Toward single pilot operations: A conceptual framework to manage in-flight incapacitation

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***Abstract*—A major challenge for the implementation of Single Pilot Operations (SPO) in commercial aviation is how to deal with the potential risk of in-flight pilot incapacitation. In this paper, a conceptual framework is presented aiming at supporting flight and landing of a single-piloted aircraft in case the single pilot on board becomes incapacitated during the flight, specifically focusing on the ground side of the Air Traffic Management (ATM) framework. This concept considers the interaction of a ground-based pilot operating through a remote cockpit position with onboard automation and air traffic controllers. A description of the foreseen operational processes and procedures allowing the transition from single-piloted aircraft to Remotely Piloted Aircraft (RPA) is provided, together with an analysis of their technical, legal, and regulatory implications.**

Keywords: operational concept; single-pilot operations (SPO); pilot incapacitation; ATM; ground station operator (GSO), liability, Remotely Piloted Aircraft Systems (RPAS)

I. Introduction

For over a decade, the concept of **Single Pilot Operations** (SPO) has been receiving growing attention from the international aviation community [1][2]. SPO refers to flying a commercial aircraft with only one pilot in the cockpit supported by onboard automation and/or a dedicated ground flight crew. Besides the perspective of possible financial benefits for airlines in operating single-piloted aircraft, leading to a decrease of the costly crew members, one main driver for the implementation of SPO is related to a potential shortage of commercial pilots in the near future [3]. Properly implemented, dependent on advances in Air Traffic Management (ATM) and automation, SPO are foreseen as one of the most promising solutions to the accomplishment of the SESAR's high-level goal of reducing the cost per flight by 50% by 2035 [4], while maintaining the same level of safety of multi-pilot operations (MPO).

One of the **key issues** for the implementation of SPO is managing in-flight pilot incapacitation, defined as "any physiological or psychological state or situation that adversely affects (pilot) performance" [5]. Several studies have considered the problem of incapacitation and investigated it with simulations [6], modeling [7], or theoretical analysis of the different possible solutions [8][9][10]. However, so far, the focus has mostly been on aspects related to the air side perspective, for example the identification of the incapacitation conditions, or the landing site selection and related automatic trajectory generation [11]. Less attention has been given to the conceptual and experimental evaluation of the role of ground support for SPO (i.e., roles and relationships between Ground Station Operators (GSO) operating from a remote cockpit position and other key ground actors, namely Air Traffic Control - ATC and Airline Operations Control Center - AOCC) (see [12] and [13]), while these roles require well defined concepts and procedures to operate in case of pilot incapacitation.

In this paper, a **conceptual framework** is presented to address the pilot incapacitation event in SPO focusing on the ground side of the ATM framework. The concept considers the interaction of a ground-based pilot with onboard automation and air traffic controllers, specifically detailing the envisaged operating methods for the transition from single-piloted aircraft to Remotely Piloted Aircraft (RPA). The work presented here is part of the project "SAFELAND – SAFE LANDing through enhanced ground support" supported by SESAR Joint Undertaking under the Horizon2020 Research and Innovation Programme. The paper is structured as follows: The next section briefly describes the methodological approach used to implement the concept. The paper then illustrates the operational concept for the SAFELAND use-case of pilot incapacitation, inscribing it inside a broader conceptual framework for future SPO of a CS-25 aircraft [14] under Instrument Flight Rules (IFR). The envisaged operational processes and procedures are described, detailing the required technical characteristics, tasks distribution, and function allocation between the involved actors. An insight on the technical challenges of future SPO is also offered. The following section addresses the main legal and regulatory implications of the concept. Finally, the last section concludes the main attributes of the conceptual framework proposed by the SAFELAND project for the event of pilot incapacitation in SPO.

II. SAFELAND CONCEPT DEVELOPMENT

The overall approach of developing the SAFELAND concept has been to carefully balance new and innovative ideas, while still anchoring the concept to a realistic future implementation. This has been done through an iterative process including identification and development of functions and interactions, relevant concept and technological assumptions and domain expert feedback.

Two main **methods** were used to derive the SAFELAND concept from several initial models to a final iteration: the Function allocation diagram and the Interaction diagram. The first, based on Social Organisation and Cooperation Analysis-Contextual Activity Template (SOCA-CAT) was used to identify and to re-assign required functions in a flight operation across the remaining actors after the pilot incapacitation has occurred. A SOCA-CAT is a method to visualize the function allocation in a socio-technical work system, such as an aircraft [15]. The second, based on Operation Event Sequence Diagram (OESD) was used to identify, develop as well as to illustrate and describe the interactions between operators and artefacts within the system [16]. In the SAFELAND concept, the operators are the remaining actors (e.g., ATC, GSO) after the pilot incapacitation has been detected, the artefacts are the different means of interaction (e.g., radio communication, data exchange), and the system is the aircraft in the emergency situation.

To develop a comprehensive SAFELAND concept, the project chose to complete the work done by internal experts with the contribution of external experts. The **developing process** was the following:

1) An online workshop took place in October 2020 with the main goal of developing different implementation options of an initial SAFELAND concept. The workshop was attended by a total of 32 experts from different fields of expertise within the consortium, such as air traffic controllers, pilots, human factors experts, legal and regulation experts, air traffic management specialists and aircraft manufacturers. Three different implementation options were developed: (i) Automation-focused variant, (ii) GS-focused variant and (iii) ATC-focused variant. The variants differed as to who should have the main responsibility for controlling the aircraft in case of single pilot incapacitation, namely (i) the onboard automation, (ii) the GSO who becomes a dedicated remote pilot (RP) for the concerned aircraft, or (iii) the GSO with support from Air Traffic Controller (ATCO). After the workshop, the variants were further developed and refined by the consortium.

2) In early 2021, the three developed variants were presented to the SAFELAND Advisory Board (AB) members at a virtual workshop with the aims of performing a preliminary evaluation and collecting objective feedback, comments, and recommendations from external experts on relevant aspects (e.g., operational acceptability, impact on workload and safety). The Automation- and GS-focused variants were considered the most promising options for the final SAFELAND concept. This statement was motivated by the perceived feasibility and operational logic of the two variants. In addition, the sequence of operational events and overall concept flow were perceived as more logical and efficient. The ATC-focused variant mostly collected negative feedback and received the least favour due to the discrepancy of roles and responsibilities of the actors (pilots, ATCOs) against today practice and doubts regarding the possibility to assign additional duties to ATCOs (i.e., to control the emergency aircraft).

3) Following the recommendations from AB, the final SAFELAND concept was generated combining certain elements taken from the Automation-focused and GS-focused variants.

The project consortium agreed to the following **assumptions** and expectations towards the end-system. The SAFELAND concept:

a) shall be applicable for aircraft operations in controlled airspace under IFR;

b) assumes nominal flight conditions of a CS-25 aircraft in commercial or cargo operations apart from pilot incapacitation;

c) addresses total pilot incapacitation only;

d) assumes the presence of a ground station that would at least monitor aircraft system and pilot health throughout the flight, operated by a human operator, the GSO;

e) assumes the presence of an onboard pilot health monitoring system capable of detecting an incapacitation and automatically informing the relevant actors. After the pilot incapacitation is detected (and verified), the emergency procedure would be to land the aircraft as soon as possible in order to not put aircraft, pilot and passenger safety at risk;

f) assumes that the single-piloted aircraft is equipped with more sophisticated automation than a current CS-25 certified aircraft (e.g., onboard pilot health monitoring system, reliable and sufficient C2 data link to other actors with reduced latency or failure/loss due to areas without coverage). Moreover,

g) onboard automation is able to refuse/reject instructions issued by any human operator from ground if they are outside the performance limits of the aircraft, hence not compliant with aircraft capabilities.

h) assumes that the aircraft, when switching from on-board to remote piloting, enters an automatic mode for a very short period of time, in which it follows the approved flight plan automatically, and then enters a semi-automatic flight mode that would allow the GSO to control the aircraft based on high level commands, such as heading, altitude or speed. Finally,

i) manual control by the GSO, using throttle and stick to control the aircraft's control surfaces, is not foreseen in the concept. This assumption was derived from the Minimum Aviation Systems Performance Specifications for Remote Pilot Stations Conducting IFR Operations In Controlled Airspace [17].

III. The SAFELAND Concept

A. *Presentation of the SAFELAND Concept*

As mentioned earlier, in future SPO the degree of automation in the cockpit will most likely be higher than in current aircraft [18]. In addition, a ground station would need to be introduced to support the single pilots mostly in non-nominal situations and to monitor their health. If necessary, the GSO would intervene and even take over control of the aircraft in case of pilot incapacitation [19].

Following the concept proposed by Schmid & Korn (2017) [8], SPO could be managed by involving **three different ground stations:** departure, cruise, and arrival ground station. During departure and arrival, one GSO would assist one single pilot at a time, whereas in cruise (when workload is normally relatively low) the GSO would support several single pilots simultaneously (see Fig.1). In nominal situations, the tasks that could be transferred to the GSO include flight planning, navigation, and communication in order to support the single pilot as needed. A more active role of the GSO could also be foreseen, but airlines would be expected to develop their own standard operating procedures (SOP) detailing the task distribution between the two roles (single pilot and GSO). However, in the SAFELAND concept, an additional actor has been introduced in cruise operations, namely a stand-by GSO. The stand-by GSO would be appointed as responsible for a single aircraft in case of an emergency during cruise (e.g., on-board pilot incapacitation).

Several studies have shown that the **handover phase** between ground stations represents one of the most critical phases during RPA control [20]. Differing configurations of the involved ground stations, for example, could lead to abrupt flight manoeuvres and eventually loss of control of the aircraft. Therefore, in the SAFELAND concept, the handover phase is of particular concern and is closely aligned with current requirement and guidelines for RPA handovers, such as EUROCAE (2020) [17] and ICAO (2015) [21]. A handover between ground stations will have to take place each time a single-piloted aircraft

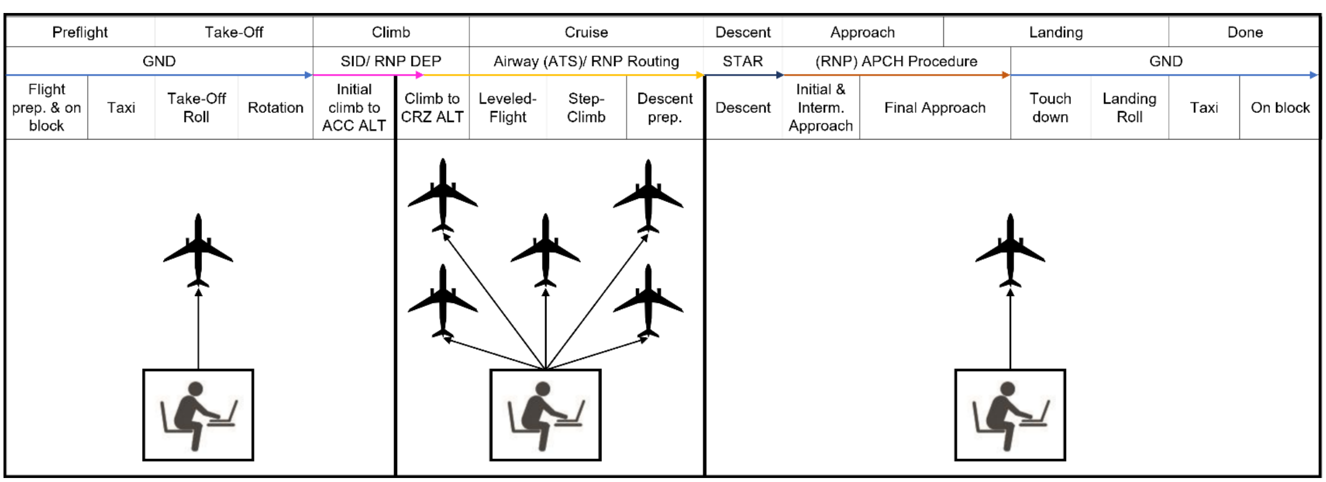

Figure 1. Assumed operational concept for SPO

enters the cruise phase after departure, and prior to the descent phase. The same handover process would also be used whenever there is a transfer of the monitoring responsibilities from one cruise GSO to another. The handover procedures involve the single pilot, the transferring and the receiving GSO, the system automation (i.e., aircraft automation and GS automation). ATC might also be involved during this procedure.

Depending on the flight phase, the SAFELAND concept envisions slightly different procedures in the event of pilot incapacitation. If the incapacitation occurs during cruise, Fig. 2 depicts the foreseen high-level steps to transfer the control of the aircraft from air to ground, whereby the GSO becomes the new Pilot-In-Command (PIC).

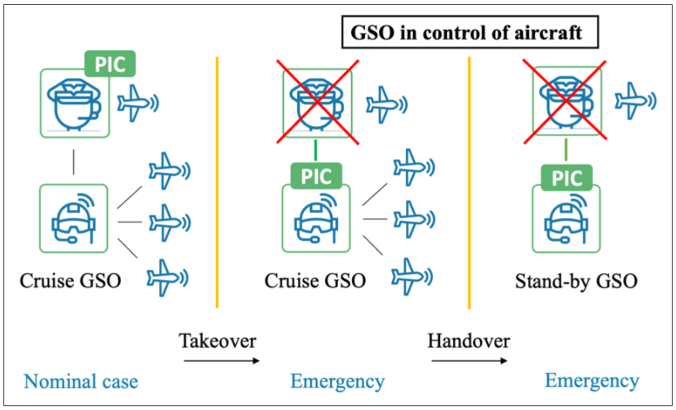

Figure 2. Pilot incapacitation in cruise: High-level steps for transferring control from air to ground

As mentioned earlier, during cruise one GSO will monitor several single-piloted aircraft simultaneously. In case of single pilot incapacitation, the responsibilities to control the aircraft will have to be transferred from air to ground. First, the cruise GSO will take over the control of the aircraft for a short period of time. However, as this actor is also monitoring other aircraft, s/he will hand over the concerned aircraft to a stand-by GSO. The stand-by GSO will only handle the incapacitated aircraft and land it safely. Fig. 3 illustrates the required processes in case of single pilot incapacitation during cruise.

In total eight steps, from the detection of the single pilot incapacitation to landing the aircraft safely, have been considered within the proposed concept. First, as soon as incapacitation is detected by the onboard pilot health monitoring system, onboard automation will disable the controls in the cockpit in order to prevent any accidental inputs by the incapacitated pilot. Second, autopilot will be engaged, and the aircraft will fly according to the last clearance received. Simultaneously, the onboard automation will transmit notification of the pilot´s incapacitation to the GSO currently monitoring this aircraft. Then the aircraft will enter a semi-automatic flight mode that would allow the GSO to control the aircraft (and thus become Pilot In Command - PIC) based on high-level commands, such as heading, altitude or speed, while attempting to contact the pilot via voice communication to confirm the incapacitation. Therefore, automation must be capable of maintaining stable flight and receiving commands from the ground. It is also envisioned that the secondary flight controls, as well as the landing gear are operated automatically, either autonomously or on request by the GSO. Once incapacitation has been confirmed and declared, the cruise GSO will take over control of the aircraft, announce it to all relevant actors (i.e., ATCOs, AOCC), enable a squawk notification (i.e., squawk 7700) and coordinate with ATC to clear the airspace around the aircraft. Once the stand-by GSO has gained sufficient situation awareness, the fourth step starts, where the cruise GSO initiates the handover process in order for the stand-by GSO to become the PIC, responsible to land the aircraft safely at the most suitable airport. The specific process of handing over control from the cruise GSO to the stand-by GSO is not foreseen to be different from the handover process taking place between two GSO in nominal situations.

Fifth, once the handover process is completed, the stand-by GSO must decide on a diversion airport. Therefore, it is foreseen that automation is able to provide a list of suitable airports to the stand-by GSO in the near vicinity of the aircraft, based on infrastructural, meteorological and airline operational conditions (e.g., the current aircraft position, available runway length and weather conditions at the potential airport). Depending on the circumstances there are different possibilities. For example, the landing airport could be (i) the original destination, (ii) one of

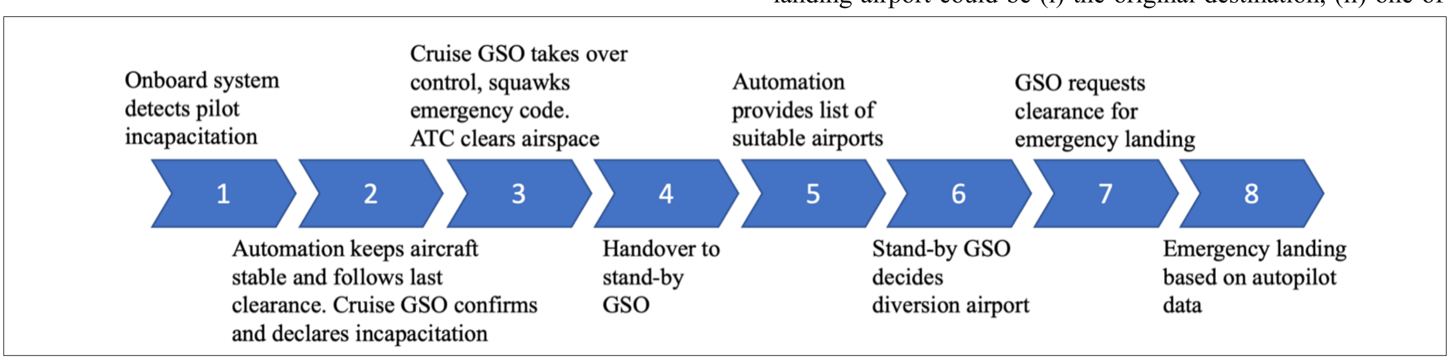

Figure 3. Pilot incapacitation in cruise: Takeover phases until safe landing

the alternate airports stated in the flight plan or (iii) a new destination. However, some specific aerodromes could already be strategically identified along the planned route and indicated in the FPL stored in the FMS, to be available to the stand-by GSO. As a result, with the assistance of ATC, and potentially some input from the Network Operations Control (NOC), the stand-by GSO will decide where to land, which is the sixth step of the process.

Seventh, after the decision has been made, the stand-by GSO needs to coordinate with ATC again to receive directions to the airport and ultimately the runway. The stand-by GSO will then be responsible for managing the autopilot and the FMS, while automation will fly the aircraft and maintain stable flight until touch-down. ATC will provide clearances (e.g., "direct to", Standard Arrival Route (STAR) and approach procedures) to the stand-by GSO, who will upload this data to the autopilot of the aircraft. Finally, in step eight, within the SAFELAND concept it is expected the aircraft being able to land autonomously (i.e., via automatic take-off and landing system - ATOL) based on the uploaded route.

The handover procedures in cruise and in departure/approach phases differ in one core aspect. During departure/arrival, the GSO is responsible for one aircraft at a time, meaning that s/he should already have an adequate mental picture of the current aircraft state and position at the moment of incapacitation. Hence, if pilot incapacitation occurs during these flight phases, the aircraft is already being monitored by the appointed GSO and there is no transfer of responsibility to a stand-by GSO.

IV. Roles and Responsibilities, Team Structure and Communications

The roles and responsibilities described for the main actors involved in SPO, i.e., on-board pilot, GSO, AOCC, ATC (various sectors from En Route down to the airport) in nominal conditions are compliant with the ICAO Rules of the Air (Annex 2) or other relevant ICAO (e.g., Doc. 4444) and National Supervisory Authorities (NSAs)/EASA provisions.

According to [8], the key responsibilities of the **on-board single pilot** are comparable to pilots' responsibilities in a two-pilot cockpit. The single pilot remains ultimately responsible for the safe and orderly operation of the flight, within airline standard operating procedures. S/he ensures that the aircraft operates in accordance with ATC clearances and with the agreed Reference Business Trajectory (RBT). The pilot is responsible for preparing, conducting, and terminating a flight, and for having a good coordination with the NOC. In normal operations, the **GSO** is required to monitor the flight and assist the on-board pilot upon request. During the departure and arrival flight phases, one GSO will be appointed to one single-piloted aircraft. The departure GSO will be responsible for monitoring the flight for the entire departure process starting from gate until passing FL100, while the arrival GSO will monitor from Top of Descent until the aircraft reaches the gate at the destination airport. Hereby, the main tasks and responsibilities for both the departure and the arrival GSO will be to constantly maintain supervisory oversight of the flight and the aircraft. During cruise, each GSO will be responsible for more than one single-piloted aircraft.

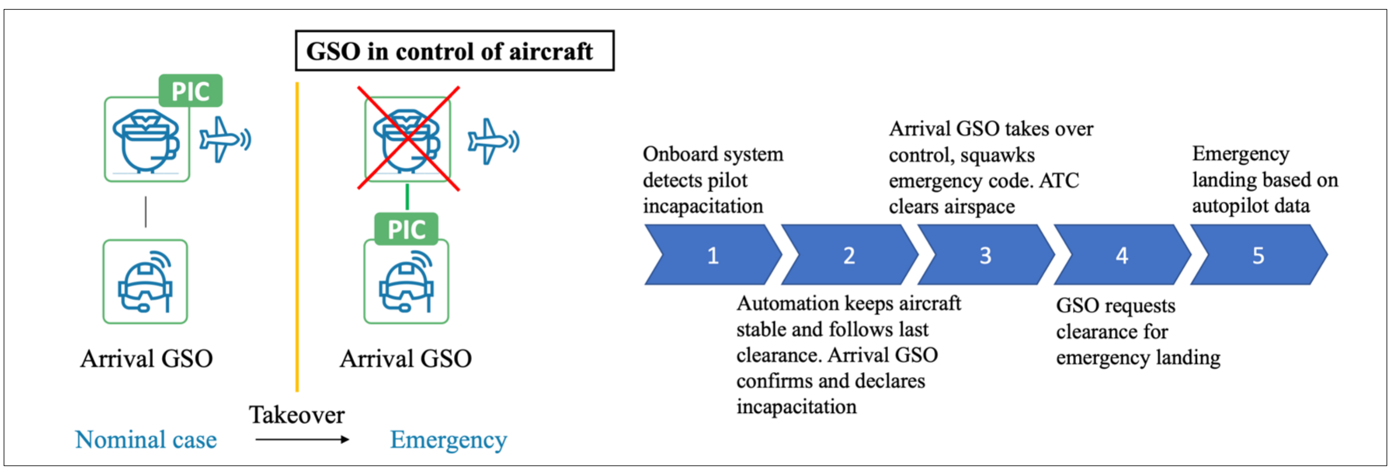

Figure 4. Pilot incapacitation during arrival: High-level steps for transferring aircraft control from air to ground, Takeover phases until safe landing

Fig. 4 illustrates the high-level steps for transferring aircraft control from air to ground and the takeover phases until safe landing in case incapacitation occurs during arrival.

Once incapacitation is confirmed, all responsibilities of the on-board pilot are transferred to the GSO who becomes the PIC, responsible for conducting the flight and land the aircraft safely, ensuring a good coordination with the other relevant actors (i.e., other GSO, ATC and AOCC).

It is foreseen that **ATC roles** and responsibilities will not change in future SPO compared to today's operations. In en-route and in approach, the Executive Controller (EC) remains responsible for providing ATC service within his/her Area of Responsibility (AoR) in order to prevent collisions between aircraft and expedite, as well as maintain an orderly flow of air traffic. The Planning Controller (PC) is mainly responsible for planning and coordination of the traffic entering, exiting, or flying within the AoR, and to provide assistance to the EC. In the airport area, the Tower Controller is responsible for the provision of air traffic services to aircraft within the control zone, or otherwise operating in the vicinity of controlled aerodromes, by issuing clearances, instructions and permission to aircraft, vehicles and persons as required for the safe and efficient flow of traffic.

Pilot incapacitation should be handled as an emergency, and procedures as defined in the ICAO Doc 4444 chapter 15 may apply: the ATC is responsible for ascertaining situation, deciding upon assistance, enlisting the aid of relevant support, providing / obtaining relevant information, and notifying the appropriate authorities. The general rule is that the incapacitated aircraft shall be given priority. The PC will be expected to perform a number of coordination tasks in order to exchange necessary information between relevant actors (e.g., ATC, AOCC, airport and firefighting units), keep all parties updated about the progress of the incapacitated aircraft and facilitate the EC in resolving the emergency situation efficiently. The Tower controller will be required to perform additional tasks (e.g., clear the final path, hold other traffic on the ground) to facilitate the safe flight operations until the concerned aircraft lands safely.

The **AOCC** of an airline represents a coordination hub responsible for monitoring and solving operational problems [22]. The flight dispatcher is responsible for the planning of an individual flight by assessing all boundary conditions that impact the flight execution. Furthermore, the flight dispatcher provides all briefing information to the flight crew including the GSO in SPO. The NOC is active once the aircraft is in flight and responsible for providing assistance by supervising and initiating appropriate actions in case the pilots have a problem (e.g., engine failure, fire, emergency descent).

In case of pilot incapacitation, there are no relevant changes expected for the Flight Dispatcher, whereas the NOC should be notified, so that they can initiate the subsequent emergency procedures. These will include coordination with the GSO to decide on the most suitable airport, and inform the other stakeholders (e.g., passenger service center). The NOC is expected to forward recommendations and analyses for change of route and/or destination aerodrome or alternate aerodrome as applicable.

V. Technical Challenges: BRLOS Command and Communications, Automation levels and functions

The future realization of the SAFELAND concept will challenge researchers to take a leap forward in communication technologies and human-machine design. The innovative characteristics of the project highlight the requirement for advancement in the following aspects, while simultaneously providing possible pathways for solutions.

A. *Beyond Radio Line of Sight (BRLOS) command and control link and communications*

The operational structure of the SAFELAND concept requires the GSO to be able to control the aircraft and communicate with other relevant actors from a remote position. This aspect introduces the need for SAFELAND operations to be supported by BRLOS command, control, and communication links. BRLOS connections augment the challenges of latency (or delay in communication) affecting control capabilities, possible reliability issues, as well as potential cybersecurity threats. The SAFELAND requirements to tackle these challenges is funded upon two aspects:

1) Apply new methods for BRLOS transmission by utilizing emerging technologies: the development of 5G communication and Low Earth Orbits (LEO) multi-hop Satellite Communication (SATCOM) is seen as a potential solution against the problematics posed by latency and reliability of connection, thanks to the performance capabilities reachable by those systems.

2) Plan for redundancy: The SAFELAND concept will function safely with different levels of connection performances and latencies, while contemporarily accounting for the possibility of total loss of connection with its ground elements or connection shutdown due to security breach. For this to be possible, multiple backups in the communication system will be required, as well as the presence of on-board automation fitted with advanced functions, including the use of machine learning based algorithms (see next section).

B. *Automation levels and functions*

Due to the remote position of the GSO and the utilization of BRLOS communication means, the SAFELAND concept requires high levels of automation. Automation development poses challenges related to human factors and technological availability. To address these issues, SAFELAND identified the main functions which the onboard automation will be required to demonstrate:

1) Aviate: the onboard automation is required to safely control the aircraft flight path, attitude, and speed, while at the same time managing secondary flight controls (such as flaps and gear). The GSO will monitor automation performance and be able to actively control these functions.

2) Flight Management: the GSO will be supported by the aircraft automation in multiple aspects of the flight, including decision making. Automation will need to be designed to manage in a "Fail Operational" way a high number of technical malfunctions, while autonomously respond to time critical events requiring prompt action to avoid flight safety impairment, such as windshear escape in final approach. Machine learning algorithms, and potentially AI, might increase the safety levels in case of total loss of connection with the ground, allowing the aircraft to operate autonomously in these conditions.

3) Human-Machine Interface: to ensure predictability and understanding of automation functions, human-machine interfaces will need to be designed, allowing the involve actors to maintain the required level of situational awareness.

C. *Legal and regulatory considerations*

The SAFELAND concept embeds two distinct but overlapping legal and regulatory fields: SPO in commercial flight and Remotely Piloted Aircraft Systems (RPAS) operations. It tackles a set of issues both of manned and unmanned aircraft, in nominal and non-nominal operations, which must be considered jointly in the analysis of regulatory and legal constraints. These aspects must then be incorporated in the SPO features at a design level, in order to work properly in case of full incapacitation of the single pilot.

SAFELAND has a significant impact on the roles and responsibilities of key actors involved. This will require regulatory modifications both at international and European level. Moreover, it will impact the legal liability schemes in case of misconduct and/or harmful events.

The main regulatory domains for SPO are Rules of the air, personnel, aircraft operations, airworthiness, occurrence investigation and reporting. Civil aviation in Europe and, in particular, ATM aspects are mainly covered by European regulations. In addition, international regulatory and standardisation bodies provide documents that partially cover SAFELAND regulatory domains. Ancillary documents, such as Acceptable Means of Compliance (AMC), Guidance Material (GM), Certification Specifications (CS), are issued by EASA as recommendations or technical guidelines. Amending 'hard rules' is a very long and cumbersome process that cannot be adopted in the development of SAFELAND concept. Therefore, the AMC to EU Reg 923/2012 [23] regarding the common rules of the air and operational provisions, the AMC to EU Reg 2015/340 [24] regarding air traffic controllers' licences and certificates, the AMC and GM to EU Reg 965/2012 [25] regarding the technical requirements and administrative procedures related to air operations, and the AMC for Large Aeroplanes CS-25 [14] regarding the airworthiness might be amended as SAFELAND result.

The ICAO RPAS Panel is involved in the domains mentioned above; therefore, the development of ICAO Standards and Recommended Practices (SARPs), procedures and guidance material for RPAS may supports the SAFELAND concept. Moreover, operations type #1 (international IFR operations of certified cargo UAS) defined by EASA for the unmanned aircraft systems' (UAS) 'certified category' (EASA, 2021)[1] may represent the "starting point" for the SAFELAND concept.

The fundamental legal issue of the SAFELAND concept concerns the relations between responsibility and legal liability of the actors involved[26][27][28]. Legal liability (from now on simply "liability") ordinarily follows from the scope of the responsibility assigned to each actor [29]. Furthermore, sometimes liability is allocated to subjects other than the ones endowed with responsibility, as in the case of strict and vicarious liability [30]. It is therefore important to define clear responsibilities (while maintaining a certain degree of operational flexibility) in order to foresee proper liability paths and thus avoid legal uncertainty and limit judicial burdening.

SAFELAND is centered around the role of a GSO who monitors the flight in nominal SPO and takes over operations in case of pilot incapacitation. The concept envisages a higher degree of automation than that employed nowadays, capable of executing a set of tasks currently assigned to pilots (e.g., landing) [31][32][33]. The responsibilities and attached liability of ATCOs do not change substantially.

In the tripartite model selected for SAFELAND, several GSOs are involved in a flight. In nominal conditions, Departure, Landing and Cruise GSOs basically act as remote co-pilots. However, their function is mainly to monitor operations: they acquire an active role only at the request of the onboard pilot. The configuration does not show blocking legal issues: however, the presence of multiple GSOs increases the liability risks related to handover procedures.

In the current legal framework, all flight operations must be conducted under the ultimate responsibility of a (human)[2] PIC. In case of single pilot incapacitation, the monitoring GSO takes control of the flight and becomes a remote PIC. S/he will then

[1] https://www.easa.europa.eu/domains/civil-drones-rpas/certified-category-civil-drones

[2] This is the main reason why automated systems cannot take primary control of the flight. This is in line with the principles of human oversight put forward by the EU with regard to all automated and AI systems (EASA AI Roadmap, AI Regulation Proposal). See also ICAO Annex 2: Rules of the Air.

be subject to liability for harmful events according to existing legislation.[3]

SAFELAND entails new training and licencing needs for all actors involved, and especially GSOs. Insurance schemes shall likewise adapt to responsibility modifications, with particular reference to PICs. The increased role of automation shall reduce the responsibilities of the human actors, shifting liability allocation to the actors behind the technology, usually within the framework of product liability [34][35]. In further development of the concept, a safety analysis regarding the main potential harmful events and misconduct in the execution of the safe landing shall enable an accurate analysis of specific liability allocation.

VI. Conclusions

In this paper, a conceptual framework has been proposed to address the event of in-flight pilot incapacitation in SPO. Even though SPO is already in operation for some business jets, operating procedures and regulations have not yet been defined or implemented for large passenger commercial aircraft. Therefore, the maturity of the proposed concept should be considered as preliminary, and several assumptions have been made which are listed in chapter 2. Summarizing, the SAFELAND concept [36] relies on **three key principles**.

First, the SAFELAND project addresses the pilot incapacitation issue for future SPO of CS-25 aircraft operated under IFR. Hereby, the proposed concept will most likely not be implemented before the year 2035, and therefore relies significantly on more sophisticated onboard automation to support the single pilot throughout the flight. In particular, in the first few moments after the pilot incapacitation, onboard automation will take over control of the aircraft flying according to the flight plan stored in the FMS. Furthermore, highly automated landing procedures are foreseen in which neither the single pilot (in nominal flight condition) nor the GSO (in incapacitated flight conditions) is required to intervene in the final approach.

Second, the SAFELAND concept has adopted parts of the Tripartite Concept proposed by [8] to its use-case. It relies on the fact that a GSO will be always monitoring the flight. In case of pilot incapacitation, depending on the flight phase, the departure/arrival or a stand-by GSO (when the aircraft is in its cruise phase) will take over the control and land the aircraft safely. The different steps of the handover procedures are closely aligned with current requirements and guidelines for RPA handovers, such as EUROCAE (2020) [17] and ICAO (2015) [21].

Finally, to ease the way for the implementation of the SAFELAND concept into the existing ATM framework, and considering legal and regulatory aspects, the concept does not require significant changes to the tasks and responsibilities of ATC and AOCC. To further assess the implications on the ATM framework and to evaluate the proposed operational concept, several exercises including real-time simulations will be conducted in the second half of the project.

The processes and procedures outlined in this document will be assessed and evaluated in a later stage of the project with the support of different stakeholders and with a variety of validation activities. The evaluation will include exploratory exercises based both on low fidelity and real-time simulations involving pilots, remote pilots, and controllers, to investigate the characteristics and the acceptability of the concept, together with safety and human factor aspects.

VII. Acknowledgment

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