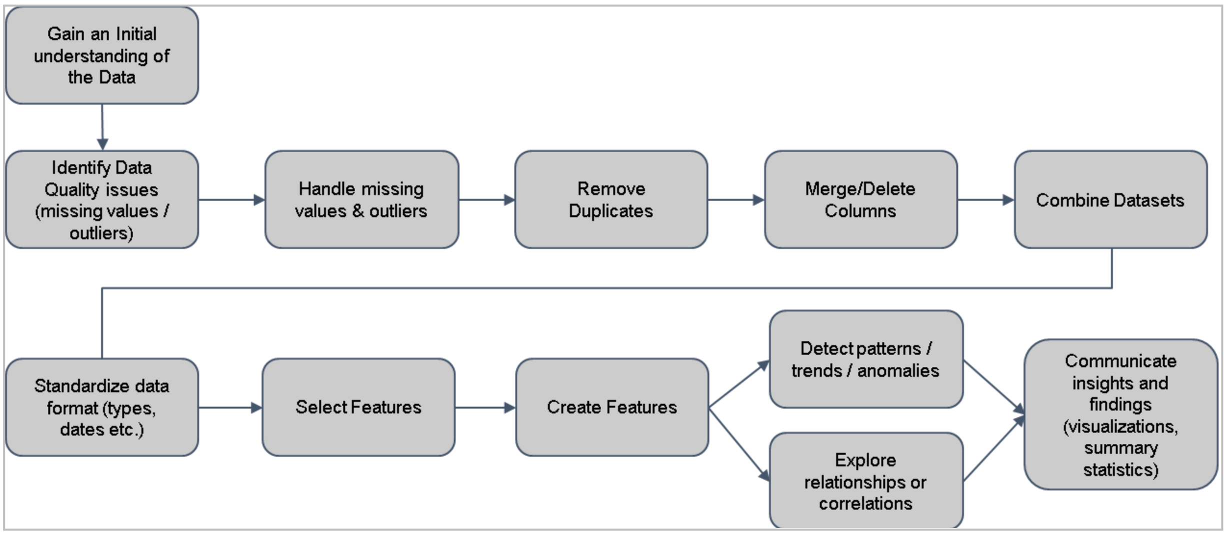

Figure 15: UC5 Airport Safety Watch Preliminary Data & verification Approach

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The first Validation then involves the AI development team presenting the results to the LTN Stack. However, this is not a ‘one-off’ process, and involves several iterations, the first of which occurred on 18th July 2023 at the 26th London Luton Airport Safety Stack Meeting, in Luton.

A set of detailed preliminary analyses were presented to the Stack Partners (e.g. see figure below), and a general Q&A discussion arose, in particular exploring what other factors might be involved, since the initial data science analysis had not derived any compelling correlations between factors from the data and incident occurrence.

Figure 16: UC5 Example screenshots of preliminary data science analysis of incident types and potential contributory factors

The discussions that arose in this very first Stack-AI interchange are summarised in the table below.

Issue	Discussion	Partners	Related Requirement and/or Validation Objective	Next Steps
Incorrect Taxi Selection	It was remarked that although LTN is not a highly complex airport with multiple runways etc., it does have a relatively high number of junctions, which can perhaps lead to	Airlines, ATC, LLA	UC5-HLR-01 UC5-HLR-02	TWR visit at next Stack Meeting to further explore factors

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	confusion or perception errors about where aircraft believe they are and where they should go next. In some larger international airports they operate a 'follow the green' system, though it is not clear that LTN could adopt such a system. In the future however, the airport will gain an ASMGCS (Airport Surface Movement Ground Control System) which gives a live-updated map of the airport surface and all aircraft (and some vehicles). This will also be augmented by CCTV particularly around 'hotspots' and to those areas that are difficult to see from the Tower.		UC5-OBJ-01 UC5-OBJ-03	underpinning incorrect taxiway selection.
Holding Point Bust	There was some discussion of hold point busts and practices at other airports. Many European airports these days have 'zones' which the aircraft crosses into and where it waits, rather than a line that the aircraft should not cross. Pilots more familiar with these zones or areas may inadvertently cross over a holding point, thinking they are supposed to enter a zone.	Airlines, ATC, LLA	UC5-HLR-01 UC5-HLR-02 UC5-OBJ-01 UC5-OBJ-03	Further exploration within airlines
Pushback Error	Stands 62 and 71 were highlighted by the data analysis presentation as being more prone to pushback error. Partners noted that Stand 62 has no sign, which might contribute to error rates (it is for business jets rather than commercial jets, and many business jet pilots are unfamiliar with LTN's layout etc.). Stand 71 is at the end (a cul-de-sac) and also might not be as well signposted as other stands. For pushback error, it was also noted that stands that occur on a bend can be tricky. In some airports the pilots no longer control the direction in which they are pushed back, and it is left to the ground handlers. One or two Stack partners could see the advantage of this, as the local staff are more familiar, and there can be misunderstanding	Airlines, ATC, LLA, Business Jets	UC5-HLR-01 UC5-HLR-02 UC5-OBJ-01 UC5-OBJ-03	Signage solutions for these two Stands to be developed. Further consideration by LTN Partners on 'tricky' stands.

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	when communicating with flight crew about what is left or right. The best form of instruction was also discussed, as to whether it should be ‘left’ or ‘right’, or a compass reference (e.g. East, South, etc.). One further suggestion was to pushback to a landmark, which could be a clearer and less confusable form of instruction.			
Other	Several Ground Handling Service (GHS) noted that they would also be interested in these types of Data Science analyses for their work sector at the airport.	GHS Partners, LLA	NA	Consider post-HAIKU.

Table 45: UC5 First Stack AI interchange

There will be two further validation 1 iterations, in November 2023 and February 2024.

5.3.2 UC#5 Exercise Description and Scope – VAL1

Exercise Description	Scope (What is being assessed)	Key R&D Objectives explored
Technical interchange at Stack and between Stack meetings to derive solutions and enhanced data requirements.	Value of insights, do they lead to practicable solutions, efficacy of solutions, and needs for changes to future reporting.	UC5-OBJ-01/02/04

Table 46: UC5 Exercise Description and Scope

5.3.3 UC#5 Planned Activities – VAL1

Thanks to the opportunity we have to discuss directly with an airport that works daily with the data we are analysing, it is possible to skip the procedure to think about a single validation at mid-point of the project and we decided to divide the validation in three phases. For this reason, we have already planned three iterations from now to the beginning of the next year, in which we can discuss the results obtained and plan next activities in a shared collaboration.

Activity	Activity Description	General Information
Interchange meetings	LTN Stack presentations and discussions	
Focused meetings on specific incident types	E.g. visit to TWR for discussion of incident contributions	

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Review of existing incident reporting schemes	Comparison against new contributor sets developed during the study	
VAL1 (first iteration)	A set of detailed preliminary analyses were presented to the Stack Partners, and a general Q&A discussion arose, in particular exploring what other factors might be involved, since the initial data science analysis had not derived any compelling correlations between factors from the data and incident occurrence.	18 July 2023 at the 26th London Luton Airport Safety Stack Meeting, in Luton
VAL1 (second iteration)		London LTN, Great Britain, November 2023
VAL1 (third iteration)		London LTN, Great Britain, February 2024

Table 47: UC5 Planned Activities

5.3.4 UC#5 Use Case Relationship and Collaborations

None at present.

5.4 UC#5 Future work and Second Validation (VAL2)

To be developed. If at the end of VAL1 there is sufficient Stack support and sufficient data, the predictive airport safety watch system will be developed and evaluated.

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6 Use Case #6 – Airport Spreading Virus Prevention

6.1 UC#6 Background

The global COVID-19 pandemic demands drastic action across the airport industry. Airports are even incurring additional operational expenses for extra cleaning and sanitization along with a touchless/frictionless travel. Due to all this, some airports/airport terminals have practically closed their commercial operations. However, many airports remain open for new operations to maintain continuity of the aviation market and business that is essential for many households, communities and to the aviation ecosystem of industries. The shops and common spaces of the airports get crowded, which can constitute a hotspot for the spreading of the virus. Public health services in every country have released guidelines and best practices for the persons that should be present in an indoor space and the distance between the persons. Towards the prevention of the virus spreading, routing of passengers may be considered in order to optimise the space available and the presence of the passengers.

6.2 UC#6 Context of the First Validation (VAL1)

6.2.1 UC#6 Key R&D Needs

Problem Statement – what is the problem to address with AI? Travel and passenger mobility present a considerable risk of COVID-19 infection to passengers, due to confined space and recirculating air (both in terminal and aircraft). The object of our platform is to provide real-time information about the indoor conditions facilitating the spread of contagious diseases such as COVID-19. Our tool will be a data-centric platform based on a wireless network of Internet of Things (IoT) sensors strategically installed in indoor environments to facilitate the monitoring and the prediction of the critical risk factors associated with the spread of COVID-19. IoT devices will be equipped with an ecosystem of sensors such as LiDAR to measure the distance between passengers and an assembly of humidity, CO_2, and tVOC (total Volatile Organic Compounds) sensors measuring indoor air quality. Dedicated AI/ML inference models will be used to forecast the arrival rates in the boarding points and the evolution of the air quality related measures, in real time. These arrival rate models will be used to model passenger flows and operations in the terminal in order to build risk-free “what if” scenarios of how infections can spread and what potential measures can be taken to better manage infection risk.

Essentially, the proposal is a mobile phone recommendation system, which will take the camera sensors as input to provide the occupancy and the number of passengers

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moving towards the airport common places. This system will substantially minimise the occupancy and queues in every common place, thus, preventing the places being overcrowded. The lidar sensor will obtain the distance between the passengers in the waiting areas and while moving. Thereafter, the air quality will be monitored to see whether intervention in the ventilation is essential.

Human Factors & Safety Risks – Potential risks and problems introduced by AI. Problems in data collection, leading to false alerts. Dynamic nature of information flow due to passenger mobile phone application, leading to real-time change in the occupied space. Passengers not following the routing recommendation of the system, leading to AI to be inconsistent.

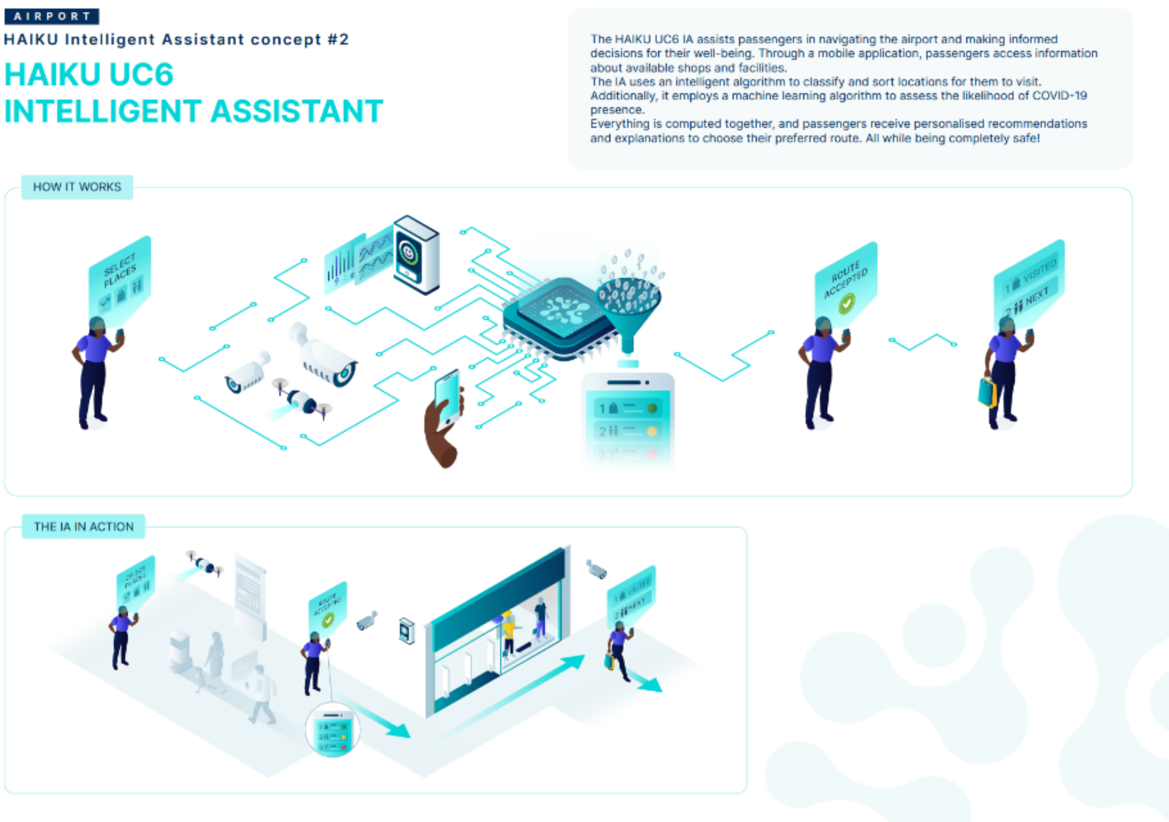

Figure 17: UC6 Intelligent Assistant Concept

6.2.2 UC#6 Operational Concept Description

The recommendation AI system will be an integrated IoT-based system which will feed near real-time data to the passengers regarding the best possible route inside the airport's common spaces. The sensors that are going to be used are cameras monitoring occupancy and real-time counting of passengers, as well as lidar to measure the distance and air quality sensors to monitor the air in the indoor environment. The recommendation system will obtain the infection probability (high/low) as a categorical variable that will be the source of the ML model that will run

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on the cloud. Thereafter with the POST method the recommendation will be fed to the passenger's mobile phone with the appropriate routing that will be set using a weighting factor comprising the occupancy, difference in queues and people moving towards each common space. Note that the preferences of the passenger will be set by the mobile phone application and will be stored in the respective database field, which will be populated according to time constraint to a different field (e.g. 2 minutes).

The system will ensure bi-directionality since the recommendation part of the system will essentially resemble a chat application with the AI bot being one person the passenger being the second. Different stages of explainability will be introduced in this manner, depending on the time constraints identified. The system will have a conversation with the passenger in different time frames. Focusing on the AI responses, the system will recognise keywords to respond accordingly to the potential clarification needed by the passenger.

Moreover, the system will comprise the use of a statistical tool for airport health and safety operators where the trends of the passenger recommendation and routing will be reported, forecasted and explained. This will be a post-operation procedure, which will give valuable information to the airport staff.

Finally, the air quality of the indoor spaces will be monitored, such as tVOC, CO2, temperature and humidity, in order to correlate them with the ventilation and assess the current settings. With this at hand, the aim is to intervene in the Heating Ventilation and Air Conditioning system (HVAC) where applicable if the air quality is poor and infections are reported in the airport.

6.2.3 UC#6 Performance Targets

In UC6 the primary KPAs are the quality of recommendation, the infection suggestion output, the routing output and the air quality output. The KPIs include but are not restricted to the routing outcome, monitoring of passengers, the distance between them, the queue of each common place, the air quality forecasting index. Following this, the respective metrics that are identified are, sequence of places to visit, the passengers' occupancy, number of persons moving towards each common space, the metres per person, the number of persons in the queue, the poor/good air quality.

KPA	Category	KPI
Optimal routing	MoE	Effective calculation of Capacity to be fed to IA
Obtaining perfect information about occupancy	MoP	Persons counting in/out
Obtaining air quality information	MoE	Air quality metrics
First response available promptly to Passenger	MoP	Speed of IA calculation

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Occupancy to be populated every two minutes	Constraint	Counting of persons
Passenger phone should immediately send preferences to populate database	Constraint	Connection to server, injection of data
IA bidirectional communication and learning	MoE	Chatting with IA evaluation
Classification of air quality should be available promptly to Health and Safety Officer	MoP	Speed of forecasting model
Effective calculation of Capacity to be fed to IA	MoE	Persons per time

Table 48: UC6 Performance Targets

6.2.4UC#6 Requirements

HL-REQ-ID	UC6-HLR-01
Requirement	The IA needs to provide optimal routing of passenger
Rationale	This will make sure that the IA will send the perfect information to the Passenger based on the input data
KPA	Optimal routing, IA performance

Table 49: UC6-HLR-01

HL-REQ-ID	UC6-HLR-02
Requirement	The IA and passenger needs to obtain perfect information regarding the occupancy in common places
Rationale	This has to do with the overall performance of the system. The Passenger needs to be informed about the occupancy obtained by the sensors. Similarly, with the IA
KPA	Obtaining perfect information about occupancy, System performance

Table 50: UC6-HLR-02

HL-REQ-ID	UC6-HLR-03
Requirement	The IA needs to obtain air quality measures to be available for the correlation and classification

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Rationale	This ensures the communication between the IA and the air quality prototypes and the perfect information that the IA needs to obtain
KPA	Obtaining air quality information, System Performance

Table 51: UC6-HLR-03

HL-REQ-ID	UC6-HLR-04
Requirement	The first response should be available within 30 seconds of the evaluation process
Rationale	The passenger needs to be engaged in the HAIT process as soon as possible by the IA
KPA	First response available promptly to Passenger, System Performance

Table 52: UC6-HLR-04

HL-REQ-ID	UC6-HLR-05
Requirement	The occupancy of the common places should be populated every 2 minutes in the database
Rationale	This constraint need to be satisfied in order to get near real time information which makes sense with the time the Passenger needs to move to certain common places of the airport
KPA	Occupancy to be populated every two minutes, sensor and system constraint

Table 53: UC6-HLR-05

HL-REQ-ID	UC6-HLR-06
Requirement	The passenger phone should immediately send the preferences to populate the database
Rationale	This ensures that the information set to the phone of each Passenger, in the form of preferences, gets immediately to the database via the web service.
KPA	Passenger phone should immediately send preferences to populate database, Constraint to be satisfied

Table 54: UC6-HLR-06

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HL-REQ-ID	UC6-HLR-07
Requirement	The IA needs to communicate bi-directionally and learn from the passenger responses
Rationale	This is the heart of the IA which will provide real time explanation to the passenger.
KPA	IA bi-directional communication and learning, System effectiveness

Table 55: UC6-HLR-07

HL-REQ-ID	UC6-HLR-08
Requirement	The classification of the air quality should be correlated and be available to the Health and Safety operators in less than 5 minutes
Rationale	Information is essential to the operator to correlate the microclimate with the occupancy of common places.
KPA	Classification of air quality should be available promptly to Health and Safety Officer, System Performance

Table 56: UC6-HLR-08

HL-REQ-ID	UC6-HLR-09
Requirement	The capacity of the common places of the airport need to be effectively calculated to be fed to the IA
Rationale	People do not like to get overcrowded not only for COVID but for waiting purposes as well.
KPA	Effective calculation of Capacity to be fed to IA

Table 57: UC6-HLR-09

6.2.5 UC#6 Key R&D Objectives

OBJ-ID	Validation Objective	Success Criteria ID	Success Criteria
UC6-OBJ-01	To assess the acceptability and operational efficiency of the recommendation by the user using their mobile phones.	UC1-CTR-01	The recommendation is considered to be operationally efficient and acceptable in terms of the routing recommendation.

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UC6-OBJ-02	To check the interconnection between sensors, application and other subsystems as an integrated one.	UC1-CTR-02	The establishment of coherent and punctual operation and cooperation of all subsystems.
UC6-OBJ-03	The operational efficiency of the health and safety system which will be operated by the health and safety staff.	UC1-CTR-03	Acceptance of the solution and verification of applicability of the outcome to the requirement.
UC6-OBJ-04	Black box and white box testing of all subsystems comprising the complete system.	UC6-CTR-04	Verification and testing success.

Table 58: UC6 Key R&D Objectives

6.3 UC#6 First Validation Plan (VAL1)

6.3.1 UC#6 Approach – VAL1

The validation exercise will have to assess the different subsystems that comprise the full system. Essentially, the KPAs and KPIs will be evaluated for the operability of the subsystems and the service they offer to the passengers and health and safety officers. The first validation will consist of the interoperability of the components of the system and elaborate on the integration at the first level with a small number of passengers. As for the AI engine the exercises that will be performed will consist of the response evaluation based on the user input and the explainability coming from the bi-directional communication.

To answer the question "did we build the right thing", the chat-like application that will provide the recommendations coming from the IA to the passenger and the bi-directional communications provides exactly that. The Passenger will populate the knowledge base where the IA was inaccurate and the IA will learn from the Passenger as well. In the opposite direction, the IA will provide the necessary information coming from other passengers and from the sensors to the Passenger, in order to convince her regarding the optimality of the recommendation. Certainly, the two agents will team-up to get the optimal routing. An example is the following: If the Passenger wants to go to the toilet, she will not go for a coffee first, due to physical need, so there will be communication with the IA to get her to a toilet first and then recommend visiting other common places in the airport.

In terms of if we are building the right thing or if we have the right design, for the former, the right specification can actually answer in conjunction to the operational requirements identified. For the latter the right design in any system is crucial and this leads to the correct implementation of the system. There are methodologies in the

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literature that allow a detailed design. Of course, amendments usually take place during the system implementation.

6.3.2 UC#6 Exercise Description and Scope – VAL1

The validation exercise will commence with the input of preferences by a small number of users using their mobile phone application. Thereafter, the AI intelligent assistant will output the appropriate messages and explanations to the recommendation page of the application, in the respective time constraints. This constitutes the primary requirement of the UC since the routing of the passengers will take place using this validation exercise. The primary objective is the optimal selection of common places based on the weighting factor of each place. This will be the primary exercise. Smaller exercises will be done for the evaluation of the subsystems, such as the sensor output, the database storage as well as the health and safety portal with the respective IA. Finally the statistics coming from the database will be evaluated.

Exercise Description	Scope (What is being assessed)	Key R&D Objectives explored
Occupancy Measurement	Person counting	Object detection together with tracker for videos obtained with cameras
Web service connection	Information obtained from phones to database	Kotlin to php and postgresql connection
ML model accuracy	Initial Random Forest classifier of infection index	Accuracy, error of classification
Chat-like application and explainability	Bot communication with Passenger	Knowledge base population, string similarity, explainability based on information obtained
Air quality sensor accurate readings	Collection of data and transmission to server and database	Hardware and software implementation
Air quality classification and human engagement	Classification and human engagement	Human engagement
Queuing of persons counting	Distance and queue from prototype	Tracker and lidar operations

Table 59: UC6 Exercise Description and Scope

6.3.3 UC#6 Exercise Scenario(s) – VAL1

The primary scenario is the collection of a small number of users who will use the routing recommendation system. Essentially, each user will place her preferences on the initial screen of the mobile phone application, and then s/he will have to move to

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the second screen to check his/her preferences, with an initial explanation that the preferences are being processed to avoid getting common places overcrowded due to COVID-19 infection. This will be done to further enhance situational awareness. Thereafter, the user will move to the recommendation screen of the application and will anticipate and finally obtain the recommendation. The user will have to accept or decline the recommendation and again the necessary explanation will be given in order to convince the user about the recommendation to be followed. When the user visits one of the places from the routing recommendation will confirm the visit and a re-calculation will take place. Queuing and distance will be evaluated as well. This scenario will comprise the validation of operation of all the subsystems as described in the exercise description and scope.

In terms of health and safety and air quality portals, the database will provide the statistics and a system whereby the operator will be able to check the forecast and intervene. The ML model will also provide the air quality's forecast validity.

1.2.1.5 UC#6 Reference Scenario(s) – VAL1

The reference scenario for the routing system will comprise the manual injection of data to the database which will mimic the user, and the responses from the user to the system recommendation to check bidirectional communication.

For health and safety, the statistics will be provided using artificial data. For the air quality again artificial data will be provided whereby the output will be a priori known.

6.3.4 UC#6 Platform / Tools & Technique – VAL1

The validation tools are a mobile phone application, a portal and a ML model UI. The equipment used are commercial cameras, a wireless camera prototype, air quality sensors, a lidar sensor and the respective programming languages, such as python, Kotlin, PHP and others that may emerge.

The technique of the validation in terms of the wireless camera prototype, comprises the comparison of different trackers, i.e DeepSort, to distinguish the different IDs of different persons within the view of the camera. Some first results showed that the trackers change by the frame and, hence they are not efficient for the tracking of persons. A different approach has been used whereby two boundary lines have been established at the left and right hand side of the camera view respectively. When the person is within the boundaries is assigned a unique ID, which is removed when the x1 of the rounding box of the detection passed one of the boundaries, with respect to the direction. In this way and by using a queuing method, since the person IDs increment according to their appearance to the camera, we can count the person only once. Queuing is managed and when it comes to distance a lida is tested to get it from the pcap file of the measurement. Note that we have identified different behaviour of the software when investigating mp4 videos and when using the web camera with live feed.

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In terms of the application we fed data to the web service via the android application and saw that the injection is successful. For the chat-like application, we need to perform some injection to the SQLLite database and string similarity to recognize similar questions by the user, or similar statements in general.

In terms of the infection classification and routing, we selected the random forest with artificial data we constructed and we aim to test the weighting factor to route the persons to the less crowded places.

For the air quality statistics and classification, different classifiers will be constructed and a human engagementHITLHITL interface will be available to the operators, in order to be able to intervene when they see faults or data that are not annotated correctly. Note that the correlation of the air quality with the trends of the occupancy will also be available.

6.3.5 UC#6 Data Collection and Analysis Methods – VAL1

The data collection will be primarily done using a PostgreSQL database whereby the necessary tables and fields will be created in order to articulate on the methods used. In particular, the routing table has fields that determine the people coming towards each common place taken from the preferences, the occupancy of each common place coming from the camera sensors as well as the queues and the respective distance. The majority of the fields are quantitative with the injection index being qualitative. For the statistics table the lot of the values will be utilised. In terms of the air quality data, the best option is to store the data to a table whereby the forecast will be done using the appropriate tool implementation. The statistics and forecast tables will include qualitative fields as well that will present whether an event is present (e.g. high infection probability).

The analysis method for the routing application will be the assessment of the weighting factor as well as the different bidirectional communication strings that will be used and recognised by the system. The weighting factor is a method coming from stochastic network optimisation and it has been successfully used in wireless networking research. The only concern we have regarding the usability of the approach is the fact that the queues are First-In First-Out (FIFO) and not Last-In First-Out (LIFO), which is the optimal.

Notably, for the lidar, the distance will be obtained by assessing the pcap file of the measurement together with the json file of the configuration.

For the health and safety portal, standard statistical analysis will be provided. For the air quality. different classifiers will be used to get the best accuracy. Statistical correlation between the person occupancy and the trends of person movement will be given to the operator, who will be able to ask questions or intervene regarding the importance.

In terms of explainability, a Shapley values method is underway which is mapped to a potential game approach, which when proven almost converges to a Nash equilibrium. If we are able to show that then the Shapley values will be shown with a single

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function, the potential function. The price of the stability of the optimisation will be shown to be 1, meaning that we may accomplish the social optimum. In terms of the SHAP method, investigation is done using an implementation in order to distinguish the Shapley values computed and how we can apply our approach.

6.3.6 UC#6 Planned Activities – VAL1

Activity	Activity Description	General Information
1. Prototype testing	Testing of the wireless camera prototype	Testing of the tracker built and the person counting
2. Networking testing	Testing of the API calls of the cameras and the air quality sensor	Testing the effective operation of the devices
3. Infection ML classifier	Testing the classifier used for the infection index	Simulation with artificial data obtained by using more reliable tools
4. Multiple sources of database insertion	Insert data to the database mimicking multiple passengers	Simulation with real tools
5. Air quality classifier and statistical tool	Testing the classifier selected for the air quality forecasting and HITL	Simulation using artificial data.
6. Chat-like bot and passenger communication	Testing the application and the explainability of the application with respect to routing recommendation	Using artificial data and with small number of users
7. Weighting factor evaluation	Testing the weighting factor to recommend optimal routing	Simulation at first and small scale demo at a later stage
8. Queuing and distance measurement	Testing the distance and the queue of people to feed the weighting factor	Demo produced with prototype and lidar
Subsystem validation (VAL1)	Activity 1, 2, 3, 5, 7, white and black box and unit testing	Q3 2023
Overall initial validation (VAL1)	Activity 1 – 8, with injected traffic	Q4 2023 – Q1 2024
Extended validation (VAL1)	Activity 1 – 8,with real traffic	Q2 2024 – Q3 2024

Table 60: UC6 Planned Activities

6.3.7 UC#6 Use Case Relationship and Collaborations

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This Use Case can only be combined with safety in airports; hence it is mostly standalone within the HAIKU project. However, we can attempt to combine it with the existing application of Luton Airport in terms of enhancing safety.

6.4 UC#6 Future work and Second Validation (VAL2)

6.4.1 UC#6 Expected R&D work

The first validation will show the effectiveness of the system and prove its concept. The second validation will be done with more users stressing the system and providing evidence that it can perform. More data will be available as well for the ML model and the classifiers that will be used.

6.4.2 UC#6 Validation Approach for the Second Validation

Installation of the system sensors to Egnatia aviation with a larger number of users being available and playing with the system. The second validation will have a higher TRL than the VAL1 (2,3 TRL) and the target will be a TRL of 5,6, which means that a product based evaluation will be undertaken, in order to make it available for purchase and not just testing.

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References

[1] M. Kendra Cherry, "VeryWellMind," 2023. [Online]. Available: https://www.verywellmind.com/what-is-biofeedback-2794875.

[2] Bayazitoglu, A. A., & Güngör, H. Effects of Meteorology Data on Crew Resource Management in Aviation. Journal of Aviation, 7(2), 300-309" 2023.

[3] M. Bratman, "Intentions, plans, and practical reason", 1987.

[4] T. &. Murphy, "Comparison of air traffic management-related operational performance: US/Europe", 2019.

[5] Eurocontrol. (2013). Delays to Air Transport in Europe – Annual 2013.

[6] Schultz, M., Lorenz, S., Schmitz, R., & Delgado, L. (2018). Weather Impact on Airport Performance. Aerospace, 5(4), 109.

[7] Lui, G. N., Hon, K. K., & Liem, R. P. (2022). Weather impact quantification on airport arrival on-time performance through a Bayesian statistics modelling approach. Transportation Research Part C: Emerging Technologies, 143, 103811.

[8] EASA, 2021. URL: https://www.easa.europa.eu/en/what-is-uam

[9] EASA, "Guidance material on the implementation of the remote tower concept for single mode of operation", 2015

[10] E. e. a. SESAR JU, "CORUS-XUAM," 2022. Project URL: https://corus-xuam.eu/.

[11] Kirwan, B., Ogica et al., "Future Sky Safety," EU Project, 2019 & 2020. Project URL: https://www.futuresky-safety.eu/

[11] SHAPLEY, Lloyd S., et al. A value for n-person games. 1953.

[12] J. F. Nash Jr, "The bargaining problem. Econometrica: Journal of the econometric society," 1950.

[13] Monderer, Dov; Shapley, Lloyd S. Potential games. Games and economic behavior, 1996, 14.1: 124-143.

[14] Lundberg, Scott M.; Lee, Su-In. A unified approach to interpreting model predictions. Advances in neural information processing systems, 2017, 30, 2017.

[15] Lui, Go Nam; Hon, Kai Kwong; Liem, Rhea P. Weather impact quantification on airport arrival on-time performance through a Bayesian statistics modeling

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

approach. Transportation Research Part C: Emerging Technologies, 2022, 143: 103811.

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