D2.1 Analysis of Potential Cognitive Computing Aided Tasks

Tasks Analysis and Use Cases

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HARVIS

HUMAN AIRCRAFT ROADMAP FOR VIRTUAL INTELLIGENT SYSTEM

This deliverable has received funding from the Clean Sky 2 Joint Undertaking under grant agreement No 831884 under European Union's Horizon 2020 research and innovation.

Abstract

The main goal of the HARVIS Project is to identify how cognitive computing algorithms, implemented in a digital assistant, could support the decision-making of single pilots in complex situations.

Following the state of the art, the second step to reach this objective is to analyze cockpit operations of large commercial aircraft such as the A350, A380 or A320, or similar.

This document presents the results of **task analysis** carried out on:

- **Aeronautical literature**: Among pilot training handbooks, industry, safety or flight companies' documentation and studies related to specific operational domains or flight phases.
- **Pilot interviews**: Beyond the rules and procedures that pilots have to follow, in field reality, many undocumented things occurs that needs to be captured during free talks about real cases.
- **Flight data analysis**: Collecting raw data coming from flight companies focusing on troubles or breakdown.

This document also describes few archetypal **uses cases** where pilots need to take a decision and where a Virtual Pilot Assistant (VPA) would be needed to support Single Pilot Operations (SPO).

These are additional information the project will use in the definition of a **roadmap** highlighting the steps needed, in terms of technology development, interaction design and training, to develop such an assistant (that will be presented in D2.2 Human Machine Interface and Envelope, D2.3 Pilot training considerations for the implementation of a digital assistant and D4.3 Technologies roadmap).

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This project has received funding from the Clean Sky 2 Joint Undertaking (JU) under grant agreement No 831884. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Clean Sky 2 JU members other than the Union

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Executive summary

This document corresponds to the D2.1 deliverable “Task analysis, concept and uses cases” within the second work package of the HARVIS project. The purpose of this document is to identify room where Cognitive Computing (CC) Algorithms could support the decision making of single pilot in complex situation, which is the main goal of this project.

Therefore, an overview of the cockpit environment and instruments has been carried out. Furthermore, a study of the current operations in the cockpit and the nature of information exchanged and delivered have been done.

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1. Introduction

1.1. Purpose and Scope of the document

This document aims at reporting an analysis of the task in the cockpit of large commercial aircraft in order to raise some high level features where a virtual intelligent system could be involved. Based on those concepts and focusing on single pilot operations context, several use cases are described and evaluated regarding their innovation degree, their alignment to the analysis of the tasks, the difficulty of their implementation and their impact on current aircraft operation (safety and performance).

1.2. Deliverable structure

This document is structured as follows:

- Section 1 summarizes the purpose and scope of this document as well as the structure it follows, and the acronyms and terminology used.
- Section 2 analyses processes and interactions driving decisions in a cockpit of large commercial aircraft.
- Section 3 raises concepts about future virtual pilot assistant design considering the future of aviation.
- Section 4 presents the use cases that were created but a posteriori deemed not relevant by several pilots.
- Section 5 presents the selected use case that were deemed relevant and interesting for further implementation

1.3. Acronyms and Terminology

The following table reports the acronyms used in this deliverable.

Term	Definition
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
CRM	Crew Resource Management
FO	First Officer
PF	Pilot Flying

PIC	Pilot In Command
PM	Pilot Monitoring
SPO	Single Pilot Operations
VPA	Virtual Pilot Assistant

Table 1: Acronyms

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2. Tasks analysis inside cockpit

An airliner cockpit is a workspace where two pilots work in a collaborative way all along the flight. The Pilot-In-Command (PIC), also called the Captain (CPT), is supported by the First Officer (FO). Furthermore, at any time during the flight, the pilots may perform two roles and associated tasks. The Pilot Flying (PF) is the pilot in control of the flight trajectory and the Pilot Monitoring (PM) is responsible for monitoring the current and projected flight path, the energy and the system states of the aircraft.

While ensuring security, safety and comfort of the passengers, pilots activity is divided in five main tasks: aircraft piloting (most often with autopilot), navigation (managing and tracking the flight route), communication with air-traffic controllers and ground support, aircraft system monitoring, and accomplishment of the company mission.

A flight is divided in 11 phases. These phases are not equivalent in term of workload. The cruise phase for example requires the pilots to perform just few tasks such as regular fuel checks every 30 minutes, communication with ATC when necessary and AC state and position monitoring. In nominal situation, this phase is not workload-heavy and pilots use to eat and rest during this flight phase. On the contrary, the approach phase is generally very loaded and conducted in a sterile cockpit (all non-essential discussions and activities forbidden under Flight Level 100) to enable pilots to be focused on the tasks.

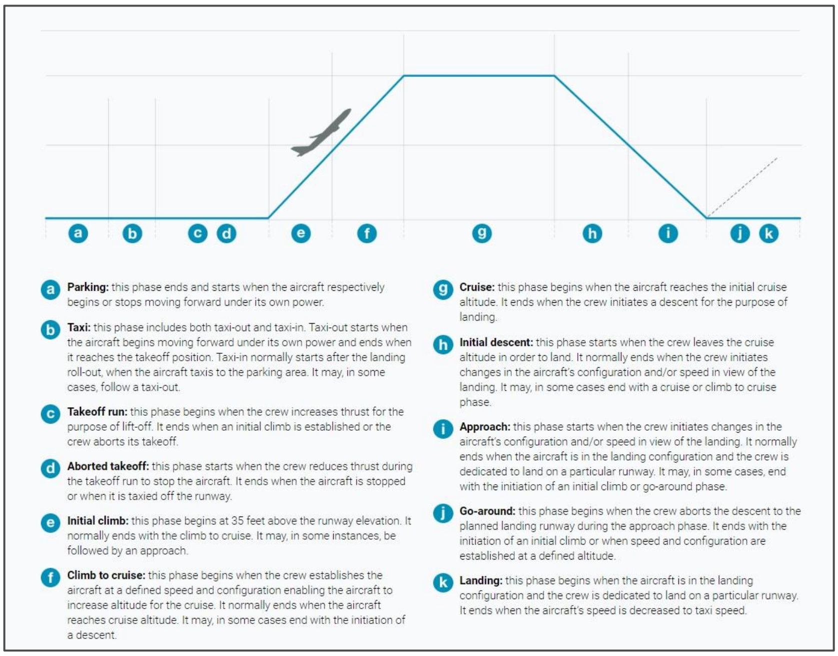

Figure 1 Flight phases description[1]

Complexity also grows when unexpected situations occur (e.g. system failures, sick passenger). Most of the time the problematic is clearly identified and pilots follow dedicated procedures. Depending on the situation, the workload can increase beyond a certain level where performance of pilots tends to decrease. It can result in a degradation of the situation awareness, an increase of the human errors rate, a lack of communication between pilots.

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[1] http://accidentstats.airbus.com/statistics/accident-by-flight-phase

To handle such situations, pilots disposes of different tools on the flight deck. They can also be helped by several entities like the airline or the ATC. Finally, the way pilots work, the Crew Resource Management, optimize the task management and the sharing of information in the cockpit.

2.1. Cockpit and pilots' work environment

Cockpits design has improved greatly from the first generation of Civil Jet Transport Aircraft (Boeing 707, Douglas DC-8) to the today generation modern Aircraft (Airbus 350, Boeing 787). As human factors grew in importance and technology advanced, pilots became more assisted either by onboard assistance (automations) or external entities (airline's Operational Control Center, Air Traffic Control). This evolution permitted to reduce the workload on the flight deck and thus the number of pilots passing from 3 to 2 in the eighties. Today, aircraft manufacturers affirm they are working on the next step: flying single pilot.

Figure 2 B707 cockpit

Figure 3 A350 Cockpit

Some may argue that pilots have become throughout years more system managers than system controllers thanks to the assistance they benefit in modern aircraft compared to the previous generations. Others simply affirm that the primary task of flying the aircraft from a point A to a point B maximizing safety, passenger comfort and efficiency has evolved over the years but remain the same. What remained constant in the years (and probably in the future) are the elements constituting the pilots' work environment, as they need to interact with automation (the cockpit instruments), the air traffic controllers and their airline centers.

2.1.1. The role of automatisms in the cockpit and their downsides.

Automatisms were introduced because they bring 4 benefits according to Wiener and Curry (1980) and Billings (1996):

- Safety
- Reliability
- Economy
- Comfort

Fadden (1990) describes 2 kinds of automation in the cockpit: The "control automation" and the "information automation". Billings in 1996 added a third one the "Management automation".

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The "control automation" is the automation devoted to the control and direction of the aircraft. The autopilot of modern aircraft is part of this category. It has relieved the pilot from the physical workload of maintaining the Aircraft stability and piloting it on the correct flight path. Thanks to the autopilot, Aircraft are today "manually" piloted only few minutes per flights.

The "information automation" concerns systems devoted to the management and presentation of relevant information to flight crew members. An example could be the Flight Warning System of Airbus aircraft. This system monitors aircraft parameters to alert the pilot and present appropriate procedures when failures occur. It relieved pilots from constantly accurately monitor all aircraft parameters to detect any abnormal behavior.

The "Management automation" are automatisms that enable pilots to control strategically rather than tactically the operations. The Flight Management Systems is an example of such automation. It enables pilots to enter the whole flight plan during flight preparation. Different options can be used like the preparation of "what-if" scenarios to anticipate navigation tasks on certain system failures occurrences.

Even if automatism have contributed to improve the work in the cockpit reducing the workload of pilots, they brought also new problematics and concerns. The ICAO (1998) for example raises the following ones:

- Loss of situational and system awareness
- Automation complacency
- Automation intimidation
- Maintenance of the captain’s command authority
- Design of the crew interface
- Pilot selection
- Training and procedures
- The role of the pilot in automated aircraft

Aircraft manufacturer emits also recommendation for pilots. Some of these recommendations directly concern automation and how pilots should work with automatisms. 2 out of the 4 Airbus Golden Rules for example are related to automatisms:

- Use the appropriate level of automation at all times,
- Understand the FMA (Flight Mode Annunciator, basically the autopilot modes) at all times.

Figure 4 Airbus Golden Rules for pilots

2.1.2. The role of ATC

The Air Traffic Controllers are in charge of Aircraft separation on ground and in the sky. There exist 3 kinds of controllers' assistances:

- **Ground control** is responsible for any airport movements areas, such as taxiways, gates, inactive runways, transitional aprons, intersections. The controller assists the crew from the gate to the runway until the take off and from the runway to the gate after the landing.

- **Tower control** is responsible for the active runway surfaces. The controller ensures a safe aircraft separation, avoid congestion and optimize traffic by sequencing all approaches and departures. Usually the support covers a 30-to-50-nautical-mile radius zone around the airport. To ensure the airport does not get overloaded or depending on weather conditions, Tower control may decide delays or re-routings and can even order to go-around if any unsafe condition is detected.

- ***En route* control** is responsible for controlling aircraft in particular volume of airspace at high altitudes between airport approaches and departures. If *en route* control mainly instructs crews to perform course adjustments, it may also provide services such as assistance in avoiding areas of weather and flight restrictions.

The voice modality is the mostly used by Air traffic controllers around the world. The written modality through CPDLC (Controller-Pilot Data-Link Communication) is more and more used to avoid frequency congestion in heavy traffic area and to exchange complex data such as oceanic clearances. The voice modality is preferred in critical areas as it gives a direct feeling of pilot's awareness and allows a direct pilot's feedback necessary in urgent situations, introducing the importance of human factor considerations in ATC assistance.

In general, it is preferable for the controller to remain directive. However, in exceptional circumstances, the controller may adopt an educational tone to explain the reasons that lead him to give clearances that may seem incomprehensible from the pilot's point of view. A questioning modality can be used through closed questions that have the value of a suggestion (*"Can you reduce your speed?")* but in any case, it is important to avoid controversy.

The following are the cues that allow the controller to assess the pilot's ability to accommodate less directive exchange arrangements:

- the state of confidence, the absence of stress in the pilot's voice.

- response times, hesitations from the pilot.

- if the controller and the pilot share the same native language.

Misunderstandings between pilots and controllers or between controllers themselves can lead to problematic situations. Phraseology, which codifies the exchanges between pilots and controllers, is very important. Here is an example of an error to illustrate it: 1-0-0 can be said 1-2 times 0 but this might be understood 1-2-0. However, there are many language shortcuts, especially since the exchanges follow a certain conciseness so as not to clutter up the frequency with unnecessary information.

In addition, as an effort to emphasize important information, the controller may decide to violate certain phraseology rules by ordering sentences in such a way as to place the most important first.

Confusion may also arise in situations involving intermediaries. During ground operations, ramp agents may not understand the issues involved in certain orders from the tower that the pilot, at the interface between this order and its execution, will not always be able to explain.

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The exchanges also follow a spatial logic: when an aircraft enters or exits certain areas, pilots expect to receive information from the controller or conversely, the controller expects to be contacted by the crew.

2.1.3. The role of the airline during a flight

Most airlines dispose of an Operational Control Center (OCC) where operational problems that crew encounter are handled, such as technical problems, weather problems, geopolitical crisis. The Flight Dispatchers are the ones that assist flight crew throughout their flights. They usually follow multiple aircraft at the same time ensuring flight preparation, en-route assistance, flight monitoring. They dispose, in the OCC, of multitude of information that may help the pilot in different situations.

In nominal situation, some airlines may transmit to pilots 2-3 hours weather forecast to help them to anticipate a potential rerouting. They can also send updated flight plan avoiding pilots to make this time-consuming task. Questions about crews flight duty time are also common.

In degraded situations, a ground pilot is in some airlines available to be the interlocutor with the flight crew. A technical support can be provided with the help of the maintenance center. In case of diversion, advices and suggestions can be made to help flight crews to choose the most appropriate airport for the airline taking into account the passengers care or the availability of maintenance teams and items.

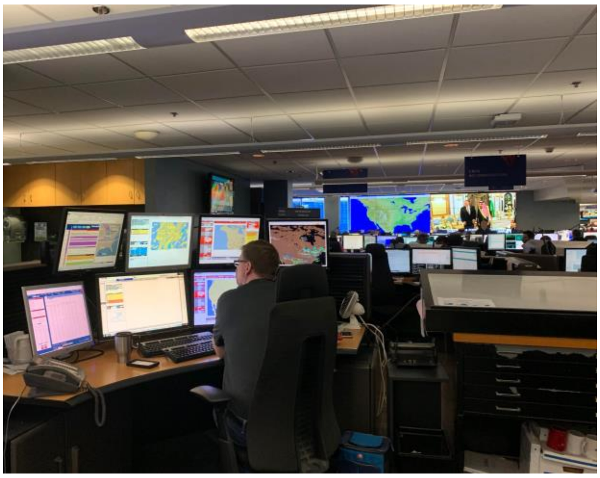

Figure 5 Delta airlines OCC

2.2. Crew Resource Management

Crew resource management (CRM) is the application of team management concepts and the effective use of all available resources to operate a flight safely. Experience has proven that the most effective way to maintain safety of flight and resolve complex situations is to combine the skills and experience of all crewmembers in the decision-making process to determine the safest course of action. CRM concept application is not limited to pilots but also other entities such as airline ground support and air traffic controller.

2.2.1. Principles

The main objective of the CRM is to optimize the teamwork in the cockpit. It consists mainly in maintaining a fluid communication between crewmembers and building and keeping good situation awareness. It enables the crewmembers to:

- Detect and identify any abnormal situation requiring crew intervention,
- Take appropriate decision,
- React accordingly,
- Share the workload,
- Avoid human errors.

The CRM rests on several principles. Here below are presented some examples.

A precise task sharing: Early on during training pilot are taught to aviate first (fly the aircraft), then navigate (know where you are, where you should be and where you want to go), communicate and finally manage systems. When two pilots are in the cockpit a proper task sharing is applied. This principle is applied all along the flight but is extremely important in abnormal situations during which the workload tends to increase. In such situations, the PF is usually in charge of the Aviate, Navigate and Communication tasks whereas the PM takes the Manage system part. When applied correctly, this task sharing permits the pilots to focus on their tasks, exchanging at precise moment such at the beginning of mitigation procedures or when the situation makes it necessary.

Checklists: They consist in a list of action that have to be performed at precise moments of the flight. Both crewmembers participate in checklist applications: usually one read the items when the other makes the appropriate action. Checklists have several objectives:

- Keeping both pilots "in the loop". Checklists force meeting point between pilot maintaining the situation awareness.
- Avoiding human errors like lapses or slips. Both pilots check that the appropriate action has been made.

BEFORE TAKEOFF	
FLT CTL	CHECKED (BOTH)
FLT INSTRUMENTS	CHECKED (BOTH)
BRIEFING	CONFIRMED
FLAPS SETTING	CONF____(BOTH)
FMA & TAKEOFF DATA	READ (PF)/ CHECKED (PNF)
TRANSPONDER	SET
ECAM MEMO	TAKEOFF NO BLUE
CABIN	SECURED FOR TAKEOFF
ENG MODE SEL	AS RQRD
TCAS	TA / RA
PACKS	AS RQRD

Figure 6 Before Take-Off Checklist A320

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Crosscheck of actions: when pilots has to operate critical controls such as controls with irreversible effects. Pilots follow a precise course of action. One pilot (usually the PM) designates the control, the other pilot (usually the PF) confirms that this is the right one and finally the action is made by the PM. The main objective of crosschecks is to avoid human errors that have severe consequences on the flight. This principle is recommended by aircraft manufacturers on specific controls but some airlines asks their pilots to apply it on all controls of the cockpits.

2.2.2. Training of the CRM

As Captain Sullenberger said, "*We had to first create a team of experts and then create an expert team*" [Carhart, Elliot. (2016)]. Pilots training is not only teaching and practicing individual piloting skills. It is also about building a good teamwork environment to optimize CRM.

At different stage of their careers, pilots are trained to CRM. Classroom sessions as well as simulator (e.g. LOFT: line-oriented flight training) and aircraft session are provided. The training is done recurrently at least annually.

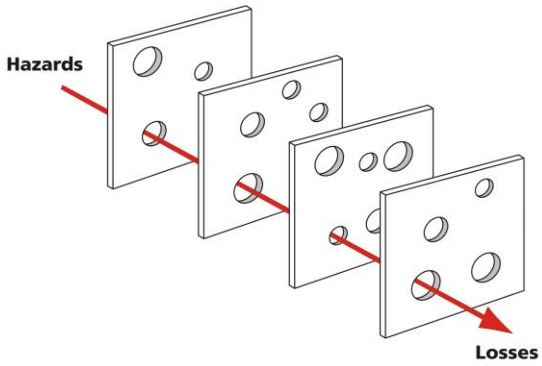
EASA (2016a), Part ORO, ORO. FC115 and ORO. FC.215 describes the content of these courses:

- Human factors in aviation; General instructions on CRM principles and objectives; Human performance and limitations; Threat and error management.
- Personality awareness, human error and reliability, attitudes and behaviours, self-assessment and self-critique; Stress and stress management; Fatigue and vigilance; Assertiveness, situation awareness, information acquisition and processing.
- Automation and philosophy on the use of automation, Specific type-related differences.
- Monitoring and intervention.
- Shared situation awareness, shared information acquisition and processing; Workload management; Effective communication and coordination inside and outside the flight crew compartment.
- Leadership, cooperation, synergy, delegation, decision-making, actions; Resilience development; Surprise and startle effect; Cultural differences.
- Operator's safety culture and company culture, standard operating procedures (SOPs), organisational factors, factors linked to the type of operations; Effective communication and coordination with other operational personnel and ground services.
- Case studies.

2.2.3. Examples of poor and good CRM through history

2.2.3.1. Poor CRM leading to an accident – TransAsia Airways Flight235

An accident is rarely the consequence of one factor. As Reason's Swiss cheese model illustrates it, it is often a combination of failures and errors that leads to critical situations and accidents. A good CRM represents a slice of cheese in Reasons Model and can be proved crucial like in the following example: TransAsia Airways Flight GE235.



On February 4, 2015, about 1054 Taipei Local Time, TransAsia Airways flight GE 235, experienced a loss of control during initial climb and impacted Keelung River, three nautical miles east from its departing runway. The accident was the result of many contributing factors which culminated in a stall-induced loss of control. During the initial climb after take-off, a problem occurred on engine number 2 resulting in the uncommanded auto feather of engine number 2 propellers. Following the occurrence, the flight crew did not perform the documented abnormal and emergency procedures to identify the failure and implement the required corrective actions. This led the PF to retard power of the operative engine number 1 and shut down it ultimately without a proper crosschecking of action of PM. After the engine number 1 was shut down, the loss of power from both engines was not detected and corrected by the crew in time to restart engine number 1. The aircraft stalled and continued descent during the attempted engine restart. The remaining altitude and time to impact were not enough to successfully restart the engine and recover the aircraft. Had the crew prioritized their actions to stabilize the aircraft flight path, correctly identify the propulsion system malfunction which was the engine number 2 loss of thrust and then take actions in accordance with procedure of engine number 2 flame out at take-off, the occurrence could have been prevented. Crew used non-standard processes and callouts during the shutdown of ENG 1 resulting in not identifying the error being made. [Aviation Safety Council 2016]

2.2.3.2. Good CRM avoiding a tragical outcome – US Airways Flight 1549

On January 15, 2009, an A320 of US Airways flight 1549 experienced an almost complete loss of thrust in both engines after encountering a flock of birds, forcing a ditching on the Hudson River about 8.5 miles from LaGuardia Airport (LGA), New York City. There were no fatalities thanks to the professionalism of the flight crew members that was underlined in the NTSB report p120: “The professionalism of the flight crewmembers and their excellent crew resource management during the accident sequence contributed to their ability to maintain control of the airplane, configure it to the extent possible under the circumstances, and fly an approach that increased the survivability of the impact.”

2.3. Future SPO perspectives

Having a single pilot in operation will imply to reallocate the tasks made by the missing pilot. We could think of keeping the actual CRM by having the assistance assuming one of the roles of PF or PM.

Following this assumption, we could imagine that the pilot could let the aircraft aviate, navigate and communicate by its own while he focuses on monitoring. The virtual assistant ensuring PF tasks while the pilot the PM tasks. On the contrary, the pilot could stay the PF while aircraft digital assistants would monitor systems. Going more into details with this assumption, a collaboration between the pilot and the on-board assistant could be envisaged on particular tasks like checklist application or crosschecking of critical controls. Without talking about feasibility of such level of assistance, such task allocations raise many comments. Even if an aircraft can aviate, navigate and communicate itself, pilots have to fly to keep their skills and stay “in the loop” in case the aircraft automatisms fail. In addition to that, if

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the pilot is not able to do his part for any reason it would means that aircraft have to be able to fly and land it autonomously, questioning the relevance of a pilot onboard.

Furthermore, the standard CRM sharing has maybe to be adapted to such high-level assistance. Maybe the SPO could delegate what he wants to the aircraft while he is focusing on what seems important to him, switching from PF to PM role as he feels the situation requires its expertise in some precise part of the human-aircraft loop.

Of course, such tools and concept of CRM will imply specific trainings but despite the fact that many difficulties seem to show all along the path, studying the SPO situation could drives in a first time at least to improve current crew assistances.

2.4. Conclusion

Pilots can rely on many cockpit assistance tools and remote human supports. They are fully trained to manage all those supports in normal and abnormal situations. However, taking a decision in a situation where a lot of inputs need to be taken in account or where the time horizon is short remains a complex task. Single pilots will be indeed more incline to perseveration or cognitive tunneling for which the second pilot was often a mitigation mean.

Gathering pertinent data at the right time, monitoring parameters on the fly and notifying when they reached some out bounds or some asked configurations, cross-checking critical actions, sharing situation awareness with ATC or AOC… all those features would push the level of assistance one step forward for a crew and even more for a single pilot in operation.

3. Virtual assistant concepts

In the next paragraph we provide a quick overview of some innovative concepts, explaining their maturity in other domains and suggesting how they could be adapted and adopted also in the flight deck. Although provided as separated concepts, they can obviously cooperate and improve each other.

3.1. Crew status analysis

CONTEXT:

In recent years, the real time assessment of the mental and physical status of operators has reached a good level of maturity, finding its way in operations and research. In the automotive domain, systems able to detect driver's attention and vigilance are common in several car models, and have been introduced in the market by Toyota, in 2006. In this case the system uses infrared sensors to monitor driver attentiveness. Specifically, the Driver Monitoring System includes a camera placed on the steering column, which is capable of eye tracking, via infrared LED detectors. If the driver is not paying attention to the road ahead and a dangerous situation is detected, the system will warn the driver by flashing lights and warning sounds. If no action is taken, the vehicle will apply the brakes (a warning alarm will sound followed by a brief automatic application of the braking system). In 2008, the Toyota Crown system went further and can detect if the driver is becoming sleepy by monitoring the eyelids. Moving into the aviation domain, those kind of systems are currently not common in commercial aircraft. Even so, a lot has been done in European research: the ACROSS project[2], investigated the use of neurophysiological measures to detect pilots situation awareness, workload, fatigue and pilot incapacitation. The concept, in this case, is to be able to anticipate critical situations (e.g. peak workload, total or partial incapacitation) or to warn ground centres so that mitigations and countermeasures can be put in place (e.g. remote control).

Figure 7: Posture, Eye gaze, EEG analysis in the ACROSS project

Similar studies have been conducted also on air traffic controllers (e.g. NINA[3] and STRESS[4] projects) demonstrating how much the technology (from the hardware and software point of view) is mature enough to deliver objective, reliable, high resolution information on a number of Human Factors metrics/concepts: mental workload, stress, fatigue, attention, vigilance. The main technical aspect to overcome is now the introduction of the needed sensors (electrodes for brain activity, sensors for heart rate, sensors for skin conductance level) in cheap, not intrusive (e.g. cameras in the cockpit) or easy to wear (e.g. wrist bands) devices, that can be realistically used during everyday operations.

CONCEPT:

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[2] https://trimis.ec.europa.eu/project/advanced-cockpit-reduction-stress-and-workload
[3] http://nina.dblue.it/
[4] http://www.stressproject.eu/

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Once this kind of devices is in place, the information could be used by an AI to check on the status of pilots, monitoring, for example, that the workload stays within reasonable limits, CRM recommendations are followed, situation awareness is good. This would become, for the AI, an additional input, to be checked against the current situations, so that the expected pilot performance is always calculated against the characteristics and requests of the current situation.

One of the possible application generated by the availability of pilots mental state information is the so called Adaptive Automation: the level of automation provided by the system is adapted to the current pilot status, so that, for example, an higher level of support is provided in case the workload exceed a pre-determined threshold; once the situation comes back to safe margins, the level of automation is set back to the previous one.

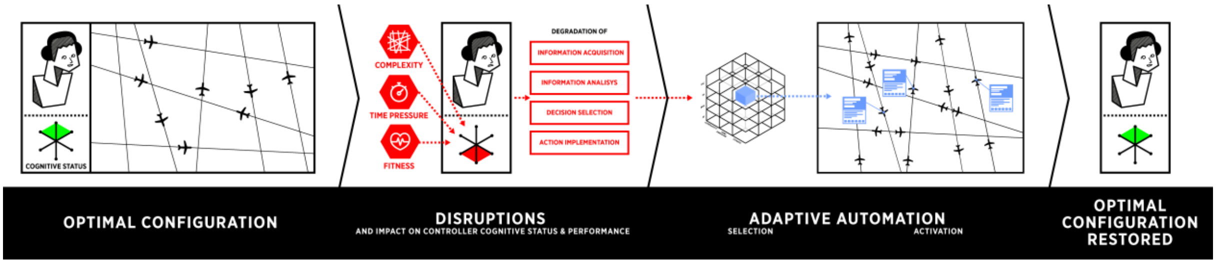

Figure 8: An example of adaptive automation in the ATM domain

Technical limits:

This particular vision of a Virtual Assistant for the cockpit, permanently monitoring the physical and mental state of the crew, faces a number of technical limits mostly related to the intrusiveness in the acquisition of *biosignals*. Today commercially available transductors are too bulky to be carried without impacting workplace ergonomics, concentration or comfort. However, electronic wearables are in constant evolution and today is very easy and cheap to measure heart beats using light-emitting diodes, and there are already in the market watches to measure even blood pressure. The trend is to have a complete *biosignal* monitoring system in the wrist, including energy harvesting from the environment for the longest autonomy possible, and connected wirelessly to an external processing unit. Having the data, today there are no other technical drawbacks to implement this concept of a Virtual Assistant for the cockpit, running for example in the Pilot's Electronic Flight Bag.

3.2. Situation diagnostic

CONTEXT:

Nowadays, a lot of information sources available both on board and on ground could be used by an AI to analyse in real time the situation, foresee future problems or diagnose malfunctions or unexpected aircraft behaviours.

At the same time, improved communication technologies are progressively solving the technical problems (e.g. latency). Moreover, costs for the services are expected to decrease in the future.

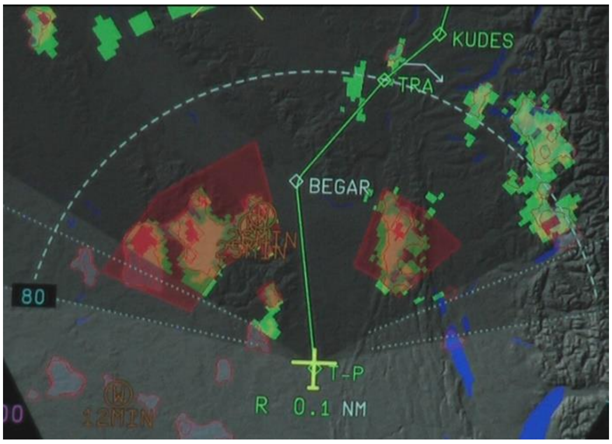

Figure 9: Weather radar + uploaded nowcast and forecast as presented to pilots in the FLYSAFE project

The fusion of data coming from different sources have already been successfully studied in several research projects such as FLYSAFE[5] and ALICIA[6]. The conclusions of these projects were that the potential is great, but the cost for the communication services and the potential pilots' information overload were the two main problems limiting the use in operations. With recent advances, AIs are becoming able to handle big amount of information at a speed enabling real-time processing.

CONCEPT:

This means that potentially relevant information could be sent on-board and combined with the one provided by the aircraft sensors to provide a better situation diagnostic to pilots. For example, an AI could monitor the weather situation using the on-board radar and forecast coming from the ground, spotting potential critical situation developing and anticipating them. The AI could "understand" complex situations using updated knowledge that is too complex to be provided to the pilot and generate an easy to understand report that can be used by the pilot to support situation awareness (event anticipating problems) and decision making.

Technical limits:

Regarding the issue of situation diagnostic some challenges may arise. First, the development of AI algorithms able to understand complex situation has been demonstrated to be technologically feasible. Algorithms capable of learning to play games such as chess or hide-and-seek have already been developed and furthermore, they are not only able to interpret situations but also to interact with the environment. However, although these systems have proved to be technologically feasible, the main concern is the training phase, as they require an extensive database and the execution of a large number of simulations. Another drawback, but more related to legislative issues, would be that the result of this training will lead in a black box that reads input variables, interpret them and generates a result, but it does not allow to know the reason of this result. A possible solution to this is the use of expert system which are rule based and the application of AI technique to generate those rules. The benefit of being rule-based is that they allow to have a traceability of the generated results.

On the other hand, although the data gathering from the different systems and agents (meteorology, air traffic, etc.) has already been resolved, the main handicap is the integration of all these information sources into a single common database, due to each one having its own structure.

Another issue to consider is how to present this information in a useful and effective way. Nowadays there is a lot of information available at the cockpit and sometime pilots might find themselves overwhelmed in complex situations with high workload or stress. A possible solution for these cases could be the use of dynamics HMIs capable of adapting to different situations and to the pilot's needs.

[5] https://cordis.europa.eu/result/rcn/52109/en
[6] https://cordis.europa.eu/project/rcn/94417/reporting/en

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3.3. Short time horizon decision

CONTEXT:

One of the factors limiting AI application is the access to databases that can be used to train it. Pushed by the hype generated by big data analysis, many companies started to collect operational data, and working on them (adding labels) they can be now used for AI training.

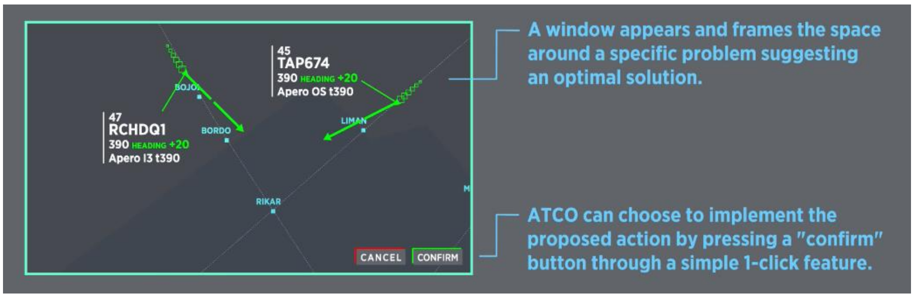

Figure 10: An example of AI generated decision making support in the ATM domain, from the NINA project

CONCEPT:

Also in the aviation domain this types of database start to be available (from traffic data to aircraft flight data) and, even with the limits generated by property issues (connected to their commercial value) they could be used to generate AI able to push higher the level of automation today available in cockpits; in fact, many technologies support information acquisition, information analysis and action execution, but only a few support at high level decision making (e.g. TCAS).

Once trained with big enough set of data, AI could solve this gap, proposing pilots solutions (or a set of limited choices among which to choose) to expected and unexpected needs, such as the choice of an alternate airport. Such an AI could take into consideration many variables, including weather, airports status, airline preferences, etc.

This is particularly relevant for decisions to be taken under pressure, during situations in which the time available is limited.

Technical limits:

In addition to the availability of the required datasets and depending on the algorithms to be used, for this use case it might be necessary to train models *online,* using streaming data science. The challenge in this case is that the data, besides its volume, is very heterogeneous and highly dynamic. Moreover, the required algorithms should be able to digest real data online, i.e. in real time, in order to provide short-time horizon decision. The main technical limit is then in the capability of the AI to handle big amounts of data in short time in order to predict the right decision to make relying on the available data inputs.

There are today initiatives like CS2-Project **Pilot3** (*A software engine for multi-criteria decision support in flight management*) involving the use of Machine Learning algorithms to support crew decisions for civil aircraft that are tackling the technical limits mentioned above.

3.4. Multi-modal conversation (Natural interaction)

CONTEXT:

We are now more and more used to interact with technologies in a multimodal way, touching screens, asking our devices to do some actions (e.g. Amazon Alexa), using gestures and, at the same time, listening to technologies providing verbal feedback to us, understanding the haptic feedback of our sport bracelet and obtaining information overlapped to reality on augmented reality glasses. These are all tentative to make the interaction with technologies as much natural and transparent as possible, reproducing some of the conversational techniques we adopt every day when speaking to other humans.

AI changed a lot in this field, enabling several new and more direct interaction (e.g. speak recognition). Chatbots emulate human conversation, enabling a direct and natural access to information. Conversation design is now a field with languages and techniques to be applied at least in the consumer market[7].

In the cockpit, on the other hand, the interaction between pilots and the aircraft is still mainly done by interacting with physical controls and reading displays, leaving a lot of space for improving the "conversation" between the pilot and the cockpit, making it smoother and potentially more proficient. The MOTO[8] project recently studied how much the use of multimodal interaction modalities can improve performance for remote towers controllers, showing that some information are better communicated through a specific mode (e.g. auditory). It also showed that the quantity of information an operator can attend to can be increased depending on the ways of providing it. Finally, the MOTO project also showed that the attention of an overloaded operation could be drawn more efficiently if the right modality is used. and how much attention can be gathered also in overloaded operator if the right modality is used (e.g. during emergencies).

CONCEPT

AI could be used to structure the interaction in the flight deck more like a dialogue in the common sense of the term. The aircraft could thus provide the information to pilots with auditory, visual or even haptic information while the pilot could answer with voice, touch, hand and body gesture, in the same way we human do when exchanging information between us.

Technical limits:

Nowadays, there is a great variety of NLP algorithms that provides text to speech, as well as speech to text capabilities, which enables a verbal communication between humans and machines. However, what is not completely resolved is the human-machine interaction in such a way that an interactive conversation can be established between both parties, as if it were two humans.

A lot of progress has been made in this field up to the development of cognitive computers that enable these algorithms to behave like a human would do, nevertheless these systems present a double complication. On the one hand, these systems normally require a huge computing capacity, so they could not be implemented in normal computers that could be integrated on an aircraft, but they require a complex infrastructure. On the other hand, these systems are developed by large companies and allow users to access these resources through the Internet, so it would be necessary to implement

[7] See as an example the Google guidelines to Conversation design: https://designguidelines.withgoogle.com/conversation/conversation-design/welcome.html#

[8] http://www.moto-project.eu/

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some means of communication between the aircraft and the cognitive computing centre. An example of this type of system would be WATSON developed by IBM.

3.5. Conclusion

These virtual assistant concepts that already exist could also be implemented on the flight deck. However, new problematics that does not exist in other domains could potentially be raised. For example, the certification side of such system based on Machine Learning appears to be a real challenge. Indeed, the training of such algorithms often leads to “black boxes” from which it is complex to understand how the solution was build. This black box problem could also represent a problem for pilots as it is important for them to understand the situation and the assistance outputs. If they do not trust the tools, they will not use it. Another problematics could be the intrusiveness and acceptance of systems monitoring pilot’s state.

These virtual assistant concepts will be developed through use cases in the next parts of the documents.

4. Considered use cases

Starting from the concepts, a work has been performed to better elaborate them and adapt them to the cockpit context finding specific application cases. This work has been performed by the consortium following an iterative selection process, with the contributions of different internal and external experts (Safety, Human Factors, Operational and technical experts). The process followed is summarised in the following image.

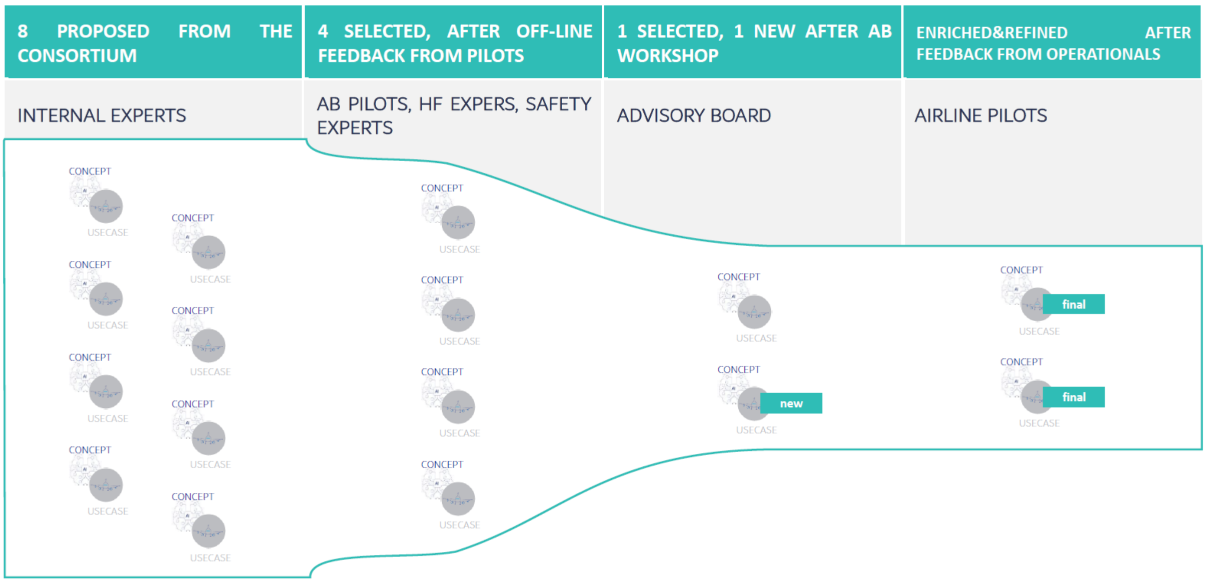

Figure 11: Concepts and use cases generation and selection process

The use cases developed in this part are the ones that have been considered but finally deemed less pertinent and interesting for future implementation.

4.1. Meteorological issue

Develop an AI able to asses pilots' state, interpret meteorological information and support pilots to apply the correct decision-making procedure in adverse situations.

The AI will be trained to asses pilots' state by gestures, face or voice recognition in other to detect stress or misunderstanding between crew members. Additionally, the system will have access to the meteorological information, as well as to the radio frequency communications. With all this information, the AI will help pilots in the decision-making procedure by asking them to follow FORDEC and besides it could do the C(heck) of FORDEC to assess the compliance of pilot's actions with the solution decided during the D(ecide) phase.

A model able to interpret weather information, will be developed. Additionally, it will be needed to implement a human cognitive model to detect pilots' stress level, as well as a voice recognition system able to understand radio frequency communications and predict misunderstanding between crew members. On the other hand, several videos where pilots have to deal with a meteorological issue will be generated using a simulator like FlightGear. With these videos and using the previous tools, the relevant information, such as, the decision or actions from pilots, etc. will be recorded. Finally, these data will be used to train an AI algorithm, which will support pilots during the decision-making process.

This use case is partially integrated in the selected use case "Aircraft Diversion in SPO" (part 5.2).

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UC Summary

Inputs	Algorithms	HMI
• Meteorological information, • Pilot stress (voice, ECG, etc) • Radio frequency voice recognition and analysis (windshear could have occurred on other aircraft and usually pilots inform ATC about it). • Aircraft State	• Keyword detections • Pilot stress detection • Rule based	• Voice (FORDEC required) • Visual • Haptic • (depending on the situation)

Innovation Degree		MEDIUM
Alignment with the analysis of the tasks		HIGH
Difficulty of implementation	Data acquisition or data generation	Pilot Monitoring
	Algorithm design effort	LOW/ High for stress
	Algorithm design training time	Medium for the stress
	Demonstration show	Difficult
Impact on current Aircraft operation	Safety	MEDIUM -It's hard to induce stress
	Performance	LOW

Working Plan

1. Develop a model able to interpret weather information.
2. Develop a human cognitive model to detect stress.
3. Implement a voice recognition system.
4. Simulate several flights with bad weather conditions
5. Record the data from those videos (actions from pilots, etc.)
6. Ask experts to label this data.
7. Use labeled data to train an AI algorithm.

4.2. Detect fatigue

Generate an AI able to detect pilot fatigue using non-intrusive sensors (i.e. cameras) and trigger relevant alerts. Drowsiness detection algorithms, based on cameras monitoring operators' eyes and posture, are already available (e.g. in the automotive domain) that could be adapted to the cockpit environment. The AI could estimate the level of fatigue, alerting the pilots in the cockpit and proposing relevant countermeasures depending on the flight phase. In case of severe fatigue related issues, the AI could also contact ground.

As the detection of fatigue is not a problematic specific to the aeronautical domain, this use case was deemed less pertinent to be maturated inside HARVIS project.

UC Summary

Inputs	Algorithms	HMI
• Camera. • Tobii camera. • Postural Sensor.	• Drowsiness detection and prediction.	• Sound and visual alerts to pilots. • Vibrations. • Messages for ground stations.

Innovation Degree		LOW
Alignment with the analysis of the tasks		MEDIUM
Difficulty of implementation	Data acquisition or data generation	LOW
	Algorithm design effort	LOW
	Algorithm design training time	LOW
	Demonstration show	LOW
Impact on current Aircraft operation	Safety	HIGH
	Performance	LOW

Working Plan

1. Adapt current fatigue detection algorithms to the cockpit environment (also considering the “overall cockpit fatigue”).
2. Teach the AI to rate the severity of the detected (or predicted) fatigue level according to the flight phase.
3. Teach the AI which type of message to provide (audio, text, vibration) and which suggestion to give (e.g. coffee assumption).
4. Generate an HMI able to provide the needed messages.

4.3. Procedure compliance in case of System/Engine failure

Develop a digital assistant that will support pilots in procedures compliance to solve problems in the event of system failures

The goal will be to develop an assistant capable to understand the environment and analyse the aircraft state in order to detect possible systems failure or abnormal situations. Once they are detected, the assistant will provide a dedicated checklist depending on the problem and the state of the aircraft, besides it will support the pilot to compliance the procedure. Additionally, the assistant will continue assessing the aircraft state and in case another error arises it will adapt the checklist and will guide the pilot to fulfil both in the proper manner, avoiding in this way possible errors or miss any step.

A model of the aircraft will be trained with data flows from a defined series of sensors generated with a simulator, so that it will be able to analyse the environment and detect failure or abnormal situation

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in a specific set of systems. In the case an event arises, the assistant which has a database that collects all the procedures, will provide the pilot the pertinent one and will guide him/her throughout the entire process. This assistance could be auditory, through commands that the assistant will read to the pilot; or even via a Laser Assisted Reality System with which the assistant will highlight the actions that the pilot should undertake. On the other hand, the system will integrate a Speech Recognition System so that the pilot can indicate to the assistant that a step has been completed or request it certain information.

After consultation of the Advisory board, this use case was deemed not pertinent as it is already at least partly implemented in modern cockpit like in the Airbus A350.

UC Summary

Inputs	Algorithms	HMI
• Aircraft state • Environment • Voice from pilot	• Word recognition • Procedure Model "True Model"	• Voice • Visual • Laser assisted Reality

Innovation Degree		LOW – Assistant for checklist compliance its not a new concept
Alignment with the analysis of the tasks		HIGH
Difficulty of implementation	Data acquisition or data generation	LOW
	Algorithm design effort	LOW
	Algorithm design training time	LOW
	Demonstration show	LOW / HIGH (if Laser are used)
Impact on current Aircraft operation	Safety	MEDIUM
	Performance	LOW

Working Plan

1. Simulate several normal and abnormal scenarios using a flight simulator.
2. Develop a model of the aircraft.
3. Generate a data base with all the procedures.
4. Develop an algorithm capable to identify the connections between the different procedures, in such a way that in case of multiple system failure, several procedures can be successfully followed.
5. Develop an Adaptive HMI to guide the pilot during the procedure compliance process.

4.4. Detect workload

Generate an AI able to detect pilot workload levels using non-intrusive sensors, to identify the cause for the workload peaks and trigger relevant alerts or actions. Workload detection algorithms, based on cameras monitoring operators' eyes (e.g. blink rate) or neurophysiological metrics (e.g. EEG activity, heart rate variability) are already available and studied in the cockpit environment.

The AI could:

- Estimate the level of workload (single and for both pilots).
- Look for the cause in case of peaks.
- Alert the pilots and proposing relevant countermeasures depending on the workload cause.
- Contact ground in case of severe workload related issues.

To look for the cause of the workload increment the AI could rely on information coming from the avionics, as well as other sources (e.g. weather radar). The workload could be expected (e.g. normal in that flight phase) or unexpected (due to a malfunction, emergency or degraded performance of the pilot). Depending on the cause, the AI should be able to suggest countermeasures, for example having the other pilot performing some task, having the pilot apply a specific procedures or reach for some missing information.

Even if the pilot's workload is a critical problematic in the aeronautical domain, this use case was deemed not relevant as multiple studies are already conducted to assess the workload of humans through neurophysiological data.

UC Summary

Inputs	Algorithms	HMI
• Pilot state (workload). • Aircraft State.	• Workload detection. • Workload cause.	• Suggestions to pilot (voice and text). • Report to ground (text).

Innovation Degree		HIGH
Alignment with the analysis of the tasks		HIGH
Difficulty of implementation	Data acquisition or data generation	HIGH
	Algorithm design effort	HIGH
	Algorithm design training time	HIGH
	Demonstration show	HIGH
Impact on current Aircraft operation	Safety	HIGH
	Performance	MEDIUM

Working Plan

1. Develop workload detection algorithms to the cockpit environment based on the available sensors.
2. Teach the AI to rate the severity of the detected (or predicted) workload level according to the flight phase.
3. Teach the AI to understand what the cause for unexpected workload peaks is.

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4. Teach the AI which type of message to provide (audio, text, vibration) and which suggestion to give (e.g. coffee assumption).
5. Generate an HMI able to provide the needed messages.

4.5. Abnormal aircraft behaviour: Icing on wings

Create an intelligent system able to analyse sensors' data flows, as well as pilot's surveillance state in order to detect abnormal aircraft behaviour and improve pilot's situational awareness.

The objective will be to train a system with a huge quantity of "normal" trajectories so that it can predict abnormal situations. Additionally, it will measure pilot's physio-psychological state to asses pilots' surveillance level. With this information the system will be able to recognise when an abnormal situation occurs and determine if the pilot is aware of the problem or even identify if she/he is addressing the issue in the proper way.

To train the system a huge quantity of "normal" trajectories under different situations will be simulated using a flight simulator such as FlightGear. Apart from this, a human cognitive model will be developed in order to asses pilot situational awareness. Finally, all the data gathered by theses system will be organised and presented to the pilots in a useful way via an HMI.

This use case was set aside as modern aircraft already alert the pilot about abnormal behaviour.

UC Summary

Inputs	Algorithms	HMI
• Aircraft state (sensor data flows). • Pilots' state (Is the pilot really aware that there might be a problem?).	• Will compare performance based on huge quantity of trajectories.	• Voice or light warning.

Innovation Degree		HIGH
Alignment with the analysis of the tasks		HIGH
Difficulty of implementation	Data acquisition or data generation	MEDIUM
	Algorithm design effort	MEDIUM
	Algorithm design training time	HIGH (but automated)
	Demonstration show	MEDIUM / HIGH
Impact on current Aircraft operation	Safety	HIGH
	Performance	HIGH

Working Plan

1. Simulate several scenarios.
2. Build a Data Pipeline for real-time data stream processing.

3. Use the gathered data to train a model of the aircraft.
4. Select sensors to asses pilots' physio-psychological state.
5. Develop a human cognitive model.
6. Develop an HMI able to warn the pilot in the proper way, depending on the situation as well as the pilots' situational awareness.

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5. Selected use cases

Discussion with airlines pilots and Air Traffic Controller led to the identification of four use cases. Those have been then discussed in a dedicated Advisory Board workshop held at ENAC on the 26th of September with the participation of pilots, safety experts, certification experts and instructors. The minutes of the workshop, detailing the feedback gathered on the use cases is available here.

Further discussion led to the selection of two situations for which a virtual assistant would greatly help pilots in their tasks. The situations are the following:

- The approach phase. During the approach the workload is high in the cockpit because the goal is to stabilize the A/C for the landing. If not stabilized, pilots will perform a go-around. In standard operations, the workload is usually very high for both pilots. The PF is focus on flying the A/C maintaining it on the flight path with adapted flight parameters and calling configuration changes while the PM is monitoring what the Pilot Flying is doing and puts efforts in keeping a good situation awareness. In single pilot operations, i.e. without the PM, the PF could have difficulties to multitask and could be subjected to cognitive tunneling.

- The diversion. It can be due to system failures or sick passengers for example. This situation is what is called an abnormal situation that pilots are rarely facing. In this timely constraint situation, workload and stress tend to increase, in standard operations and even more in Single pilot operations. The objective of pilots in this situation is to mitigate the consequences of the potential system failure while gathering all the necessary information to prepare a possible emergency landing.

A virtual assistant concept was chosen for each of these situations.

5.1. Non-Stabilized approach support

For this use case, an on-board digital assistant that will assist the pilot during the approach will be designed. The primary objective will be to help the pilot to perform a stabilized approach. This in-flight assistant will be able to detect and announce deviations of flight parameters, as well as assess pilot's state to analyse whether he/she is taking the appropriate corrective actions.

As the flying task in the cockpit is extremely demanding, it is very difficult for pilots to perform other tasks at the same time. In standard operations and even more in Single pilot operations for which there is no Pilot Monitoring, the approach phase is generally workload heavy. If the pilot is flying manually (voluntarily or due to a system failure), it is very important for him to be able to stay "ahead of the aircraft" by keeping a good situation awareness. An adaptive, interactive and contextual on-board flight assistant could support the pilot in this task the same way the Pilot Monitoring does. Tasks of this assistant could be the following:

- Monitoring of aircraft parameters and alerting in case of deviation

- Suggestions of corrective actions

- Go-around order

One of the features of the assistant will be to be adaptive to the situation, being discreet if the approach goes well and more intrusive/directive when things go wrong. The key element of this assistant will be the trust the pilot can put on it. If the pilot knows that the assistant will monitor and back-up him if the situation worsens then he will be able to dedicate a part of his focus on other tasks like the communication with ATC or the evolving weather monitoring. Moreover, letting the pilot perform the fly task will enable him to "stay in the loop" and avoid loss of situation awareness.

This assistant will contribute to make flight more safe, economic and ecologic. As the assistant will only advise and not make corrective actions, pilots will have the possibility to keep flying manually voluntarily contributing to maintaining their skill level. As a consequence, they will be more efficient in case of autopilot failure, thus contributing to safety. The argument is also economic and ecologic as the assistant may also decrease the number of go around by reducing the number of non-stabilized approach (NSA).

The main idea is to create a rule-based Expert System using Machine Learning techniques. For development, Pilots will be required to tag and classify a large number of approach segment. They will label the difficulty of the situation and the parameters to focus on to increase the chance of stabilized approach. At gate, they will also indicate if a go-around is necessary. Thanks to this labelling, the assistant will be able to estimate the difficulty of situations, make appropriate suggestions to improve the situation and eventually assist in the go-around decision.

Additionally, to improve the timing relevancy of the assistant intervention, an eye tracking system will be developed to analyse what the pilot is looking at and the movement she/he performs.

Figure 12 AI potential learning principle

Use cases summary

Context of the scenario: The pilot is flying manually (voluntarily or due to a system failure) during the approach

UC1.1: The pilot does not check some important flight parameter in the control panel (e.g. altitude).

- **Expert system**: The developed eye-tracking algorithm detects that the pilot is not paying enough attention to the area corresponding to the altitude and that these parameters deviate from what was planned.
- **Digital assistant**: After deviation, a voice issues a specific indication with “Check altitude”.

UC1.2: The AC has an unusual trajectory approaching the identified stabilization point

- **AI system:** The IA detects that the situation will normally lead the pilot to go-around.
- **Digital assistant:** On stabilization point the digital assistant assess that the stabilization parameters are not met, a voice advises the pilot to go around.

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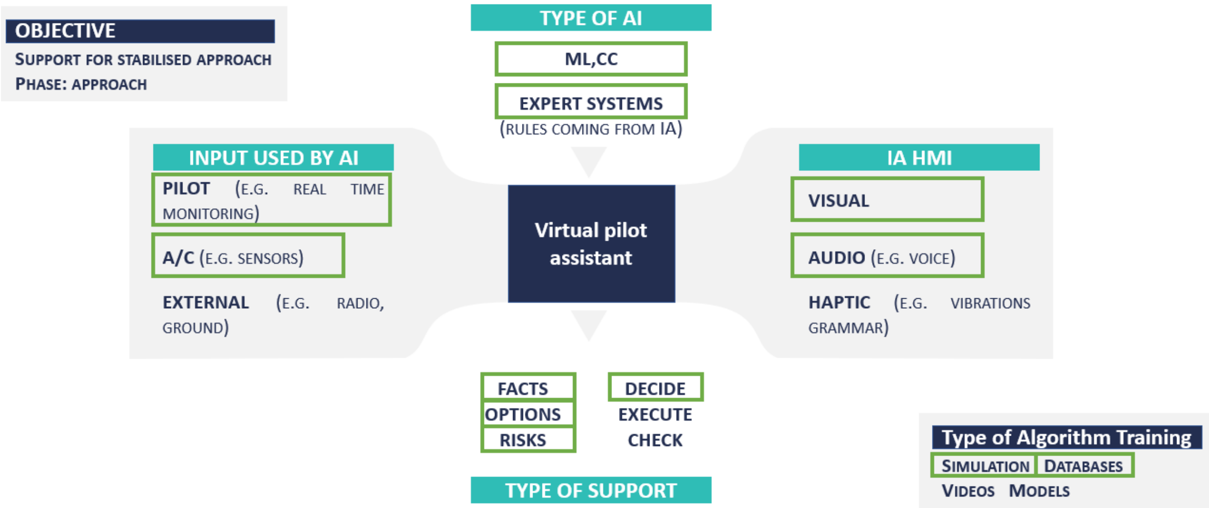

Figure 13: UC 1 AI concept summary

Inputs	Algorithms	HMI
• Realtime aircraft parameters. • Pilots expertise about flight data records. • Pilot eye tracking.	• ML system trained based on pilots expertise. • Eye tracking: blinking, gaze, trajectory, etc.	• Voice saying: “check glideslope”, “check airspeed”, etc. • Voice saying: “Go around”.

Innovation Degree		HIGH – System Expert based on rules extracted from Machine Learning trained by expertise
Alignment with the analysis of the tasks		HIGH – Assistance designed as virtual PM
Difficulty of implementation	Data acquisition or data generation	MEDIUM – It can be gathered from company flight data records
	Algorithm design effort	MEDIUM / HIGH – For eye tracking
	Algorithm design training time	MEDIUM – Community
	Demonstration show	MEDIUM – Wizard of Oz
Impact on current Aircraft operation	Safety	HIGH
	Performance	HIGH

Working Plan

1. Simulate approach segments flight data records.
2. Generate approach videos, recording the information available in the cockpit.
3. Ask pilots to classify each video.
4. Order the labeled data.
5. Train a ML algorithm with this data.
6. Extract rules to develop the Expert System.
7. Develop an Eye Tracking System.

8. Adapt Expert System output considering Eye Tracking System output.
9. Validate the stabilized approach assistant.

5.2. Aircraft Dynamic Rerouting Support

For this use case the digital assistant is committed to help the pilot during rerouting in flight, for example providing options in emergencies or anticipating radar vectors in the arrivals. A typical situation for rerouting is diversion to alternate airports.

A diversion is often required during high workload situation like severe system failures, a sick passenger, or just for meteorological reasons (dense fog, storms, etc.). In conventional operations when a diversion is needed, the pilot in command and first officer discuss on the multiple options they have and try to choose together the solution they think is the best. The role of the digital assistant will be the same as the second pilot. It will take into account characteristics of nearby airports, the METAR at destination, the airline facilities to take care of passengers, among other factors. It may then propose several options to the pilot, presenting the risks and the benefits for each of them, letting the pilot have the final decision. In this scenario, the digital assistant takes care of the Options in a FORDEC procedure. Then during the diversion process, the digital assistant may re-evaluate dynamically the situation, keeping the pilot updated only with the precise information he needs to manage the situation. The workload associated to the rerouting should be reduced, allowing the pilot to focus on flying the aircraft safely and handle other critical tasks (like mitigating the consequences of a system failure).

Besides diversion, changes to the flight plan are common during the flight, especially in the arrival at the end of the en-route phase. Variations to the standard arrivals are often due to air traffic congestion, weather issues, maintenance operations at the airport, emergencies, etc. Pilots become aware of these facts only when the Air Traffic Controller contacts them. This situation increases the pilot workload in a critical flight phase. In high energy situation (high speed and/or altitude) for example, pilots can be forced to ask for a holding to slow down and descent. This Digital Assistant will assist the pilot during the descent, by anticipating the possible variations in the arrival routes, as well as providing them with different trajectories in case of emergency. In this sense, the assistant will show the most likely options that the ATC would suggest, so that pilots can act accordingly with anticipation, which leads to reducing their workload and stress.

The Digital Assistant in this use case requires to know the cause for the rerouting. The main inputs to be: a stream with the aircraft route, the aircraft's state and position, the status of the crew and passengers, a database of the terrain, airports and airlines facilities available, among others.

The first challenge in this use case will be to create a relevant and representative dataset to train the AI. The second challenge will be to develop the appropriate interaction between the digital assistant and the pilot to make the digital assistant really helpful.

Use Case Summary

Context of the scenario: Rerouting is required for any reason
UC2.1: The diversion is due to a sick passenger

- **AI system:** the AI system will gather and compute information about the performances of the AC (Fuel On Board, systems limitations…), available airports (weather, NOTAM, airline's Pilot reports, type of approaches usually flown, etc.) and their medical assistances (time to the nearest hospital for example).

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- **Digital assistants:** the assistant will support the pilot in the application of a FORDEC-like procedure will present the available options, underlying the risks and benefits for each of them.

UC2.2: Arrival route anticipation

- **AI system:** the AI system will gather and compute information about the performances of the AC (Fuel on board, trajectory, systems limitations, …), airport traffic, airport information (NOTAM, type of approaches usually flown, …) and meteorological information.
- **Digital assistants:** the assistant will assist the pilot during the descent suggesting different approach routes by anticipating the possible indications of the ATC.

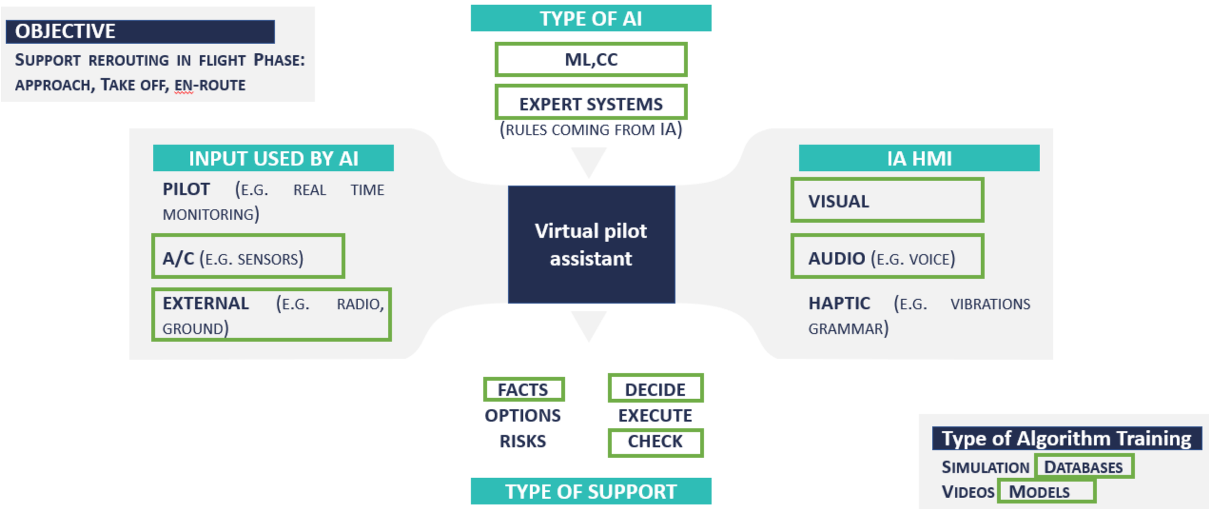

Figure 14: UC 2 AI concept summary

Inputs	Algorithms	HMI
• Airports, terrain and airline facilities database. • Aircraft state and position.	• Machine learning. • Expert system.	• Vocal. • Audio. • Visual.

Innovation Degree		HIGH – current A/C systems do not make decisions just gather, analyze and show information.
Alignment with the analysis of the tasks		The Assistant will suggest the pilots feasible options to reduce their workload
Difficulty of implementation	Data acquisition or data generation	MEDIUM/HIGH – Real flights trajectories data are available, but weather and traffic data is difficult to find.
	Algorithm design effort	MEDIUM / HIGH – It is needed to develop a predictive model for a/c trajectories and another one to understand current a/c situation

	Algorithm design training time	MEDIUM
	Demonstration show	Simulation with real data and a chatbot
Impact on current Aircraft operation	Safety	HIGH
	Performance	HIGH

Working Plan

1. Pilots' interview to define which parameters are taken into account in the diversion process
2. Creation of several scenarios requiring a diversion
3. Ask pilots to choose the best diversion options for each scenario
4. Train a ML algorithm with this data.
5. Extract rules to develop the Expert System.
6. Validate the Expert System.

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6. Conclusion

This deliverable is the second step of the project.

It gathers an analysis of the tasks that pilots have to perform, how complex they are, which assistances exist and finally what problems will raise to move to single pilot in operation. It also lists the main cognitive computing concepts that already exist and then proposes how they could be applied in the aeronautical domain to support Single Pilot Operations.

2 use cases for this digital assistant were kept for further implementation. The support during the approach phase and the support during a diversion. These two situations are indeed complex and workload heavy in standard operations and will be even more in Single Pilot Operations.

The next step is now to precise where the pilot will be in the loop of human-assistant partnership. This will be done in D2.2 Human-Machine performance envelope.

It will also be necessary to clarify how such assistant could be designed, what are the current limitations and what could be done to go beyond them. This will be done in D3.1 Cognitive Algorithm Design.

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