User-Centered Design of an Intelligent Pilot Advisory System for Non-Emergency Scenarios: A Case Study

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Affidavit

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Abstract

Artificial Intelligence (AI) is being used in an increasing number of fields, so including it aviation as well only comes natural. Therefore, the Intelligent Pilot Advisory System (IPAS) is being developed as a research platform. and is supposed to assist pilots in their decision making. Previously, the research was focused on the IPAS's application in emergency scenarios. In this thesis, the IPAS is extended for use in non-emergency scenarios to support pilots in normal operation. Hereby, this research explores what functions the system could offer to pilots that are useful to them, pilots' willingness to use such a system in non-emergency situations, and how to design this system for optimal usability, focusing on explainability and trustworthiness. To design a suitable system, a workshop was held with experts to brainstorm possible functionalities. Hereby, the idea for a Mission Monitoring and Advisory Function (MMAF) was developed. The MMAF encompasses the IPAS to continuously monitor the conditions along the flight route, as well as at the destination airport and to provide updates, strategic insights, and recommendations to the pilots. Additionally, the IPAS is supposed to identify suitable alternate airports in the area. To develop a User-Interface (UI) for such a system, current guideline from research and industry were considered and an iterative user-centered design process was utilized. Lastly, the system was tested in a mixed-methods, between-subjects study with 18 pilots in an Airbus 320 cockpit simulator to evaluate its usability and the impact of explanatory details on user's trust. The results showed that the pilots were willing to use such a system and that the developed interface has a good usability with a System Usability Scale (SUS) score of 75.49 and a Post-Study System Usability Questionnaire (PSSUQ) score of 2.52. Regarding the perceived trustworthiness of the system, there was no significant difference between both groups, except in the perceived sufficiency of information provided to establish adequate trust. Here, in the second session, the group with more explanatory details rated that they perceived their information to be more sufficient to trust the system adequately. Furthermore, the results highlighted areas for improvement in the interface and showed other possible functionalities to consider in the future.

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Abbreviations

AI Artificial Intelligence.

AICIS AI Crew Interaction System.

AICOM AI Core Module.

ATC Air Traffic Control.

ATPL Airline Transport Pilot License.

CPL Commercial Pilot License.

CPT Captain.

CWC Cross Wind Component.

DLR German Aerospace Center.

DST Decision Support Tools.

EASA European Union Aviation Safety Agency.

FAA Federal Aviation Administration.

FO First Officer.

HAI Human-AI Interaction.

HAT Human-AI Teaming.

HCD Human-Centered Design.

HCT Human-Computer Trust.

IA Information Architecture.

ICAO International Civil Aviation Organisation.

ILS Instrument Landing System.

IPAS Intelligent Pilot Advisory System.

MMAF Mission Monitoring and Advisory Function.

MPL Multi-Crew Pilot License.

NOTAM Notice to Air Missions.

PSSUQ Post-Study System Usability Questionnaire.

SATI SHAPE ATM Trust Index.

SD Standard Deviation.

SFO Senior First Officer.

SUS	System Usability Scale.
UCD	User-Centered Design.
UI	User-Interface.
UX	User-Experience.

1 Introduction

Artificial Intelligence (AI) is being adopted across various sectors for a multitude of applications. These include Decision Support Tools (DST), which are currently being developed and researched e.g. for the clinical sector (Sutton et al., 2020; Vasey et al., 2022). Given the promising potential of these systems, it is reasonable to pursue the development of similar systems in the field of aviation. Therefore, the integration of this technology into the cockpit of aircraft lays at hand. To date, the potential applications of such technologies in aviation are still under discussion, as is the nature of the resulting collaboration between humans and AI. Safety-critical domains such as aviation present unique challenges for both AI in general and Human-AI Teaming (HAT) in particular. These challenges are due to AI, especially deep learning, often acting as a black box, as the reason for decisions and the resulting recommendations are difficult to trace and understand (Rai, 2020). Accordingly, this collaboration raises important questions regarding the trustworthiness and explainability of AI systems, as highlighted by EASA (2020).

For these reasons the German Aerospace Center (DLR) is developing an Intelligent Pilot Advisory System (IPAS) as a research platform to investigate the use of AI in the cockpit, including the human-factor involved (Würfel et al., 2023). So far, especially the use of the IPAS in emergency situations has been researched, with a focus on supporting the FORDEC decision making process for finding suitable alternate airports (Djartov & Würfel, in press). FORDEC is an aviation decision-making model created in the 1990s to structure and rationalize complex decision processes using six phases: Facts, Options, Risks and Benefits, Decision, Execution and Check (SKYbrary, 2024b).

But the potential AI offers applies to non-emergency scenarios as well. Firstly, as Ternus et al. (2024) argue, advancements in AI and the growing availability of aviation data have made it feasible to significantly enhance pilot assistance systems. This data, when integrated into systems like the IPAS, could potentially enhance pilots' situation awareness and decision-making processes. AI algorithms, capable of real-time data analysis and interpretation, could provide pilots with a comprehensive analysis of the current situation and best courses of action, thereby improving flight safety and efficiency.

Secondly, the commercial advantages of implementing the IPAS in normal operations are noteworthy. Limiting the use of the IPAS to only emergency scenarios which are rare may not justify the monetary investment and integrating the IPAS into everyday operations could prove to be more worthwhile for airlines. Furthermore, the IPAS may enhance efficiency and therefore potentially bring noticeable cost reductions for airlines, e.g. through lowered fuel usage, or fewer delays. (Ternus et al., 2024)

Lastly, pilots may lack practical experience using the system, which could influence their trust in the IPAS. Regular use of the IPAS is likely essential for pilots to build familiarity and accurately evaluate its recommendations. Without experience automation bias could occur, discussed by Lee and See (2004), which refers to the tendency to either over-rely on or distrust automation. By regularly using the IPAS in non-emergency scenarios, pilots could better calibrate their trust in the system based on its actual capabilities, thereby counteracting automation bias. (Ternus et al., 2024)

Therefore, in this thesis, the implementation of an ‘Intelligent Pilot Advisory System for Non-Emergency Situations’ is explored. Thereby, the objective of this thesis is to address multiple key questions. Firstly, what functions such a system might offer that are useful to pilots and secondly, if pilots are willing to use such a system for non-emergency situations. Moreover, it is explored how to design such a system for optimal usability. Since explainability and trustworthiness play a big role in Human-AI Interaction (HAI) it is analysed how explainability could be established via User-Interfaces (UIs) and to what extent those explanatory details contribute to the system’s trustworthiness.

To achieve this, first, the current status of the IPAS is presented and foundations for developing such a system are laid out in section 2. Then, a workshop with domain experts was conducted to identify user needs and brainstorm possible functionalities, as described in section 3. Following this, a prototype was developed in an User-Centered Design (UCD) process, as described in section 4. Lastly, in section 5, the final evaluation of this prototype is presented, as well as the resulting design recommendations for the further development of the IPAS for non-emergency scenarios in section 6.

2 Foundations

2.1 Intelligent Pilot Advisory System

As already stated, at present, the DLR develops the IPAS as a research platform for the exploration and demonstration of AI-based assistance systems in the flight deck of commercial aircraft (Würfel et al., 2023). It was first introduced by Würfel et al. (2023) and its development is divided into two research areas: The development and research of the AI Crew Interaction System (AICIS) and the AI Core Module (AICOM). Figure 1 illustrates the system concept, including its components and their respective tasks, as well as the flow of information.

Hereby, the IPAS Data Collector is responsible for collecting data from the aircraft and the surrounding environment. This data is then analysed by the AICOM. The AICIS serves as the interface between the crew and the AI system, for example by processing input from the crew and displaying options and recommendations generated by the A system. (Würfel et al., 2023)

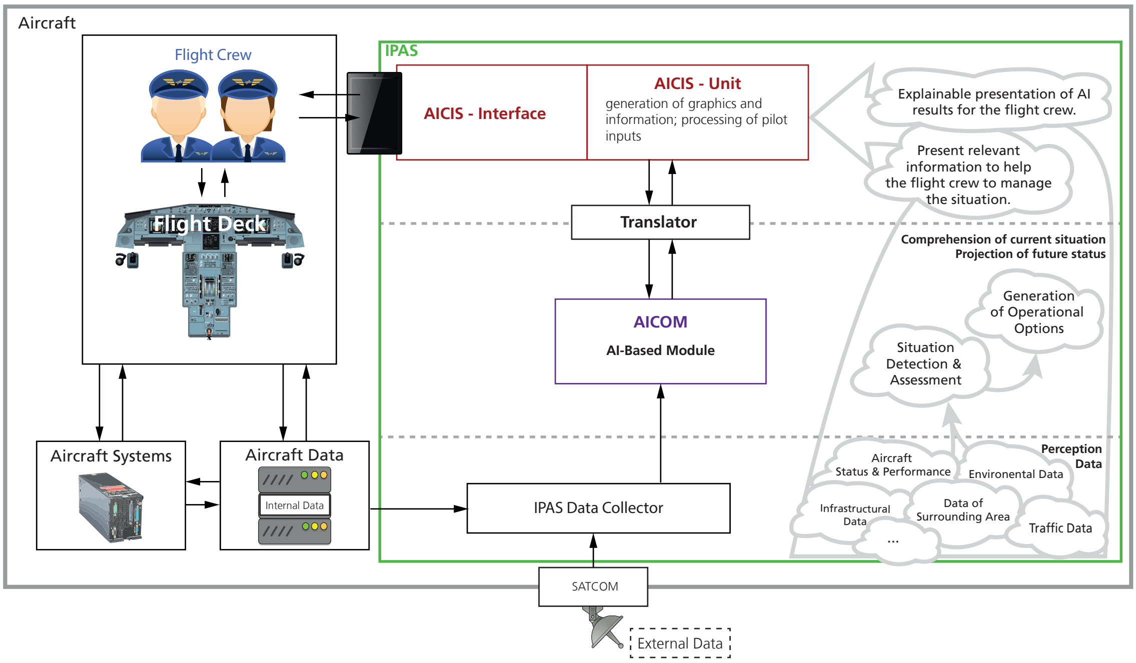

Figure 1: The Conceptual System Model of the IPAS. Source: (Würfel et al., 2023).

Thereby, the system concept and AICIS are developed according to an iterative development model called "Human System Exploration" by Flemisch et al. (2022) to explore, test and extend new ideas, user requirements and system designs in each iteration which Würfel and Flemisch (2024) elaborate on. Accordingly, the development of the IPAS began with an exploratory design process that involved conducting semi-structured interviews with seven active airline pilots as described by Würfel et al. (2023). Hereby, these pilots provided insights into the current limitations of cockpit systems and their needs for additional support. The interviews focused on identifying gaps in existing support systems and discussing potential functionalities for an AI-based decision support system (Würfel et al., 2023). The pilots highlighted several problem areas and applications where additional support is needed. A significant issue identified was the lack of projection support for strategic flight planning, with pilots expressing the need for better forecasting of weather and traffic conditions along the flight route (Würfel et al., 2023). Another major concern was the need for a system that could interpret technical errors and assess their operational impact, as the current systems provide information that is often too complex or time-consuming to interpret during critical situations (Würfel et al., 2023). The pilots also shared their general concerns and ideas about AI-based decision support. Key requirements included the need for system transparency, where pilots must understand the criteria used by the AI to evaluate options and the timeliness of the data. Additionally, there was a strong emphasis on the need for regular training and familiarization with the new system to ensure high levels of acceptance and usability (Würfel et al., 2023).

To date, the focus for the development of the IPAS has been on supporting the search and evaluation of alternate airports in emergencies (Würfel et al., 2024). For this use-case several prototype versions have already been developed and tested with commercial pilots in flight simulator studies, as described by Würfel et al. (2024). In the study described by Würfel et al. (2024) the pilots were confronted with a series of emergency situations, handling in-flight technical problems, and resolving these using the IPAS to decide on suitable alternate airport options (Würfel et al., 2024). The current prototype of the IPAS evaluates multiple criteria, including weather conditions, wind, runway specifications, and assistance systems to suggest the optimal options. Hereby, each option is assigned a calculated IPAS rating and the IPAS offers not only the recommendations but also presents all necessary information to pilots, allowing them to understand and potentially validate the system's decisions (Djartov & Würfel, in press). More specifically, in the current version of the IPAS, the system recognizes technical malfunctions and firstly displays the according impact of this situation on the mission and the resulting requirements for the alternate airports (Djartov & Würfel, in press). Then, the pilots get directed to the 'Airport List' page. Here, the airports are rated according to the calculated requirements (Djartov

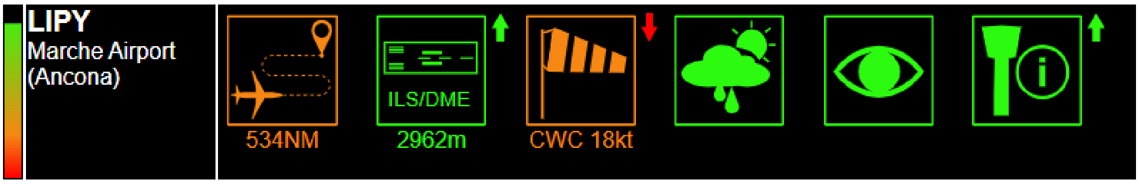

Figure 2: Airport Rating with Factor Groups. Source: (Djartov & Würfel, in press)

& Würfel, in press). The rating is displayed through a general IPAS rating and six so called factor groups (distance, runway, wind, weather, visibility, and airport operations) which were first explored by Riedesel (2023). Those factor groups summarize the specific factors that are relevant to decide on an alternate airport through colored icons, indicating the status of the airport, as can be seen in figure 2. If the pilots wish to be informed about the specific factors that contributed to the IPAS rating and that make up the factor groups, they can click on the respective airport for the 'Airport Detail' view. In this view, they see all factors listed, with their values and the rating marked through their coloring (Djartov & Würfel, in press).

2.2 Usability and User-Centered Design

Human-Centered Design (HCD), also known as UCD, as per DIN EN ISO 9241-210 (2019), refers to a methodology in system design and development aimed at improving the usability of interactive systems by focusing on their use and incorporating knowledge and techniques from ergonomics and usability studies. Abras et al. (2004) further summarize UCD as a design process in which end-users influence how a design takes shape. Hereby, the primary goal is to enhance the usability of interactive systems (DIN EN ISO 9241-210, 2019, p. 9). Usability, as defined in DIN EN ISO 9241-11 (2018, p. 9) refers to how well a system, product, or service can be used by certain users in a specific context to achieve particular goals effectively, efficiently, and to their satisfaction. Effectivity, hereby, refers to the accuracy and completeness with which users achieve specific goals and efficiency to the resources used in relation to the results achieved, oftentimes time, cost or human effort (DIN EN ISO 9241-11, 2018, p. 11). Furthermore, Nielsen (1994, p 26) emphasizes that usability is not a one-dimensional property, but consists of many components. He additionally names aspects such as learnability, memorability, and errors. Learnability means that the system should be learned quickly, memorability that the operation should be easy to remember, so that one can quickly get back into it even after a longer period of non-use, and errors refer to the fact that the system should have a low error rate and users

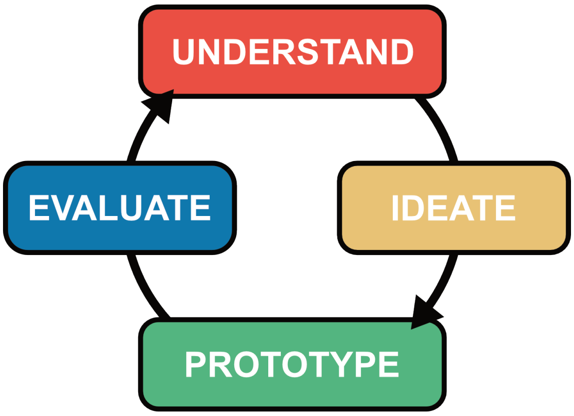

Figure 3: Typical UX Design Process. Source: Own representation based on Steimle and Wallach (2022) and Hartson and Pyla (2018)

can easily recover from errors.

Despite the diversity of User-Experience (UX) design processes presented in literature, such as the concepts of Steimle and Wallach (2022), Norman (1990) and Hartson and Pyla (2018), they share fundamental similarities in their sequence. These processes typically begin with a phase focused on understanding user needs. Following this, ideas and design concepts are developed, prototypes are created, and lastly user testing and evaluations are carried out which is repeated, as depicted in figure 3.

Implementing human-centered design and usability principles in systems can yield various benefits, such as improved productivity, enhanced user well-being, stress reduction, increased accessibility, and reduced risk of harm (DIN EN ISO 9241-210, 2019, p. 9).

2.3 Artificial Intelligence in Aviation

As the integration of AI is a relevant topic in aviation, regulations and standards are currently being developed. Here, AI not only transforms products and services but also introduces new business models, affecting certification, rulemaking, organization approvals, and standardization processes (EASA, 2023). EASA (2020, 2023) has therefore already published two roadmaps that target the integration of AI in aviation and recommend the concept of a HCD approach. The guidelines elaborate on characterizing and classifying AI applications based on their interaction with human operators and level of autonomy. Hereby, EASA (2020, 2023) categorizes AI applications in aviation into three general levels.

Level 1 AI is called ‘Assistance to Human’ and is subdivided into two categories: Level

1A and Level 1B. Hereby, Level 1A is called ‘Human Augmentation’ and describes Artificial Intelligence that is supporting human operators by enhancing their capabilities through automation support to information acquisition and analysis. This augmentation is about extending human sensory and cognitive abilities, aiding in data handling and interpretation without making decisions. Level 1B or ‘Human Cognitive Assistance’, steps further into aiding decision-making processes. Here, the AI assists in cognitive tasks, suggesting potential decisions that a human operator then can validate and implement. (EASA, 2023)

The next higher level, level 2 AI is defined as ‘HAT’ and further categorized into level 2A ‘Human-AI Cooperation’ and level 2B ‘ Human-AI Collaboration’. Here the interaction between AI systems and human operators is in focus. The AI can autonomously make decisions and implement actions. However, these functions are closely monitored by humans. Accordingly. operators retain the authority to intervene and override the AI’s actions, ensuring that the system remains under human control. (EASA, 2023)

Level 3 AI is called ‘Advanced Automation’ and categorized into Level 3A and Level 3B. Level 3A represents systems where AI performs decision-making and actions that humans can override. This level allows AI considerable operational autonomy while still providing humans with the ability to intervene if necessary. Level 3B represents fully autonomous AI and describes systems that operate independently, making decisions and taking actions without human override capabilities. (EASA, 2023)

Furthermore, there are multiple other papers on classifying applications into levels of AI, that make similar, more detailed categorizations like those of Anderson et al. (2018), Save et al. (2012) and Save (2014).

2.4 Guidelines for Human-AI Interaction and Decision Support Tools

There are many guidelines addressing HAI. Firstly, EASA (2020) highlighted four crucial building blocks for creating a trustworthy AI framework, that is displayed in figure 4, to address the challenges of AI in aviation and HAI. Those building blocks are ‘Trustworthiness Analysis’, ‘Learning assurance’ or ‘AI Assurance’, ‘AI Explainability’ or ‘Human factors for AI’ and ‘Safety Risk Mitigation’. Hereby, the ‘Trustworthiness Analysis’ is based on an AI framework by the European Commission (2019) and is intended to ensure that AI applications fulfill essential safety, security, and ethical standards. ‘Learning as-

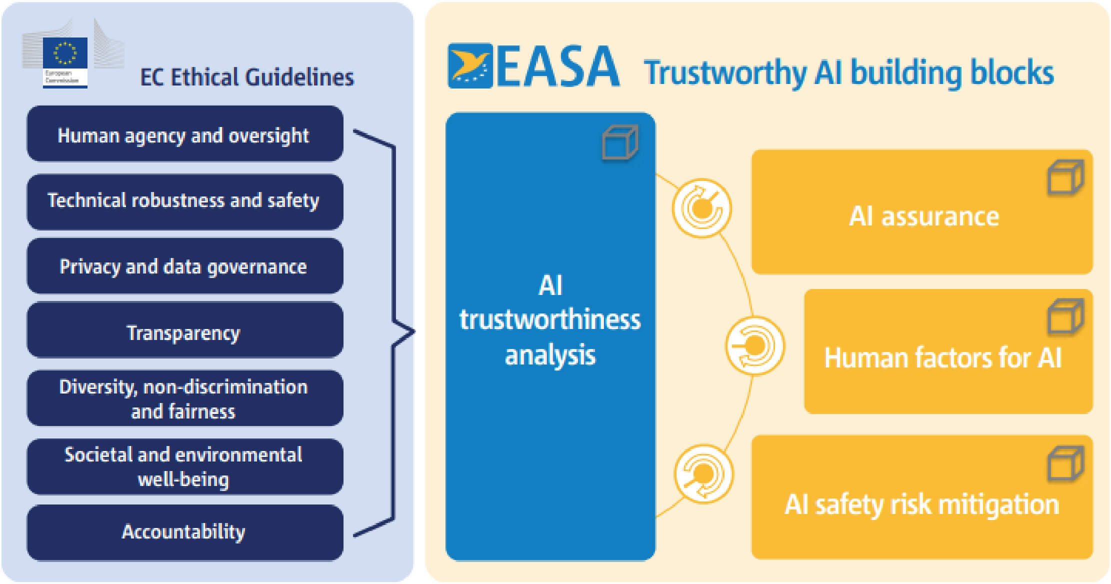

Figure 4: EASA's AI Trustworthiness Concept. Source: (EASA, 2023, p. 17)

surance' addresses that AI systems should continue to learn and adapt in a safe, secure, and reliable manner throughout their lifecycle. Next, 'AI Explainability' is supposed to allow operators to understand and trace the decision-making process of AI, fostering effective HAI. Lastly, safety risk mitigation strategies are outlined to manage risks associated with AI systems, particularly addressing the challenges posed by the inherent black-box nature of AI technologies where direct insight into decision processes may be limited. (EASA, 2020, p. 16ff.)(EASA, 2023, p. 17f)

Furthermore, in both AI roadmaps, the explainability of AI systems in aviation is closely tied to their automation levels. For Level 1A AI systems, which enhance human capabilities without altering decision-making processes, existing guidelines such as CS/AMC 25.1302 from EASA (2007) are sufficient. These guidelines ensure systems are predictable and understandable under normal operating conditions, aligning with the fundamental requirements for explainability at this level (EASA, 2007). As AI systems evolve to Level 1B and beyond, where they begin to assist in or replace human cognitive functions, the complexity and the necessity for explainability increase. For these higher levels, Level 2 and Level 3, where AI systems exhibit greater autonomy and decision-making capabilities the need for explainability is critical (EASA, 2020). Therefore, EASA (2024) published a first guide for level 1 and 2 machine learning applications, which breaks down multiple system requirements according to its autonomy level, as shown in table 1.

Name	**Objective**
EXP-02	For each of these stakeholders (or groups of stakeholders), the applicant should characterise the need for explainability to be provided, which is necessary to support the development and learning assurance processes.
EXP-04	The applicant should design the AI-based system with the ability to deliver an indication of the level of confidence in the AI/ML constituent output, based on actual measurements or on quantification of the level of uncertainty.
EXP-10	For each output of the AI-based system relevant to task(s) (per Objective CO-02), the applicant should characterise the need for explainability.
EXP-11	The applicant should ensure that the AI-based system presents explanations to the end user in a clear and unambiguous form.
EXP-12	The applicant should define relevant explainability so that the receiver of the information can use the explanation to assess the appropriateness of the decision / action as expected.
EXP-13	The applicant should define the level of abstraction of the explanations, taking into account the characteristics of the task, the situation, the level of expertise of the end user and the general trust given to the system.
EXP-16	The applicant should design the AI-based system so as to enable the end user to get upon request explanation or additional details on the explanation when needed.
HF-05	For complex situations under normal operations, the applicant should design the AI-based system with the ability to identify a suboptimal strategy and propose an improved solution.

Table 1: Applicable Objectives by EASA. Source: (EASA, 2024, p. 113f)

In addition, Zingale and Woroch (2019) have published a guide for the FAA for DST in Air Traffic Control (ATC) in the National Airspace System in the United States which also poses relevance for pilot DST. Here, the development of such systems as well as how to best train users to work with those tools is discussed. Zingale and Woroch (2019) emphasize the importance of clearly highlighting recommended options over others to ensure that users can make decisions quickly and accurately. Moreover, DSTs should provide information about the reliability or certainty of decisions. It is also mentioned that these tools should inform users about the conditions under which recommendations are reliable to promote a better understanding of the DST's functionality in different scenarios. The use of consistent and meaningful terminology and symbols is essential to avoid confusion and ensure that information is easily understandable. Another key aspect mentioned in the handbook is to support situation awareness by clearly indicating the operational status of the system and operational efficiency. In addition to the mentioned design principles, the guidelines also emphasize the need for comprehensive user training and the need for HAT segments within the human-automation system. (Zingale & Woroch, 2019)

Building on the EASA's and FAA's aviation-specific guidelines for AI, Microsoft (2019) and Google (2019) offer comprehensive frameworks for HAI as well.

The guidelines for HAI by Microsoft (2019) aim to enhance UXs with AI technologies by addressing behavior across different interaction phases. Microsoft (2019) states that AI systems should initially clearly communicate their capabilities and limitations to set realistic user expectations. During regular use, AI interactions should be timed based on user context and provide relevant information. When handling errors, AI systems should support efficient invocation, dismissal, and correction. Furthermore, it is highlighted that the system should provide explanations for its actions to maintain transparency. Microsoft (2019) further suggests that AI systems should remember recent interactions over time to personalize user experiences, adapt cautiously to avoid disruptions, encourage granular feedback, and notify users about significant updates.

Similarly, Google (2019) provides comprehensive guidelines for developing AI systems that prioritize HAI. Hereby, the importance of understanding user needs is emphasized, ensuring that AI products deliver value and meet user expectations through continuous evaluation. The guidebook emphasizes the importance of understanding users' mental models and recommends that AI systems should clearly state their ability, reliability, and benevolence to contribute to users' trust. Google (2019) further highlights the importance of making AI decisions understandable and transparent to build trust and reliability, as well as providing transparent error messages and fallback options.

Hereby, trust as per (Madsen & Gregor, 2000), is "the extent to which a user is confident in, and willing to act on the basis of, the recommendations, actions, and decisions of an artificially intelligent decision aid". This definition is based on a definition from McAllister (1995).

3 User Needs Assessment

In order to identify which functions the IPAS can provide to pilots in non-emergency scenarios, potential users and experts were involved as recommended by Google (2019). For this purpose, the target user group for the system is first identified and defined. Following that, the employed methodology is outlined and the results are discussed, detailing the functions that the IPAS can provide and how those might be implemented in an UI.

3.1 Identification of User Group

The user group for the IPAS consists of pilots of all ages. Nevertheless, a distinction must be made between military and civilian pilots, as the requirements for both professional groups can differ (Glicksohn & Naor-Ziv, 2016). According to Glicksohn and Naor-Ziv (2016) a pilot with a military background needs to be able to react quickly to fast-changing situations, in a multitasking environment. The pilot must function in a very flexible manner while fulfilling the mission. Here, the pilot is the sole commander of the aircraft. In turn, Glicksohn and Naor-Ziv (2016) state that civil pilots are trained to act in a very organised, structured and 'by-the-book' manner. In their environment there are checklists and predefined protocols that cover the majority of the scenarios which might be encountered during the flight. Decisions are made together with the co-pilot, although the final decision is ultimately made by the captain. Hormann and Maschke (1996, p. 177) describe the characteristics of good transport pilots as 'sociability, well-balanced self-assertiveness, and orientation toward actions and activity'. Since the current focus of the IPAS lies in civil aviation, the following discussion will consider civil professional pilots.

3.2 Methodology

To identify user needs and generate ideas for functionalities of the IPAS in non-emergency scenarios a workshop was held[1]. The event was designed to encourage collaborative and creative thinking among participants from interdisciplinary backgrounds and involve users in the process of developing such a system.

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[1] This workshop, along with its results, which was conducted for this thesis, has been simultaneously published in Ternus, S., Würfel, J., Papenfuß, A., Wies, M., & Rumpler, M. (2024, June). Exploring Functionalities for an Intelligent Pilot Advisory System in Normal Operation. In International Conference on Human-Computer Interaction (pp. 235-247). Cham: Springer Nature Switzerland.

3.2.1 Participants

A total of seven participants attended the workshop, representing a range of areas of expertise. The workshop participants consisted of employees from the DLR, with four males and three females. Furthermore, six attended in person while one provided input online. The professionals participated voluntarily and were not paid. These participants included three pilots, as well as data science and HAT researchers. More specifically, one of the pilots has a military background, having previously operated military cargo planes for short and medium-haul flights. Currently, this pilot is engaged in commercial cargo operations covering the same distances. The second pilot is focused on long-haul cargo flights, while the third pilot works in civil aviation, particularly for short and medium-haul flights. (Ternus et al., 2024)

3.2.2 Procedure

As described by (Ternus et al., 2024) the workshop was conducted over a full day and consisted of four main parts. The first session, 'Introduction and Objectives,' provided an overview of the current state of the IPAS and the reasoning for developing functionalities for the IPAS for non-emergency operations. The goals and desired outcomes of the workshop were presented, along with a briefing on the methods that will be used.

In the second part of the workshop, the 'Ideation Session', participants were asked to develop creative ideas for functionalities for the IPAS in normal operations. Firstly, the 6-3-5 ideation method was employed to generate a wide array of ideas. This technique involved each participant writing down three ideas in five minutes, passing their ideas to the next participant, who could add to these ideas. This process was repeated until everyone had contributed to everyone else's idea, quickly resulting in a large number of ideas (Steimle & Wallach, 2022).

Following this, the next part of the workshop consisted of structuring the many brainstormed ideas and getting an overview over them. Therefore, mind mapping was used to visually organize and group these ideas, encouraging discussions around their interconnections. To do this, the participants first transferred their ideas to card-board and step-by-step added them to a flip chart where they saw them fit. Afterward, the group of participants discussed the displayed ideas and grouped them as can be seen in figure 5. This technique was supposed to help participants see relationships between ideas, to identify ideas that occurred more than once and develop more cohesive concepts. Hereby, the participants discussed the most promising and effective ideas and used them to create a comprehensive list of potential functionalities for the IPAS in non-emergency operation.

The session continued with the formulation of ‘How-Might-We’ questions. Those questions are open-ended prompts that are structured to begin with ‘How might we...’ and are designed to encourage collaborative and creative problem-solving by focusing on specific aspects of a problem (Steimle & Wallach, 2022). This method aims to frame the ideas into actionable opportunities.

Finally, in the last part, the design studio method was utilized to facilitated rapid prototyping and iterative feedback to further refine the ideas. For this, participants created multiple quick sketches or models either on paper or with Lego. Afterward, everyone presented their ideas and received immediate feedback.

3.2.3 Identified Functionalities

During the workshop a multitude of user needs were identified and many ideas regarding opportunities for the IPAS to support pilots in normal operations were generated, as described by Ternus et al. (2024), and can be seen in figure 5.

Hereby, ideas were generated regarding the potential of the IPAS to support the pre-flight briefing process. An idea was proposed that the IPAS could monitor the briefings and filter out the most important information, providing pilots with concise summaries. This integration could help pilots get more insight into the data basis of the IPAS and its reasoning for recommendations to be able to better align their mental models.

Moreover, suggestions were made regarding the IPAS providing information about operational limitations and technical constraints of the aircraft in specific situations. Additionally, an idea was presented that predictive analytics could enable the IPAS to forecast probable approach routes and track miles, thereby aiding decision-making and ensuring a safer and more efficient approach and landing. Furthermore, during the workshop, participants envisioned the potential of IPAS to suggest optimized flight paths and speed, thereby facilitating the reduction of fuel consumption which in return contributes to environmental sustainability. Another brainstormed idea was that the IPAS provides an ‘what-if’ feature. This feature should enhance decision-making capabilities by simulating potential emergency situations and proposing optimal actions to take in response.

Figure 5: Mindmap of Generated Ideas during the Workshop. Source: Own representation

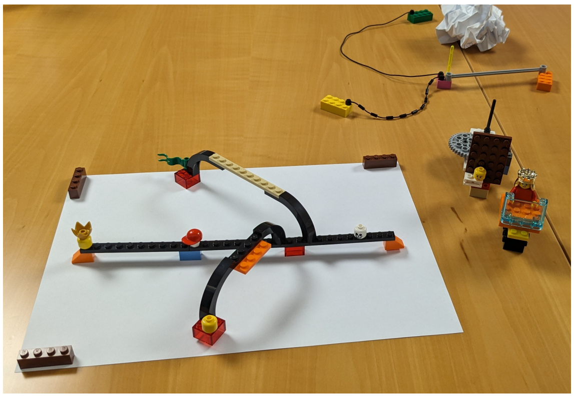


Figure 6: Lego Serious Play Model of the IPAS. Source: Own representation

However, the central concept that emerged from the workshop was the idea of a Mission Monitoring and Advisory Function (MMAF) as the main feature. Hereby, the IPAS is conceived not only as a tool but also as an assistant throughout the flight, continuously informing the pilots of any alterations in conditions and occurrences that may affect the flight plan or prove relevant to them, as modelled trough Lego serious play in figure 6. Accordingly, MMAF's core functionality revolves around the assessment of various factors influencing flight trajectory, efficiency, and safety. Hereby, the IPAS's task is to provide real-time updates on factors such as Notice to Air Missions (NOTAM), traffic and weather conditions that could potentially influence a flight plan. A NOTAM is a notice containing information essential to personnel concerned with flight operations (Federal Aviation Administration, 2021). Consequently, the IPAS assumes the dual role of an information provider and a decision-support system. Therefore, it firstly displays information, that is relevant to the mission and secondly, provides recommendations regarding the optimal course of action. This continuous monitoring is supposed to ensure that pilots are always informed of the latest developments, thereby allowing for more informed decision-making.

Additionally, the workshop participants envisioned the IPAS to also continuously update pilots with possible alternative airports for their current location. This function should be similar to the IPAS for emergencies to gain familiarity with the display.

Lastly, the IPAS was imagined to optimize pilot communication. By assisting in communication between aircraft, airline operations centers and ATC, the system could streamline information exchange.

3.2.4 User Requirements

Following the brainstorming of ideas for the IPAS in non-emergency operation and identifying underlying user needs, the focus now shifts to deriving specific user requirements to develop a first prototype. Hereby, the cruise phase is particularly of interest, as it mostly represents the majority of a flight and is a crucial stage in flight operations (REStARTS, 2023). Accordingly, the focus is on the MMAF because discussions during the workshop highlighted it as a central theme. This also aligns with the user needs identified in the initial IPAS study, described by (Würfel et al., 2023). Moreover, this functionality corresponds with the objective HF-05 by EASA (2024), as the system is leveraging data to identify the optimal course of action and giving recommendations based on that.

Concentrating on the MMAF ensures a robust foundation for subsequent integration of other functions like the ‘what-if’ feature. While in-flight optimization and green operation remain critical, these areas are predominantly managed by ATC and are already being investigated in this context e.g. by Hunger et al. (2024), and may be integrated into the prototype at a later stage. Additionally, the function to continuously update pilots on possible alternate airports nearby should be integrated, since this was identified as another major component, also in generating familiarity. This familiarity is supposed to help generate appropriate trust in the system and its displays for emergencies.

The main functional requirements that can therefore be derived and should be realized in the following design process are as follows:

1. Real-time MMAF:
    - The IPAS should continuously monitor flight conditions including NOTAMs, traffic and weather.
    - The IPAS should provide real-time updates to pilots regarding any changes in conditions that might impact the flight.
    - The IPAS should give advice fitting to the situation on how to react to the recognized factors and events.
2. Continuous updates on nearby alternate airports:
    - Throughout the flight, the IPAS should continuously update pilots with alternate airport options for the case of an abnormal situation.
    - The system should rate the alternate airports depending on specific criteria that match the rating of the IPAS for emergency situations.

The most important non-functional requirements can be derived from Riedesel (2023), as these requirements for the IPAS for emergency operations also apply to non-emergency operations. Riedesel (2023) states that the system must be effective, efficient, and satisfactory to meet usability requirements. It should also be clearly interpretable. Additionally, the system must adhere to established standards of language and spelling, including the use of recognized abbreviations and correct color application. Furthermore, symbols should be derived from familiar motifs to ensure direct and accurate interpretation, aligning with the principles of correspondence between the system and reality, and recognition

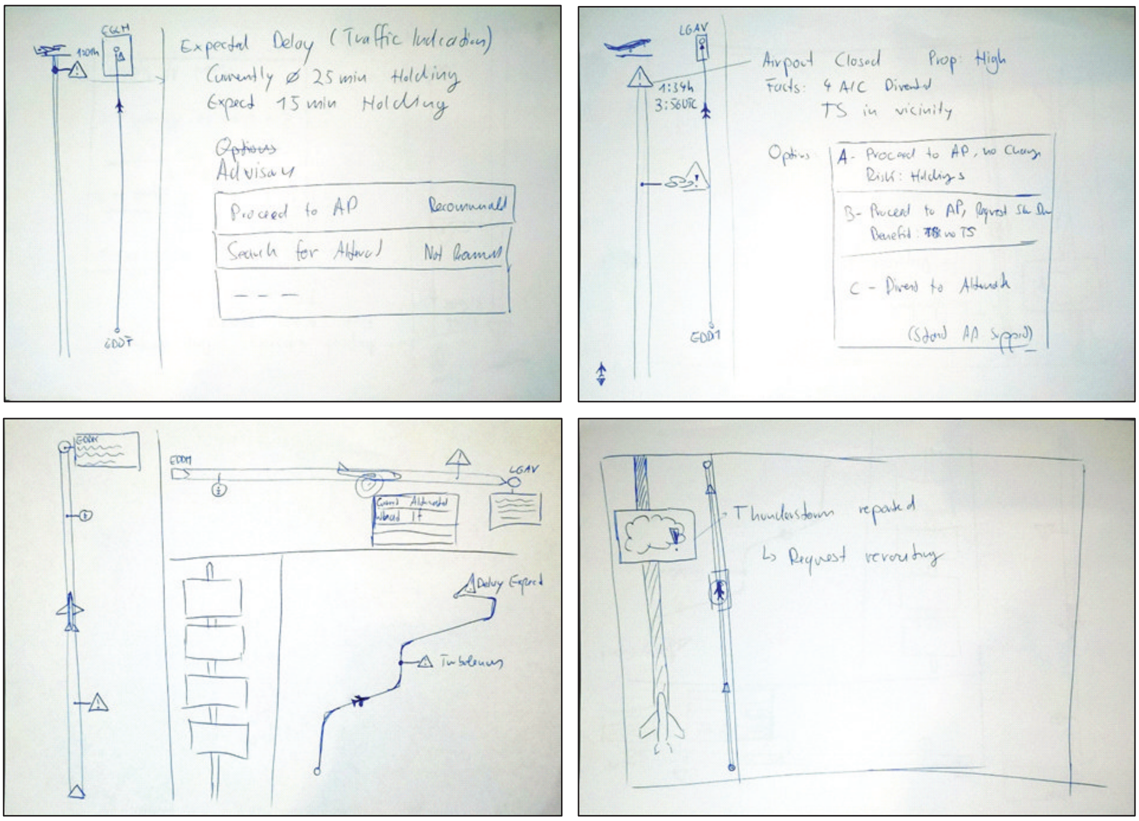


Figure 7: Sketches from the ‘Design Studio’ method of the workshop depicting ideas for the Design of the MMAF. Source: Representation by workshop participants, first depicted in (Ternus et al., 2024)

over memorization. Other non-functional requirements mentioned include error avoidance and the use of minimal design to prevent distractions (Riedesel, 2023).

In addition to these usability-focused requirements, the trustworthiness of the IPAS is a critical component for the integration of AI into aviation, as highlighted by EASA (2020, 2023). The IPAS’s trustworthiness must therefore be a key factor in the non-functional requirements, encompassing the ethical requirements for trustworthy AI that were introduced in section 2.4 and should be considered in the following design process.

3.2.5 Design Ideas

After identifying possible functionalities for the IPAS in non-emergency situations, during the ‘Design Studio’ of the workshop first ideas were developed regarding the structure and design of these functionalities. Hereby, the focus was particularly on the identified user requirements and therefore specifically on the MMAF. There were various ideas for designing this mode, including both horizontal and vertical timeline designs, as well as displaying the route from a bird’s-eye perspective (see figure 7). For these displays, icons were used in various ways to label the events along the route or timeline. Other ideas

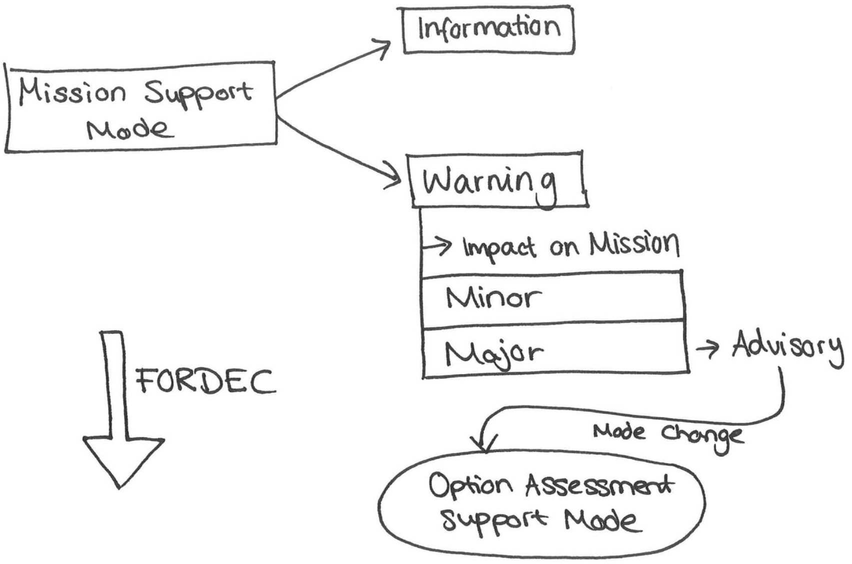


Figure 8: First Idea of the Structure of the IPAS. Source: Own representation

included displaying the flight path with an altitude display, marking the different flight phases, or displaying the events as a chronological list.

Additionally, there were ideas that the entire route could be displayed as a whole but also zoomed in to display only the next occurring events.

Furthermore, considerations were given to the possible Information Architecture (IA), the role of the IPAS in non-emergency operations, and its interaction with the established emergency module of the IPAS. It was envisioned that the events would be classified into different levels of severity. Two types of events were conceived: Information and warnings. These should be visually distinguishable, and in the case of a strong severity, i.e. in the case of a warning, a switch to the ‘Option Assessment Support’ mode can be made, as can be seen in figure 8. This ‘Option Assessment Support’ mode represents the emergency module developed to date, which supports the selection of an alternative airport. (Ternus et al., 2024)

4 Interface Development

The development of the IPAS's UI plays a crucial role in ensuring effective interaction between pilots and aircraft systems. Therefore, in this chapter, the iterative development of an IPAS's prototype for non-emergency situations is described. First, the design of the prototype is presented, followed by its implementation.

4.1 Prototype Design

As suggested by Google (2019) and in line with the human-centric approach by EASA (2020), the development followed a HCD process. It was closely aligned with the human-centred development standards of DIN EN ISO 9241-11 (2018) and DIN EN ISO 9241-210 (2019). Hereby, the generated ideas from the workshop described in section 3.2 form the basis of the following design process. The main objective of the UI development for IPAS was to create an efficient, trustworthy and user-friendly system that facilitates pilot decision-making and the systems trustworthiness according to the specifications and principles described in section 2.

4.1.1 Initial Design Phase and Low Fidelity Protoryping

Figure 9: Horizontal Timeline Design. Source: Own representation

Firstly, multiple low-fidelity paper prototypes were created based on the design ideas developed in the workshop as depicted in figures 9, 10 and 11. Hereby, the designs for the IPAS for non-emergency situations were based on the IPAS design for emergency situations. The display size of 818 pixels in width and 1028 pixels in height was therefore used. Furthermore, the basic structure adopted consists of a purely informative, non-interactive header, an interactive main area and large, square back buttons in the footer if

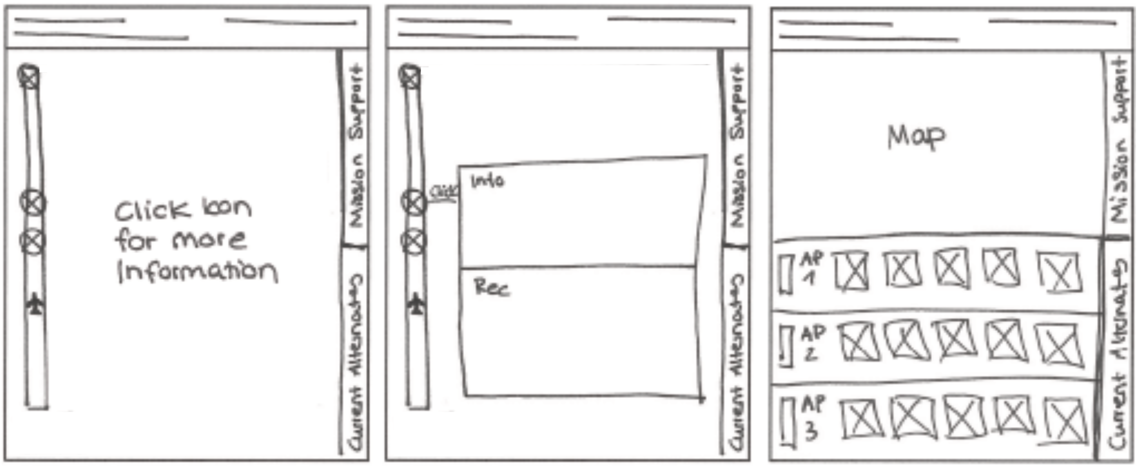


Figure 10: Vertical Timeline Design. Source: Own representation

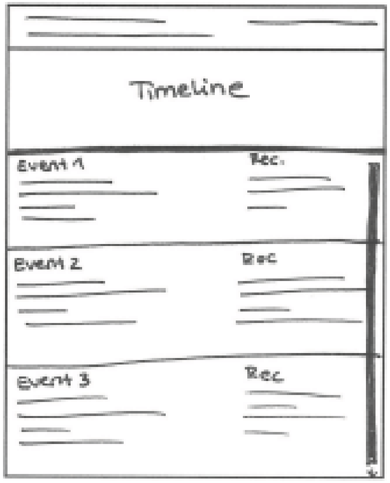


Figure 11: Horizontal Timeline Design with Event List. Source: Own representation

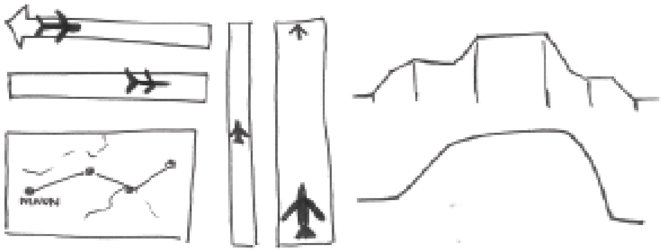


Figure 12: Timeline Design Ideas. Source: Own representation

needed.

Moreover, based on the structure developed in the workshop shown in figure 8, three classification categories were created to visualize the influence of events and structure the information. Accordingly, a notification category was added, expanding beyond the existing information and warning categories, as depicted in figure 13. The different classes were defined as follows: Information are events with no impact on the mission, that are simply displayed to ensure that pilots receive all necessary details clearly, thereby, likely improving situation awareness. Notifications occur in instances of an event that might have a minor impact on the planned flight. Lastly, warnings, are events that the IPAS expects to have a high impact on the mission and a diversion might me necessary. For this type active event, a button is included to facilitate the mode switch to the Option Assessment Support mode. The prioritization of information is considered with critical warnings

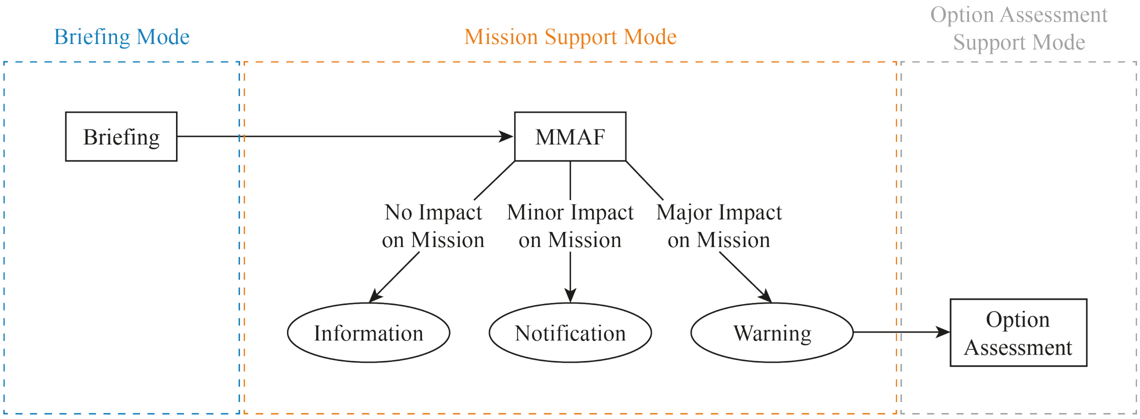


Figure 13: Proposed Structure of the IPAS. Source: Own representation from (Ternus et al., 2024)

(a) Information (b) Notification (c) Warning

Figure 14: Icons for Message Categories Symbolizing Mission Impact. Source: Own representation

prominently displayed and less urgent notifications placed in a more subtle manner.

In a first internal evaluation of the low-fidelity prototypes with an aerospace engineer and another IPAS researcher, the design requiring users to click on an icon for more information (shown in figures 9 and 10) was preferred over displaying all information at once (as seen in figure 11). This approach aims to reduce information overload and provide on-demand access, allowing users to obtain necessary information as needed.

Furthermore, according to the specifications of EASA (2007, p. 1-F-1) in CS/AMC 25.1302 information must be clear and accessible. Therefore, the vertical and horizontal straight timeline design was preferred due to its ability to provide a better and more comprehensive overview of the entire process and its efficient use of space. This design allows for better integration of icons, making it simpler and more intuitive for users to understand and interact with the interface. This simpler design and easy access to the information is supposed to reduce the cognitive effort required by the users to gain an overview over the route, therefore improving efficiency and user satisfaction.

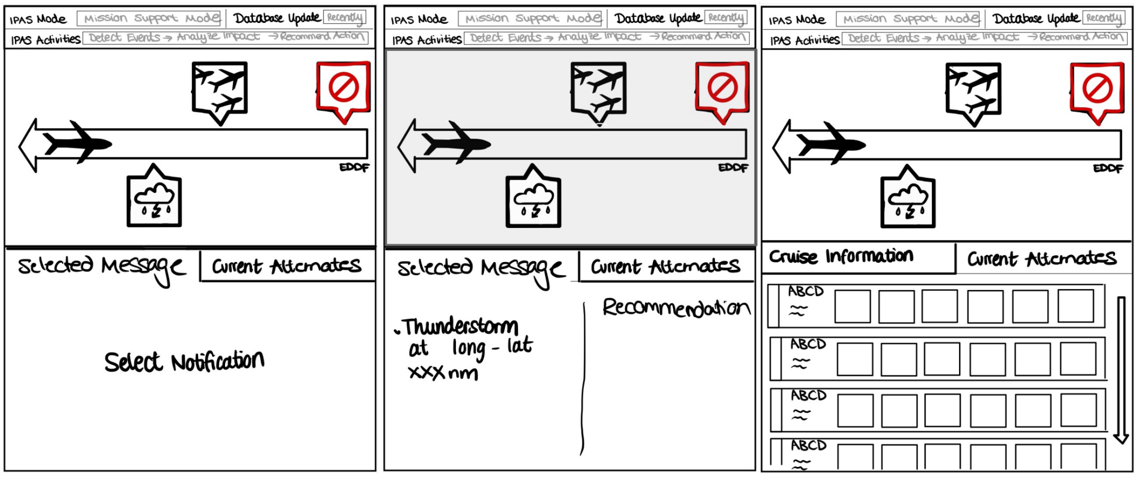


Figure 15: Prototype with Horizontal Timeline. Source: Own representation

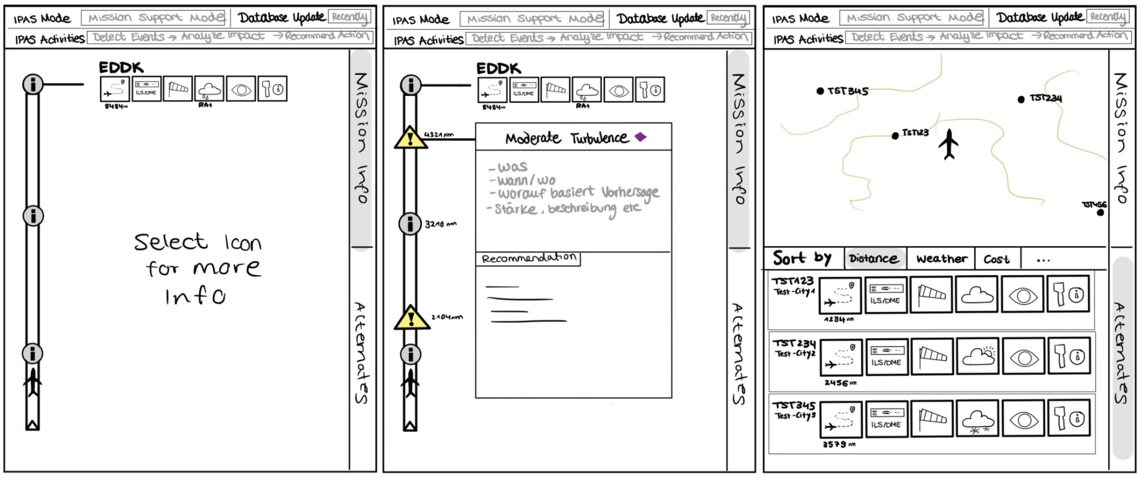


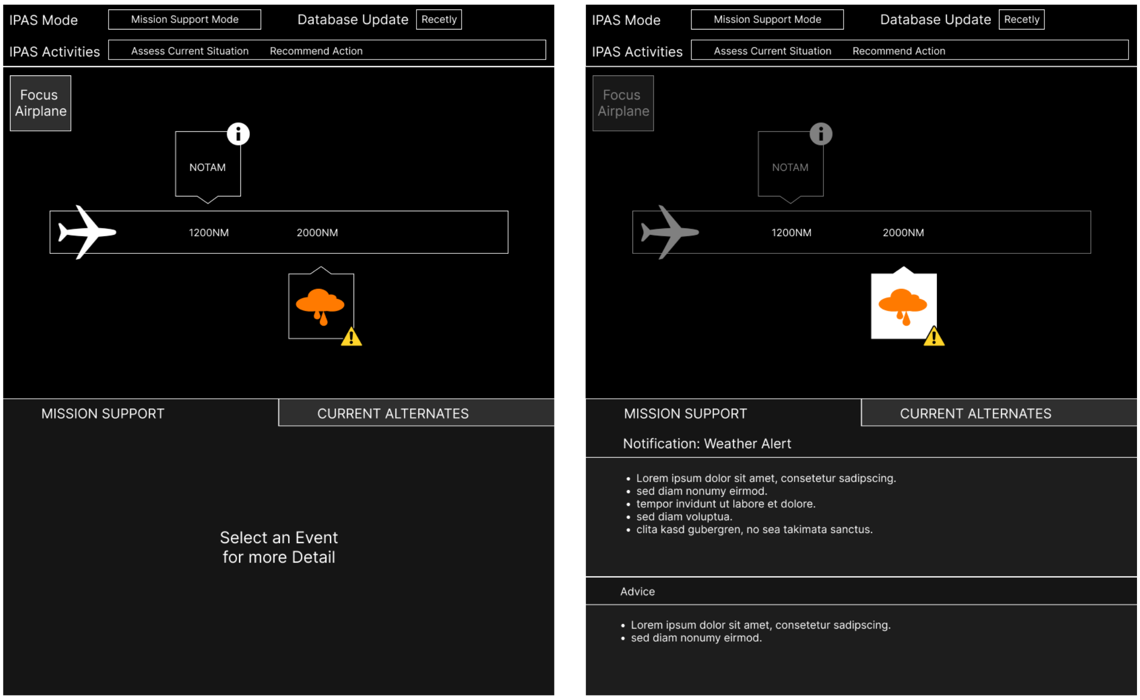
Figure 16: Prototype with Vertical Timeline. Source: Own representation

4.1.2 High Fidelity Prototyping

Due to the results of the first evaluation the designs of figures 9 and 10 were developed further, which resulted in the prototypes that can be seen in figures 15 and 16. During this design iteration, the icons shown in figure 14 were created based on the developed IA and added to the designs.

Moreover, a destination airport status was added to the vertical timeline design, in order to fill the white space sensibly and to give the pilots a quick overview of the rating of their destination airport. This destination airport status was modeled after the alternate airport list from the IPAS design for emergency situations, depicting various factor icons for an initial overview of the airport, as well as the overall IPAS rating and the destination airport name. This was done to follow Jakob's Law, the principle outlined by Yablonski (2024), that suggests that users intuitively understand interfaces that feature familiar patterns and conventions based on their previous experiences. Particularly, this repeated use should create more familiarity with this type of representation and therefore appear more intuitive and trustworthy if an emergency occurs.

Based the created sketches in figures 15 and 16, both prototypes were then realized as high-fidelity prototypes in Figma[2]. Hereby, more details were added to the Figma prototypes as shown in figures 17 and 18. Firstly, the IPAS for emergencies' colors were used and information on the distances to the events were added. Secondly, the font and font-sizes were adopted from the original system as well, using sans-serif fonts as per the FAA's recommendation (Zingale & Woroch, 2019, p. 5-3). Also, according to those recommendation the readability of information was considered, ensuring readable font-sizes and high contrasts (Zingale & Woroch, 2019, p. 5-2). The header design of the IPAS for emergencies was adopted as well, meeting the FAA's requirement to display operational status and database updates (Zingale & Woroch, 2019).



Select an Event
for more Detail

Notification: Weather Alert

- Lorem ipsum dolor sit amet, consetetur sadipscing.
- sed diam nonumy eirmod.
- tempor invidunt ut labore et dolore.
- sed diam voluptua.
- clita kasd gubergren, no sea takimata sanctus.

Advice

- Lorem ipsum dolor sit amet, consetetur sadipscing.
- sed diam nonumy eirmod.

Figure 17: Figma Prototype with Horizontal Timeline. Source: Own representation

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[2] https://www.figma.com/ - Last Accessed: 2024-05-16

Notification: Lorem Ipsum

- Lorem ipsum dolor sit amet, consetetur sadipscing.
- sed diam nonumy eirmod.
- tempor invidunt ut labore et dolore.
- sed diam voluptua.
- clita kasd gubergren, no sea takimata sanctus.

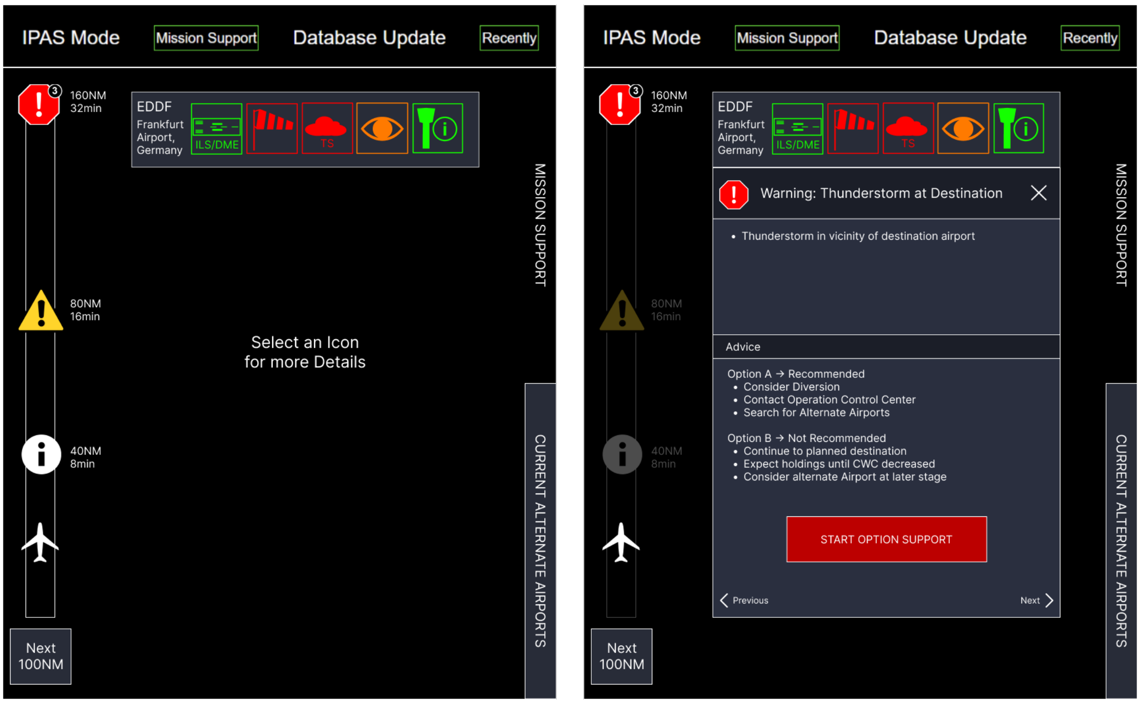
Advice

- Lorem ipsum dolor sit amet, consetetur sadipscing.
- sed diam nonumy eirmod.

Figure 18: Figma Prototype with Vertical Timeline. Source: Own representation

This prototype version was again evaluated with the help of two pilots and an aerospace engineer. In this evaluation both design variants were tested in Figma and discussed. Participants appreciated the design of both versions. Nevertheless, it became apparent that fitting the entire flight route into the horizontal display was very difficult due to space constraints. The icons would either be too small to click on effectively, or a zoomed-in view would always be necessary. However, a zoomed-in view that does not depict the whole route was deemed insufficient and contrary to the idea of the MMAF. This was a significant advantage of the vertical timeline design. With the selected display size of 818 by 1028 pixels, there was enough space to provide a good overview of the entire route, also providing space for a direct overview of the destination airports status as depicted in figures 16 and 18.

Next, one participant mentioned that both timestamps and distances are relevant for estimating when an event will occur, noting that individual preferences vary regarding which measurement to use. Another participant noted that the message classification was not as obvious when opening a message, when represented only by a highlighted icon in the timeline. Additionally, one participant indicated that the activities the IPAS performs are familiar to pilots through their training, making it unnecessary to explicitly include this information in the header.



Select an Icon
for more Details

Warning: Thunderstorm at Destination

- Thunderstorm in vicinity of destination airport

Advice

Option A → Recommended
- Consider Diversion
- Contact Operation Control Center
- Search for Alternate Airports

Option B → Not Recommended
- Continue to planned destination
- Expect holdings until CWC decreased
- Consider alternate Airport at later stage

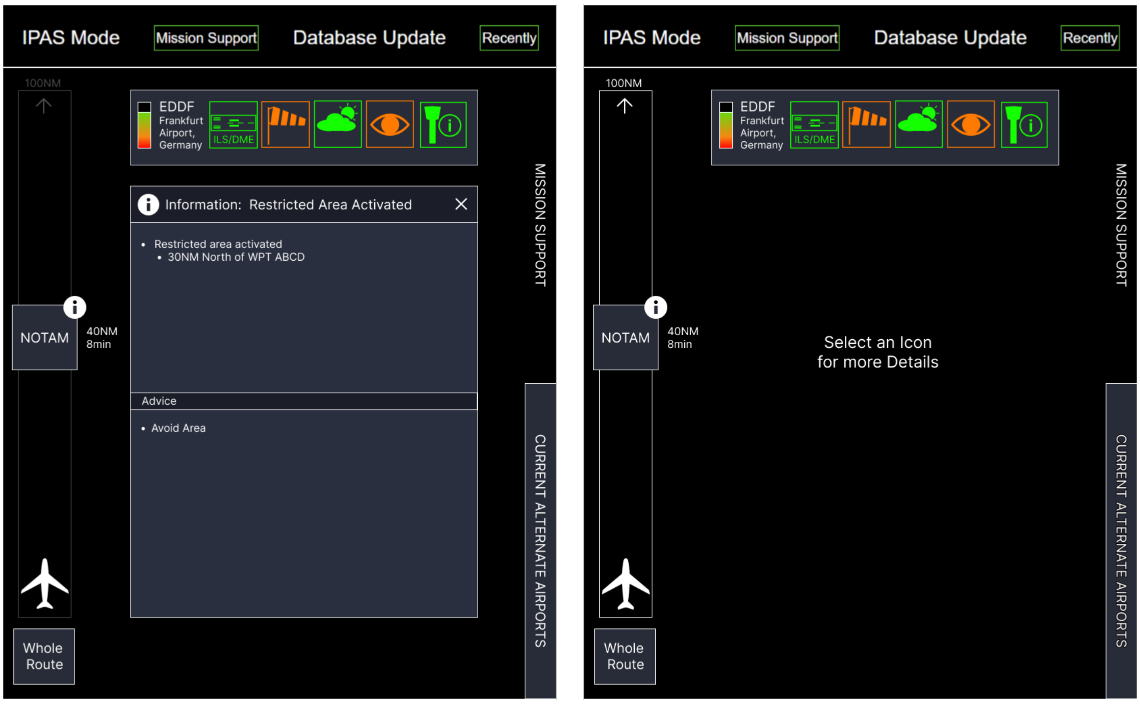
Figure 19: Improved IPAS Design. Source: Own representation

4.1.3 Design Refinement and Explanatory Pages

As a result of this evaluations, the vertical timeline design shown in figure 18 was further developed resulting in the design depicted in figure 19. Here, both timestamps and distances were added to all events and the destination airport. Next, the distance factor group was removed from the airport status. To enhance clarity and usability, the header was modified to include only the mode and timing of the last database update, as per the participants feedback. Furthermore, icons were added to the message boxes to visually represent the message type, providing immediate visual cues and a new feature was introduced to display multiple messages in one location, marked by a small circle at the top-right corner of the icons. Moreover, as can be seen in figure 19 in case of a warning multiple possible solutions are provided, highlighting which solution is recommended and which one is not, as per Zingale and Woroch (2019).

Then, two scenarios, described in more detail in section 5.1.3, were developed with the help of an aerospace engineer and two pilots and then included into the Figma prototype. All event information and icons were added to the prototype as can be seen in appendix C. Hereby, the FAA guideline to use consistent terminology and symbols to prevent confusion was utilized (Zingale & Woroch, 2019, p. 10).

Moreover, the concept of the zoomed-in view, as proposed in the workshops design studio,



Information: Restricted Area Activated

- Restricted area activated
  - 30NM North of WPT ABCD

Advice

- Avoid Area

Select an Icon for more Details

Figure 20: Zoomed in View. Source: Own representation

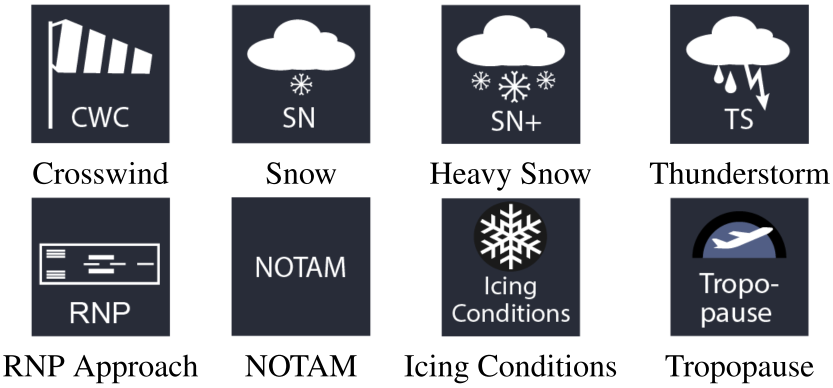


Table 2: Detailed Icons for the Zoomed-in View. Source: Own representation

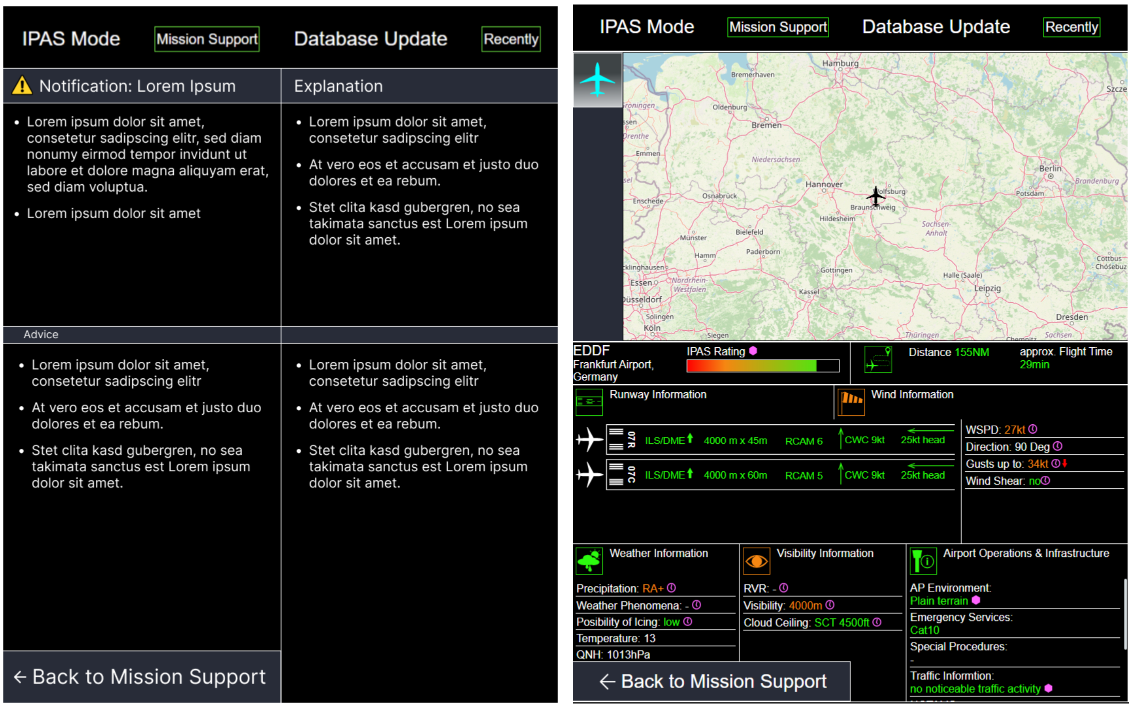
was incorporated into the design. The navigation between the two timeline views was implemented via a button, located below the timeline. As illustrated in figure 20, in the zoomed-in view the route is displayed in greater detail with the aircraft remaining stationary at the base of the route. In contrast to the full-route view, the event icons move toward the aircraft rather than the aircraft moving itself. Furthermore, the icons have been expanded to include a more detailed design that directly indicates the nature of the event. Additionally, the classification icons are added to the top right-hand corner of those icons, to signal the expected mission impact of the events and link the icons to those of the zoomed-out view.

In this context, the icons from table 2 were designed. The symbols should be familiar symbols that are standardized for the entire system, as the FAA guidelines specify that consistent terminology and symbols should be used (Zingale & Woroch, 2019, p 5-4, 5-5). Therefore, a windsock is chosen to represent all messages regarding wind. This decision was made, as this symbol is used in the airport status groups as well and therefore familiar and easy to identify. Similarly, weather events are displayed through their respective weather symbols, also present in the airport status factor groups. Accordingly, weather events related to snow are represented through a snowflake symbol coming out of a cloud. Depending on the strength of the snowfall the amount of snowflakes change. To avoid confusion with the snow icon, the icon for icing-conditions features a more detailed snowflake without a cloud, set against a dark circle background. Like the other weather events, thunderstorms are represented through a cloud but in this case with a lightning strike and raindrops. Moreover, the icon for the message that the Instrument Landing System (ILS) is out of order and RNP is to be used includes a depiction of a runway, known from the airport status factor groups as well, with bold 'RNP' below making it quickly recognizable to pilots. For NOTAM's, the icon simply displays the text 'NOTAM'. This direct approach ensures clarity and avoids any ambiguity, as the term is standard in aviation. Finally, the tropopause icon features an airplane crossing two air layers.

Lastly, according to the requirement of EASA (2023) and pattern 1b by Microsoft (2019), the implementation of the various explanatory levels was started. Hereby, the guidelines introduced in section 2.4 were utilized for this purpose. The guidelines outlined by EASA (2024) state that for each system output relevant to user tasks, the necessity and depth of explanations should be determined according to objective EXP-02. This decision depends on factors such as the nature of the task, the type of stakeholder, and the complexity of the AI system (EASA, 2024). Considering users as stakeholders in the development of the UI and given the non-critical nature of the system as well its role in providing information and recommendations, a moderate, more abstract level of explanation is appropriate.

The explanations are added by two types of pages. First, the 'Message Detail' page (see figure 21a) should provide explanations for the messages on the timeline. Secondly, the 'Airport Detail' page (see figure 21b) provides information on the respective factors that contributed to the IPAS rating and displays a more detailed status of the airports.

The first draft of the 'Message Detail' page shows the icon and headline again in the header. The message and advice are displayed on the left side. Directly next to them on the right side is the explanation for the message and advice respectively, which is



⚠ Notification: Lorem Ipsum

- Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua.
- Lorem ipsum dolor sit amet

Explanation

- Lorem ipsum dolor sit amet, consetetur sadipscing elitr
- At vero eos et accusam et justo duo dolores et ea rebum.
- Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

Advice

- Lorem ipsum dolor sit amet, consetetur sadipscing elitr
- At vero eos et accusam et justo duo dolores et ea rebum.
- Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

- Lorem ipsum dolor sit amet, consetetur sadipscing elitr
- At vero eos et accusam et justo duo dolores et ea rebum.
- Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

← Back to Mission Support

EDDF
Frankfurt Airport, Germany
IPAS Rating ●
Distance 155NM
approx. Flight Time 29min

Runway Information
07R ILS/DME 4000 m x 45m RCAM 6 CWC 9kt 25kt head
07C ILS/DME 4000 m x 60m RCAM 5 CWC 9kt 25kt head

Wind Information
WSPD: 27kt
Direction: 90 Deg
Gusts up to: 34kt
Wind Shear: no

Weather Information
Precipitation: RA+
Weather Phenomena: -
Posibility of Icing: low
Temperature: 13
QNH: 1013hPa

Visibility Information
RVR: -
Visibility: 4000m
Cloud Ceiling: SCT 4500ft

Airport Operations & Infrastructure
AP Environment: Plain terrain ●
Emergency Services: Cat10
Special Procedures: -
Traffic Informtion: no noticeable traffic activity ●

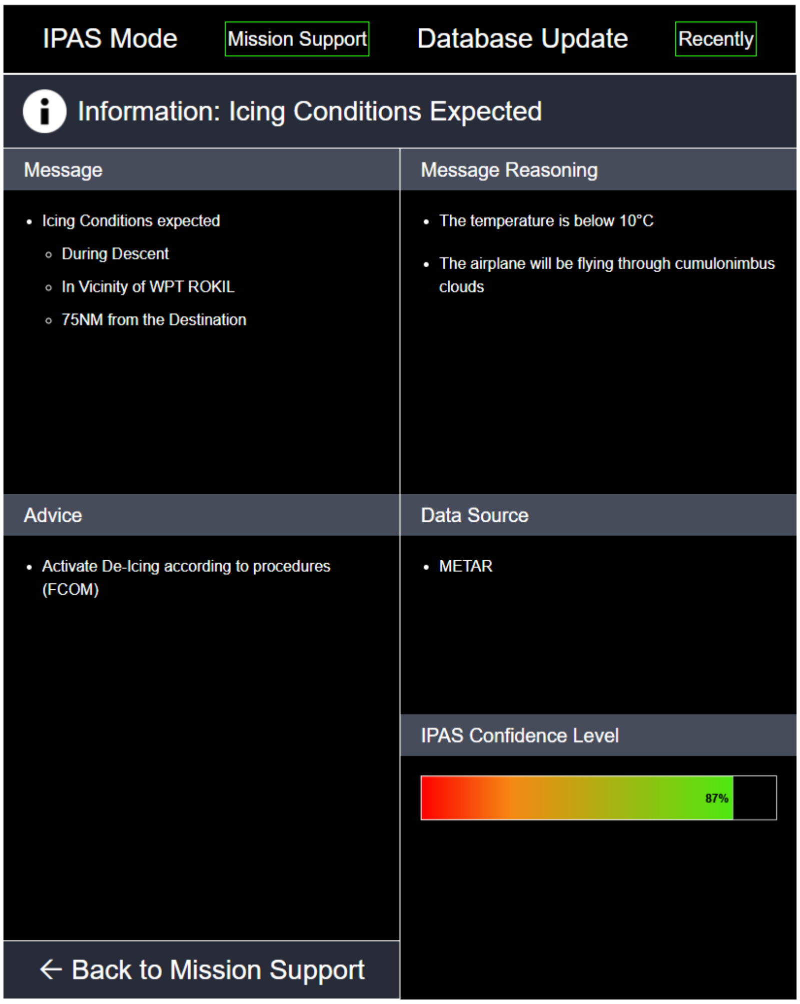
← Back to Mission Support

(a) Message Detail Page (b) Airport Detail Page

Figure 21: First Draft of the Explanatory Pages. Source: (a) Own representation, (b) (Djartov & Würfel, in press)

supposed to explain why the message was produced and why the recommended action is necessary. The ‘Airport Detail’ page design was adapted from the IPAS for emergency situations design shown in section 2.1, as it was already tested and effectively breaks down the factors contributing to the IPAS rating (Djartov & Würfel, in press). It is designed to give pilots all necessary information about the airports and help them understand the IPAS rating and its factor groups. It also provides further insight into the reasoning behind the systems recommendations by offering the underlying data.

Then, the ‘Message Detail’ page was refined further, as can be seen in figure 22. This was based on objective EXP-11 by EASA (2024), which emphasizes that explanations should be clear and unambiguous, preventing overwhelming users with excessive details. Therefore, more structure, more graphical elements and less text should be utilized. Additionally, objective EXP-04 of EASA (2024) necessitates that explanations be validated with actual measurements or quantified uncertainty levels (EASA, 2024). Therefore, a data source was added to allow verification of the displayed messages and data. This objective also supports the inclusion of a confidence level indicator. This guideline is consistent with that of Zingale and Woroch (2019), highlighting the need for including information on the certainty of decisions and the recommendations of Microsoft (2019) and Google (2019), stating that AI systems should clearly communicate their abilities,



Information: Icing Conditions Expected

Message

- Icing Conditions expected
  - During Descent
  - In Vicinity of WPT ROKIL
  - 75NM from the Destination

Message Reasoning

- The temperature is below 10°C
- The airplane will be flying through cumulonimbus clouds

Advice

- Activate De-Icing according to procedures (FCOM)

Data Source

- METAR

IPAS Confidence Level

87%

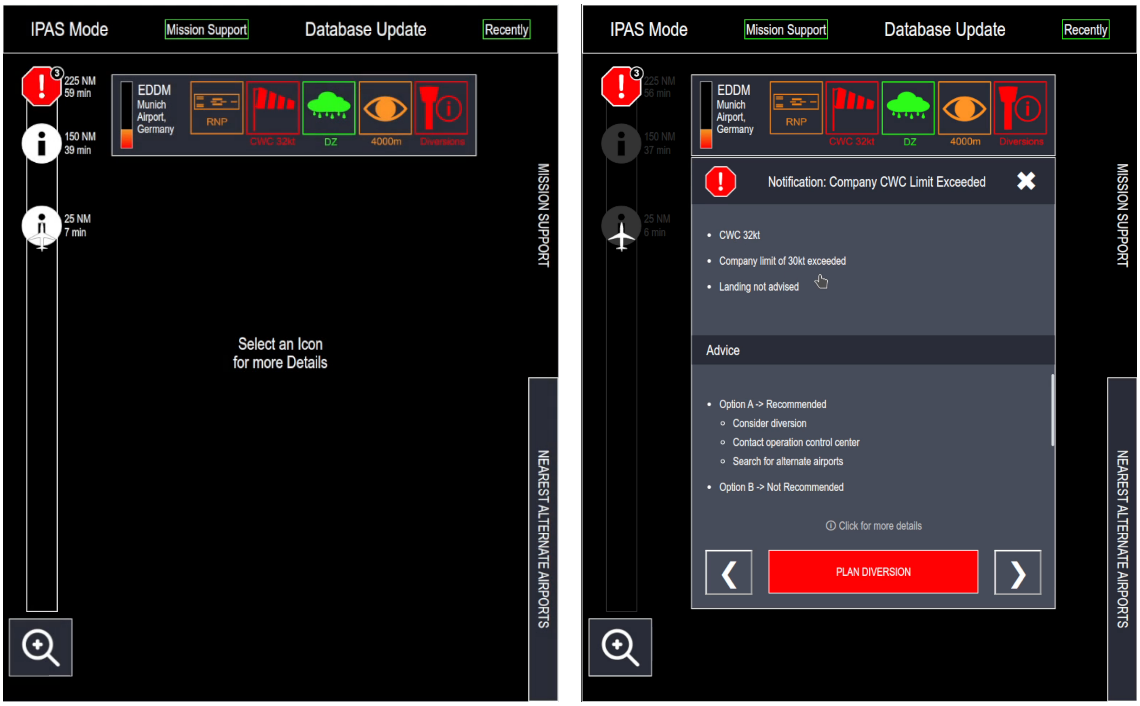
Figure 22: Improved Message Detail Page Design. Source: Own representation

reliability, and benevolence. Notably, this should not remain the only measure to indicate the systems reliability as this should be briefed in trainings and included in the respective handbook. Moreover, to give pilots the opportunity to verify the messages and data themselves a data source was added to the 'Message Detail' page. Both explanatory pages can be accessed on-demand by clicking on the message boxes or airport status, as outlined in objective EXP-16 of EASA (2024).

Finally, the last iteration before the final evaluation encompassed a run-through of the scenarios with a pilot and a computer scientist using the simulator prototype from section 4.2, this time testing the prototype with the developed scenarios. Throughout this rehearsal, some usability issues and challenges were observed and documented. Firstly, one of the participants did not realize that they were able to click on the message boxes for more detailed explanations. Furthermore, the participants did not identify the button below the timeline as a way to switch between the zoomed-in and zoomed-out view. Secondly, they criticized the name of the mode switch button, which was not immediately obvious to them. Lastly, one of the participants searched for the destination's alternate airports on the 'Nearest Alternate Airports' page. This behavior was noted, and ideas were developed to address this.

4.1.4 Final Iteration

Because of the issues observed, several changes were made to the prototype. An instruction text was added to inform users they could click on the message boxes for more detailed explanations, as can be seen in figure 23b. Additionally, the button to switch to the IPAS's emergency 'Option Support Mode' was changed from 'Start Option Support' to 'Plan Diversion' to make it clearer what functionality hides behind this mode and follow Krug's (2014) first law of usability for a more intuitive design. Since the button below the timeline did not leave much room for a call to action, an icon was chosen to represent the zoom-in and zoom-out view switch, as depicted in figures 23a and 23c. In this step, the integration of the destionation's alternate airport into the 'Nearest Alternate Airports' page was not yet included due to a time limit and the need for a more thorough evaluation. With these final adjustments, the prototype appears as shown in figure 23 with the explanatory pages of figures 21b and 22.



Notification: Company CWC Limit Exceeded

- CWC 32kt
- Company limit of 30kt exceeded
- Landing not advised

Advice

- Option A -> Recommended
  - Consider diversion
  - Contact operation control center
  - Search for alternate airports
- Option B -> Not Recommended

ⓘ Click for more details

(a) Homepage (b) Homepage with Open Message

(c) Zoomed-in View (d) Nearest Alternate Airports

Figure 23: Final Implemented Simulator Prototype. Source: Own representation.

4.2 Prototype Implementation

The implementation of the high-fidelity prototype for the advisory systems interface involved transforming the design into functional code using HTML, CSS, and vanilla JavaScript. No plugins or frameworks were used. This choice was made primarily for administrative reasons, as the previous components were implemented this way to ensure the new prototype module can be seamlessly integrated into the emergency scenarios prototype also facilitating a seamless continuation of work. Furthermore, a more complex and flexible prototype implementation was not necessary since the nature of this prototype was to be a ‘throw-away’ prototype for evaluating the interface at a flat panel simulator, as described in section 5. The connection to the simulator to receive position values is hereby established via RabbitMQ and the data is stored in an aircraft class and continuously updated.

To realize this prototype, the new home page for mission support and its zoomed-in view from figure 23, as well as the ‘Message Detail’ page from figure 22, needed to be implemented. Additionally, the ‘Nearest Alternate Airports’ page and ‘Airport Detail’ page needed to be modified from the IPAS for emergency scenarios.

4.2.1 Homepage

The home page consists of three main components: The airport status, the timeline and the message area, as shown in figure 23a. On the timeline, the aircraft moves upwards according to the distance to the destination airport. This was implemented using a JavaScript function that receives the entire route distance and the current location. The remaining distance to the destination airport is then calculated and the CSS attribute ‘top’ of the aircraft is set on the timeline in the corresponding ratio. In addition, the event messages are displayed on the timeline via the three category icons as defined in the design. For this, at start, a function is called that sets the top attribute values of all events through their distance to the destination. Those icons can then be clicked on and thus fill the third main area of the home page, the message area. Clicking on the icons displays the message box. Accordingly, the background is darkened, except for the clicked icon, which is implemented through the CSS attribute ‘z-index’. If the airplane crosses the section where the event is located, it and its message box are faded out and the darkening of the rest of the timeline is switched off, which is checked by comparing the two top values. Other components of the home page are the sidebar, which can be used to navigate to the ‘Nearest Alternate Airports’ page, and a button below the timeline that can be used to switch to the zoomed-in view of the timeline.

4.2.2 Zoomed-in View

The zoomed-in view, depicted in figure 23c, has a similar structure and mirrors the home page and is therefore implemented similarly. The only difference is that the timeline and aircraft are more prominent and the icons move toward the aircraft instead of the aircraft moving upwards. This was again implemented through a JavaScript function that receives the total distance and additionally the distance of the events to the destination airport. The position of the events is continuously updated and accordingly the distance to the events decreases, which results in them moving downwards. In addition, as described in section 4.1.3, the icons are replaced by more descriptive icons, which symbolize what event was detected.

4.2.3 Message Detail Page

The last page implemented was the ‘Message Detail’ page from figure 22, which was implemented via an HTML table. The confidence scale was added via a png-image for simplicity reasons.

4.2.4 Alternate Airport- and Airport Detail Page

The adjustments that were made for the ‘Nearest Alternate Airports’ (see figure 23d) and ‘Airport Detail’ page (see figure 21b) were mainly in regard to the map section. The map was made bigger while removing the display of the gross weight, fuel on board and range. CSV files were used to insert airport data into the airport list and ‘Airport Detail’ page. Therefore, new CSV files were created for the new scenarios described in section 5.1.3 with the information about the airports. Hereby, the functions for reading and outputting these CSV files were slightly adapted. As the prototypes are not yet connected to an actual AI, the outputs of the system were created by hand. Furthermore, the sidebar was added to the ‘Nearest Alternate Airports’ page at the right side of the page, the number of airports was reduced from four to three and the proportions were adjusted.

4.2.5 Airport Status Change

In addition, a function was developed to change the status of the destination airport. For this purpose, the distance to the destination airport is queried again and respective airport statuses with their associated ‘Airport Detail’ views are shown or hidden from a corresponding distance. In addition, the icons at the destination airport are updated in the same way. Hereby, new notifications and a warning are triggered.

5 Interface Evaluation

In order to test the IPAS for non-emergency scenarios with regard to its functions and trustworthiness, as well as its usability, a study was carried out which is described in more detail in the following sections.

5.1 Methodology

5.1.1 Participants

The study encompassed a sample of 19 pilots who participated voluntarily in this research for a compensation, with one participant being excluded from further evaluation, as described in section 5.2.1. The sole inclusion criteria for the participants in the experiment was that they were professional pilots with a Airbus licence, with no additional exclusion criteria applied. Their mean age was 36.67 years, with a Standard Deviation (SD) of 9.57 years and a mean overall flight experience of 4,361.11 hours (SD = 3,884.82) and a mean flight experience of 422.22 hours (SD = 161.78) in the last 12 months. Since age and total flight hours were queried in intervals, to calculate the mean the representative values were set as the midpoint of each age and flight experience interval. For age groups with an open interval (<30 and >59), the representative values were determined by assuming the values 25 and 65. For the category of flight experience over 10,000 hours, 15,000 hours was used to calculate the mean. The exact age distribution within the sample was as follows: 12 pilots were aged between 30 and 39 years, three pilots were aged under 30 years, one pilot was aged between 40 and 49 years, one pilot was aged between 50 and 59 years and lastly one pilot was aged 60 years or older. All participants were male and all but one pilot were of German nationality. Hereby, eight pilots were flying for Lufthansa, three for Condor, three for European Air Transport and four for other companies. Regarding rank, 13 of the 18 pilots were First Officers (FOs), while two held the position of Senior First Officer (SFO) and three held the position of Captain (CPT). Additionally, the distribution of the highest flying license among the participants was as follows: 12 held a Airline Transport Pilot License (ATPL), four held a Multi-Crew Pilot License (MPL), and two held a Commercial Pilot License (CPL). Lastly, the participants attitude toward AI was measured based on a questionnaire proposed by Schepman and Rodway (2023). Hereby, the participants total mean was 6.83 (SD = 1.70) on a scale from one to ten, with group 1 having a mean of 6.86 (SD = 1.19) and group 2 of 6.81 (SD = 2.12). The detailed

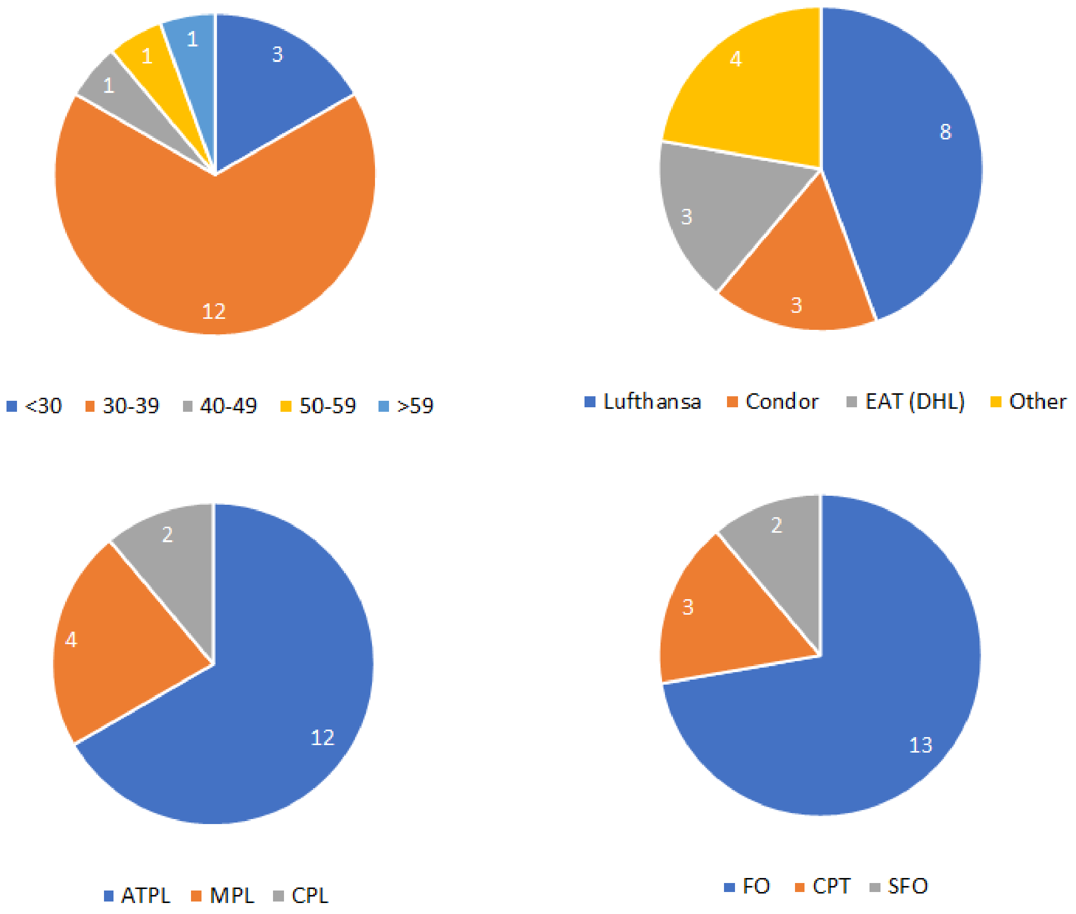


Figure 24: Distribution of Participants. Source: Own representation

rating can be seen in appendix B.

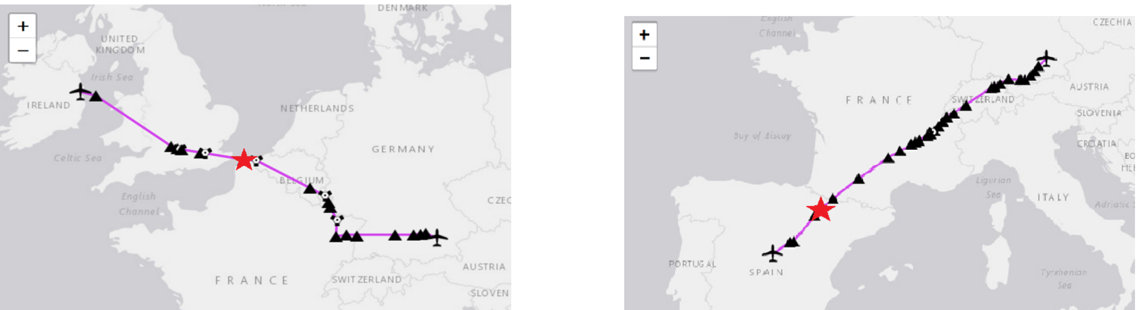
5.1.2 Apparatus

The experimental study was conducted using two distinct versions of the prototype interface designed in section 4 with different levels of explanatory detail.

The prototypes for both groups included the home page with the timeline and airport status, the zoomed-in view of the timeline, and the ‘Nearest Alternate Airport’ page depicted in figure 23. Group 1 was additionally shown the two additional explanatory pages that are depicted in figures 22 and 21b, the ‘Message Detail’ page and the ‘Airport Detail’ page.

Furthermore, both prototypes were integrated in a flat panel simulator, called the iSim, replicating the cockpit interface of an Airbus 321 (see figure 25). While not as immersive as full-flight simulators, this type of simulator presented suitable since they are very flexible in their interface adaptation and are suitable for rapid prototyping. The simulator

Figure 25: Flat Panel Simulator iSim. Source: Jakob Würfel (2022)



(a) Scenario1

(b) Scenario 2

Figure 26: Flight Route of both Scenarios. Source: Created with Online Flight Planner[3]

facilitated quick modifications to the cockpit interface, allowing for effective testing of different interface designs in a controlled environment.

5.1.3 Scenarios

In order to ensure suitable use-cases for the evaluation of the prototypes, two scenarios were developed with the help of two pilots and an aerospace engineer, as mentioned in section 4, so that the pilots could gain a greater insight into possible messages and displays of the application and to be able to analyze the influence of repeated uses. Therefore, these scenarios were designed to be comparable. Scenario 1 was imagined to take part toward the end of a flight from Dublin to Munich, shortly before descent, and scenario 2 was imagined to take part rather at the beginning of a flight from Madrid to Munich, right before the cruise phase as displayed in figure 26, marked by a red star. The messages of

	Scenario 1	Scenario 2
Inf	Icing condition	Tropoause
	Taxiway closure	Volocopter activity
Notif	ILS out of order	Severe weather enroute
	High CWC	Runway closure
Warn	CWC company limit exceeded	Expected closure of both runways

Table 3: Scenarios for the Final Evaluation. Source: Own representation

scenario 1, as shown in table 3, consisted of information announcing icing conditions, a closed taxiway at the destination airport, a notification for a strong Cross Wind Component (CWC) and a failed ILS, as well as a warning that the CWC is exceeded for landing. The notification for strong CWC is triggered when the airplane is 240nm from the destination and the corresponding warning is triggered in a distance of 225nm from the destination airport. The messages of scenario 2, as shown in table 3, consisted of information that the tropopause will be crossed, a volocopter activity, notifications of a closed runway due to snowfall and severe weather along the route that would likely have to be avoided, as well as a warning that both runways will likely be closed at landing time again due to the snowfall. Again the notification for the closed runway and the warning on the likely closure of both runways is triggered gradually, at a distance of 720nm and 695nm respectively. The exact scenarios and designs with all values can be found in appendix C.

Hereby, since the AI for IPAS for non-emergency scenarios was not yet developed, the data was simulated, similar to the Wizard of Oz method by Dahlbäck et al. (1993). Consequently, the data provided to the pilots in this study was generated by the author, with assistance from the aforementioned experts in generating the scenarios.

5.1.4 Research Design and Procedure

This study employed a mixed-methods between-subjects experiment design. Here, participants are only exposed to one version of the system, either with explanations (group 1) or without (group 2). Although, according to MacKenzie (2024), within-subject designs require fewer participants, Jhangiani et al. (2019) note that these designs are susceptible to carryover effects. Such effects arise when exposure to previous conditions affects performance in subsequent conditions (Jhangiani et al., 2019). This issue might be particularly relevant when participants, familiar with the explanatory details from an initial scenario, carry over gained trust to the following scenario, even in the absence of those

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[3] http://onlineflightplanner.org/ Last Accessed: 2024-06-24

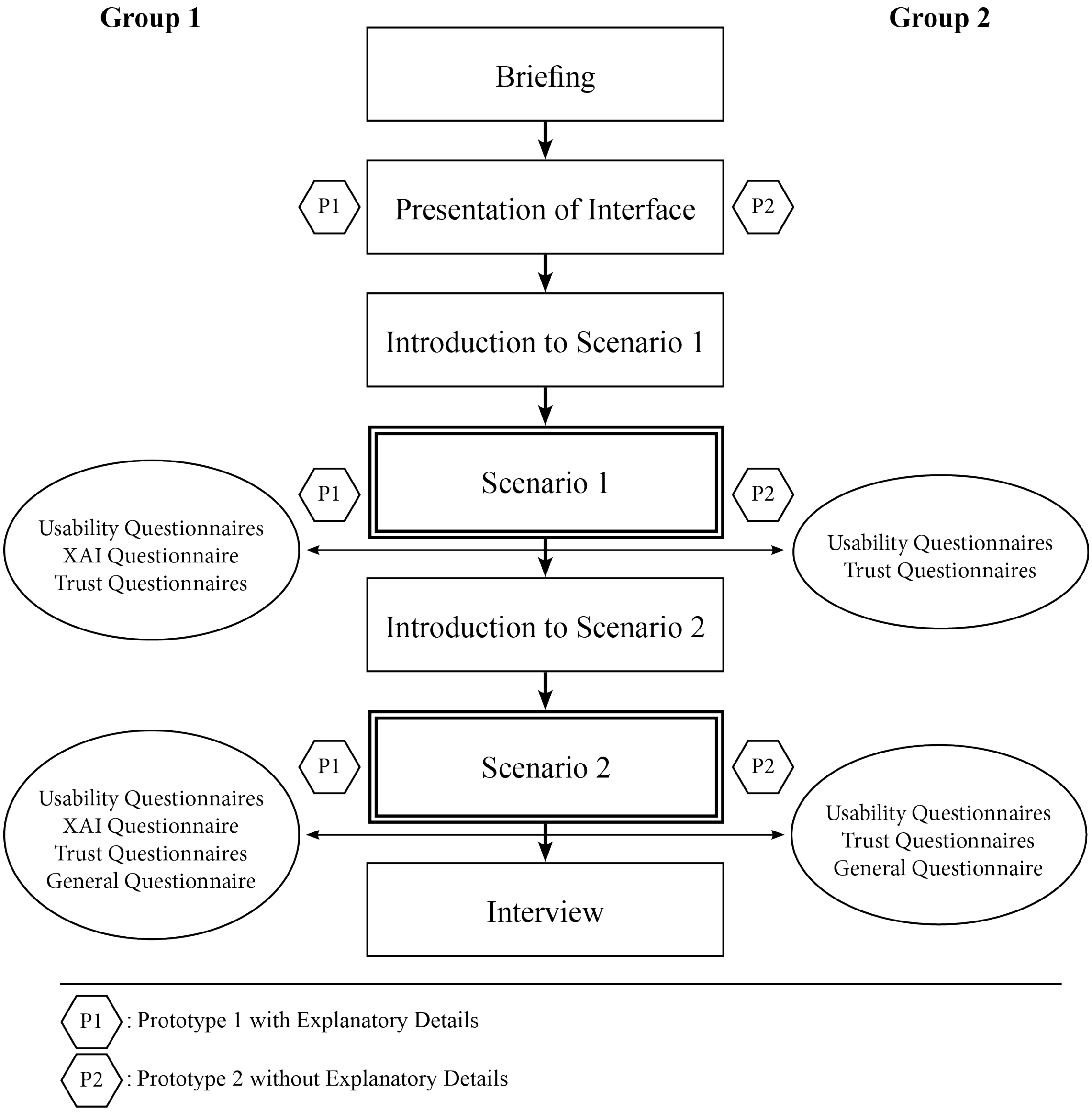

Figure 27: Experiment Design. Source: Own representation

explanations.

Moreover, a matched-groups designs, described by Bordens and Abbott (2010, p. 299 ff.), was utilized and accordingly the participants were divided into two groups based on age and attitudes toward AI. This was set up to ensure that groups were comparable in terms of age and potential biases or preconceived notions about AI, which could influence their interaction with and perceptions of the system.

Guided by five primary hypotheses, this methodology wants to determine if:

1. The pilots were willing to use the IPAS for normal operations.
2. The usability was satisfactory and what could be improved in this regard.

3. The UX improves between the two scenarios.
4. The pilots found the system trustworthy.
5. More explanatory details enhance the pilots trust in the system.

The study began with a comprehensive briefing about the aims and procedures, followed by an introduction to the simulator's interface and functionalities for normal operations. Following this, pilots were introduced to the first scenario and underwent it in the flat-panel simulator with their assigned system version. During the simulation, participants were encouraged to verbalize their thought processes via the think-aloud method, captured through audio and video recordings.

Immediately after the scenario, pilots filled out usability and trust questionnaires and provided immediate feedback and ideas for the 'Option Support Mode'. After completing the questionnaires, the second scenario described in section 5.1.3 was completed. At the conclusion of this scenario, participants received the same usability and trust questionnaires as well as additional questions regarding their general evaluations of the system and their opinion on design decisions. All questionnaires can be found in appendix A.

The study ended with a semi-structured interview for each pilot, aiming to delve deeper into their experiences with the system. These interviews were conducted to gain a more detailed insight into the participants experience with the system. Hereby, group 2 was also introduced to the explanatory pages and asked for their feedback.

The usability and trust questionnaire data was analyzed using the Mann-Whitney U test, a non-parametric method suitable for ordinal data from the same population. This test is ideal for small samples as it does not assume normal distribution and is robust against outliers and skewed distributions (McKnight & Najab, 2010; without author, 2023). Thereby, only results where a statistical significance was measured will be presented.

Lastly, qualitative data from the think-aloud protocols and interviews were transcribed with Adobe Premiere[4] and analyzed thematically to extract prevailing themes about the systems usability, desired functions and opinions on the explanatory details and their influence on pilots' trust.

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[4] https://www.adobe.com/de/products/premiere.html Last Accessed: 2024-05-12

5.1.5 Metrics

A variety of techniques are employed to assess usability and trust, with data collection occurring at different points throughout the study as described above. Since this is a mixed-methods approach quantative measures are used, as well as qualatitive measures. The quantative measures for the systems usability were the System Usability Scale (SUS) and Post-Study System Usability Questionnaire (PSSUQ) questionnaire. In addition to usability evaluations, trust and explainability are crucial aspects of user acceptance and interaction with systems. Therefore, a explainability and four trust questionnaires were utilized as well: the Human-Computer Trust (HCT) Scale, the SHAPE ATM Trust Index (SATI) trust questionnaire, a custom trust questionnaire developed based on the roadmaps by EASA (2020, 2023) and a general trust questionnaire.

The SUS, developed by Brooke (1995), evaluates the usability of systems, products, or services through ten 5-point Likert scale items. The PSSUQ consists of 16 7-point Likert scale items, where 1 represents a positive rating and 7 a negative rating, and measures user satisfaction in three subcategories: ‘System Usefulness’, ‘Information Quality’, and ‘Interface Quality’. In this study items 7 and 8 were excluded since they were not applicable. The explainability questionnaire, adapted from the explanation satisfaction scale of Hoffman et al. (2023, p. 4), assesses users’ satisfaction with AI system explanations on a 5-point Likert scale. Next, the HCT Scale by (Madsen & Gregor, 2000) includes 25 items on a 5-point Likert scale to evaluate users’ trust in technology, covering the aspects of perceived reliability, perceived technical competence, perceived understandability, faith, and personal attachment. Even though this questionnaire is designed to measure trust in a system that was in use for a longer period of time, it was chosen because of its reliability and good fit to the study. The SATI questionnaire by Goillau et al. (2003), part of the Single European Sky ATM Research program, is specific to aviation and measures trust in air traffic management systems through six statements rated on a 7-point Likert scale. Additionally, a trust questionnaire was developed based on the AI trustworthiness concept outlined by EASA (2020, 2023) and the European Commission (2019). Hereby, the questionnaire items were created to address all dimensions of trustworthiness through seven statements that the participants should rate on a five-point Likert scale from one, meaning strongly disagree, to five, meaning strongly agree. Lastly, a general trust questionnaire was used to directly measure trust and the effect of explanations, and a general evaluation and design decisions questionnaire was used to assess overall system satisfaction and functionality. All questionnaires and their respective questions can be found in appendix A.2.

For qualitative measures, the think-aloud method was utilized during the simulator sessions, as well as a semi-structured interview, as described in the previous section. The think-aloud method, which involves participants verbalizing their thoughts and decision-making processes while performing tasks, provides real-time insights on cognitive processes. The semi-structured interview allows for in-depth exploration of participants' experiences and perceptions, giving the opportunity for more open-ended feedback and ideas.

5.1.6 Ethical Considerations

The study adhered to ethical guidelines outlined by the DLR. Informed consent was obtained from all participants, and confidentiality was maintained throughout the study. Participants were assured of their right to withdraw from the study at any time without consequence. Furthermore, participants were informed about video and audio recordings and gave their consent.

5.2 Results

5.2.1 Exclusion of Participant

It must be noted that one participant's data had to be excluded from the final analysis due to an unexpected error in the UI during their session. This error disrupted the intended interaction and altered the participant's perception of the system. The anomaly likely influenced the participant's responses and interactions in a manner not consistent with other sessions, thereby skewing the data collected from this run. To maintain the integrity and comparability of the study results, this set of data was excluded as it no longer represented a controlled, consistent environment similar to that experienced by other participants.

5.2.2 Questionnaires

The usability assessment through the SUS yields scores of 75.28 (SD = 10.57) for group 1 in scenario 1, rated as B and 77.22 (SD = 10.70) for scenario 2, rated B+ and scores of 73.33 (SD = 4.25) and 76.11 (SD = 6.98) for group 2 in the respective scenarios, rated as B- and B. This result positions the IPAS for non-emergency scenarios prototype within the

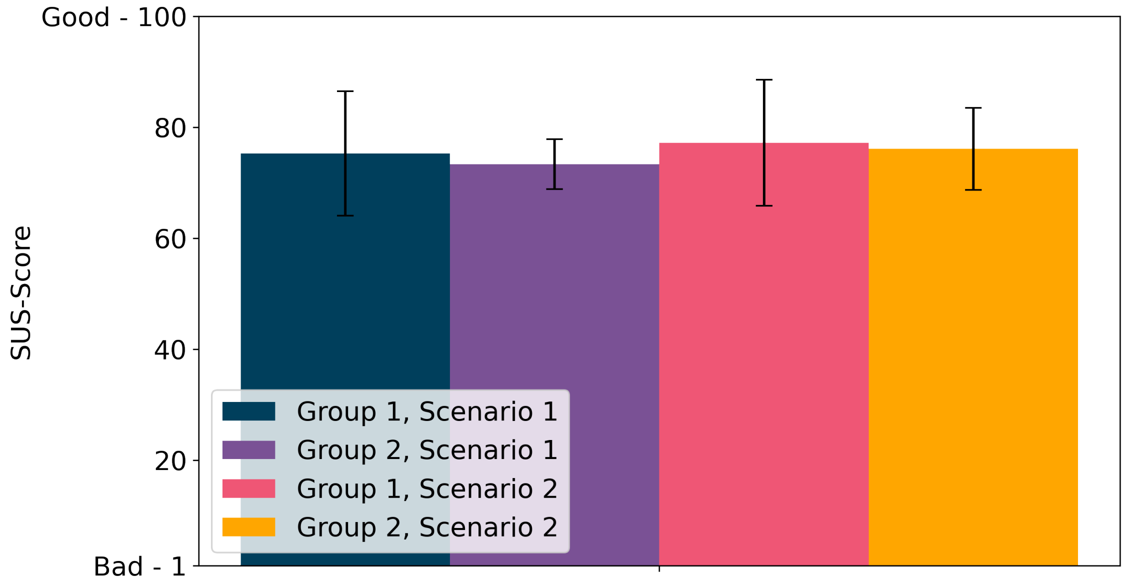

Figure 28: SUS Score of both Groups over both Scenarios. Source: Own representation

70th to 79th percentile relative to the benchmarked usability scores of Lewis and Sauro (2018), indicating that users generally regard the system as good in terms of usability. According to Sauro and Lewis (2012), a SUS score above 68 is considered above average and suggests that the system is more likely to be accepted by users. Therefore, the achieved mean score of 75.49 over both groups and scenario shows an above average UX and aligns with industry standards for acceptable interfaces.

The overall PSSUQ scores were 2.64 (SD = 0.86) in scenario 1 and 2.32 (SD = 0.68) in scenario 2 for group 1 and 2.81 (SD = 0.69) in scenario 1 and 2.33 (SD = 0.36) in scenario 2 for group 2, where lower scores represent more positive evaluations. This score compares favorably with the benchmark mean of 2.82 reported by Sauro and Lewis (2012). By this measure, the IPAS for non-emergency scenarios ranks overall slightly higher than average for both groups and scenarios. Detailed analysis of the PSSUQ subscores revealed that group 1 rated the ‘System Usefulness’ as 2.44 (SD = 0.93) in scenario 1 and 2.06 (SD = 0.65) in scenario 2, and group 2 rated the ‘System Usefulness’ 2.48 (SD = 0.59) in scenario 1 and 2.22 (SD = 0.38) in scenario 2, both lying below the benchmark of 2.8 by Sauro and Lewis (2012). ‘Information Quality’ scores were 2.89 (SD = 0.83), 2.50 (SD = 0.81) for group 1 and 2.86 (SD = 0.88), as well as 2.14 (SD = 0.47) for group 2, thereby also being lower than the benchmark of 3.02. The last subscale, ‘Interface Quality’ was rated 2.78 (SD = 1.07) and 2.63 (SD = 0.76) by group 1 and 3.33 (SD = 0.72) and 2.63 (SD = 0.51) by group 2. These results, particularly for group 2 in scenario 1, lie notably above the benchmark of 2.49. Especially, the question ‘This system has

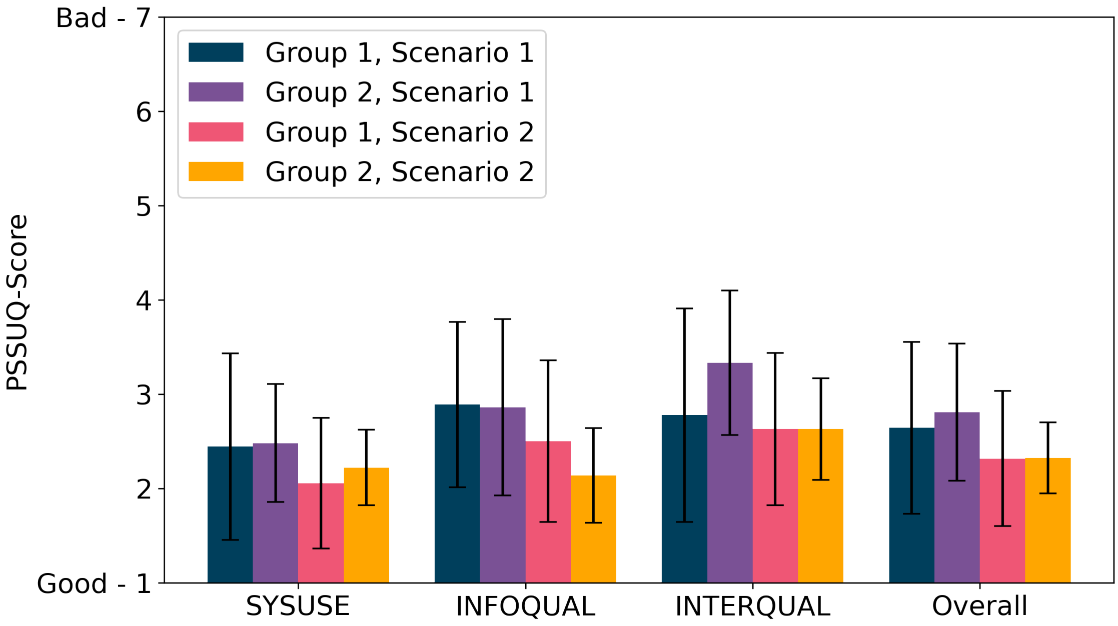

Figure 29: PSSUQ Overall Score and Subscores of both Groups and Scenarios. Source: Own representation

all the functions and capabilities I expect it to have' was rated comparably higher as can be seen in appendix B. Here, the Mann-Whitney U test revealed a significant difference between the groups' scores for this question in scenario 1 (U = 16.0, n1 = n2 = 9, P < 0.05). However, in scenario 2, the difference between the groups was not statistically significant (U = 33.0, n1 = n2 = 9, P = 0.52).

Scale	Benchmark			Session 1		Session 2	
	Lower Limit	Mean	Upper Limit	Group 1	Group 2	Group 1	Group 2
SysUse	2.57	2.8	3.02	2.44	2.48	2.06	2.22
InfoQual	2.79	3.02	3.24	2.89	2.86	2.50	2.14
InterQual	2.28	2.49	2.71	2.78	3.33	2.63	2.63
Overall	2.62	2.82	3.02	2.64	2.81	2.32	2.33

Table 4: Comparison of PSSUQ Results with Benchmark Means. Source: Benchmarks taken from (Sauro & Lewis, 2012)

Despite the utilization of explanations in group 1's interface, the quantitative data gathered from these measures did not reveal statistically significant differences in trust between the two groups except in one measure.

The overall HCT scores for both groups clustered around the midpoint of 3 on a scale of 1 to 5. Group 1 had a overall mean score of 3.37 (SD = 0.48) for the first scenario and a score of 3.43 (SD = 0.45) for the second one, while group 2 had a mean score of 3.24 (SD = 0.41) in scenario 1 and 3.26 (SD = 0.42) in scenario 2. Within the HCT, the understandability scores were relatively high, with group 1 scoring a mean of 3.85

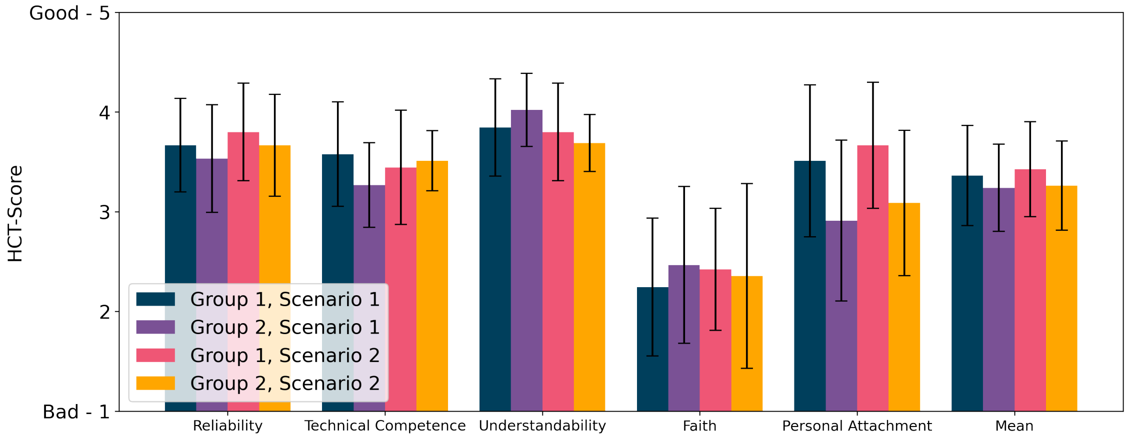

Figure 30: HCT Scores over both Scenarios and Groups. Source: Own representation

(SD = 0.46) and 3.8 (SD = 0.46) and group 2 scoring 4.02 (SD = 0.35) and 3.67 (SD = 0.27). Contrasting, the faith scores were notably low for both groups, with group 1 at 2.24 (SD = 0.65) for scenario 1 and 2.42 (SD = 0.57) for scenario 2 and group 2 at 2.47 (SD = 0.74) and 2.36 (SD = 0.87) as depicted in figure 30. Even though there was no significance found, as displayed in figure 30, the ‘Personal Attachment’ subscale revealed the most differences, with group 1 scoring higher at 3.51 (SD = 0.72) and 3.67 (SD = 0.60) compared to group 2 at 2.9 (SD = 0.76) and 3.09 (SD = 0.69).

The SATI results mirrored those observed in the HCT-Scale, showing no significant overall difference in trust between the two groups. Group 1 rated their prototype a mean of 4.5 (SD = 1.05) in scenario 1 and 4.67 (SD = 0.94) in scenario 2, while group 2 rated theirs 4.04 (SD = 0.87) and 4.37 (SD = 0.98), positioning the IPAS above the midpoint range of 3 used in this scale. Throughout all questions group 1 scored higher than group 2, except in question 6, but not significantly, as can be seen in figure 31 and appendix B.

In the custom questionnaire designed around the guidelines by (EASA, 2020) for trustworthy AI, the responses did also not demonstrate a significant difference in trust levels between the groups. The general mean score of group 1 was 3.30 (SD = 0.41) in scenario 1 and 3.48 (SD = 0.37) in scenario 2, while group 2 had mean scores of 3.48 (SD = 0.42) and 3.46 (SD = 0.48) respectively, as can be seen in figure 32. Both groups rated question 1 ‘I believe the system enhances my decision-making without undermining my control as a pilot’ relatively high with 3.89 (SD = 0.57) and 4.11 (SD = 0.57) for group 1 as well as 3.78 (SD = 0.79) and 3.89 (SD = 0.74) for group 2, as can be seen in appendix B. The question with the lowest rating was question 6 for both groups which asked if the participants believe that the system considers environmental well-being in its decision-making

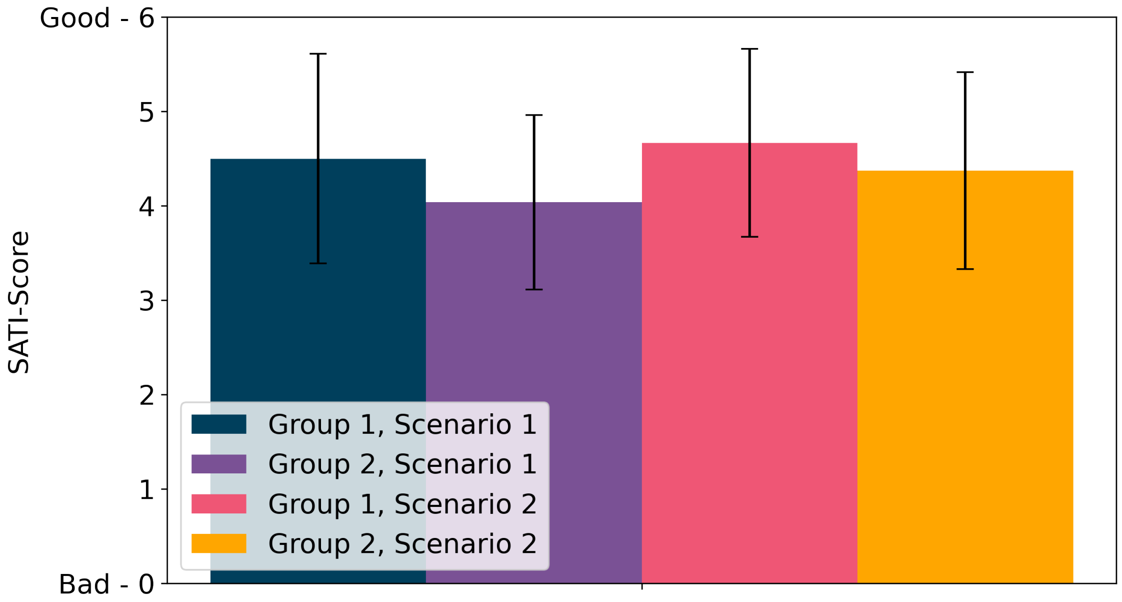

Figure 31: SATI Scores over both Scenarios and Groups. Source: Own representation

process. Hereby, group 1 had a mean score of 2.56 (SD = 0.50) and 2.44 (SD = 0.50). Group 2 rated this question 3.0 (SD = 0.47) in both scenarios as depicted in figure 32.

Furthermore, the general questions about trust in the system shown in figure 33 showed no significant difference in trust between the two groups, except in one question. Both groups rated their trust in question 1 3.67 with group 1 having a standard deviation of 0.82 and group 2 of 0.67 in scenario 1. In the second scenario both groups again had the same mean of 3.78 with group 1 having a standard deviation of 0.79 and group 2 of 0.63. In the next question group 1 rated their trust in the system 3.33 (SD = 1.25) and 3.56 (SD = 1.17) and group 2 rated it 3.56 (SD = 0.83) in both scenarios. When answering the question if the participants have enough information to trust the system adequately there was no significant difference in scenario 1 with group 1 rating it 3.11 (SD = 1.28) and group 2 rating it 2.67 (SD = 0.94). However, in the second scenario a significant difference between both groups could be measured (Mann-Whitney U = 61.5, n1 = n2 = 9, $P < 0.05$), with group 1 rating this question 3.78 and group 2 rating it 2.67, with a median score of 3 in group 1 and 2 in group 2. In question 4 group 1 rated the statement ‘The explanations help me to trust the system more adequately’ with a score of 4.00 in both scenarios, saying they agree. In the last question regarding trust asking if the participants believed to trust the system adequately group 1 rated this higher with 3.87 (SD = 1.03) and 4.00 (SD = 0.82) compared to group 2’s rating of 3.33 (SD = 0.94) and 3.44 (SD = 1.07).

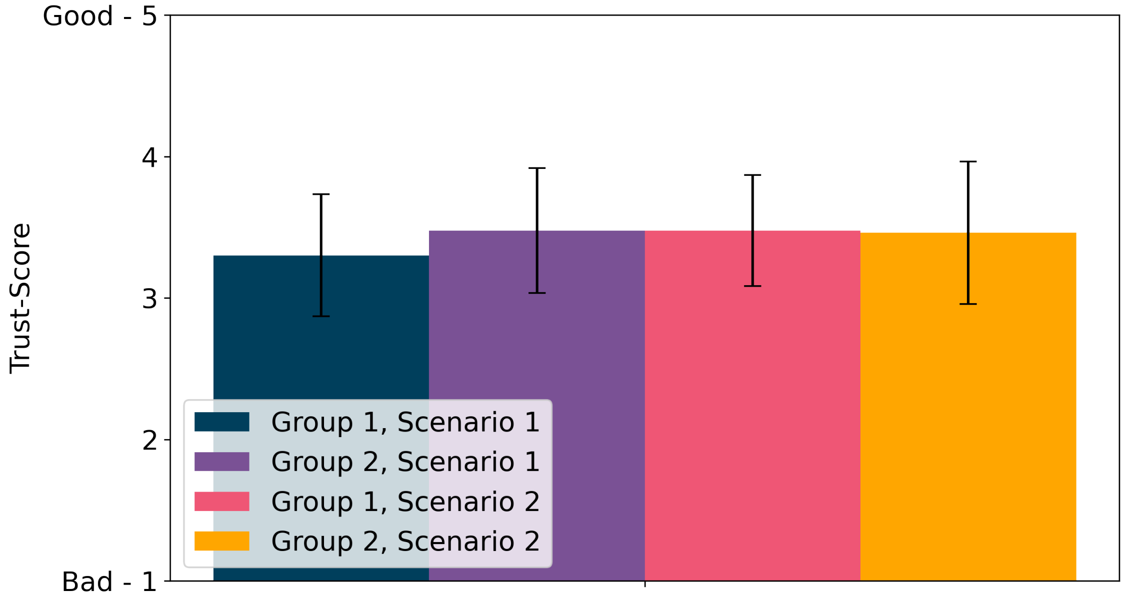

Figure 32: Trust Scores based on the EASA (2020) Guidelines for Trustworthy AI over both Scenarios and Groups. Source: Own representation

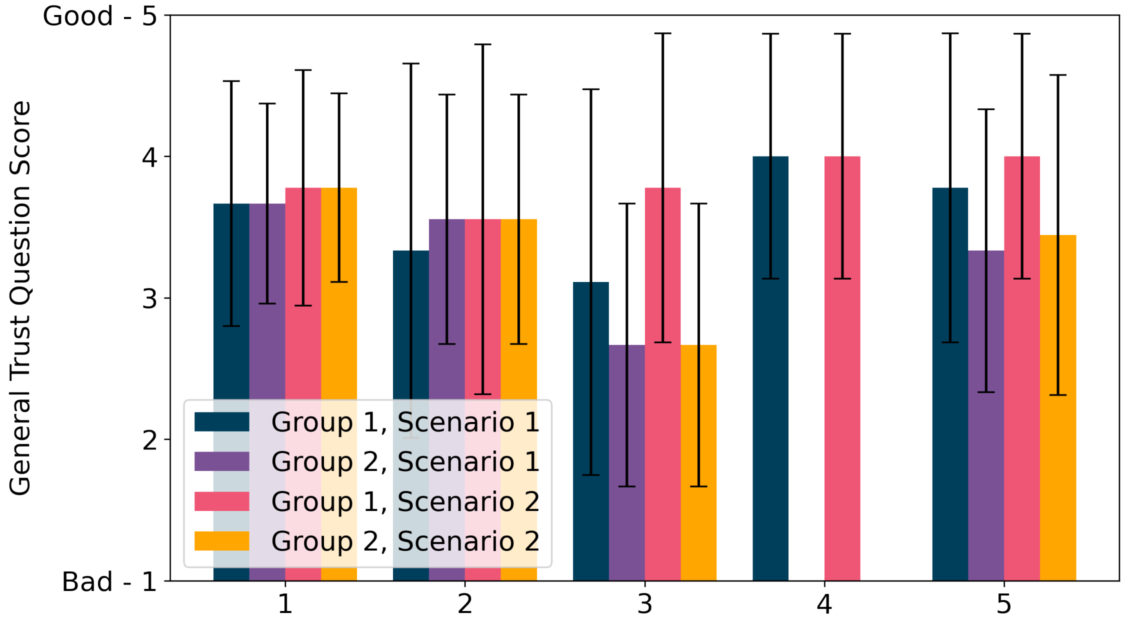

Figure 33: General Trust Scores over both Scenarios and Groups. Source: Own representation

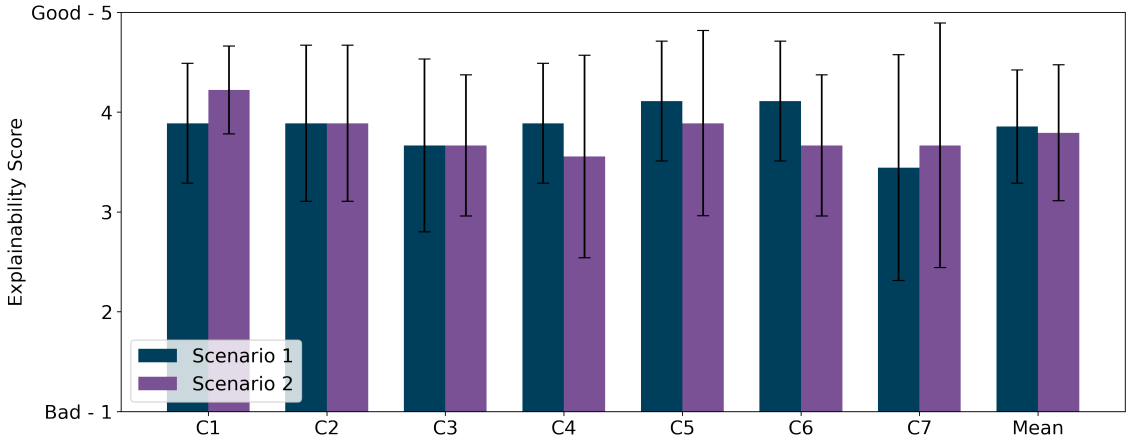

Figure 34: Explainability Questionnaire Results. Source: Own representation

Regarding the Explainability Questionnaire, group 1 rated it with a mean of 3.86 in scenario 1 and 3.79 for scenario 2. In the first scenario the highest rated questions were questions 5 and 6 with a mean of 4.11. In the second scenario the highest rated question was question 1 with a mean of 4.22. All questions were rated over 3.44 as depicted in figure 34.

Lastly, the questions of the general evaluation questionnaire revealed several key insights. Regarding regular use for mission support, 16 out of 18 pilots indicated that they would like to use the system regularly. Integration into normal flight operations was viewed positively by the same number of respondents. When asked if the explanations provided by the system made it more likely they would use it regularly, eight out of the nine participants of group 1 agreed and one disagreed. Regarding this, seven out of the nine pilots of group 1 and the same amount of group 2 preferred more explanatory details. Out of group 1, one participant wanted fewer details and one wanted the same amount they were given. From group 2, two were satisfied with the current level of explanations. The explanations were deemed helpful in understanding the system better by all the pilots of group 1 except one.

In terms of satisfaction with the IPAS, three pilots of group 1 were very satisfied, five were satisfied and one was unsatisfied. In group 2 seven pilots were satisfied with the system and two were neither satisfied nor unsatisfied.

In regard to the implemented functionalities, 15 out of 18 participants found the option to display the nearest alternate airports helpful, while three did not find it helpful. Remarkably, all pilots expressed a desire to sort or change the displayed alternates according to certain criteria. Moreover, an overview of all possible alternate airports along the route was desired by 16 out of the 18 pilots. In regard to the explanatory pages, all participants of group 1 stated that they found the ‘Airport Detail Page’ and the ‘Message Detail’ page helpful. Furthermore, ten participants deemed the close-up view not helpful, while eight said it was helpful.

Continuing with the specific features and design decisions to which feedback was gathered, the feature to hide message-icons after the aircraft has flown past them was favored by 56%, with 44% against it. Answering the question whether the pilots would like to be able to hide the icons themselves, 28% did not want this and 67% were favorable toward this option. Furthermore, the distinction between information, notification and warning was clear to all pilots except one. Similarly, the visual distinction between these categories was clear or unclear to the same amount respectively. More information on why a message was classified as information, notification or warning was desired by 33% of pilots, while 44% did not want this information and 22% were unsure. Nevertheless, the division into these categories made sense to all 18 respondents. Finally, auditory feedback for new messages was favored by one pilot for all messages, six wanted it only for notifications and warnings, eight only for warnings, and three did not want auditory feedback at all.

5.2.3 Think-Aloud Findings

During the scenarios, the pilots often reacted similarly to the various events. When it came to the activation of the anti-ice system, the pilots stated they would follow the instructions if deemed necessary, since they can independently assess the need based on real-time conditions. For the message on volocopter activity, which operate at much lower altitudes, no immediate action was required and most suggested that this information might be omitted as it is not relevant to them. In regard to the notification and warning of the crossed CWC limit, most pilots said they would start preparing for a potential diversion and monitor how the situation develops and contact their operation control center for instructions, since they were able to remain largely on their planned route while making necessary preparations. Three pilots already decided on diverting.

In scenario 2, when presented with the tropopause information, pilots generally received it without strong reactions. Some considered it unnecessary, while others found it useful for flight planning and listened to the recommended actions. Recommendations regarding turbulence were predominantly followed by pilots either by adjusting flight levels or the speed. Some pilot of group 2 wanted to additionally check in with ATC if the turbulences were really registered. Two pilots said that they would wait until the level is reached and only then, when turbulences are registered, would they adjust the height and speed. Moreover, the weather front notification was registered by all pilots, though immediate action was not taken, due to the weather event being more than an hour away. Nevertheless, when asked all pilots said they would rather have this information earlier than later allowing them to plan accordingly. In regard to the warning of scenario 2, all pilots began preparations for potential evasive action but continued their current path, as they were still at the beginning of their planned flight and still in Spain. One pilot stated that he would directly search for an alternate, although again near Munich.

Concerning the pilots' interaction with the system, during the think-aloud sessions, it was obvious that the pilots had mostly no trouble interacting with the system. Notably, individuals in the group with explanations (group 1) engaged more deeply with the application, particularly appreciating features such as the data source and 'Airport Detail' views. Participants of group 2 on the other hand missed this information. For example, participant 18 specifically asked where the system gets the weather information from and four pilots of group 2 asked for some sort of original data source. Moreover, most of the participants in group 2 clicked on the airport status to get more information on the airports, even though this function was not introduced to them in the briefing.

In terms of usability, the interaction and think-alouds revealed problems regarding the IA. Some participants wanted to see the destination alternate airports earlier, as participant 1 specifically noted that he would have liked to see them at the beginning of the scenario. Others looked for the destination's alternate airports on the 'Nearest Alternate Airports' page.

Another problem that was noticed during the simulator session was that three participants were not able to directly find the sidebar for navigating between the two main functions or did not recognize its use. Those participants were looking for a navigation option in the header.

In addition, when interacting with the prototype in group 1, it was noticeable that several participants forgot and did not realize that they could click on the messages to obtain more precise information and explanatory details about the message. Accordingly, those participants only used this function when they were reminded of it. Moreover, regarding the ‘Message Detail’ page, three participants of group 1 who utilized this page, wished that they were able to click on the data source and be directly redirected to the original source, which was confirmed in the interviews.

Furthermore, participants gave feedback on user interactions with the messages and the amount of text presented. Two participant expressed that the volume of text demanded significant attention, which could be overwhelming. However, other participants found the amount of text to be acceptable and necessary, indicating a divergence in user preferences.

Another common issue identified was the failure to notice new messages when only the number on the icon changed. This occurred despite the presence of pop-up notifications, suggesting that the visual cue of the changing number was insufficient to capture users’ attention during their ongoing tasks. Regarding pop-ups, multiple users reported that these notifications could be somewhat distracting, interrupting their workflow. One pilot recommended that pop-ups should be included, but should not occupy the entire screen. He suggested more subtle notifications that would allow pilots to continue working without significant interruption while ensuring that the notifications remained noticeable and did not fade into the background. Furthermore, it was noted by multiple participants that they wished for read messages to be marked.

Lastly, the participants were each asked what functionalities and information they wished for in the ‘Option Support Mode’. Thereby, all pilots expressed their desire for weather information. Many also wished for other details that are included in the current ‘Airport Detail’ page like the runway in use, the runway length and condition, as well as the approach procedure. Furthermore, seven pilots said they would like more operational information, like passenger transport options. In case of a diversion, six pilots mentioned that they would appreciate overview about the capacities of the surrounding airports and an indication where the other aircraft are headed. Hereby, three pilots also added that they would like a fuel overview, specifically that they would like information on how much fuel it takes to get to the alternate airport, with how much fuel left they are estimated to land and how many approaches they can fly until they finally need to divert. In this regard, one pilot mentioned the display of a so called Equal-Time Point, that is a point on the route which is located at the same flying time from two suitable enroute alternate airports (SKYbrary, 2024a).

5.2.4 Interview Findings

During the interviews, the insights from the think-aloud sessions and the questionnaires were further emphasized. All but two participants stated that the IPAS would integrate well into their regular flight operations and the same number of respondents expressed a willingness to use it. When asked how they liked the design most participants said that they appreciated the minimalist design and clarity, finding it intuitive. Hereby, as already measured through the general questionnaire at the end of the study the distinction between different types of messages was clear to everyone except one and considered useful and helpful. Some pilots found the idea to filter out certain types of messages to be a useful feature. However, others expressed concerns about withholding information from their colleagues in the cockpit when sharing one IPAS display.

Regarding the displayed 'Nearest Alternate Airports' page, 16 out of the 18 participants appreciated this page and found it helpful, as stated in the general questionnaire. Nevertheless, multiple ideas were generated to further improve this page. Firstly, an idea was introduced to be able to scroll along the map and be able to select a specific area where possible alternate airports are shown. Secondly, a participant suggested in this context to be able to pin airports and delete them via common swiping gestures. Hereby, an idea was introduced as well to be able to select two airports and get a direct comparison of their specific status and corresponding data. Furthermore, it was proposed multiple times that all possible alternates were to be shown on the map, with their status marked by a circle in their respective IPAS rating color: green, amber or red. Those airports on the map should then be selectable. Next, multiple participants wished for the ability to enter the International Civil Aviation Organisation (ICAO) code of a desired alternate airport. Those codes are used to identify aerodromes. Furthermore, the idea of integrating the destination alternates into the 'Nearest Alternate Airports' page was supported by all participants.

Even though the zoomed-in view was voted to be unhelpful by ten participants in the general questionnaire, during the interview, the participants stated that it was a unnecessary feature for the specific scenarios but that this functionality could be useful for long-haul flights or if there are many messages enroute.

Moreover, 13 of the participants stated that they trusted the system. Notably, four participants said that the experience with the system will play a particularly important role regarding their trust in it. For example, participant five stated: "I think that if you have a good experience three times, then you think the system is very good. If you have a bad one twice, you question it all the more. I think that experience plays a very big role". Furthermore, some participants stated that they would verify the data.

Contrary to the questionnaires results, the additional explanatory details were perceived as overall positive and the participants confirmed that they believe they help them to trust the system better. Hereby, one participant said: ‘That was extremely good and I found that I could really understand how the message came about. And I also realize how that helps with basic trust’. Another stated that at first, he did not trust the system, but with more information and explanations, his trust in the system increased. In this regard, specifically the data source was emphasized to help user trust. Everyone from group 1 stated that they appreciated this information, whereby some said it could be even more detailed. Participants of group 2 explicitly asked for such information, as participant ten stated: "[With some messages] I somehow lack the source of where it comes from [and] if the information is evidence-based [...]." Generally, when asked about it, participants of group 2 also stated that they believe such information will foster greater trust. Thereby, seven participants also expressed a desire for the inclusion of direct links to original sources. In addition to the data source, a timestamp for the information and messages was desired by the participants, especially for weather information. Regarding this, one participant mentioned that the information needs to be updated regularly, suggesting that having the latest updates is important and that a timestamp would be beneficial.

Conversely, the participants stated that they are not sure how much they will gain from the confidence level. One participant said it might be useful if the system shows when it is uncertain but leans in a particular direction. However, they were unsure if this might cause confusion in everyday operations. Several participants confirmed that experience is the most important factor in being able to assess this value, but that they could not determine whether this element itself is useful to better assess the system and trust it more appropriately.

The last element that should contribute to the explanation of the IPAS’s assessment and provide more context is the ‘Airport Detail’ page. As confirmed in the questionnaire, all participants found this page helpful, but there was some disagreement about the design. One participant said that he particularly likes the graphical representation with the CWC, while another would rather like a conventional presentation. In addition, one participant emphasizes that he likes the grouping and that it makes it clearer because it helps to know where to look for information, while others found it to be a bit cluttered. In this regard, one participant suggested a function that allows to switch between the graphical and conventional data display.

Hereby, most participants also favored an additional, on-demand explanation of the weighting that the IPAS rating represents that was researched by Schog (in press). In particular, participants would appreciate more information on how the individual factors are weighted in the IPAS rating. Participant one, said that this function could also help to check whether an important factor has been overlooked. When selecting an alternate airport, the IPAS would be like a third opinion in the cockpit, with which the crew could verify or question their own assessment.

Lastly, further functionalities suggested included displaying common short tracks that are frequently approved by ATC on the map. In regard to finding suitable alternate airports participants also suggested displaying where other aircraft are headed during diversions and providing more detailed information on fuel calculations, as mentioned before in the think-alouds.

5.3 Discussion

5.3.1 Discussion of Usability Results

The results clearly showed a willingness among pilots to use the IPAS for non-emergency operations, with 16 out of 18 participants affirming this. Regarding the systems usability, the findings indicate that users generally found the system to be satisfactory. However, while this score is good, it still proves room for improvement. Studies like that of Bangor et al. (2009) indicate that a SUS mean of 85.5 or higher is indicative of excellent usability. This suggests that while the IPAS performs well in terms of usability, enhancements could elevate the UX from good to excellent. Hereby, rethinking the IA and how the division between emergency and non-emergency modes is presented to the user may play an important role in improving the usability. Additionally, implementing the proposed changes that are presented in section 6, should further improve user-satisfaction.

Hereby, a feature the participant appreciated was the implementation of the three classification categories. All but one participant understood the differences in messages and stated that this classification helped in gaining a better overview. However, this clarity in classification might be due to the controlled environment of the study, where the classifications were given with the help of domain experts and therefore inherently aligned with the participant's expectations. Translating this system into a real-world application with an AI-driven classification might pose multiple challenges. Firstly, those classifications might be less straightforward and harder for users to interpret. Additionally, developing an algorithm capable of accurately classifying these events poses a significant challenge. The algorithm would need to account for a wide range of variables and context-specific details to categorize events accurately based on their influence on the flight and severity. Therefore, while the initial reception of the event classification is promising, ensuring the same level of user satisfaction and understandability in the AI-based implementation could potentially require further refinement and research.

Further elaborating on usability, the system achieved an above average score for the PSSUQ in all scales except in 'Interface Quality'. As elaborated in section 5.2, the main reason for this was statement 15 'This system has all the functions and capabilities I expect it to have', showing a significant difference between group 1 and 2 in scenario 1. As noted in the think-alouds, the participants wished for more information about the airports and underlying data for the IPAS rating, which might be the reason for the particularly low rating and difference in both groups, as group 1 was provided this information. Furthermore, many additional features were brainstormed, and these user needs are still present, which might be the reason why both groups rated this question comparably lower.

The lack of significant differences observed in scenario 2 could be due to several factors. One possibility is that the system's limitations were more apparent with the messages of scenario 1, even though the scenarios were designed to be comparable. Moreover, in scenario 2, users might have adapted to the system's functionality and become more familiar with it. Generally, it can be derived from this that the additional explanations are desired from participants and that even more functionalities are wished for, which is reflected in the think-aloud and interview results.

Moreover, even though there is no statistically significant difference between the usability results between the scenarios, a tendency can be seen in figure 28 and 29 that the usability rating is increasing with multiple uses. This trend suggests that repeated exposure to the system might lead to a gradual increase in user satisfaction and proficiency.

Furthermore, within the HCT questionnaire a difference between both groups is noticeable in the subcategory 'Personal Attachment'. This was driven by responses to the questions ‘I find the system suitable to my style of decision making’, ‘I like using the system for decision making’ and ‘I have a personal preference for making decisions with the system’, as can be seen in the results in appendix B. This indicates that the explanatory details might lead to a greater preference for using the system, as it aligns better with the pilots’ decision-making style, further indicating that the explanatory details not only enhanced personal attachment but also have a positive impact on usability, making the system more user-friendly and effective.

5.3.2 Discussion of Trust Results

Next, when evaluating the trustworthiness of the system, all questionnaire results were positive. The average trust scores were above the midpoint, indicating that pilots generally have higher than average trust in the IPAS. Additionally, in comparison to a study by Papenfuss et al. (2020), which reported an average SATI score of 3.7 among air-traffic controllers, this studies results suggest a higher level of user trust with the SATI in the IPAS, although it should be noted that the trust levels might differ between the two professions, making direct comparisons difficult.

This above average level of trust may be due to a high organizational trust or a generally positive attitude toward AI demonstrated by the majority of participants. Nevertheless, the results of custom questionnaires are difficult to interpret, due to the lack of benchmark values, which should be kept in mind in this regard.

Moreover, in some questionnaires like the general trust questionnaire high standard deviations could be observed in the responses which suggest significant variability in trust levels among participants. In particular, group 1 had a notable outlier: Participant 11 often rated the questions 1 to 2 points lower than all other participants, especially in the general trust questionnaire where such a high standard deviation was measured. This participant was also the only one of group 1 who expressed unwillingness to use such a system. Similarly, group 2 had an outlier in participant 6, whose overall ratings were lower than those of the other participants of group 2. This variability could have multiple reasons. For participant 6 of group 2, those ratings might be due to his particularly low attitude toward AI, as can be seen in appendix B. The same cannot be said for participant 11, who rated his attitude toward AI averagely. Here, the particular low ratings may be attributed to his perception of insufficient data and explanations provided by the system.

In the interview, participant 11 emphasized the high importance of having access to raw data and expressed a desire for more detailed information. He stated that the given explanatory details increased his trust, but not to his desired level. Accordingly, these high standard deviations highlight the need for a more nuanced understanding of the factors influencing trust and suggest that while overall trust is positive, individual perceptions can vary widely. The ratings of participants 6 and 11 indicate that not all pilots share the same level of trust, and understanding the reasons behind such disparities is crucial for improving the system's acceptance and trustworthiness.

Moreover, regarding the HCT questionnaire, comparably low faith scores could be observed. This could be attributed to the training of pilots, that teaches them to critically assess information, particularly in ambiguous or uncertain situations (Federal Aviation Administration, 2009). Moreover, pilots' reluctance to depend blindly on automated systems is desired, since research indicates that high levels of trust and reliance on automation can lead to complacency and automation bias, where significant system errors may be overlooked (Parasuraman & Manzey, 2010).

When examining how the trust is influenced by the presence of explanatory details and therefore the difference in the groups, the results were mixed. Group 1 had slightly higher or the same scores in most statements compared to group 2, but there was no significant difference in trust levels between the groups, except when it came to the perceived adequacy of information provided to increase user trust. Here, as shown in the previous section, participants in group 1, who received additional explanatory details, felt they had more sufficient information to trust the system adequately in the second, but not the first scenario. The reasons for this could be due to several facts like the difference in the scenarios, using the system more often or the higher utilization of the explanation page. However, there was a specific shift in rating for participants 5, 8 and 15. Notably, participants 8 and 15 did not remember the function of the 'Message Detail' page and only started using it in scenario 2, as they were reminded of it, which is what could have influenced their changed rating. This interpretation is supported by the results of the question 'The explanations help me to trust the system more adequately' from the general trust questionnaire in figure 33. Only group 1 answered this question, and the results show that participants agreed that the explanations helped them trust the system more adequately. Furthermore, even if there is no significant difference between both groups in the question 'I trust the system adequately', it is noteworthy that the average mean score of group 1 is higher than that of group 2. Summarizing, these results indicate that participants in both groups generally had a high level of trust in the system. While group 2 had basic trust in the system but no firm evidence to justify adequate trust, group 1 had more certainty in the adequacy of their trust due to the additional explanatory details.

The quantitative and qualitative results for trust indicate that while there was an individual perception of increased trust due to the explanations, this did not translate into statistically significant differences across the broader trust measures used. This suggests a complex relationship between the perceived and measurable impacts of design elements on trust, highlighting the need for further exploration into how interface design can effectively enhance user trust in environments like aviation. The discrepancy between the quantitative findings and the qualitative feedback could be attributed to several factors. The controlled, laboratory setting might have instilled a baseline level of trust in the data provided, reducing the perceived necessity for further explanation. Moreover, the hypothetical nature of the data, which was fabricated for the experiment, might have been inherently clear and understandable, thus diminishing the apparent value of additional explanations. Additionally, the traditional questionnaires used might not have been sensitive enough to capture the nuances of how explanatory details influence user perception and trust.

These findings generally encourage a critical evaluation of how trust is measured. It points to the necessity of integrating both qualitative and quantitative approaches to fully understand the dimensions of trust in HAI.

5.4 Limitations

This study has several limitations that must be acknowledged. Firstly, the small sample size of the study might impact the generalizability of the findings and reduce the statistical power, potentially limiting the ability to detect significant effects. Nevertheless, it is important to note that this study was designed to provide preliminary insights and guide future research. The data collected from this study can still offer valuable trends and patterns as a base for larger-scale studies.

Another limitation is that only men participated in the study. While this demographic characteristic mirrors the predominantly male pilot population, it still restricts the generalizability of the findings to all pilots. Furthermore, it should also be noted that all but one of the participants were pilots of German nationality. Possible cultural differences are therefore not covered in this study.

Moreover, the voluntary nature of the study likely attracted individuals with a particular interest in AI, automation, and technological advancements. This self-selection bias means that those who are less interested or more skeptical about these topics may be underrepresented. Consequently, the sample may skew toward more favorable perceptions of AI and automation.

Another limitation of this study is that all measures were subjective, based on participant self-reports. Future research should consider incorporating objective measures for more reliable and consistent data.

The study's use of a flat panel simulator and artificial scenarios is another limitation, as these conditions might influence how participants perceive the system and their trust in it. These simulated environments do not perfectly replicate real-world conditions, which may affect the perceived risks and perceived trustworthiness of such a system.

Lastly, the balancing of groups in studies with a between-subject design poses challenges (Jhangiani et al., 2019). This difficulty was reinforced in this study because participant data like age, rank, and their attitude toward AI were collected only on the day of the study. Consequently, it was not possible to predict the characteristics of participants on upcoming days, leading to potential imbalances, despite the taken efforts.

6 Recommendations and Future Directions

6.1 Recommendations for Usability and Functionalities

The study offered several insights for improving the IPAS interface for non-emergency scenarios. Participants appreciated the simple interface, despite their need for extensive background information. The solution of presenting information on-demand was well-received in this regard, balancing simplicity with the desire for detailed data.

A main point that was noted by the participants regarding the systems usability, as described in section 5.2, is the IA of the destinations alternate airports. Accordingly, these should be integrated into the ‘Nearest Alternate Airport’ page. Hereby, it should be considered whether the strict division of modes should be presented to users in this form. In the event of an emergency, e.g. a warning could be displayed on the timeline as well, indicating that a technical error has been detected. This message could then be linked to the ‘Nearest Alternate Airports’ page. The requirements for these airports could be displayed on a separate page, which could also be accessed in non-emergency scenarios to show the general technical constraints of the aircraft, which could help users become more familiar with this page.

In addition, as all participants wished for an option to sort the airports according to a selectable criterion, this function should be integrated to the ‘Nearest Alternate Airports’ page. In general, according to the results presented in section 5.2, the ‘Nearest Alternate Airports’ page should be more interactive so users can scroll in the map, select an area where they want to search for alternate airports, be able to input the ICAO codes of airports themselves and possible pin, delete or compare specific airports. Accordingly all alternate airports could be included in the display with their status indicated by the IPAS’ rating colors. The capacity of airports could hereby also be indicated.

The map should furthermore be expanded. Thunderstorm cells, possible shortcuts and other aircraft’s routes could be included via multiple layer on the map. Those functionalities should be tested.

Moreover, the navigation via the sidebar could be reconsidered and the space of the header better utilized for this purpose. Since the use would be learnt in training, this is not too much of a problem, but the more intuitive the design, the easier it is to use the system

(Blackler et al., 2002). Hereby, new ways should be investigated to draw users' attention to new messages along the timeline, as the current display through a message counter and pop-ups did not seem sufficient. As described in section 5.2, many participants wanted read messages to be marked. This could be indicated with a color, a check mark or contrast highlighting, similarly to known messenger services. This function could help to gain a better overview and additionally solve the problem of new messages not being noticed. Accordingly, a design realization of the read marker should be implemented and tested in the following.

Regarding the results on the design decisions, it should be investigated in more detail whether important information is lost if message icons are hidden when events are in the past and whether a manual option to hide messages would be more suitable. Finally, since the majority of participants wanted auditory feedback for new messages but not for other information, this feature should be included and its impact explored.

Another element that requires further investigation is the use of the zoomed-in view. During the scenario, pilots indicated that the zoomed-in view was not as beneficial because the scenarios did not necessitate its use. This suggests that its utility may vary depending on the length of the flight and the number of events occurring. Accordingly, this function could be tested in a more appropriate setting where its use might be more beneficial.

6.2 Recommendations for User Trust

Regarding recommendations to improve user trust, displaying a data source proved to be a good way of increasing confidence in the system.

Furthermore, the 'Airport Detail' page should be integrated into the final design, as an option to provide more on-demand information about airports to help pilots better assess situations. Given differing preferences for the 'Airport Detail' pages design, a switchable representation to accommodate both conventional and graphical views could be implemented and tested.

Hereby, the idea of adding the data source to the 'Airport Detail' view for all displayed information could also be included and tested.

Additionally, the functionality to click on the data source to view the original source should be added and tested as well, as this was predicted by the pilots to promote trust. Moreover, this could also offer the possibility of easier access to various manuals and handbooks. With regard to the pilots' trust in the IPAS, the usefulness of a confidence scale should be examined more closely, as some said that they would have to use the scale over a longer period to assess its usefulness and to check whether it matches their own judgement and actual experience.

Concerning the classification of messages, the majority of participants did not want any further explanation as to why a message was classified as information, notification or warning and preferred an explanation on how the classification generally works in the manual. Accordingly, this information should be added to the manual and discussed in training. Nevertheless, as discussed in section 5.3, the implementation of a real classification algorithm needs further exploration.

Generally, to better understand the dynamics of the influence of explanatory details on trust future studies could investigate the use of other questionnaires, more specific to the hypothesis at hand. Furthermore, the design of the study might be rethought to a design where participants are exposed to both versions of the system. This would allow a direct comparison through the participants. Nevertheless, order effects might present themselves in those designs, which might cloud the clarity of the results, which was the original reason to deviate from such a study design. Another possibility could be extending the study over several days or weeks, which could provide further insights into how trust and usability perceptions develop over time and how sustained exposure to explanatory details might influence trust in a more realistic setting.

6.3 Further Research Topics

In the next step, the feasibility of integrating user feedback to refine the AI, as per Microsoft (2019), could be investigated. Hereby, users could give feedback if the predicted events became true and whether the following recommendation was approved or followed. However, the recommendation of Microsoft (2019) to personalize the user's experience by learning from their actions over time is not recommended, as this was strongly opposed by participants during the interviews. Additionally, many of the recommended design principles by Microsoft (2019), such as conveying the consequences of user actions and notifying users about changes, can be integrated into the training process. Microsoft (2022) further elaborated on responsible AI development, which should be taken into account when developing the AI module and overall functional system.

Lastly, other functionalities that should be explored are displays regarding remaining and needed fuel and more detailed overviews of operational information of the airports, since those were wished for by multiple participants. Thereby, the exploration of the other identified user needs and ideas could be investigated further to enhance the IPAS for non-emergency operations. Topics for further research could include integrating the system into briefing processes to monitor and summarize key information. Additionally, research could explore forecasting probable approach routes and tracking miles, as well as suggesting optimized flight paths and speeds to improve fuel efficiency and reduce emissions. Finally, the potential of IPAS to streamline and enhance communication between aircraft, ATC, and other relevant systems could be investigated.

7 Conclusion

In this thesis, the potential applications of an IPAS for non-emergency situations and the design options for such a system were explored. Thereby, the main objective was to identify the key functionalities of the IPAS and the willingness of pilots to use such a system, to explore how the IPAS might be designed to ensure good usability and trustworthiness, and to determine whether the inclusion of explanatory details helps to enhance trust in the system.

To achieve this, a workshop was organized with experts in the field who brainstormed different ideas for areas of application and functionalities for the IPAS in non-emergency scenarios. These ideas were then grouped and evaluated, and ultimately, the MMAF was developed as the main element. The IPAS should hereby continuously analyse and evaluate all information along the route, identify potential challenges and communicate them to the pilots. It should then provide recommendations on how to react to these events. Additionally, the IPAS for non-emergency scenarios is intended to identify and evaluate alternate airports in the area. Based on those ideas, a prototype was developed, taking into account the guidelines discussed in section 2. The development of the IPAS prototype followed a user-centered, iterative design process. Hereby, two versions were developed: One with explanatory details added to explain all messages and airport ratings and a version without those explanatory details. The two versions were then evaluated in a final mixed-methods, between-subject study with 18 pilots. The pilots were divided into two groups (one with explanatory details, one without) and were required to complete two scenarios in a flat-panel simulator. Hereby, they were given several questionnaires on usability and their trust in the system, and an interview was conducted at the end.

This study showed a high willingness of participants to use such a system, although the selected sample has its limitations. Furthermore, the designed system proved to have a good usability, although some potential improvements were found. In particular, the IA needs to be adjusted, possibly removing the division between emergency and non-emergency mode. In addition, the questionnaires revealed an average level of trust in the IPAS for non-emergency situations in both groups, which did not differ significantly between the groups. However, it was noticeable that group 1 stated that they felt that they had enough information to trust the system adequately, compared to group 2 which did not. Different to the questionnaires results in the think-alouds and interviews revealed that the pilots felt that the explanatory details increased their trust in the system and helped them to better assess it. In particular, the data source and airport detail page were perceived as helpful in this regard. The confidence scale was found to be rather unhelpful and more experience would be required to properly assess its usefulness. Additionally, the version with explanatory details seemed to better fit the pilots' decision-making style, thereby positively influencing its usability.

This difference between the quantitative and qualitative findings indicate the necessity of integrating both approaches in order to gain a comprehensive understanding of the dimensions of HCT and the need for further research.

In conclusion, many useful functionalities were explored in this thesis, which were well received and said to integrate well into pilots' workflow. Nevertheless, while the system has a good usability, there are some suggestions for improvement and there is further need to explore the influence of explanatory details on user trust.

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A Questionnaires

A.1 Demographic Questionnaire

Welcome to the HMI laboratory of the German Aerospace Center (DLR).

At the beginning of the study, we ask you to provide the basic data required to analyse the study. This data will be analysed anonymously.

Section A:

A1. **Please enter your two-digit subject code.**

☐☐

Section B:

B1. **Please state your gender.**

Male ☐
Female ☐
Non-binary ☐
Not specified ☐

B2. **How old are you?**

< 30 years old ☐
30-39 years old ☐
40-49 years old ☐
50-59 years old ☐
> 59 years old ☐

B3. **Please state your nationality.**

☐

B4. **If you agree to the HRV measurement: Please enter your current weight (in whole numbers, i.e. 74.3 = 74 or 81.8 = 82).**

☐☐☐☐☐☐☐☐☐☐

B5. **If you agree to the HRV measurement: Please enter your height (in cm, e.g. 182).**

☐☐☐☐☐☐☐☐☐☐

B6. **What is your highest flying licence?**

ATPL ☐

MPL ☐

CPL ☐

Andere ☐

B7. **In which year did you first obtain your commercial pilot's licence?**

Please enter the year as a 4 digit number.

☐☐☐☐

B8. **How many flying hours have you obtained in total so far?**

0 - 1500 ☐

1501 - 3000 ☐

3001 - 5000 ☐

5001 - 10 000 ☐

über 10 000 ☐

B9. **How many flying hours have you obtained in the last 12 months?**

Please enter the number of hours only in digits.

☐

B10. **Which type rating did you hold in the past or are you currently holding?**

I currently hold the following type rating... ☐☐☐☐☐☐☐☐☐☐

I had the following type ratings, but they are currently not active... ☐☐☐☐☐☐☐☐☐☐

B11. **Are you currently employed in an aviation-related position/as a pilot?**

Yes ☐

No ☐

B12. **Which airline is your employer?**

B13. **Which rank do you hold in your current or previous employment?**

CPT ☐

SFO ☐

FO ☐

keine ☐

Section C:

C1. **Below you will find sentences about the attitude toward Artificial Intelligence (AI). Please state how much you agree or disagree with those statements.**

	Not at all									Completly Agree
I think AI technology is positive for humanity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I think I will use AI technology in the future	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I believe that AI will improve my work	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I believe that AI will improve my life	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

C2. **Are there AI Tools that you regularly use? If yes, which ones and why?**

A.2 Experiment Questionnaires

SUS	1	2	3	4	5
1. I think that I would like to use this system frequently.	○	○	○	○	○
2. I found the system unnecessarily complex.	○	○	○	○	○
3. I thought the system was easy to use.	○	○	○	○	○
4. I think that I would need the support of a technical person to be able to use this system.	○	○	○	○	○
5. I found the various functions in this system were well integrated.	○	○	○	○	○
6. I thought there was too much inconsistency in this system.	○	○	○	○	○
7. I would imagine that most people would learn to use this system very quickly.	○	○	○	○	○
8. I found the system very cumbersome to use.	○	○	○	○	○
9. I felt very confident using the system.	○	○	○	○	○
10. I needed to learn a lot of things before I could get going with this system.	○	○	○	○	○

SUS. 1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree

PSSUQ	1	2	3	4	5	6	7	N.A.
System Usefulness								
1. Overall, I am satisfied with how easy it is to use this system.	○	○	○	○	○	○	○	○
2. It was simple to use this system.	○	○	○	○	○	○	○	○
3. I was able to complete the tasks and scenarios quickly using this system.	○	○	○	○	○	○	○	○
4. I felt comfortable using this system.	○	○	○	○	○	○	○	○
5. It was easy to learn to use this system.	○	○	○	○	○	○	○	○
6. I believe I could become productive quickly using this system.	○	○	○	○	○	○	○	○
Information Quality								
7. The system gave error messages that clearly told me how to fix problems.	○	○	○	○	○	○	○	×
8. Whenever I made a mistake using the system, I could recover easily and quickly.	○	○	○	○	○	○	○	×
9. The information (such as online help, on-screen messages, and other documentation) provided with this system was clear.	○	○	○	○	○	○	○	○
10. It was easy to find the information I needed.	○	○	○	○	○	○	○	○
11. The information was effective in helping me complete the tasks and scenarios.	○	○	○	○	○	○	○	○
12. The organization of information on the system screens was clear.	○	○	○	○	○	○	○	○
Interface Quality								
13. The interface of this system was pleasant.	○	○	○	○	○	○	○	○
14. I liked using the interface of this system.	○	○	○	○	○	○	○	○
15. This system has all the functions and capabilities I expect it to have.	○	○	○	○	○	○	○	○
Overall								
16. Overall, I am satisfied with this system.	○	○	○	○	○	○	○	○

PSSUQ Questionnaire. 1: Strongly Agree to 7: Strongly Disagree, N.A.: Not applicable

Explainability	1	2	3	4	5
The explanations provide sufficient detail on the factors taken into account for generating the messages.	○	○	○	○	○
With the help of the explanations I understand why the messages are shown and why the corresponding advice was given.	○	○	○	○	○
The explanations regarding the messages are satisfactory.	○	○	○	○	○
The explanations provide insight into the accuracy of the messages.	○	○	○	○	○
The explanations of the messages help me with my decision making when deliberating how to proceed.	○	○	○	○	○
The explanations help me understand how I can use the messages in my decision making.	○	○	○	○	○
The explanations of the messages seem complete.	○	○	○	○	○

Explainability Questionnaire. 1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree

HCT	1	2	3	4	5
Perceived Reliability					
1. The system always provides the advice I require to make my decision.	○	○	○	○	○
2. The system performs reliably.	○	○	○	○	○
3. The system responds the same way under the same conditions at different times.	○	○	○	○	○
4. I can rely on the system to function properly.	○	○	○	○	○
5. The system analyzes problems consistently.	○	○	○	○	○
Perceived Technical Competence					
6. The system uses appropriate methods to reach decisions.	○	○	○	○	○
7. The system has sound knowledge about this type of problem built into it.	○	○	○	○	○
8. The advice the system produces is as good as that which a highly competent person could produce.	○	○	○	○	○
9. The system correctly uses the information I enter.	○	○	○	○	○
10. The system makes use of all the knowledge and information available to it to produce its solution to the problem.	○	○	○	○	○
Perceived Understandability					
11. I know what will happen the next time I use the system because I understand how it behaves.	○	○	○	○	○
12. I understand how the system will assist me with decisions I have to make.	○	○	○	○	○
13. Although I may not know exactly how the system works, I know how to use it to make decisions about the problem.	○	○	○	○	○
14. It is easy to follow what the system does.	○	○	○	○	○
15. I recognize what I should do to get the advice I need from the system the next time I use it.	○	○	○	○	○
Faith					
16. I believe advice from the system even when I don't know for certain that it is correct.	○	○	○	○	○
17. When I am uncertain about a decision I believe the system rather than myself.	○	○	○	○	○
18. If I am not sure about a decision, I have faith that the system will provide the best solution.	○	○	○	○	○
19. When the system gives unusual advice I am confident that the advice is correct.	○	○	○	○	○
20. Even if I have no reason to expect the system will be able to solve a difficult problem, I still feel certain that it will.	○	○	○	○	○
Personal Attachment					
21. I would feel a sense of loss if the system was unavailable and I could no longer use it.	○	○	○	○	○
22. I feel a sense of attachment to using the system.	○	○	○	○	○
23. I find the system suitable to my style of decision making.	○	○	○	○	○
24. I like using the system for decision making.	○	○	○	○	○
25. I have a personal preference for making decisions with the system.	○	○	○	○	○

HCT Questionnaire. 1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree

SATI	0	1	2	3	4	5	6
1. ... the system was useful.	○	○	○	○	○	○	○
2. ... the system was reliable.	○	○	○	○	○	○	○
3. ... the system worked accurately.	○	○	○	○	○	○	○
4. ... the system was understandable.	○	○	○	○	○	○	○
5. ... the system worked robustly (in difficult situations, with invalid inputs, etc.).	○	○	○	○	○	○	○
6. ... I was confident when working with the system.	○	○	○	○	○	○	○

SATI Questionnaire. 0: Never, 1: Seldom, 2: Sometimes, 3: Often, 4: More Often, 5: Very Often, 6: Always

Trust based on EASA's AI Roadmap	1	2	3	4	5
1. I believe the system enhances my decision-making without undermining my control as a pilot.	○	○	○	○	○
2. I am confident in the system to be reliable and safe under various conditions.	○	○	○	○	○
3. I believe my data will be handled safely and responsibly by the system.	○	○	○	○	○
4. The system's decision making processes are understandable and transparent to me.	○	○	○	○	○
5. I believe the advice provided from the system is free from bias.	○	○	○	○	○
6. I believe the system considers environmental well-being in its decision making process.	○	○	○	○	○
7. I believe there are effective mechanisms in place for addressing potential inaccuracies or failures in the advice provided by the system.	○	○	○	○	○

Trust Questionnaire based on EASA's AI Roadmap. 1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree

General Trust Questionnaire	1	2	3	4	5
Trust in the presented Information					
1. How often did you trust the information the system gave you?	○	○	○	○	○
Trust in the System					
2. I trust the system.	○	○	-	○	○
3. I have enough information to trust the system adequately.	○	○	-	○	○
4. The explanations help me to trust the system more adequately.	○	○	-	○	○
5. I trust the system adequately.	○	○	-	○	○

General Trust Questionnaire. Question 1: 1: Never, 2: Seldom, 3: Sometimes, 4: Often, 5: Always. Questions 2-5: 1: Strongly Disagree, 2: Disagree, 3: Agree, 4: Strongly Agree

Question	**Options**
1. Would you like to use the system regularly for mission support?	○ Yes ○ No
2. Would the system integrate well into your normal flight operations?	○ Yes ○ No
3. Do the explanations make it more likely that you would use the system for mission support regularly?	○ Yes ○ No
4. Would you like more or fewer explanatory details for the system's decisions?	○ Fewer explanatory details ○ As it is ○ More explanatory details
5. Do you think that the explanations help you to understand the system better?	○ Yes ○ No
6. How satisfied were you with the IPAS?	○ Very Unsatisfied ○ Unsatisfied ○ Neither unsatisfied nor satisfied ○ Satisfied ○ Very Satisfied

General Evaluation Questionnaire

Question	**Options**
1. Do you want the message-icons (information, notification & warning) to be hidden when the aircraft has flown past them?	○ Yes ○ No ○ I don't know / I don't care
2. Would you like to be able to hide the message-icons permanently when you no longer want to see them (disregarding when they take place)?	○ Yes ○ No ○ I don't know / I don't care
3. Did you find the option to display the current alternate airports helpful?	○ Yes ○ No
4. Would you like to be able to sort or change the displayed alternate airports according to certain criteria?	○ Yes ○ No ○ I don't know / I don't care
5. Would you like an overview over all possible alternate airports along your route?	○ Yes ○ No ○ I don't know / I don't care
6. Did you find the "Airport Detail Page" helpful?	○ Yes ○ No
7. Did you find the "Message Detail Page" helpful?	○ Yes ○ No
8. Did you find the close up view of the route (in which you can only see the next 100NM) helpful?	○ Yes ○ No
9. Was the difference between information, notification and warning clear?	○ Yes ○ No
10. Was the distinction between information, notification and warning visually clear?	○ Yes ○ No

Design Decision Questionnaire

B Results

Group 1

VPNR	**AI1**	**AI2**	**AI3**	**AI4**	**Mean**
1	9	9	10	7	**8.75**
4	6	6	8	4	**6**
5	7	6	8	5	**6.5**
8	4	3	7	5	**4.75**
9	8	7	6	6	**6.75**
11	6	6	6	6	**6**
15	7	9	10	3	**7.25**
16	8	8	9	9	**8.5**
17	7	7	9	6	**7.25**
Mean	**6.89**	**6.78**	**8.11**	**5.67**	**6.86**

Group 2

VPNR	**AI1**	**AI2**	**AI3**	**AI4**	**Mean**
2	7	6	7	7	**6.75**
3	10	8	10	10	**9.5**
6	2	2	2	2	**2**
7	8	8	8	7	**7.75**
10	8	9	10	7	**8.5**
13	5	5	7	3	**5**
14	8	8	10	6	**8**
18	7	8	8	8	**7.75**
19	6	7	7	4	**6**
Mean	**6.78**	**6.78**	**7.67**	**6.00**	**6.81**

Attitude towards AI

Group 1 - Mid Experiment

VPNR	SUS Score	SUS 100 Scale
1	28	70
2	26	65
5	32	80
8	33	82.5
9	33	82.5
11	21	52.5
15	36	90
16	31	77.5
17	31	77.5
Mean	**30.11**	**75.28**

Group 2 - Mid Experiment

VPNR	SUS Score	SUS 100 Scale
2	27	67.5
3	26	65
6	29	72.5
7	30	75
10	31	77.5
13	31	77.5
14	29	72.5
18	31	77.5
19	30	75
Mean	**29.33**	**73.33**

Group 2 - Post Experiment

VPNR	SUS Score	SUS 100 Scale
1	30	75
4	30	75
5	32	80
8	35	87.5
9	32	80
11	23	57.5
15	39	97.5
16	27	67.5
17	30	75
Mean	**30.89**	**77.22**

Group 2 - Post Experiment

VPNR	Mean	SUS_Score
2	29	72.5
3	27	67.5
6	27	67.5
7	30	75
10	35	87.5
13	34	85
14	28	70
18	32	80
19	32	80
Mean	**30.44**	**76.11**

SUS Results

Group 1 - Mid Experiment

VP#	1	2	3	4	5	6	SYS	9	10	11	12	INFO	13	14	15	INTER	16	Mean
1	2	2	2	2	2	1	1.83	3	4	3	3	3.25	2	2	2	2.00	2	2.29
4	3	3	3	2	3	2	2.67	5	2	3	4	3.50	3	3	3	3.00	2	2.93
5	2	2	2	3	1	3	2.17	2	1	3	2	2.00	2	2	3	2.33	3	2.21
8	3	2	3	4	2	2	2.67	4	3	3	2	3.00	1	2	3	2.00	2	2.57
9	5	2	5	2	2	2	3.00	2	3	2	3	2.50	2	2	3	2.33	2	2.64
11	5	5	5	6	3	4	4.67	3	6	4	6	4.75	5	6	6	5.67	5	4.93
15	1	1	2	2	1	1	1.33	3	3	1	2	2.25	3	3	2	2.67	2	1.93
16	2	2	2	2	2	2	2.00	2	2	2	2	2.00	2	2	3	2.33	2	2.07
17	2	1	1	2	2	2	1.67	3	3	3	2	2.75	2	2	4	2.67	2	2.21
MEAN	2.78	2.22	2.78	2.78	2.00	2.11	2.44	3.00	3.00	2.67	2.89	2.89	2.44	2.67	3.22	2.78	2.44	2.64

Group 2 - Mid Experiment

VP#	1	2	3	4	5	6	SYS	9	10	11	12	INFO	13	14	15	INTER	16	Mean
2	3	3	3	3	2	4	3.00	3	3	3	2	2.75	3	2	4	3.00	3	2.93
3	3	3	3	3	3	2	2.83	5	4	2	3	3.50	5	3	4	4.00	2	3.21
6	2	2	2	5	2	4	2.83	5	5	4	2	4.00	2	4	5	3.67	5	3.50
7	2	2	2	2	2	2	2.00	3	2	2	2	2.25	2	2	3	2.33	2	2.14
10	2	1	2	2	2	2	1.83	1	3	2	2	2.00	2	2	3	2.33	2	2.00
13	2	2	3	2	2	2	2.17	2	3	2	1	2.00	2	3	4	3.00	3	2.36
14	4	3	6	3	3	3	3.67	5	5	3	5	4.50	5	3	6	4.67	5	4.21
18	2	2	2	2	2	2	2.00	1	2	3	2	2.00	2	2	6	3.33	2	2.29
19	2	2	3	2	1	2	2.00	3	3	2	3	2.75	3	2	6	3.67	3	2.64
MEAN	2.44	2.22	2.89	2.67	2.11	2.56	2.48	3.11	3.33	2.56	2.44	2.86	2.89	2.56	4.56	3.33	3.00	2.81

Group 1 - Post Experiment

VP#	1	2	3	4	5	6	SYS	9	10	11	12	INFO	13	14	15	INTER	16	Mean
1	3	2	2	1	2	2	2.00	2	2	2	3	2.25	2	2	3	2.33	2	2.14
4	2	2	2	2	2	2	2.00	4	3	2	5	3.50	3	2	3	2.67	2	2.57
5	2	2	2	2	1	2	1.83	1	2	2	2	1.75	2	2	2	2.00	2	1.86
8	2	2	2	2	2	1	1.83	2	3	2	1	2.00	1	2	5	2.67	3	2.14
9	3	2	2	2	2	2	2.17	2	2	1	2	1.75	2	2	2	2.00	2	2.00
11	4	3	3	5	3	4	3.67	4	4	4	5	4.25	5	4	5	4.67	4	4.07
15	1	1	1	1	1	1	1.00	3	2	1	2	2.00	2	2	3	2.33	1	1.57
16	2	2	2	2	2	2	2.00	2	2	3	2	2.25	2	2	3	2.33	2	2.14
17	2	2	2	2	2	2	2.00	4	2	2	3	2.75	2	2	4	2.67	2	2.36
VP#	2.33	2.00	2.00	2.11	1.89	2.00	2.06	2.67	2.44	2.11	2.78	2.50	2.33	2.22	3.33	2.63	2.22	2.32

Group 2 - Post Experiment

VP#	1	2	3	4	5	6	SYS	9	10	11	12	INFO	13	14	15	INTER	16	Mean
2	3	2	2	2	2	2	2.17	3	3	3	3	3.00	2	2	2	2.00	2	2.36
3	2	2	2	2	2	2	2.00	2	2	2	2	2.00	2	2	5	3.00	3	2.29
6	2	2	3	5	2	4	3.00	2	2	2	2	2.00	2	2	4	2.67	5	2.79
7	2	2	2	2	2	2	2.00	2	2	2	2	2.00	2	2	3	2.33	2	2.07
10	2	2	2	2	2	2	2.00	2	2	2	1	1.75	2	2	3	2.33	2	2.00
13	2	1	3	3	1	2	2.00	1	3	2	1	1.75	2	2	4	2.67	3	2.14
14	3	3	3	3	2	3	2.83	3	3	3	3	3.00	3	3	5	3.67	3	3.07
18	2	2	2	2	2	2	2.00	2	2	2	2	2.00	1	2	6	3.00	3	2.29
19	2	2	2	2	2	2	2.00	2	1	2	2	1.75	2	2	2	2.00	2	1.93
VP#	2.22	2.00	2.33	2.56	1.89	2.33	2.22	2.11	2.22	2.22	2.00	2.14	2.00	2.11	3.78	2.63	2.78	2.33

PSSUQ Results

Group 1 - Mid Experiment

VPNR	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**Mean**
1	5	5	5	5	5	5	5	**5.00**
4	3	4	4	4	4	4	3	**3.71**
5	3	3	2	4	4	4	3	**3.29**
8	4	3	3	4	4	3	2	**3.29**
9	4	4	4	4	3	4	3	**3.71**
11	4	4	4	4	4	4	2	**3.71**
15	4	5	4	4	5	5	5	**4.57**
16	4	4	3	3	4	4	4	**3.71**
17	4	3	4	3	4	4	4	**3.71**
Mean	**3.89**	**3.89**	**3.67**	**3.89**	**4.11**	**4.11**	**3.44**	**3.86**

Group 1 - Post Experiment

VPNR	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**Mean**
1	5	4	4	4	5	4	5	**4.43**
4	4	4	4	4	4	3	2	**3.57**
5	4	4	3	4	4	4	4	**3.86**
8	4	4	3	3	3	4	3	**3.43**
9	4	4	4	4	5	4	5	**4.29**
11	4	2	3	2	2	2	2	**2.43**
15	5	5	5	5	4	4	5	**4.71**
16	4	4	4	4	4	4	4	**4.00**
17	4	4	3	2	4	4	3	**3.43**
Mean	**4.22**	**3.89**	**3.67**	**3.56**	**3.89**	**3.67**	**3.67**	**3.79**

Explainability Questionnaire Results

Group 1 - Mid Experiment

VPNR	SATI1	SATI2	SATI3	SATI4	SATI5	SATI6	Mean
1	5	5	5	6	3	4	**4.67**
4	4	6	6	3	6	6	**5.17**
5	4	4	5	6	4	3	**4.33**
8	6	5	5	4	5	2	**4.50**
9	4	3	3	4	3	4	**3.50**
11	1	3	3	2	3	1	**2.17**
15	5	6	6	6	6	4	**5.50**
16	6	6	6	6	6	5	**5.83**
17	4	5	6	5	4	5	**4.83**
Mean	**4.33**	**4.78**	**5.00**	**4.67**	**4.44**	**3.78**	**4.50**

Group 2 - Mid Experiment

VPNR	SATI1	SATI2	SATI3	SATI4	SATI5	SATI6	Mean
2	4	4	4	4	3	4	**3.83**
3	4	3	3	2	3	2	**2.83**
6	2	3	3	6	6	2	**3.67**
7	5	6	6	5	5	6	**5.50**
10	5	5	5	5	5	5	**5.00**
13	4	4	3	5	4	4	**4.00**
14	2	3	3	3	3	3	**2.83**
18	5	5	3	5	6	5	**4.83**
19	2	5	5	5	3	3	**3.83**
Mean	**3.67**	**4.22**	**3.89**	**4.44**	**4.22**	**3.78**	**4.04**

Group 1 - Post Experiment

VPNR	SATI1	SATI2	SATI3	SATI4	SATI5	SATI6	Mean
1	5	4	5	6	6	5	**5.17**
4	4	4	4	4	5	5	**4.33**
5	5	4	4	5	4	5	**4.50**
8	5	4	6	3	6	3	**4.50**
9	5	4	4	5	4	4	**4.33**
11	2	3	3	3	3	1	**2.50**
15	6	6	6	6	6	6	**6.00**
16	5	6	5	6	6	5	**5.50**
17	5	5	5	5	6	5	**5.17**
Mean	**4.67**	**4.44**	**4.67**	**4.78**	**5.11**	**4.33**	**4.67**

Group 2 - Post Experiment

VPNR	SATI1	SATI2	SATI3	SATI4	SATI5	SATI6	Mean
2	4	3	3	4	3	4	**3.50**
3	5	5	5	5	5	5	**5.00**
6	2	3	3	5	3	2	**3.00**
7	5	6	6	5	6	6	**5.67**
10	5	5	6	6	6	6	**5.67**
13	4	4	4	5	4	4	**4.17**
14	3	3	3	3	3	3	**3.00**
18	5	5	5	5	5	5	**5.00**
19	4	4	3	5	5	5	**4.33**
Mean	**4.11**	**4.22**	**4.22**	**4.78**	**4.44**	**4.44**	**4.37**

SATI Results

Group 1 - Mid Experiment

VPNR	EASA1	EASA2	EASA3	EASA4	EASA5	EASA6	EASA7	Mean
1	4	4	5	4	4	2	3	**3.71**
4	4	4	4	4	3	3	4	**3.71**
5	3	3	4	2	3	2	2	**2.71**
8	4	4	5	2	4	2	3	**3.43**
9	4	3	3	2	2	3	3	**2.86**
11	3	2	4	2	2	3	3	**2.71**
15	5	3	5	4	2	2	2	**3.29**
16	4	4	4	3	4	3	3	**3.57**
17	4	4	5	4	3	3	3	**3.71**
Mean	**3.89**	**3.44**	**4.33**	**3.00**	**3.00**	**2.56**	**2.89**	**3.30**

Group 2 - Mid Experiment

VPNR	EASA1	EASA2	EASA3	EASA4	EASA5	EASA6	EASA7	Mean
2	4	4	4	4	3	3	4	**3.71**
3	4	4	4	3	5	3	4	**3.86**
6	2	2	4	2	3	3	2	**2.57**
7	4	4	4	4	3	3	3	**3.57**
10	5	4	3	4	3	2	4	**3.57**
13	3	2	5	3	2	3	3	**3.00**
14	4	3	4	4	3	3	3	**3.43**
18	4	4	5	4	3	4	4	**4.00**
19	4	4	4	4	3	3	3	**3.57**
Mean	**3.78**	**3.44**	**4.11**	**3.56**	**3.11**	**3.00**	**3.33**	**3.48**

Group 1 - Post Experiment

VPNR	EASA1	EASA2	EASA3	EASA4	EASA5	EASA6	EASA7	Mean
1	4	4	5	4	4	2	4	**3.86**
4	4	4	4	4	3	3	4	**3.71**
5	4	4	4	5	4	2	3	**3.71**
8	5	3	5	3	4	2	3	**3.57**
9	4	4	3	4	2	2	4	**3.29**
11	3	2	4	2	2	3	2	**2.57**
15	5	4	5	3	2	2	2	**3.29**
16	4	4	4	3	4	3	4	**3.71**
17	4	4	4	4	3	3	3	**3.57**
Mean	**4.11**	**3.67**	**4.22**	**3.56**	**3.11**	**2.44**	**3.22**	**3.48**

Group 2 - Post Experiment

VPNR	EASA1	EASA2	EASA3	EASA4	EASA5	EASA6	EASA7	Mean
2	4	3	3	3	3	3	4	**3.29**
3	4	3	4	3	4	3	2	**3.29**
6	2	1	3	3	3	3	2	**2.43**
7	4	4	4	4	3	3	3	**3.57**
10	5	4	3	4	4	3	4	**3.86**
13	4	4	4	3	3	2	3	**3.29**
14	4	3	4	4	4	3	3	**3.57**
18	4	4	5	5	4	4	4	**4.29**
19	4	4	4	4	3	3	3	**3.57**
Mean	**3.89**	**3.33**	**3.78**	**3.67**	**3.44**	**3.00**	**3.11**	**3.46**

Results of Trust Questionnaire based on EASA's AI Roadmap

Group1 - Mid Experiment

VP#	1	2	3	4	5	Relia.	6	7	8	9	10	TC	11	12	13	14	15	Und.	16	17	18	19	20	Faith	21	22	23	24	25	PA	Mean
1	4	4	3	5	5	4.20	4	4	3	3	4	3.60	4	4	4	4	3	3.80	4	3	4	2	4	3.40	4	4	4	4	4	4.00	3.80
4	3	4	4	4	4	3.80	4	4	4	3	4	3.80	4	4	4	3	4	3.80	1	2	1	1	2	1.40	3	4	4	4	3	3.60	3.28
5	2	3	3	3	4	3.00	3	4	2	3	4	3.20	3	3	4	4	4	3.60	2	2	2	2	2	2.00	3	4	4	4	4	3.80	3.12
8	3	4	4	4	5	4.00	4	4	3	4	5	4.00	3	3	4	4	4	3.60	2	2	3	1	2	2.00	2	2	4	4	3	3.00	3.32
9	4	4	4	3	4	3.80	4	4	3	3	4	3.60	4	4	4	3	4	3.80	3	2	2	2	2	2.20	1	4	4	4	3	3.20	3.32
11	2	3	3	3	3	2.80	3	2	1	3	3	2.40	2	2	4	3	4	3.00	2	1	1	1	1	1.20	1	1	2	3	3	2.00	2.28
15	4	4	5	3	4	4.00	5	3	4	4	5	4.20	4	5	5	5	5	4.80	2	4	4	1	3	2.80	5	4	5	5	5	4.80	4.12
16	3	4	4	4	4	3.80	4	4	3	3	4	3.60	4	4	4	4	4	4.00	3	2	3	2	3	2.60	2	4	4	4	4	3.60	3.52
17	3	4	3	4	4	3.60	4	4	3	4	4	3.80	4	5	4	4	4	4.20	3	2	3	2	3	2.60	2	4	4	4	4	3.60	3.56
M	3.11	3.78	3.67	3.67	4.11	3.67	3.89	3.67	2.89	3.33	4.11	3.58	3.56	3.78	4.11	3.78	4.00	3.84	2.44	2.22	2.56	1.56	2.44	2.24	2.56	3.44	3.89	4.00	3.67	3.51	3.37

Group 2 - Mid Experiment

VP#	1	2	3	4	5	Relia.	6	7	8	9	10	TC	11	12	13	14	15	Und.	16	17	18	19	20	Faith	21	22	23	24	25	PA	Mean
2	3	3	3	4	4	3.40	4	3	3	3	3	3.20	4	3	4	3	4	3.60	4	2	4	2	2	2.80	3	4	4	4	4	3.80	3.36
3	3	4	3	4	4	3.60	4	3	2	3	3	3.00	3	3	4	4	4	3.60	4	2	4	2	4	3.20	2	3	4	4	3	3.20	3.32
6	2	3	3	3	3	2.80	3	3	2	3	2	2.60	4	4	4	5	4	4.20	1	1	1	1	1	1.00	1	1	2	2	1	1.40	2.40
7	4	4	4	4	4	4.00	4	4	3	3	3	3.40	4	4	4	4	4	4.00	2	2	3	2	3	2.40	2	2	4	4	4	3.20	3.40
10	4	5	4	4	5	4.40	4	4	5	3	4	4.00	5	4	4	4	5	4.40	2	1	3	3	3	2.40	4	4	4	4	4	4.00	3.84
13	4	4	3	3	4	3.60	4	4	4	3	2	3.40	4	5	4	4	4	4.20	2	3	1	1	1	1.60	2	4	2	2	1	2.20	3.00
14	3	3	3	3	3	3.00	3	3	2	3	3	2.80	3	4	4	3	4	3.60	3	3	3	2	3	2.80	1	3	3	3	3	2.60	2.96
18	3	4	5	4	4	4.00	4	4	1	4	4	3.40	4	5	5	5	4	4.60	4	4	4	3	3	3.60	2	2	4	4	4	3.20	3.76
19	2	4	3	3	3	3.00	3	4	4	4	3	3.60	4	4	4	4	4	4.00	3	3	2	2	2	2.40	1	1	3	4	4	2.60	3.12
M	3.11	3.78	3.44	3.56	3.78	3.53	3.67	3.56	2.89	3.22	3.00	3.27	3.89	4.00	4.11	4.00	4.11	4.02	2.78	2.33	2.78	2.00	2.44	2.47	2.00	2.67	3.33	3.44	3.11	2.91	3.24

HCT Results - Scenario 1

Group 1 - Post Experiment

VP#	1	2	3	4	5	Relia.	6	7	8	9	10	TC	11	12	13	14	15	Und.	16	17	18	19	20	Faith	21	22	23	24	25	PA	Mean
1	4	4	3	4	5	4.00	4	4	3	3	4	3.60	4	4	4	4	3	3.80	4	3	4	2	4	3.40	4	4	4	4	4	4.00	3.76
4	4	4	4	4	4	4.00	4	4	4	3	4	3.80	4	4	4	3	4	3.80	2	1	2	1	2	1.60	3	4	4	4	4	3.80	3.40
5	3	4	4	3	4	3.60	2	4	2	3	4	3.00	3	4	4	4	4	3.80	3	2	3	2	3	2.60	4	4	4	4	3	3.80	3.36
8	3	4	5	4	5	4.20	4	3	2	4	4	3.40	4	4	4	3	4	3.80	2	2	2	1	2	1.80	3	3	4	4	3	3.40	3.32
9	4	4	4	3	4	3.80	4	4	2	3	4	3.40	4	4	4	4	4	4.00	3	2	3	3	4	3.00	1	4	4	4	4	3.40	3.52
11	1	3	3	3	3	2.60	2	2	1	3	3	2.20	2	3	4	2	2	2.60	2	1	2	2	2	1.80	1	2	3	3	3	2.40	2.32
15	5	5	5	2	4	4.20	5	3	4	4	5	4.20	4	5	5	4	4	4.40	1	3	4	2	4	2.80	5	4	5	5	5	4.80	4.08
16	4	4	4	4	4	4.00	4	4	3	4	4	3.80	4	4	4	4	4	4.00	3	2	3	2	3	2.60	2	4	4	4	4	3.60	3.60
17	4	4	3	4	4	3.80	4	4	3	4	3	3.60	4	4	4	4	4	4.00	3	1	3	2	2	2.20	2	4	4	5	4	3.80	3.48
M	3.56	4.00	3.89	3.44	4.11	3.80	3.67	3.56	2.67	3.44	3.89	3.44	3.67	4.00	4.11	3.56	3.67	3.80	2.56	1.89	2.89	1.89	2.89	2.42	2.78	3.67	4.00	4.11	3.78	3.67	3.43

Group 2 - Post Experiment

VP#	1	2	3	4	5	Relia.	6	7	8	9	10	TC	11	12	13	14	15	Und.	16	17	18	19	20	Faith	21	22	23	24	25	PA	Mean
2	4	4	4	4	4	4.00	4	3	4	4	4	3.80	3	3	2	4	4	3.20	2	2	2	2	2	2.00	3	4	4	4	4	3.80	3.36
3	3	4	4	4	5	4.00	4	3	3	3	4	3.40	3	4	4	4	3	3.60	4	3	3	2	4	3.20	2	2	4	4	4	3.20	3.48
6	2	3	3	2	3	2.60	3	3	2	4	2	2.80	3	3	4	4	4	3.60	1	1	1	1	1	1.00	1	1	2	2	1	1.40	2.28
7	3	4	4	4	4	3.80	4	4	3	3	4	3.60	4	4	4	4	4	4.00	2	2	3	2	3	2.40	2	2	4	4	4	3.20	3.40
10	5	4	4	4	5	4.40	4	4	4	3	4	3.80	4	4	4	4	4	4.00	4	2	3	3	4	3.20	3	4	4	4	4	3.80	3.84
13	3	4	4	3	5	3.80	4	3	4	4	3	3.60	3	4	2	4	4	3.40	1	1	1	1	1	1.00	2	4	3	3	2	2.80	2.92
14	3	4	3	3	4	3.40	3	3	4	4	3	3.40	3	3	4	4	4	3.60	2	2	3	1	3	2.20	1	4	4	4	4	3.40	3.20
18	2	4	4	4	3	3.40	4	4	2	4	4	3.60	4	4	4	4	4	4.00	4	3	4	3	4	3.60	2	3	4	4	4	3.40	3.60
19	3	3	4	4	4	3.60	3	4	3	4	4	3.60	4	4	4	3	4	3.80	3	2	3	2	3	2.60	1	2	4	4	3	2.80	3.28
M	3.11	3.78	3.78	3.56	4.11	3.67	3.67	3.44	3.22	3.67	3.56	3.51	3.44	3.67	3.56	3.89	3.89	3.69	2.56	2.00	2.56	1.89	2.78	2.36	1.89	2.89	3.67	3.67	3.33	3.09	3.26

HCT Results - Scenario 2

Group 1 - Mid Experiment

VPNR	InfTrust	Trust	EnoughInf	EnoughInfAde	AdequatTrust	Sum
1	5	5	5	5	5	5.00
4	4	4	4	4	4	4.00
5	3	2	2	4	4	3.00
8	4	4	2	4	2	3.00
9	4	4	4	4	4	4.00
11	3	2	2	2	2	2.00
15	2	1	1	5	5	3.00
16	4	4	4	4	4	4.00
17	4	4	4	4	4	4.00
Mean	**3.67**	**3.33**	**3.11**	**4.00**	**3.78**	**3.56**

Group 2 - Mid Experiment

VPNR	InfTrust	Trust	EnoughInf	EnoughInfAde	AdequatTrust	Sum
2	4	4	2		4	3.33
3	4	4	2		2	2.67
6	3	2	2		2	2.00
7	4	4	4		4	4.00
10	5	4	4		4	4.00
13	3	2	2		2	2.00
14	3	4	2		4	3.33
18	4	4	4		4	4.00
19	3	4	2		4	3.33
Mean	**3.67**	**3.56**	**2.67**		**3.33**	**3.19**

Group 1 - Post Experiment

VPNR	InfTrust	Trust	EnoughInf	EnoughInfAde	AdequatTrust	Sum
1	5	5	4	4	5	4.50
4	4	4	4	4	4	4.00
5	4	4	4	4	4	4.00
8	3	4	4	4	4	4.00
9	4	4	4	5	4	4.25
11	4	2	1	2	2	1.75
15	2	1	5	5	5	4.00
16	4	4	4	4	4	4.00
17	4	4	4	4	4	4.00
Mean	**3.78**	**3.56**	**3.78**	**4.00**	**4.00**	**3.83**

Group 2 - Post Experiment

VPNR	InfTrust	Trust	EnoughInf	EnoughInfAde	AdequatTrust	Sum
2	3	4	2		4	3.33
3	4	4	2		2	2.67
6	3	2	2		2	2.00
7	4	4	4		4	4.00
10	5	4	4		5	4.33
13	3	2	2		4	2.67
14	4	4	2		2	2.67
18	4	4	4		4	4.00
19	4	4	2		4	3.33
Mean	**3.78**	**3.56**	**2.67**		**3.44**	**3.22**

General Trust Questionnaire Results

Group 1 - General Evaluation

VPNR	E1	E2	E3	E4	E5	E6
1	Yes	Yes	Yes	Fewer explanatory details	Yes	Satisfied
4	Yes	Yes	Yes	More explanatory details	Yes	Satisfied
5	Yes	Yes	Yes	More explanatory details	Yes	Satisfied
8	Yes	Yes	Yes	More explanatory details	Yes	Satisfied
9	Yes	Yes	Yes	More explanatory details	No	Very satisfied
11	No	No	No	More explanatory details	Yes	Unsatisfied
15	Yes	Yes	Yes	As it is	Yes	Very satisfied
16	Yes	Yes	Yes	More explanatory details	Yes	Very satisfied
17	Yes	Yes	Yes	More explanatory details	Yes	Satisfied

Group 2 - General Evaluation

VPNR	E1	E2	E3	E4	E5	E6
2	Yes	Yes		More explanatory details		Satisfied
3	Yes	Yes		More explanatory details		Satisfied
6	No	No		More explanatory details		Neither
7	Yes	Yes		As it is		Satisfied
10	Yes	Yes		As it is		Satisfied
13	Yes	Yes		More explanatory details		Satisfied
14	Yes	Yes		More explanatory details		Neither
18	Yes	Yes		More explanatory details		Satisfied
19	Yes	Yes		More explanatory details		Satisfied

General Evaluation Questionnaire Results

Group 1 - Design Decisions

VPNR	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes -> W
4	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No
5	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	IDK	Yes	Yes -> N, W
8	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes -> N, W
9	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes -> N, W
11	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes -> W
15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes -> W
16	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes -> W
17	Yes	IDK	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes -> W

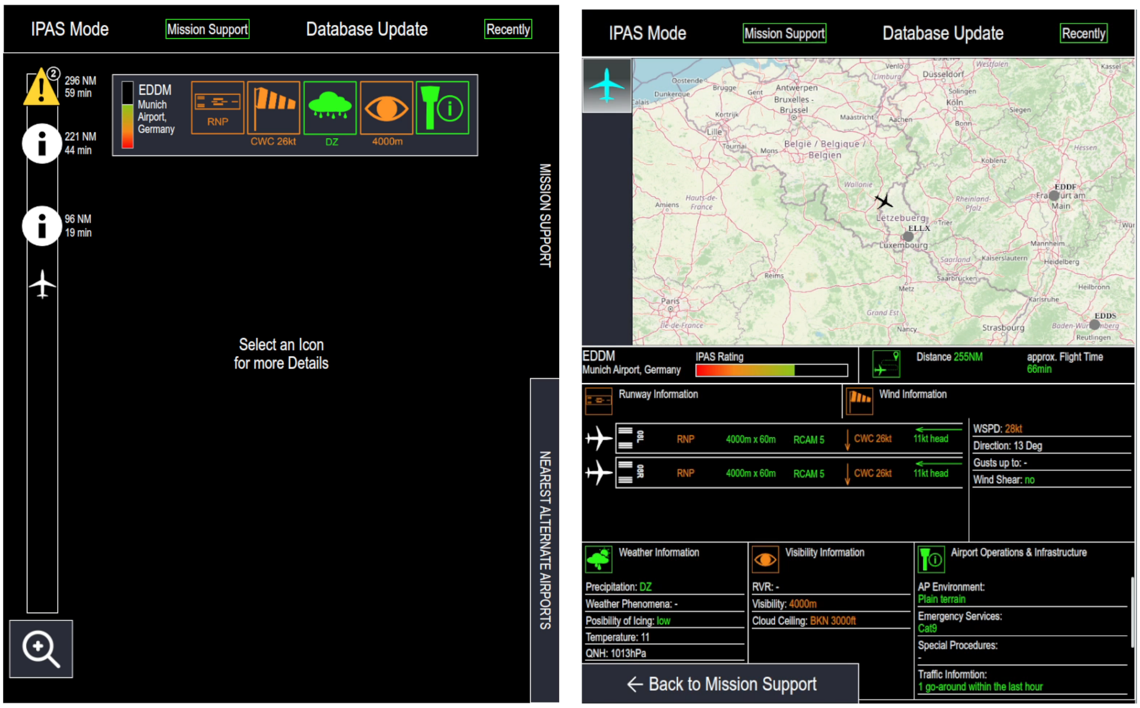
Group 2 - Design Decisions

VPNR	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
2	No	Yes	Yes	Yes	Yes			No	Yes	Yes	No	Yes	No
3	No	Yes	Yes	Yes	Yes			No	Yes	Yes	Yes	Yes	Yes -> I, N, W
6	Yes	Yes	No	Yes	Yes			Yes	Yes	Yes	IDK	Yes	Yes -> W
7	Yes	No	Yes	Yes	Yes			Yes	Yes	Yes	No	Yes	Yes -> N, W
10	Yes	Yes	Yes	Yes	Yes			No	Yes	Yes	No	Yes	Yes -> N, W
13	No	Yes	Yes	Yes	Yes			No	Yes	Yes	IDK	Yes	Yes -> N, W
14	Yes	Yes	No	Yes	No			Yes	Yes	Yes	Yes	Yes	Yes -> W
18	No	Yes	Yes	Yes	Yes			Yes	Yes	Yes	IDK	Yes	No
19	Yes	Yes	Yes	Yes	Yes			No	Yes	Yes	No	Yes	Yes -> W

Design Decision Questionnaire Results

C Scenario Design

Scenario 1



EDDM Munich Airport, Germany

Distance 255NM

approx. Flight Time 66min

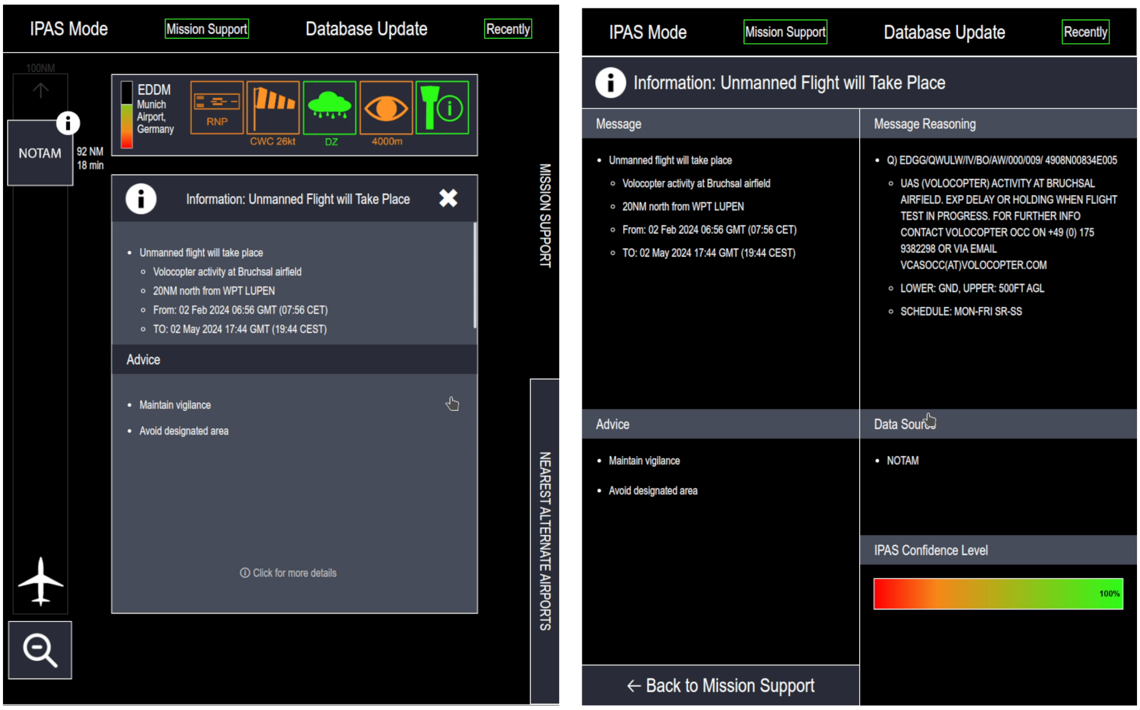
WSPD: 28kt
Direction: 13 Deg
Gusts up to: -
Wind Shear: no

Precipitation: DZ
Weather Phenomena: -
Posibility of Icing: low
Temperature: 11
QNH: 1013hPa

RVR: -
Visibility: 4000m
Cloud Ceiling: BKN 3000ft

AP Environment: Plain terrain
Emergency Services: Cat9
Special Procedures: -
Traffic Informtion: 1 go-around within the last hour

Status at the beginning.



Information: Unmanned Flight will Take Place

Message

- Unmanned flight will take place
  - Volocopter activity at Bruchsal airfield
  - 20NM north from WPT LUPEN
  - From: 02 Feb 2024 06:56 GMT (07:56 CET)
  - TO: 02 May 2024 17:44 GMT (19:44 CEST)

Message Reasoning

- Q) EDGG/QWULW/IV/BO/AW/000/009/ 4908N00834E005
  - UAS (VOLOCOPTER) ACTIVITY AT BRUCHSAL AIRFIELD. EXP DELAY OR HOLDING WHEN FLIGHT TEST IN PROGRESS. FOR FURTHER INFO CONTACT VOLOCOPTER OCC ON +49 (0) 175 9382298 OR VIA EMAIL VCASOCC(AT)VOLOCOPTER.COM
  - LOWER: GND, UPPER: 500FT AGL
  - SCHEDULE: MON-FRI SR-SS

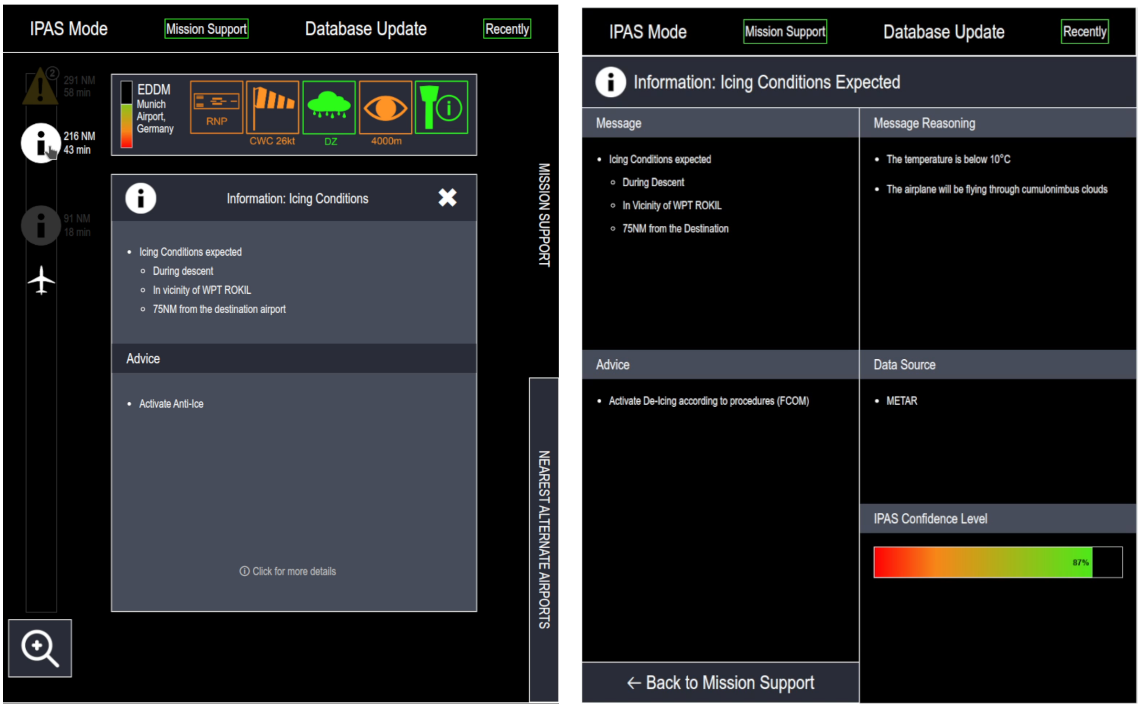
Advice

- Maintain vigilance
- Avoid designated area

Data Source

- NOTAM

Information of volocopter activity at an enroute airfield.



Information: Icing Conditions

- Icing Conditions expected
  - During descent
  - In vicinity of WPT ROKIL
  - 75NM from the destination airport

Advice

- Activate Anti-Ice

Information: Icing Conditions Expected

Message

- Icing Conditions expected
  - During Descent
  - In Vicinity of WPT ROKIL
  - 75NM from the Destination

Message Reasoning

- The temperature is below 10°C
- The airplane will be flying through cumulonimbus clouds

Advice

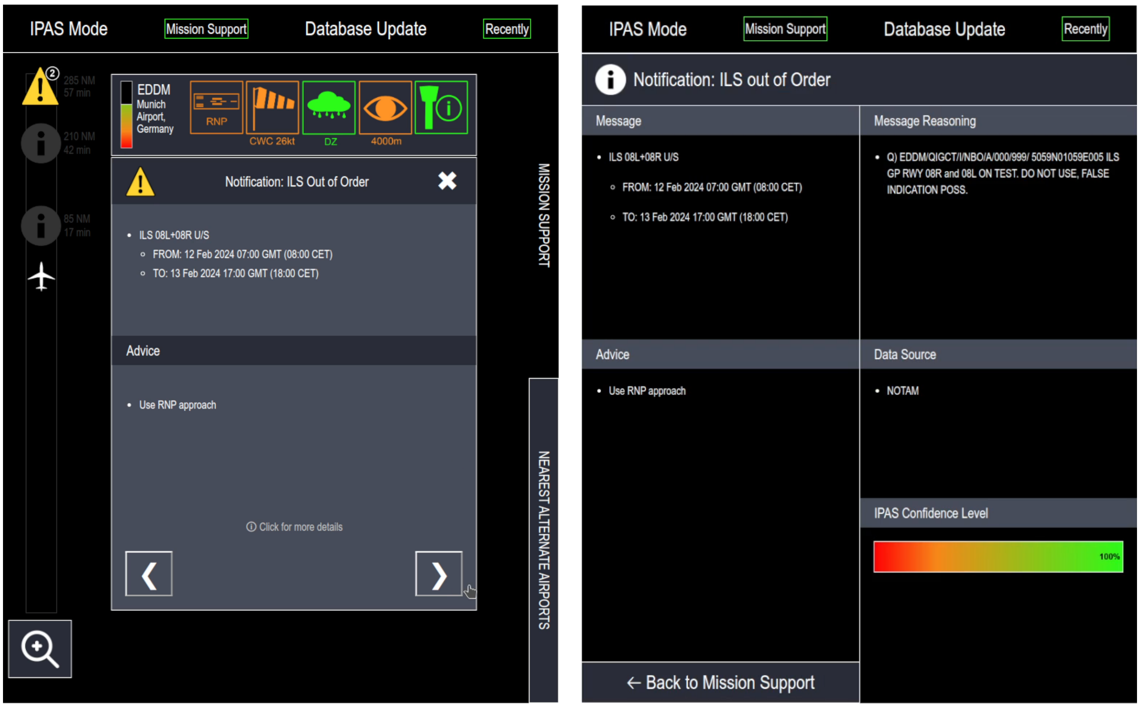
- Activate De-Icing according to procedures (FCOM)

Data Source

- METAR

IPAS Confidence Level

Information that icing conditions will take place in decscent.



Notification: ILS Out of Order

- ILS 08L+08R U/S
  - FROM: 12 Feb 2024 07:00 GMT (08:00 CET)
  - TO: 13 Feb 2024 17:00 GMT (18:00 CET)

Advice

- Use RNP approach

Notification: ILS out of Order

Message

- ILS 08L+08R U/S
  - FROM: 12 Feb 2024 07:00 GMT (08:00 CET)
  - TO: 13 Feb 2024 17:00 GMT (18:00 CET)

Message Reasoning

- Q) EDDM/QIGCT/I/NBO/A/000/999/ 5059N01059E005 ILS GP RWY 08R and 08L ON TEST. DO NOT USE, FALSE INDICATION POSS.

Advice

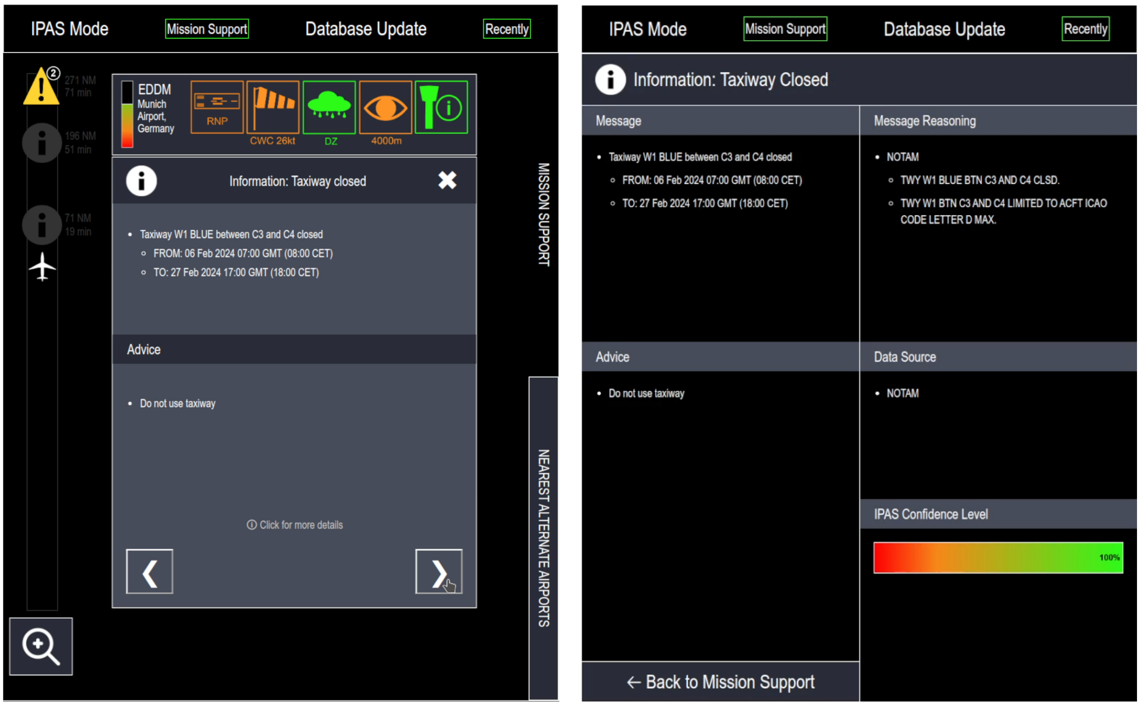
- Use RNP approach

Data Source

- NOTAM

IPAS Confidence Level

Notification that the ILS is out of order and an RNP approach is recommended.



Information: Taxiway closed

- Taxiway W1 BLUE between C3 and C4 closed
  - FROM: 06 Feb 2024 07:00 GMT (08:00 CET)
  - TO: 27 Feb 2024 17:00 GMT (18:00 CET)

Advice

- Do not use taxiway

ⓘ Click for more details

Information: Taxiway Closed

Message

- Taxiway W1 BLUE between C3 and C4 closed
  - FROM: 06 Feb 2024 07:00 GMT (08:00 CET)
  - TO: 27 Feb 2024 17:00 GMT (18:00 CET)

Message Reasoning

- NOTAM
  - TWY W1 BLUE BTN C3 AND C4 CLSD.
  - TWY W1 BTN C3 AND C4 LIMITED TO ACFT ICAO CODE LETTER D MAX.

Advice

- Do not use taxiway

Data Source

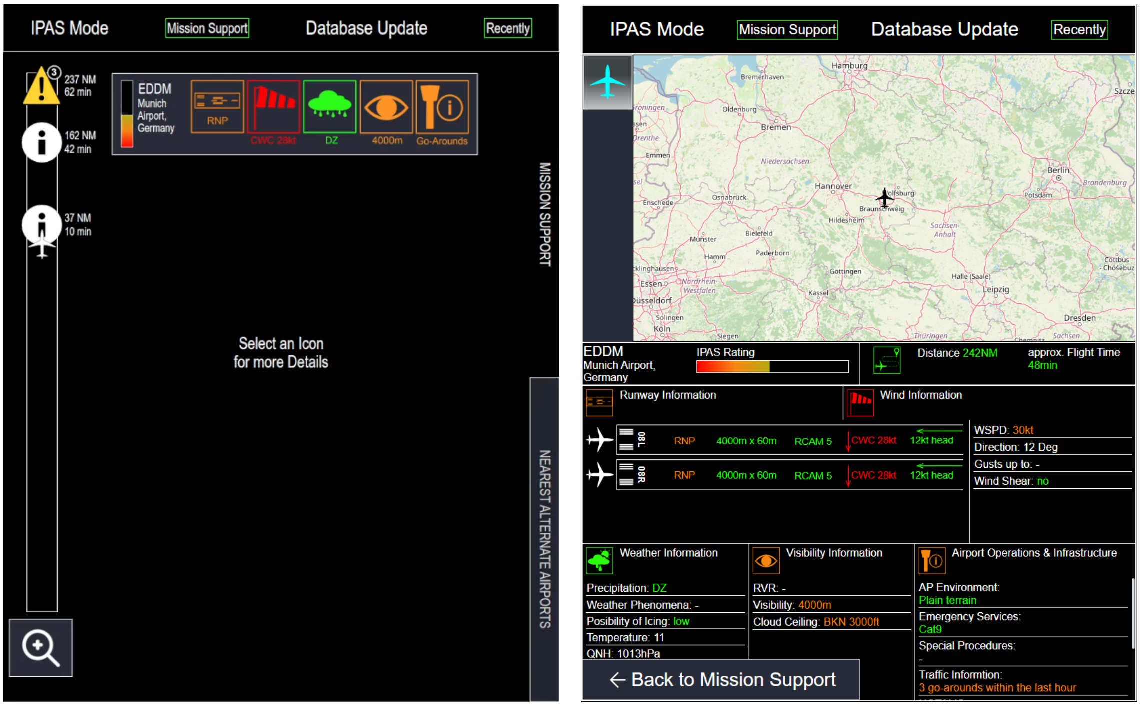
- NOTAM

IPAS Confidence Level

100%

← Back to Mission Support

Information that the taxiway is closed.



Select an Icon for more Details

EDDM
Munich Airport, Germany

IPAS Rating

Distance 242NM

approx. Flight Time 48min

Runway Information

08L	RNP	4000m x 60m	RCAM 5	CWC 28kt	12kt head
08R	RNP	4000m x 60m	RCAM 5	CWC 28kt	12kt head

Wind Information

WSPD: 30kt
Direction: 12 Deg
Gusts up to: -
Wind Shear: no

Weather Information

Precipitation: DZ
Weather Phenomena: -
Posibility of Icing: low
Temperature: 11
QNH: 1013hPa

Visibility Information

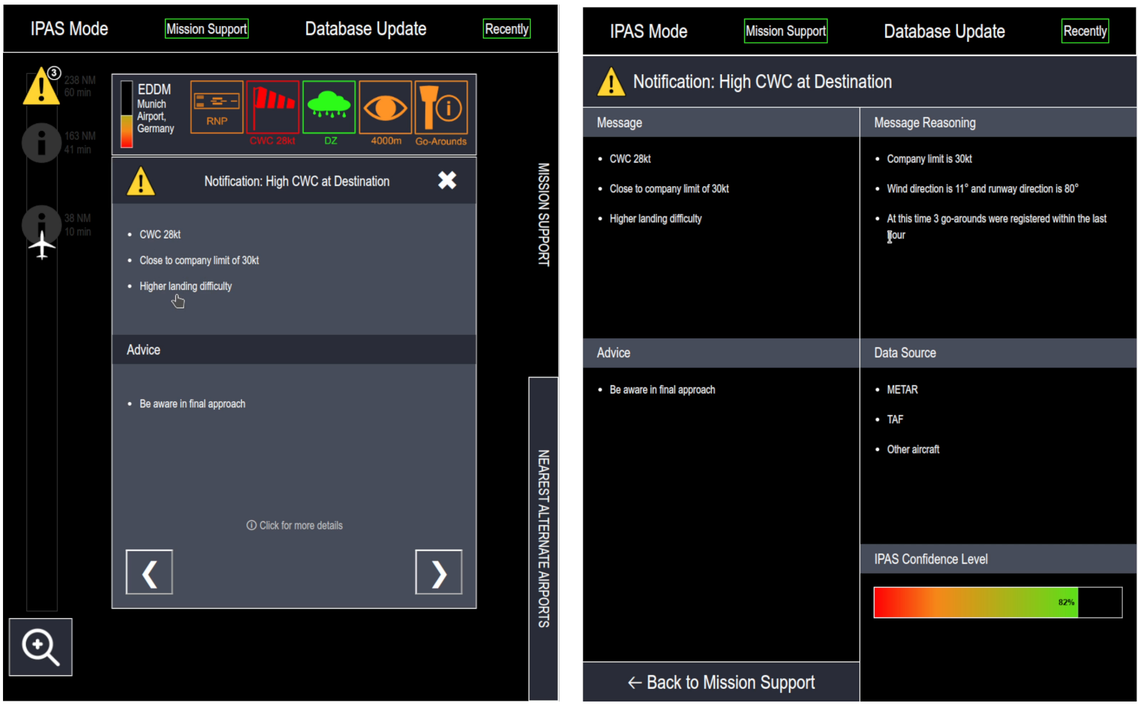
RVR: -
Visibility: 4000m
Cloud Ceiling: BKN 3000ft

Airport Operations & Infrastructure

AP Environment: Plain terrain
Emergency Services: Cat9
Special Procedures: -
Traffic Informtion: 3 go-arounds within the last hour

← Back to Mission Support

First status change: The wind gets stronger and the CWC worsens.



Notification: High CWC at Destination

- CWC 28kt
- Close to company limit of 30kt
- Higher landing difficulty

Advice

- Be aware in final approach

Notification: High CWC at Destination

Message

- CWC 28kt
- Close to company limit of 30kt
- Higher landing difficulty

Message Reasoning

- Company limit is 30kt
- Wind direction is 11° and runway direction is 80°
- At this time 3 go-arounds were registered within the last hour

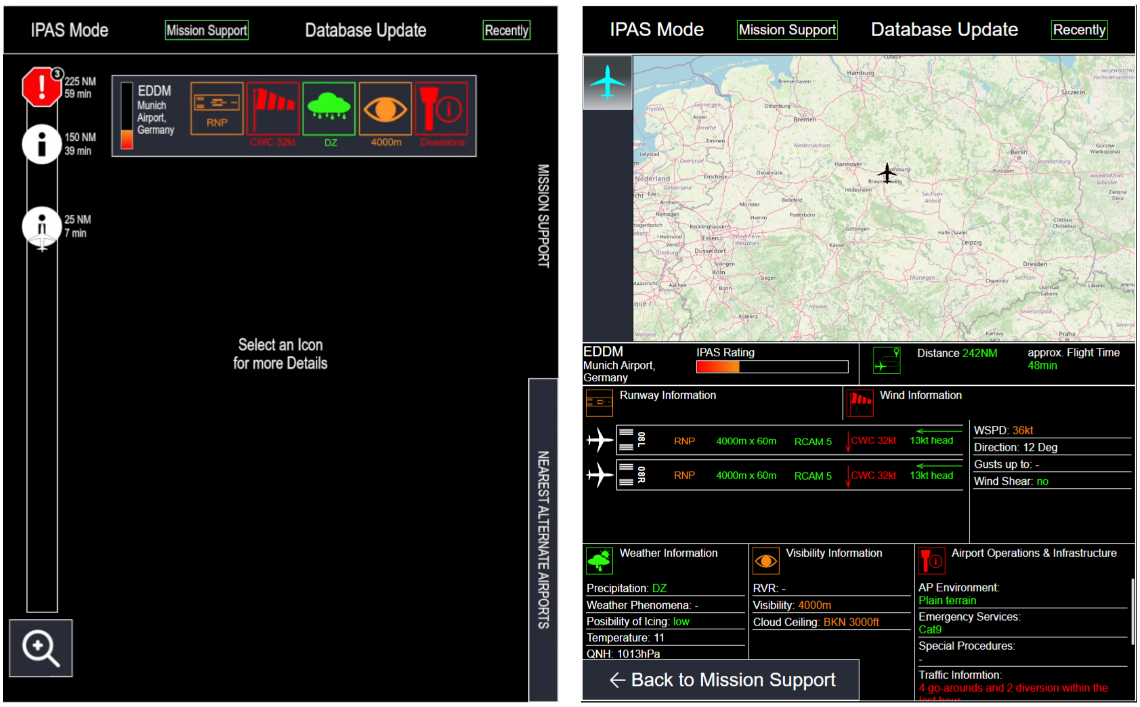
Advice

- Be aware in final approach

Data Source

- METAR
- TAF
- Other aircraft

Notification that the CWC is almost at limit.



Select an Icon for more Details

EDDM
Munich Airport, Germany
IPAS Rating
Distance 242NM
approx. Flight Time 48min

Runway Information

08L	RNP	4000m x 60m	RCAM 5	CWC 32kt	13kt head
08R	RNP	4000m x 60m	RCAM 5	CWC 32kt	13kt head

Wind Information

WSPD: 36kt
Direction: 12 Deg
Gusts up to: -
Wind Shear: no

Weather Information

Precipitation: DZ
Weather Phenomena: -
Posibility of Icing: low
Temperature: 11
QNH: 1013hPa

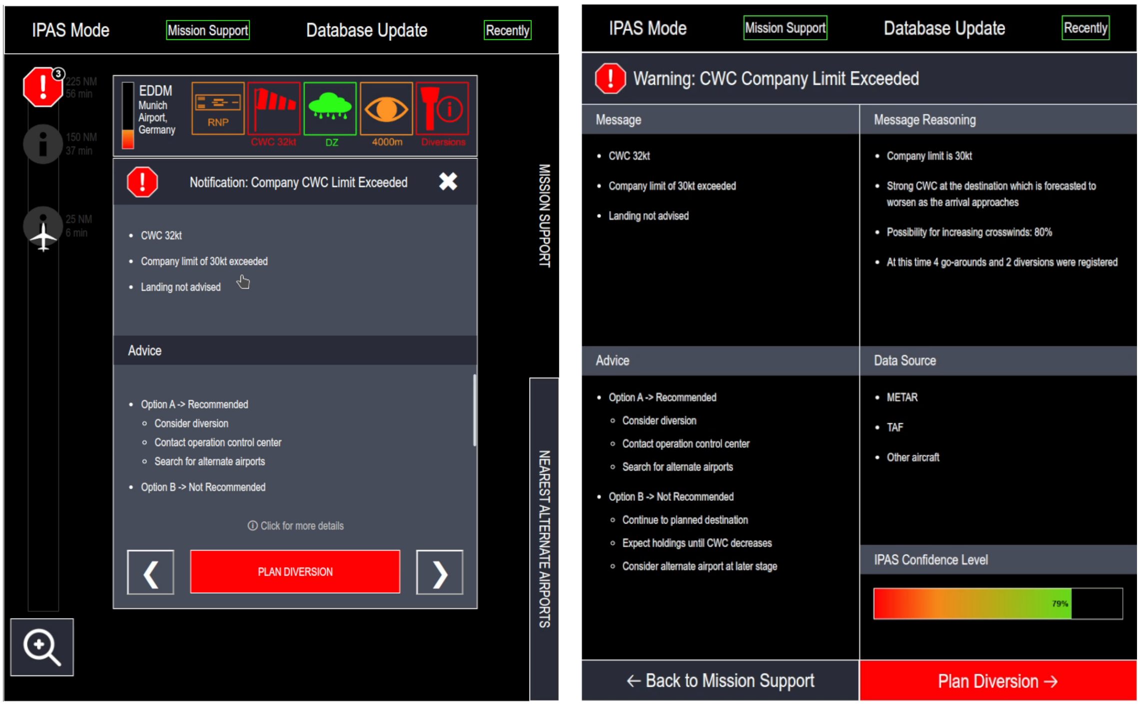
Visibility Information

RVR: -
Visibility: 4000m
Cloud Ceiling: BKN 3000ft

Airport Operations & Infrastructure

AP Environment: Plain terrain
Emergency Services: Cat9
Special Procedures: -
Traffic Informtion: 4 go-arounds and 2 diversion within the

Second status change: The wind gets even stronger and the CWC crosses the company limit.



Notification: Company CWC Limit Exceeded

- CWC 32kt
- Company limit of 30kt exceeded
- Landing not advised

Advice

- Option A -> Recommended
  - Consider diversion
  - Contact operation control center
  - Search for alternate airports
- Option B -> Not Recommended

Warning: CWC Company Limit Exceeded

Message

- CWC 32kt
- Company limit of 30kt exceeded
- Landing not advised

Message Reasoning

- Company limit is 30kt
- Strong CWC at the destination which is forecasted to worsen as the arrival approaches
- Possibility for increasing crosswinds: 80%
- At this time 4 go-arounds and 2 diversions were registered

Advice

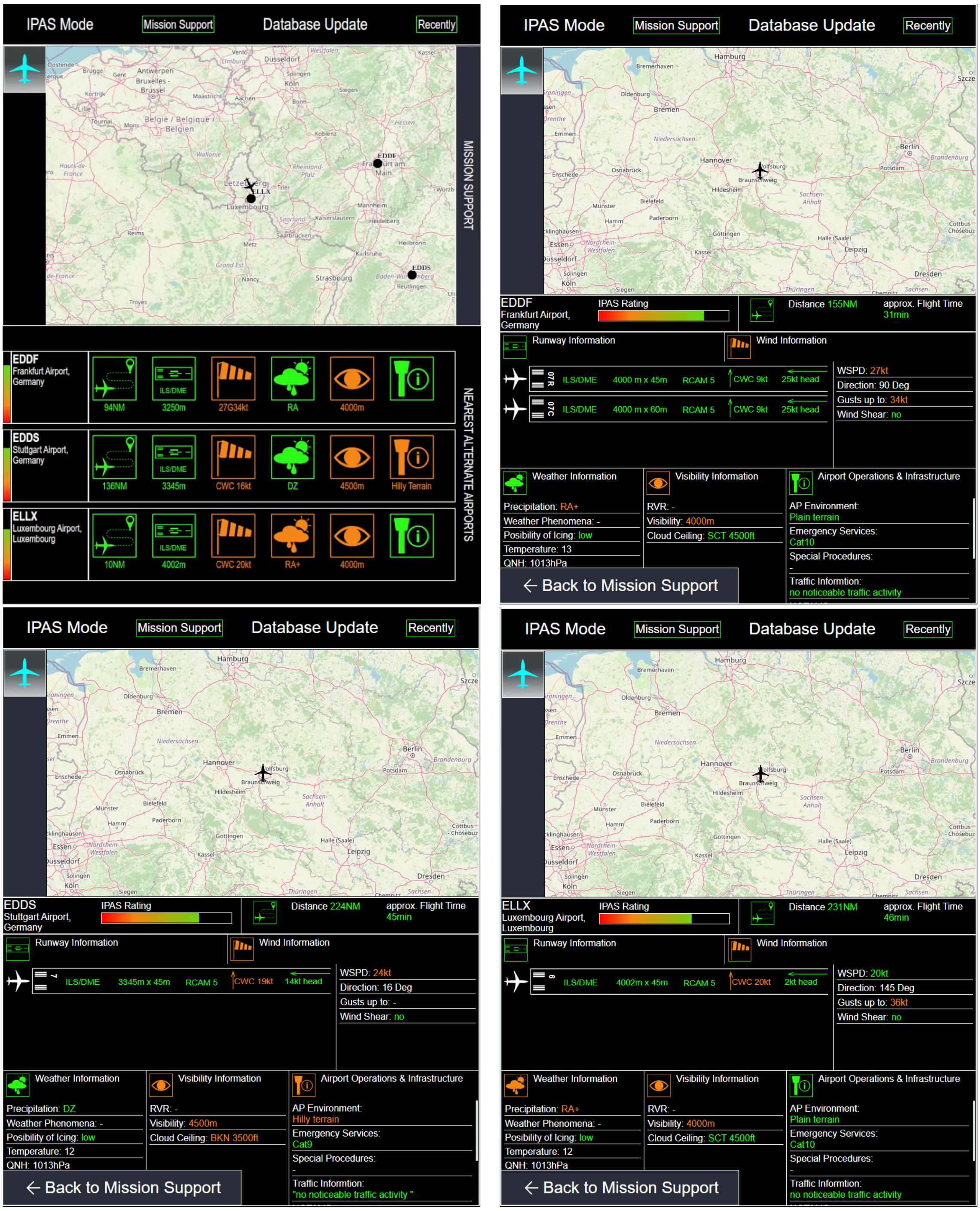
- Option A -> Recommended
  - Consider diversion
  - Contact operation control center
  - Search for alternate airports
- Option B -> Not Recommended
  - Continue to planned destination
  - Expect holdings until CWC decreases
  - Consider alternate airport at later stage

Data Source

- METAR
- TAF
- Other aircraft

IPAS Confidence Level

Warning that the CWC Limit is crossed and diversion is recommended.



EDDF Frankfurt Airport, Germany — 94NM — ILS/DME 3250m — 27G34kt — RA — 4000m

EDDS Stuttgart Airport, Germany — 136NM — ILS/DME 3345m — CWC 16kt — DZ — 4500m — Hilly Terrain

ELLX Luxembourg Airport, Luxembourg — 10NM — ILS/DME 4002m — CWC 20kt — RA+ — 4000m

EDDF
Frankfurt Airport, Germany
IPAS Rating
Distance 155NM
approx. Flight Time 31min

Runway Information
07R ILS/DME 4000 m x 45m RCAM 5 CWC 9kt 25kt head
07C ILS/DME 4000 m x 60m RCAM 5 CWC 9kt 25kt head

Wind Information
WSPD: 27kt
Direction: 90 Deg
Gusts up to: 34kt
Wind Shear: no

Weather Information
Precipitation: RA+
Weather Phenomena: -
Posibility of Icing: low
Temperature: 13
QNH: 1013hPa

Visibility Information
RVR: -
Visibility: 4000m
Cloud Ceiling: SCT 4500ft

Airport Operations & Infrastructure
AP Environment: Plain terrain
Emergency Services: Cat10
Special Procedures: -
Traffic Informtion: no noticeable traffic activity

EDDS
Stuttgart Airport, Germany
IPAS Rating
Distance 224NM
approx. Flight Time 45min

Runway Information
7 ILS/DME 3345m x 45m RCAM 5 CWC 19kt 14kt head

Wind Information
WSPD: 24kt
Direction: 16 Deg
Gusts up to: -
Wind Shear: no

Weather Information
Precipitation: DZ
Weather Phenomena: -
Posibility of Icing: low
Temperature: 12
QNH: 1013hPa

Visibility Information
RVR: -
Visibility: 4500m
Cloud Ceiling: BKN 3500ft

Airport Operations & Infrastructure
AP Environment: Hilly terrain
Emergency Services: Cat9
Special Procedures: -
Traffic Informtion: "no noticeable traffic activity "

ELLX
Luxembourg Airport, Luxembourg
IPAS Rating
Distance 231NM
approx. Flight Time 46min

Runway Information
6 ILS/DME 4002m x 45m RCAM 5 CWC 20kt 2kt head

Wind Information
WSPD: 20kt
Direction: 145 Deg
Gusts up to: 36kt
Wind Shear: no

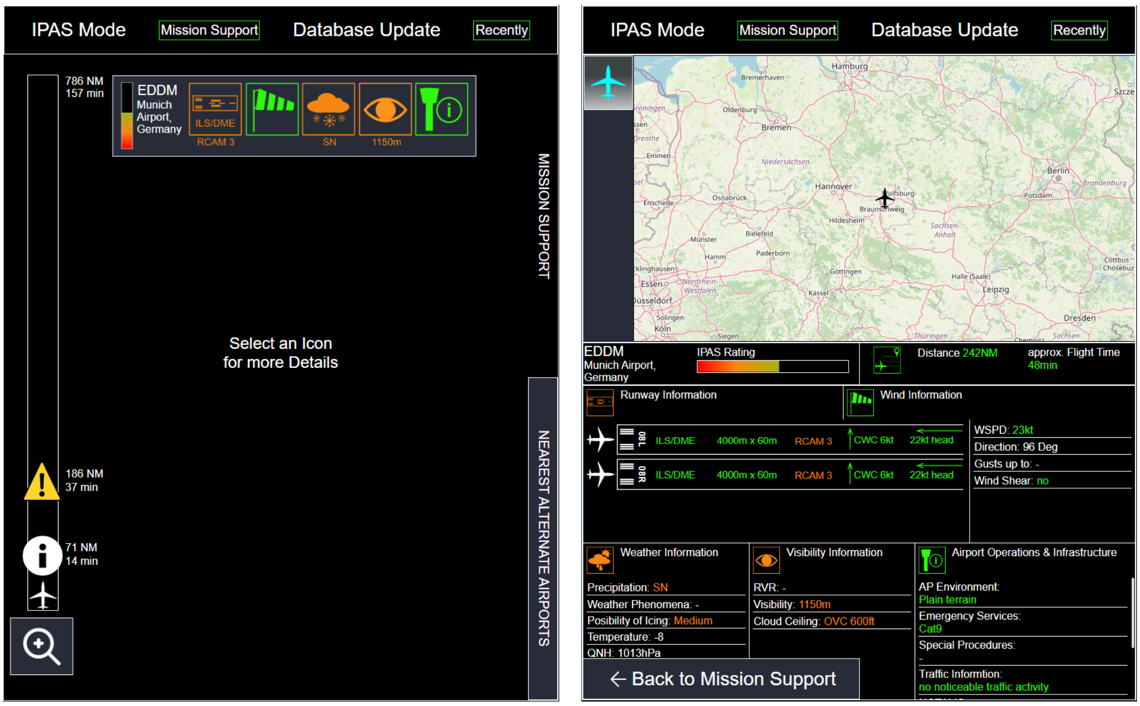
Weather Information
Precipitation: RA+
Weather Phenomena: -
Posibility of Icing: low
Temperature: 12
QNH: 1013hPa

Visibility Information
RVR: -
Visibility: 4000m
Cloud Ceiling: SCT 4500ft

Airport Operations & Infrastructure
AP Environment: Plain terrain
Emergency Services: Cat10
Special Procedures: -
Traffic Informtion: no noticeable traffic activity

Nearest alternate airports and the respective ‘Airport Detail’ pages.

Scenario 2



Select an Icon for more Details

EDDM
Munich Airport, Germany
IPAS Rating
Distance 242NM
approx. Flight Time 48min

Runway Information

08L	ILS/DME	4000m x 60m	RCAM 3	CWC 6kt	22kt head
08R	ILS/DME	4000m x 60m	RCAM 3	CWC 6kt	22kt head

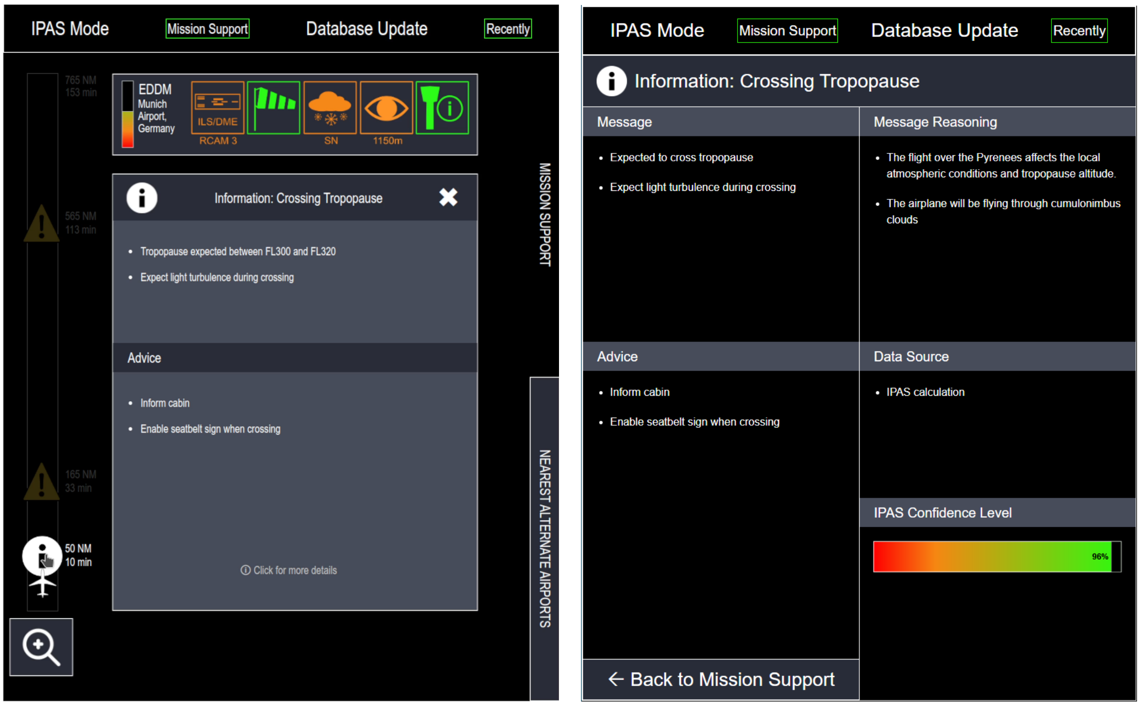
Wind Information
WSPD: 23kt
Direction: 96 Deg
Gusts up to: -
Wind Shear: no

Weather Information
Precipitation: SN
Weather Phenomena: -
Posibility of Icing: Medium
Temperature: -8
QNH: 1013hPa

Visibility Information
RVR: -
Visibility: 1150m
Cloud Ceiling: OVC 600ft

Airport Operations & Infrastructure
AP Environment: Plain terrain
Emergency Services: Cat9
Special Procedures: -
Traffic Informtion: no noticeable traffic activity

Status at the beginning.



Information: Crossing Tropopause

- Tropopause expected between FL300 and FL320
- Expect light turbulence during crossing

Advice

- Inform cabin
- Enable seatbelt sign when crossing

Information: Crossing Tropopause

Message

- Expected to cross tropopause
- Expect light turbulence during crossing

Message Reasoning

- The flight over the Pyrenees affects the local atmospheric conditions and tropopause altitude.
- The airplane will be flying through cumulonimbus clouds

Advice

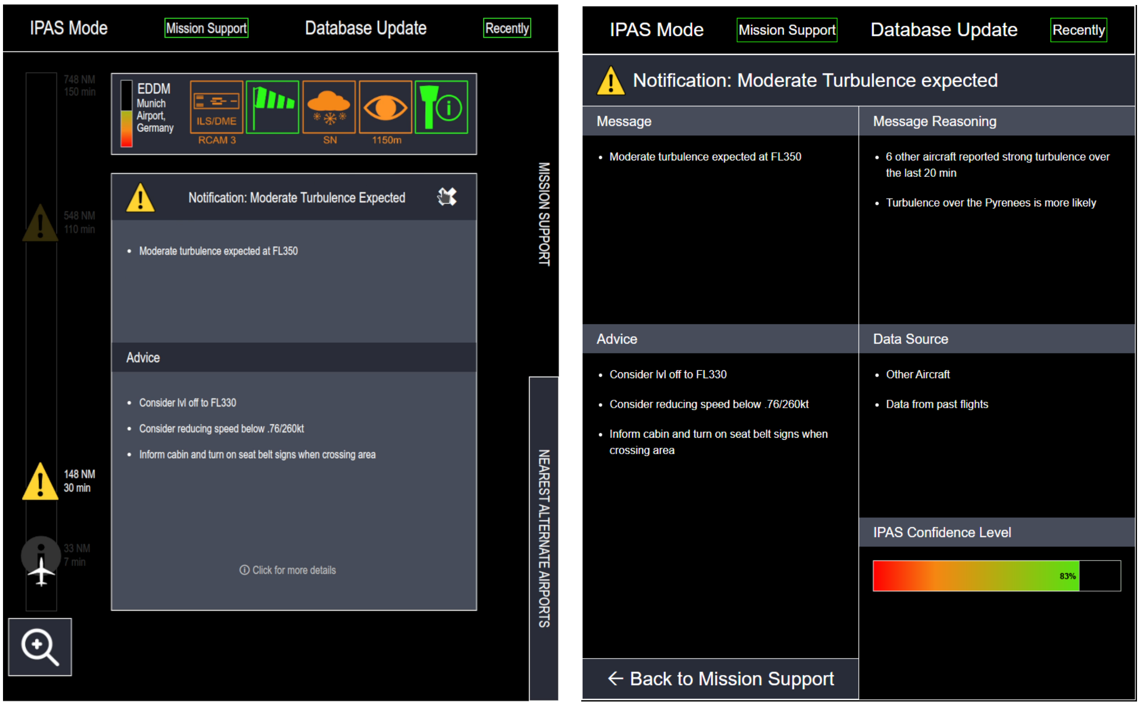
- Inform cabin
- Enable seatbelt sign when crossing

Data Source

- IPAS calculation

IPAS Confidence Level

Information that the tropopause will be crossed.



Notification: Moderate Turbulence Expected

- Moderate turbulence expected at FL350

Advice

- Consider lvl off to FL330
- Consider reducing speed below .76/260kt
- Inform cabin and turn on seat belt signs when crossing area

Notification: Moderate Turbulence expected

Message

- Moderate turbulence expected at FL350

Message Reasoning

- 6 other aircraft reported strong turbulence over the last 20 min
- Turbulence over the Pyrenees is more likely

Advice

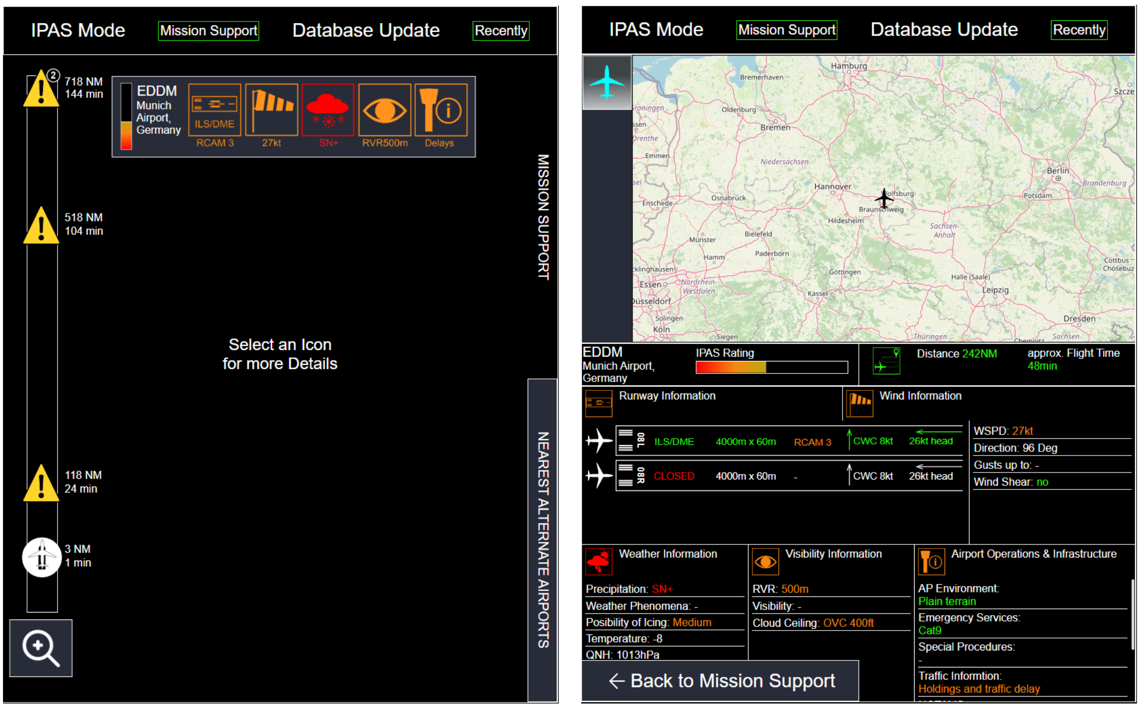
- Consider lvl off to FL330
- Consider reducing speed below .76/260kt
- Inform cabin and turn on seat belt signs when crossing area

Data Source

- Other Aircraft
- Data from past flights

IPAS Confidence Level: 83%

Notification that turbulences are expected over the Pyrenees.



EDDM
Munich Airport,
Germany

Distance 242NM

approx. Flight Time 48min

Runway Information

08L	ILS/DME	4000m x 60m	RCAM 3	CWC 8kt	26kt head
08R	CLOSED	4000m x 60m	-	CWC 8kt	26kt head

Wind Information

WSPD: 27kt
Direction: 96 Deg
Gusts up to: -
Wind Shear: no

Weather Information

Precipitation: SN+
Weather Phenomena: -
Posibility of Icing: Medium
Temperature: -8
QNH: 1013hPa

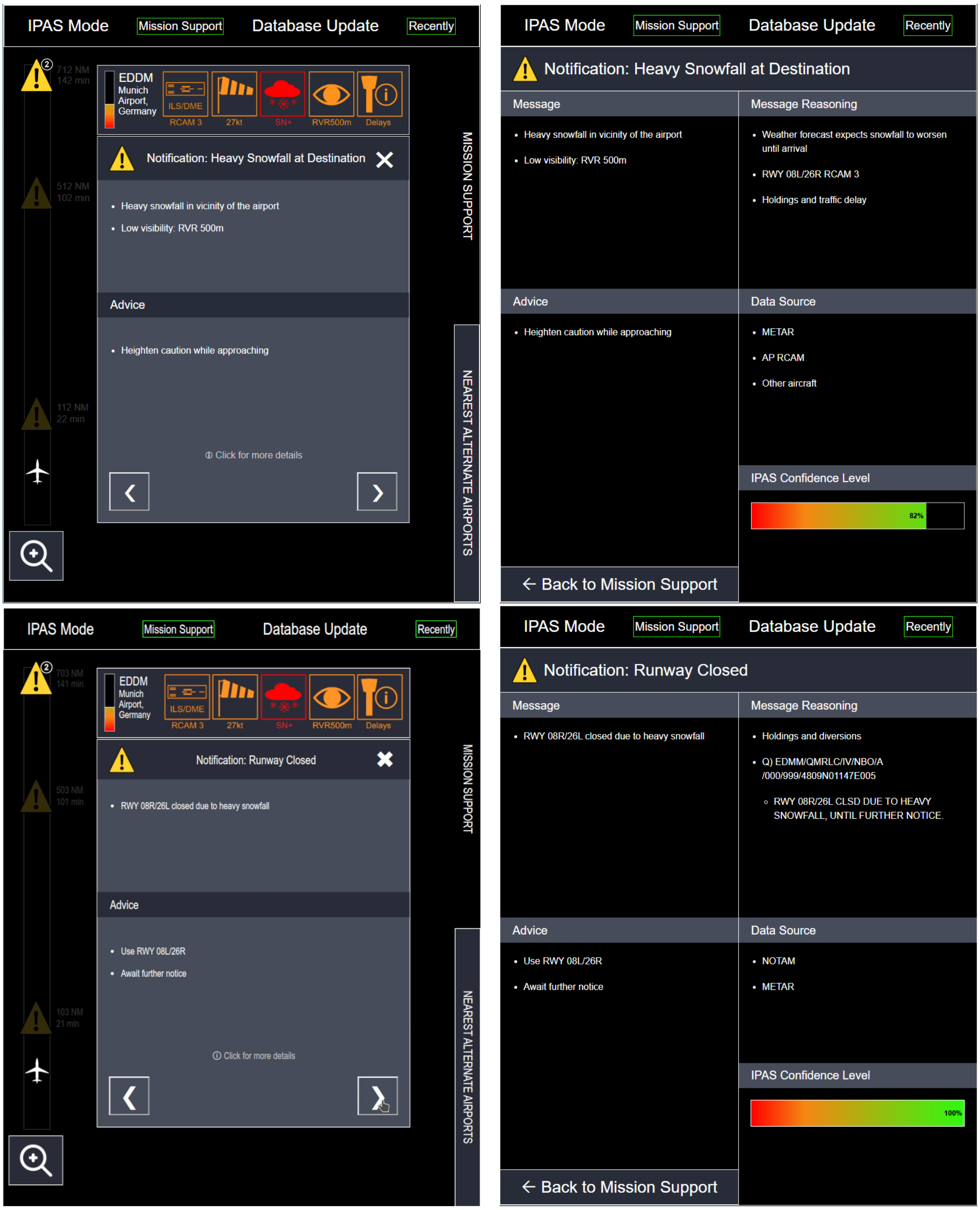
Visibility Information

RVR: 500m
Visibility: -
Cloud Ceiling: OVC 400ft

Airport Operations & Infrastructure

AP Environment: Plain terrain
Emergency Services: Cat9
Special Procedures: -
Traffic Informtion: Holdings and traffic delay

First status change: One of the two runways closes due to storm and the other runways conditions worsend.



Notification: Heavy Snowfall at Destination

- Heavy snowfall in vicinity of the airport
- Low visibility: RVR 500m

Advice

- Heighten caution while approaching

Notification: Heavy Snowfall at Destination

Message

- Heavy snowfall in vicinity of the airport
- Low visibility: RVR 500m

Message Reasoning

- Weather forecast expects snowfall to worsen until arrival
- RWY 08L/26R RCAM 3
- Holdings and traffic delay

Advice

- Heighten caution while approaching

Data Source

- METAR
- AP RCAM
- Other aircraft

IPAS Confidence Level

Notification: Runway Closed

- RWY 08R/26L closed due to heavy snowfall

Advice

- Use RWY 08L/26R
- Await further notice

Notification: Runway Closed

Message

- RWY 08R/26L closed due to heavy snowfall

Message Reasoning

- Holdings and diversions
- Q) EDMM/QMRLC/IV/NBO/A /000/999/4809N01147E005
  - RWY 08R/26L CLSD DUE TO HEAVY SNOWFALL, UNTIL FURTHER NOTICE.

Advice

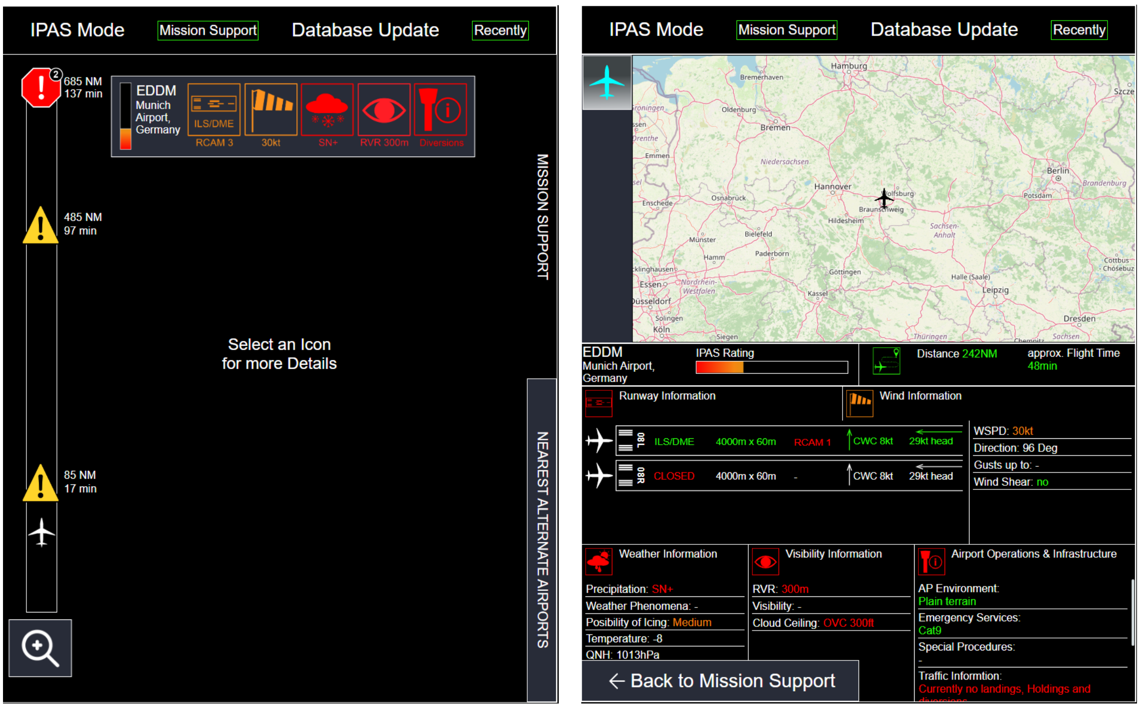
- Use RWY 08L/26R
- Await further notice

Data Source

- NOTAM
- METAR

IPAS Confidence Level

Notifications over heavy snow and a closed runway due to the snowfall.



685 NM
137 min

485 NM
97 min

85 NM
17 min

EDDM
Munich Airport, Germany
ILS/DME RCAM 3
30kt
SN+
RVR 300m
Diversions

Select an Icon
for more Details

EDDM
Munich Airport, Germany

IPAS Rating

Distance 242NM

approx. Flight Time
48min

Runway Information

08L	ILS/DME	4000m x 60m	RCAM 1	CWC 8kt	29kt head
08R	CLOSED	4000m x 60m	-	CWC 8kt	29kt head

Wind Information

WSPD: 30kt
Direction: 96 Deg
Gusts up to: -
Wind Shear: no

Weather Information

Precipitation: SN+
Weather Phenomena: -
Posibility of Icing: Medium
Temperature: -8
QNH: 1013hPa

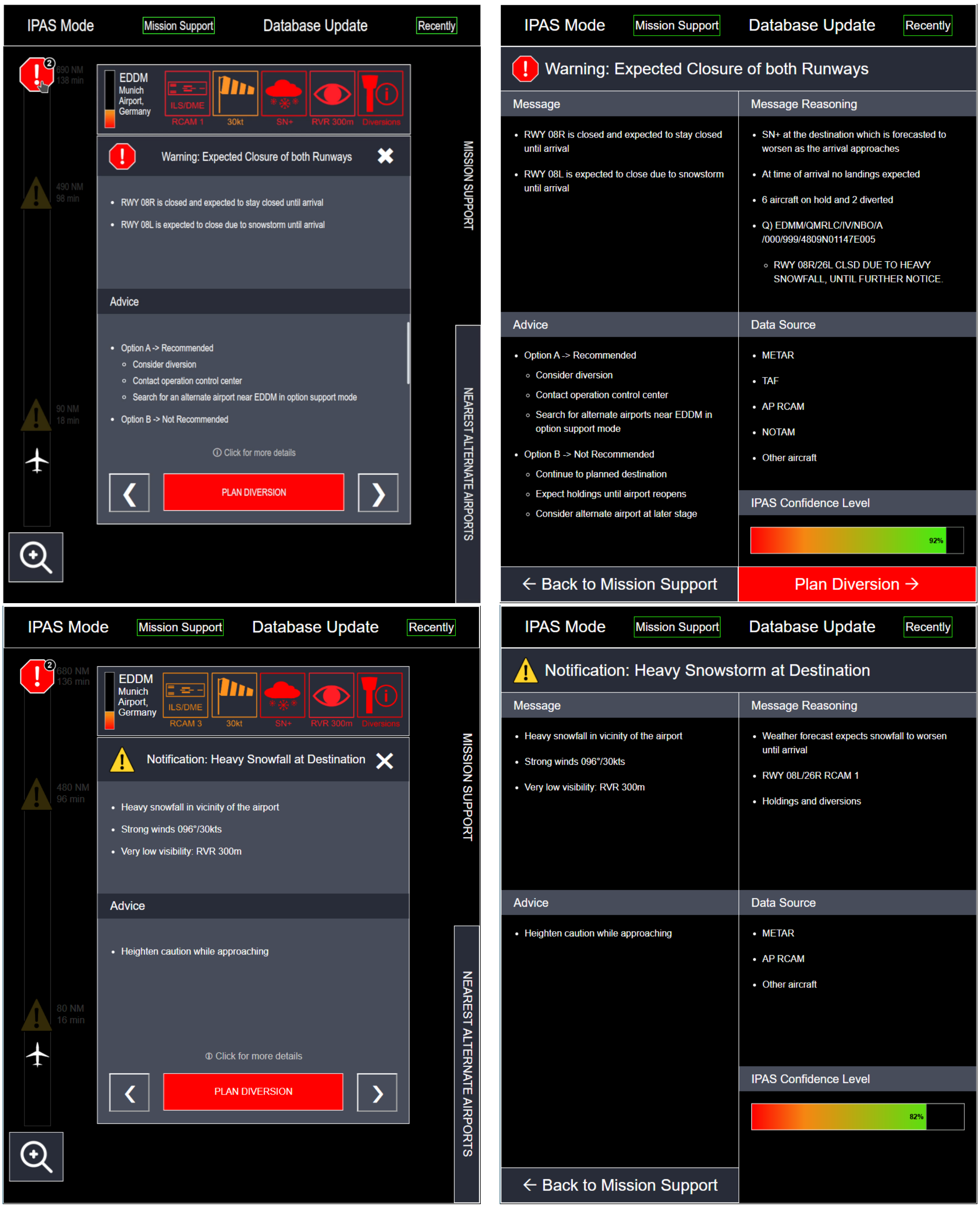
Visibility Information

RVR: 300m
Visibility: -
Cloud Ceiling: OVC 300ft

Airport Operations & Infrastructure

AP Environment:
Plain terrain
Emergency Services:
Cat9
Special Procedures:
-
Traffic Informtion:
Currently no landings, Holdings and diversions

Second status change: Both runways are expected to close to the the worsening snow storm until arrival.



Warning: Expected Closure of both Runways

- RWY 08R is closed and expected to stay closed until arrival
- RWY 08L is expected to close due to snowstorm until arrival

Advice

- Option A -> Recommended
  - Consider diversion
  - Contact operation control center
  - Search for an alternate airport near EDDM in option support mode
- Option B -> Not Recommended

Warning: Expected Closure of both Runways

Message

- RWY 08R is closed and expected to stay closed until arrival
- RWY 08L is expected to close due to snowstorm until arrival

Message Reasoning

- SN+ at the destination which is forecasted to worsen as the arrival approaches
- At time of arrival no landings expected
- 6 aircraft on hold and 2 diverted
- Q) EDMM/QMRLC/IV/NBO/A /000/999/4809N01147E005
  - RWY 08R/26L CLSD DUE TO HEAVY SNOWFALL, UNTIL FURTHER NOTICE.

Advice

- Option A -> Recommended
  - Consider diversion
  - Contact operation control center
  - Search for alternate airports near EDDM in option support mode
- Option B -> Not Recommended
  - Continue to planned destination
  - Expect holdings until airport reopens
  - Consider alternate airport at later stage

Data Source

- METAR
- TAF
- AP RCAM
- NOTAM
- Other aircraft

IPAS Confidence Level

Notification: Heavy Snowfall at Destination

- Heavy snowfall in vicinity of the airport
- Strong winds 096°/30kts
- Very low visibility: RVR 300m

Advice

- Heighten caution while approaching

Notification: Heavy Snowstorm at Destination

Message

- Heavy snowfall in vicinity of the airport
- Strong winds 096°/30kts
- Very low visibility: RVR 300m

Message Reasoning

- Weather forecast expects snowfall to worsen until arrival
- RWY 08L/26R RCAM 1
- Holdings and diversions

Advice

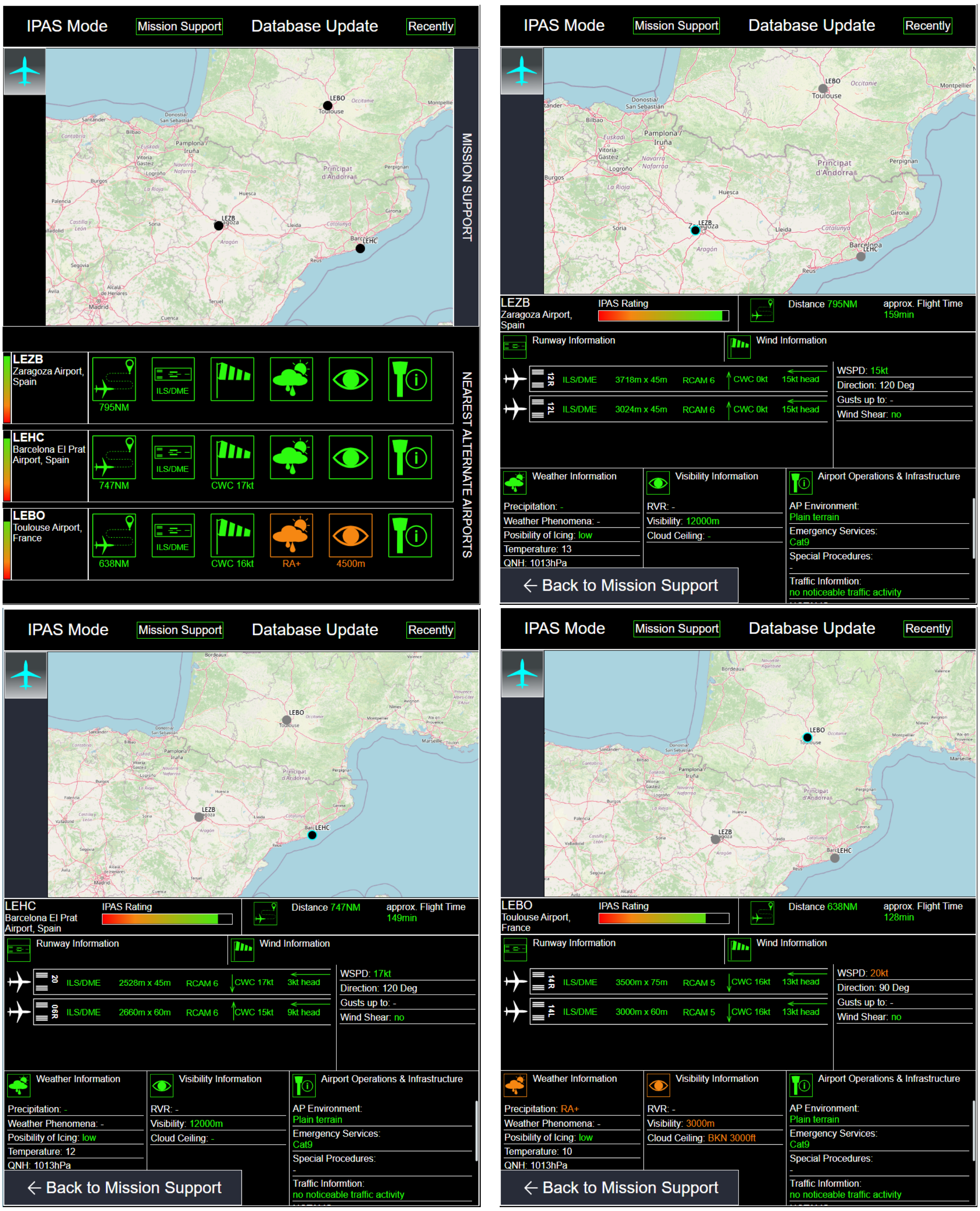
- Heighten caution while approaching

Data Source

- METAR
- AP RCAM
- Other aircraft

IPAS Confidence Level

Warning that both runways are expected to close until arrival and the snowstorm worsened.



LEZB Zaragoza Airport, Spain	795NM	ILS/DME				
LEHC Barcelona El Prat Airport, Spain	747NM	ILS/DME	CWC 17kt			
LEBO Toulouse Airport, France	638NM	ILS/DME	CWC 16kt	RA+	4500m	

LEZB
Zaragoza Airport, Spain
IPAS Rating
Distance 795NM
approx. Flight Time 159min

Runway Information

12R	ILS/DME	3718m x 45m	RCAM 6	CWC 0kt	15kt head
12L	ILS/DME	3024m x 45m	RCAM 6	CWC 0kt	15kt head

Wind Information
WSPD: 15kt
Direction: 120 Deg
Gusts up to: -
Wind Shear: no

Weather Information
Precipitation: -
Weather Phenomena: -
Posibility of Icing: low
Temperature: 13
QNH: 1013hPa

Visibility Information
RVR: -
Visibility: 12000m
Cloud Ceiling: -

Airport Operations & Infrastructure
AP Environment: Plain terrain
Emergency Services: Cat9
Special Procedures: -
Traffic Informtion: no noticeable traffic activity

LEHC
Barcelona El Prat Airport, Spain
IPAS Rating
Distance 747NM
approx. Flight Time 149min

Runway Information

20	ILS/DME	2528m x 45m	RCAM 6	CWC 17kt	3kt head
06R	ILS/DME	2660m x 60m	RCAM 6	CWC 15kt	9kt head

Wind Information
WSPD: 17kt
Direction: 120 Deg
Gusts up to: -
Wind Shear: no

Weather Information
Precipitation: -
Weather Phenomena: -
Posibility of Icing: low
Temperature: 12
QNH: 1013hPa

Visibility Information
RVR: -
Visibility: 12000m
Cloud Ceiling: -

Airport Operations & Infrastructure
AP Environment: Plain terrain
Emergency Services: Cat9
Special Procedures: -
Traffic Informtion: no noticeable traffic activity

LEBO
Toulouse Airport, France
IPAS Rating
Distance 638NM
approx. Flight Time 128min

Runway Information

14R	ILS/DME	3500m x 75m	RCAM 5	CWC 16kt	13kt head
14L	ILS/DME	3000m x 60m	RCAM 5	CWC 16kt	13kt head

Wind Information
WSPD: 20kt
Direction: 90 Deg
Gusts up to: -
Wind Shear: no

Weather Information
Precipitation: RA+
Weather Phenomena: -
Posibility of Icing: low
Temperature: 10
QNH: 1013hPa

Visibility Information
RVR: -
Visibility: 3000m
Cloud Ceiling: BKN 3000ft

Airport Operations & Infrastructure
AP Environment: Plain terrain
Emergency Services: Cat9
Special Procedures: -
Traffic Informtion: no noticeable traffic activity

Nearest alternate airports and the respective ‘Airport Detail’ pages.