SAFELAND Final Concept

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SAFELAND

SAFE LANDING THROUGH ENHANCED GROUND SUPPORT

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Abstract

SAFELAND is developing a future concept of operations for single pilot operations, dealing with the event of single pilot incapacitation. The concept is developed with the contribution of different stakeholders and will be validated by internal and external experts.

This deliverable describes the final SAFELAND concept proposing an operational concept to handle the issue of pilot incapacitation in single pilot operations. This deliverable concludes the work done in work package (WP) 1, and is the result of task T1.4. Hereby, this deliverable is based on the work performed in T1.2 *Initial Concept*, T1.3 *Legal, Regulatory and Economy constraints* and takes the suggestions and recommendations provided by the Advisory Board (AB) members as part of a dedicated workshop (T3.2) into account.

This document has three main parts. First, this document illustrates an operational concept for SPO in commercial aviation for nominal flight conditions, in which a ground station operator (at least) monitors the flight at all times (cf. chapter 3). A clear definition of the foreseen roles and responsibilities, technical challenges, as well as operational processes and procedures is provided in order to describe the envisaged framework to which the SAFELAND concept shall be applied.

Second, this document aims to provide an operational concept for the SAFELAND use-case of pilot incapacitation in future single pilot operations (cf. chapter 4). Hereby, legal and regulatory implication of the SAFELAND concept are examined, the changes to the foreseen roles and their responsibilities are described in detail, and the required technical characteristics on the overall air traffic management framework are analysed. Furthermore, by providing a sequence of processes for different flight phases, a clear guideline on the operating method for the SAFELAND use-case is detailed.

Finally, a summary of the key principles of the chosen final concept, the challenges ahead and the way forward (i.e. evalutation exercise in WP3) are outlined as a conclusion to WP1.

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1 Introduction

The main goal of SAFELAND is to describe a concept for Single Pilot Operations (SPO) in case of pilot incapacitation during flight, and until the aircraft lands safely. SAFELAND focuses on the ground side and in particular on the role Air Traffic Management (ATM) could have in managing the emergency situation.

In the first deliverable of work package (WP) 1 (*D1.1 Model of Flight Tasks*) (SAFELAND Project, 2020) the functions that need to be executed to enable safe flight operations of a CS-25 certified aircraft in controlled airspace under Instrument Flight Rules (IFR) were described using methods from Cognitive Work Analysis (CWA), i.e. work domain analysis, control task analysis, and social organization and cooperation analysis. In a next step, the interactions between the different actors for selected, critical functions and flight phases were described. The analysis was carried out for dual, single and remotely piloted aircraft and the differences between the different aircraft configurations were discussed. In deliverable *D1.2 SAFELAND Initial Concept* (SAFELAND Project, 2021a) the initial version of the SAFELAND concept was described, with different implementation options in case of pilot incapacitation in SPO. An online workshop was held on the 27th and 28th October 2020, where the three variants of a SAFELAND concept were elaborated, focusing on re-assigning the functions, tasks and responsibilities between the involved entities (i.e. Air Traffic Control, ATC; Airline Operations and Control Center, AOCC; Ground Station, GS and automation) after the pilot incapacitation has occurred. Each variant of the concept has a different focus as to who is mainly responsible for controlling or issuing commands to the aircraft (automation, GS or ATC). The variants were described by three key elements, namely (i) the function allocation diagram, (ii) the interaction diagram and (iii) the location of the GS. These elements are the same as used in Task 1.1 to describe the model of flight tasks.

1.1 Purpose and scope of the document

This document details the final version of the SAFELAND concept aiming at **providing a conceptual approach for handling the rare occurrence of onboard single pilot incapacitation in future SPO**. Hereby, this document concludes the activities done in WP1 *Definition of Concept* and has evolved from the previous work and deliverables created in WP1, and from the supporting activities conducted in WP3 *Concept Evaluation*. This deliverable:

- focuses on the detailed description of the processes and operational procedures required in case of pilot incapacitation,
- illustrates the tasks distribution, as well as function allocation between the involved actors (i.e. onboard Single Pilot (SP), Ground Station Operator (GSO), ATC, AOCC) for nominal and off-nominal flight condition,
- defines the roles and responsibilities of these actors in detail and
- addresses technical characteristics needed for remotely supervising and controlling the concerned aircraft.

As a result, this deliverable proposes a comprehensive, yet feasible concept to address the pilot incapacitation event in SPO focusing on the ground side of the ATM framework by specifically detailing the envisaged operating methods for the critical phase in the transition from single piloted aircraft to Remotely Piloted Aircraft (RPA). More details on the methodology and the approach taken to create this document can be found in chapter 2.

1.2 Structure of the document

In total, this document consists of 6 chapters, which are further subdivided into subsections. The chapters and their main topics are the following:

- Chapter 1 describes the purpose and scope of this document. Furthermore, it details the structure of the document and provides a list of the used acronyms.
- Chapter 2 details the **methodologies that were used** within this document. First, the fundamental approach for creating this document is given, including a list of assumptions that were made in order to develop this final SAFELAND concept, as well as a summary of the recommendations received from an Advisory Board (AB) workshop. Hereafter, two methods commonly used to facilitate the understanding of activity in complex work systems (such as aerospace systems), namely the Social Organization and Collaboration Analysis – Contextual Activity Template (SOCA-CAT) and the Operational Event Sequence Diagram (OESD), are described. Within this document, these methods will be further used to describe the proposed concept in detail.
- Chapter 3 details the **envisaged framework for future SPO in commercial aviation** conducted in controlled airspace under Instrument Flight Rules (IFR) for nominal flight conditions. Within this chapter, details with respect to the operational concept, legal and regulatory considerations as well as roles and responsibilities of SPO in nominal flight conditions are described. Furthermore, this chapter makes some considerations regarding technical challenges of SPO, as well as the foreseen operating method for a specific phase, such as the handover from one GSO to another.
- Chapter 4 describes the implications of the SAFELAND use-case (i.e. onboard single pilot incapacitation) on the proposed concept for future SPO. Hereby, this chapter illustrates **the envisaged changes that will occur in case of pilot incapacitation** on the aforementioned topics. Especially, the roles and responsibilities of the involved actors, as well as the operating method for taking over control of the aircraft by a GSO are described in detail.
- Chapter 5 summarizes the main ideas detailed in this document concerning **the final SAFELAND concept for future SPO in case of pilot incapacitation.**
- Chapter 6 lists the references used within this document.

1.3 List of acronyms

Term	Definition
AB	Advisory Board
ABIA	Avionics Based Integrity Augmentation
A/C	Aircraft
ACS	Area Control Surveillance
ADS-C	Automatic Dependent Surveillance - Contract
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
AMC	Acceptable Means of Compliance
AOCC	Airline Operation Control Center
AoR	Area of Responsibility
AP	Autopilot
ARINC	Aeronautical Radio Inc.
ASSIST	Acknowledge Separate Silence Inform Support (principle)
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATIS	Automatic erminal Information Service
ATIS	Announce Taq Information Solve (principle)
ATS	Air Traffic Service
ATM	Air Traffic Management
BRLOS	Beyond Radio Line of Sight
C2 datalink	Command & Control datalink
CPDLC	Controller Pilot Data Link Communications
CS	Certification Specification
CMS	Crew Monitoring System
CWP	Controller Working Position
DAA	Detect And Avoid
DLS	Data Link Service
EASA	European Union Aviation Safety Agency
EC	Executive Controller (ATCO)
EU	European Union
eVTOL	Electric Vertical Take Off and Landing
ERCS	European Risk Classification Scheme
FAF	Final Approach Fix

FMC	Flight Management Computer
GDT	Ground Data Terminal
GM	Guidance Material
GS	Ground Station
GSO	Ground Station Operator (Ground Remote Pilot)
HALE	High Altitude Long Endurance aircraft
HF	High Frequency
HP	Human Performance
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IVHM	Integrated Vehicle Health Management
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
KPI	Key Performance Indicator
LOC-I	Loss of Control In-Flight
LOS	Line Of Sight
ND	Navigation Display
NOC	Network Operation Control
NOTAM	Notices To Airmen
MALE	Medium Altitude Long Endurance aircraft
MCP	Multi Control Panel
METAR	Meteorological Aerodrome Report
OESD	Operational Event Sequence Diagram
PC	Planning Controller (ATCO)
PFD	Primary Flight Display
PIC	Pilot In Command
PIO	Pilot Induced oscillation
RBT	Reference Business Trajectory
RISC	Recognise Identify Separate Communicate (principle)
RLOS	Radio Line of Sight
RMT	Reference Mission Trajectory
RMT	Rule Making Task (in the regulatory context)
RNP	Required Navigation Performance
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RPIC	Remote Pilot In Command

RTF	Radiotelephony
SA&CA	Separation Assurance and Collision Avoidance
SATCOM	Satellite Communication
SERA	Standardised European Rules of Air
SITA	Societe International Telecommunications Aeronautiques
SJU	SESAR Joint Undertaking
SOCA-CAT	Social Organisation and Cooperation Analysis - Contextual Activity Template
SOP	Standard Operating Procedures
SP	(onboard) Single Pilot
SPO	Single Pilot Operations
STAR	Standard Terminal Arrival Route
SVS	Synthetic Vision Supplement
TAF	Terminal Aerodrome Forecast
TAS	Time Airspace Silence (principle)
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
VHF	Very High Frequency
VoIP	Voice over Internet Protocol
VTOL	Vertical Take-Off and Landing
WP	Work package

Table 1: List of Acronyms

2 Methodology

2.1 Approach

This deliverable (*D1.4 Final Concept*) derives from the three different implementation options described in deliverable D1.2 (SAFELAND Project, 2021a) and proposes one final SAFELAND concept combining elements of the three different options. Based on a project internal workshop held in October 2020, **three different implementation options have been developed**, and are described in D1.2. In particular, the three different variants differ as to who should have the main responsibility for controlling the aircraft in case of onboard single pilot incapacitation. The three actors were (i) onboard automation (i.e. Group Automation), (ii) GSO becoming a dedicated remote pilot (RP) for the concerned aircraft (i.e. Group GS) and (iii) GSO with support from the Air Traffic Controller, ATCO (i.e. Group ATC). Hereby, the key attributes of the developed variants of a SAFELAND concept were the following: First, in each variant of the concept the GS shall be located at the AOCC in order to ensure a fast and efficient communication line between the GSO and other airliner employees, as well as to ensure that the liability for the aircraft remains at the airline. Second, due to liability concerns each variant concluded that flight authority cannot be transferred to automation but would have to be given to a human operator on the ground. Third, Group ATC introduced a new actor into the ATM framework (apart from the GSO) named “dedicated ATCO” in order to support the GSO in controlling the aircraft from the ATC side.

In a next step, the legal, regulatory and economical implication of these three concept variants were analysed in D1.3 (SAFELAND Project, 2021b). The main considerations identified in D1.3 have been taken into account in the proposed final concept (cf. chapter 3.2 and chapter 4.2). Moreover, as part of WP3 and task T3.2 *Preliminary Evaluation*, the three different implementation options were presented, discussed and analysed during a SAFELAND Advisory Board workshop held in January 2021. By taking the recommendations and suggestions provided by the various subject matter experts attending the workshop, the final concept has been developed as a combination of certain elements especially taken from the implementation variants proposed by Group GS and Group Automation. See section 2.1.2 for more information about the workshop.

In order to ensure that Human Performance (HP) aspects are systematically identified and considered in the SESAR operational and technological developments, SESAR Joint Undertaking (SJU) developed a HP assessment process (SJU, 2020). Even though SAFELAND hasn’t yet reached the V1 maturity level, which is the first V-phase addressed in the assessment, we have attempted to cover the most relevant HP aspects in this deliverable, using the HP argument structure provided in the guidance material. The following topics are central for an HP assessment:

- Roles, responsibilities, operating methods and human tasks (**Argument 1**): We have attempted to identify the roles affected by the SAFELAND solution and provide a preliminary description of the responsibilities of the human actors (cf. chapters 3.3 and 4.3). Moreover, operating methods were described, ensuring that they support the human in carrying out their tasks (cf. chapters 3.5 and 4.5).
- Technical support systems and Human-Machine Interface (**Argument 2**): In chapters 3.4 the technical challenges in SPO and in chapter 4.4 the technical characteristics of SAFELAND are

described. Hereby, the most appropriate allocation of tasks between the human and the machine (i.e. automation level) are discussed.

- Team structure and team communication (**Argument 3**): Preliminary impact of the final SAFELAND concept on team composition is also addressed when describing the different roles (chapters 3.3 and 4.3), as well as the operating method for the specific phases in chapters 3.5 and 4.5. Furthermore, considerations with respect to automation and human integration are discussed in chapter 4.4.4. The assessment focused on an appropriate allocation of tasks between human actors; as well as an initial assessment of the communication needs between team members when handling the emergency situation.
- The final Argument (**Argument 4**) covers potential transition factors, that is, all aspects that may affect the transition to the proposed concept. This argument is not expected to be covered in-depth before V2 level, therefore we will not address it here (pre-V1). However, aspects related to acceptance of the concept will be examined in the evaluation exercise as part of task T3.3 *Simulations*, as well as in a 2nd AB workshop as part of T3.4 *Final Evaluation* later in the project. Furthermore, section 4.3 addresses the competence and training requirements of the involved actors when describing the different roles and responsibilities.

2.1.1 Assumptions/ Scoping

As SAFELAND is marked as an exploratory research project, the maturity of the proposed concept should be considered as preliminary, and the findings, including processes and procedures outlined in this document will be evaluated in a later stage of this project. In order to develop a comprehensive SAFELAND concept addressing the ground side of the ATM framework and the communication between the involved actors in particular, the consortium agreed to the following assumptions and expectation towards the end-system:

- The SAFELAND concept shall be applicable for aircraft operations in controlled airspace under IFR.
- The SAFELAND concept assumes nominal flight conditions of a CS-25 aircraft in commercial or cargo operations apart from pilot incapacitation.
- The SAFELAND concept addresses total pilot incapacitation. Partial incapacitation including the possibility of a pilot recovery was not taken into account.
- The SAFELAND concept 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. Furthermore, in order to have (financial) advantages compared to dual piloted operations, one GSO is assumed to be monitoring several aircraft at the same time during cruise. In an emergency event of one aircraft, the GSO would transfer the concerned aircraft to a dedicated stand-by GSO, who would be solely responsible for the concerned aircraft until landing.
- Within the SAFELAND concept, 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 without latency or failure/ loss due to areas without coverage). Onboard automation is able 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. In addition, the landing airport supports ILS CAT IIIc approaches, which are currently not operational.
- The SAFELAND concept 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.

- The SAFELAND concept assumes that the aircraft, when being controlled remotely, enters an automatic mode for 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 (cf. chapter 4.5.2). Manual control, 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 (EUROCAE, 2019).

2.1.2 Recommendations from the AB workshop

As part of task T3.2 *Preliminary Evaluation*, a workshop with the SAFELAND AB was conducted virtually in late January 2021 with the aim of collecting objective feedback and comments from different external experts on the SAFELAND initial concept variants that were developed in task T1.2 *Concept Development*. Primary means used to gather the critiques were discussion sessions, voting and written comments (using an interactive tool *Mentimeter*). The workshop outcomes were analysed and reported in the deliverable D3.2 *Preliminary Evaluation Results*.

Based on the feedback received during the workshop, the project has concluded that the automation and GS focused concepts are the two most promising alternatives for the final SAFELAND concept. These preferences have been motivated by the perceived feasibility and operational logic of the two solutions and, in addition to that, the sequence of operational events and overall concept flow seemed more logical and efficient. The ATC focused concept mostly collected negative feedback and received the least favour. The rationale behind this was the confusions generated by the concept concerning roles and responsibilities of each actor involved, and of the doubts raised concerning the possibility of assigning additional duties to ATCOs for the control of the emergency aircraft.

It was suggested that the final concept should allow for a combination of the automation concept and the GS concept. The reason for this is that the required features in the two concepts are not yet available but need to be developed in the coming years. Since the pace and progress of the technical development is unknown, it is considered favourable to maintain freedom to combine the most promising parts of each concept in order to optimize the final design.

The workshop results (i.e., positive/negative feedback and recommendations) were highly valuable and used in a refinement of the final SAFELAND concept taking into account the fine-grained aspects derived from the automation and GS concept variant, and discarding the specific operational configuration of the ATC focused solution.

2.2 Function allocation diagram (SOCA-CAT)

As described in deliverable D1.2 *Initial SAFELAND Concept* (SAFELAND Project, 2021a), a SOCA-CAT is a method to visualize the function allocation in a socio-technical work system, such as an aircraft flying in controlled airspace. In a SOCA-CAT, the functions are mapped against the different situations that a work system experiences. For each function and situation, it is coded, if (1) the function is active in the respective situation and (2) who is involved in the execution of the function. The SOCA-CAT does not consider which of the actors is best placed to conduct the activities necessary to execute the function, nor is there consideration of the best way of completing the activities (e.g. Naikar, Moylan, & Pearce, 2006 and Stanton, Harris & Starr, 2016).

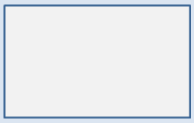
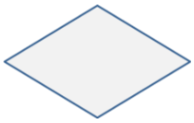
The SOCA-CATs developed and presented in deliverables D1.1 and D1.2 were adapted to match the most important situations and the functions during a single pilot incapacitation event. Two SOCA-CATs were developed, one for nominal SPO conditions (cf. chapter 3.5.1) and one for the single pilot incapacitation (cf. chapter 4.5.1)

2.3 Interaction flow diagram (OESD)

As detailed in D1.2 *Initial Concept* (SAFELAND Project, 2021a) function allocation techniques, such as the SOCA-CAT, are a good and established way of describing allocation of functions in a system on a high level. However, they fail to provide insight into the interactions of the involved actors that are necessary to achieve the purposes of the functions. That said, a technique is needed that provides this detailed insight. The method chosen for SAFELAND is the Opertaional Event Sequence Diagram (OESD). An OESD provides a basic yet thorough premise whereupon allocation of work can be evaluated with regards to the work process. OESDs illustrate and describe the interactions between operators and artefacts of a system and facilitate the comparison between alternative activity allocations and system configurations (Harris, Stanton & Starr, 2015; Huddlestone, Sears & Harris, 2017). The output of an OESD is a sequence of operational events and task processes over time that are depicted using a standardized set of symbols. Table 2 depicts the symbols used in an OESD (cf. D1.2 *Initial Concept* (SAFELAND Project, 2021a) and a short explanation of their meanings.

As mentioned earlier, the SAFELAND concept envisages the handover of aircraft responsibility and during single pilot incapacitation, aircraft control, between two GSOs. Studies have shown that the handover phase represent one of the most critical phases during RPA control (Hobbs & Lyall, 2016). Therefore, in the SAFELAND concept, the handover phase is of particular concern. In this document OESDs are used to illustrate the interaction concepts for the aircraft handover phases between GSOs during nominal SPO conditions (cf. chapter 3.5.2) and during the single pilot incapacitation (cf. chapter 4.5.2). The OESDs are based on the recommendations by the International Civil Aviation Organisation (ICAO; ICAO, 2015a and ICAO 2017) as well as the flow diagrams for RPA handover between two remote pilot stations described in EUROCAE (2019).

Table 2. Symbols used in OESDs.

Symbol	Meaning
	Process or Task
	Decision
	Display
	Manual operation
	Speech communication
	Data communication
	Connector

3 Single Pilot Operations in commercial aviation

Even though the coverage of SPO in normal conditions is out of scope for SAFELAND, in order to derive a concept for dealing with pilot incapacitation (cf. chapter 4), it was necessary **to make at least some high-level assumptions about the operational concept for nominal conditions.** Therefore, this chapter provides an overview of a possible approach and operational concept for SPO, based on internal discussions and expert knowledge in SAFELAND, as well as on findings from scientific literature.

At this point it is important to clarify that today there are already jet and turboprop aircraft flown by one pilot. However, pilots who fly commercial aircraft are held to higher medical and safety standards, and they are required to hold the appropriate license and training before they can operate large commercial planes. All non-scheduled flights that are not operated by commercial airlines or by the military are identified as general aviation (GA). In the fiscal year 2017 the GA fatal accident rate in the USA (the world's largest single aviation market) was 0.84 per 100,000 flight hours (Flight Safety Foundation, 2017). By comparison, the international scheduled airline fatal accident rate in 2019 was 0.17 fatal accidents per *million* flight hours, according to IATA (Skybrary, 2020b). The fatal accident rate in GA is unacceptable from a safety perspective for commercial aviation. In normal SPO in commercial aircraft the fatal accident rate will need to be similar or better than that achieved by two-pilot crews and nowhere near those of current single pilot operations in GA. There are many more differences between GA and commercial aviation than simply the different number of pilots. The whole chain from manufacturing, minimum equipment, maintenance, training etc. differs when you go from GA to commercial. Therefore, for the remaining of this document, SPO refers exclusively to its implementation in current operations for large commercial transport jets (e.g. large passenger aircraft).

3.1 Operational concepts for SPO

Numerous scientific publications argue that in future SPO, the degree of automation will most likely be higher than in current aircraft cockpits (e.g. Stanton, Harris & Starr, 2016) and that a ground station will need to be introduced to, at least, monitor the health of the single pilot, but also to intervene and even take over control of the aircraft in case a pilot incapacitation occurs (e.g. Lim, Bassien-Capsa, Ramasamy, Liu & Sabatini, 2017). Other publications propose to introduce a ground station that supports the single pilot only by request during cruise (when workload is normally relatively low) and/or to have a ground station assisting the single pilot permanently during departure and approach flight phases with higher workload (Schmid & Korn, 2017). This latter concept, proposed by Schmid & Korn (2017), envisions the presence of dedicated Departure, Cruise and Arrival remote co-pilots. Especially for the departure and arrival remote co-pilots, it is envisioned that they would support the single pilot as needed in flight planning, navigation, and communication in nominal flight conditions. In off-nominal situations and in case of pilot incapacitation they may take over command and control of the aircraft.

From the aforementioned literature, it may be derived that in future SPO, ground stations will be involved to at least monitor aircraft system and pilot health. Therefore, in SAFELAND, **the presence of**

such a ground station is assumed also during nominal conditions of SPO. Following the concept proposed by Schmid & Korn (2017), the presence of three different ground stations is assumed, which are the departure, cruise and arrival ground stations. During departures and arrivals, a ground station will assist one single pilot serially, at a time, while in cruise one ground station is responsible for multiple single piloted aircraft (cf. Figure 1).

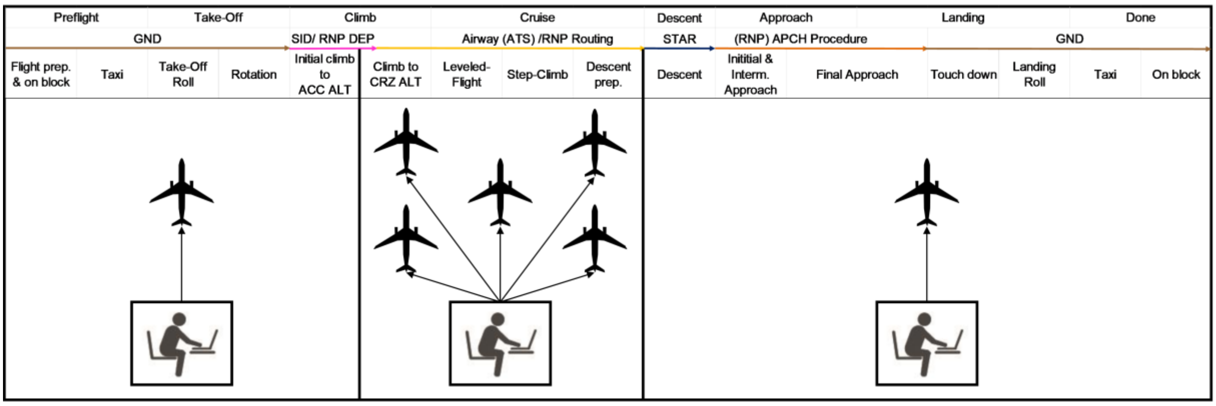


Figure 1. Assumed operational concept for SPO.

As such, a handover between GS will have to take place each time a single piloted aircraft enters the cruise phase after departing an airport and when entering the arrival phase. Unlike Schmid & Korn (2017), SAFELAND does not assume that the remote pilot in the ground station would actively execute pilot tasks during nominal conditions. Only during off-nominal conditions, such as single pilot incapacitation, would the remote pilot need to actively take over control of the aircraft. In principle, a more active role of the GSO operator also during nominal flight conditions could also be foreseen. However, description of task allocation, the potential need for dedicated phraseology, and the specific procedures for team communication (ensuring mutual cross-checking, readback confirmations /monitoring, duplication of calculations) between the single pilot and the GSO, are out of scope for SAFELAND. Arguably airlines might develop their own standard operating procedures detailing the task distribution between the two roles.

In the end, what shape the control take over by the remote pilot will take and what their tasks will be, will naturally depend on the automation capabilities implemented in the aircraft (cf. chapter 4.1).

3.2 Legal and Regulatory characteristics

This chapter examines the main legal issues and the regulatory framework related to SPO in the SAFELAND concept. The analysis takes into consideration the results of SAFELAND deliverable D1.3 *Legal, Regulatory and Economy constraints* (SAFELAND Project, 2021b) and deliverable D3.2 *Preliminary Evaluation Results* (SAFELAND Project, 2021c).

The SAFELAND concept **embeds two distinct but overlapping legal and regulatory fields**: Single Pilot Operations conducting a commercial flight and Remotely Piloted Aircraft Systems (RPAS) operations. It tackles a complex of issues both of manned and unmanned aircraft, of “ordinary” and “abnormal” operations. Its implementation requires a discussion and the tailoring of an appropriate set of legal constraints and regulatory provisions. In this perspective, it is important to point out that, while applying differently to SPO nominal flight conditions and to the off-nominal RPAS flight conditions caused by the pilot’s full incapacitation, legal and regulatory features of the two phases must be considered jointly. In fact, the SAFELAND legal and regulatory needs must be outlined and incorporated in the SPO features at a design level, in order to work properly in case of full incapacitation of the single pilot.

3.2.1 Regulatory Framework

The European regulations issued by European institutions (e.g. European Commission and European Parliament) and developed by EASA regulate the civil aviation in Europe and, particularly, ATM aspects. The regulations related to the SAFELAND concept are provided in D1.3 Table 2 (SAFELAND Projct, 2021b) where the related domain of interest for each regulation and the type of intervention are clearly stated. The main regulatory domains that should be considered in SPO are:

- Rules of the air
- Personnel (Licensing, Crew Requirements, ATCOs competencies)
- Aircraft operations
- Airworthiness
- Accident investigation and occurrence reporting

Regulatory international bodies (e.g. ICAO, EASA) and standardisation bodies (e.g. JARUS) provide regulations that cover partially the abovementioned domains in SPO. The Acceptable Means of Compliance (AMC) and the Guidance Material (GM) provided by EASA (EASA, 2021) has recommendations, guidelines or technical guidance publications that can be proposed to be amended as result from the SAFELAND project. On the other hand, amending 'hard rules' is a very long and cumbersome process that cannot be adopted in the development of SAFELAND concept.

The Commission Implementing Regulation (EU) No 923/2012 of 26th September 2012 (EU, 2012a) laid down the common rules of the air and operational provisions regarding services and procedures in air navigation. Some aspects related to air traffic management are evolving in the SAFELAND concept and some changes could be required in the "Rules of the Air". Therefore, regarding the rules of the air, Rule Making task RMT.0476, which is employed to regularly update the Commission Implementing GM associated to the Commission Implementing Regulation (EU) 923/2012, can be used to update the AMC of the Standardised European Rules of Air (SERA) in relation to SAFELAND results.

Personnel domain can be covered through recommendations focusing on AMC1 ATCO.D.010(a)(2)(vi) to Commission Regulation (EU) 2015/340 of 20th February 2015 (EU, 2015) regarding Area Control Surveillance rating (ACS) training. Different functions will be given to the operator considering the involvement of a GSO (consequently a Remote Pilot) in SPO. Proposals to amend legally binding rules should be better kept to minimum; therefore, AMC and GM to Commission Regulation (EU) 965/2012 of 5th October 2012 (EU, 2012b) can be amended.

Large aircraft refer to CS-25 Large Aeroplane Certification to ensure that the design of the various products and parts are fully compliant with all certification requirements. In order to implement SPO, the Book 2 of Certification Specifications and AMC for Large Aeroplanes CS-25 (EASA, 2020) might need to be amended in relation to SAFELAND results.

In addition, the involvement of the remote pilot (GSO) depends on the level of automation. High automation levels (i.e. Level 4 in JARUS levels) (JARUS, 2019) reduces the involvement of human actors. With such a degree of onboard automation, a remote pilot would be able to command the aircraft (e.g. change heading), however not able to manually control via throttle and stick. Moreover, this higher level of automation would enable the aircraft to land automated based on FMS or autopilot data obtained from a human operator (i.e. GSO in case of pilot incapacitation). Taking the envisaged timeframe for SAFELAND into account (i.e. implementation by 2035 and beyond), the SAFELAND concept proposes to consider higher levels of automation (i.e. Level 4 in JARUS levels) onboard of the aircraft whereby the GSO will be able to command the aircraft, but not manually control it from ground. However, this might require some adaptations to the existing regulations in aviation domain, which are already been investigated by the European Commission (cf. paragraph below).

With regard to the role of automation, it should be noted that a proposal for an EU "Regulation laying down harmonized rules on artificial intelligence (artificial intelligence act) and amending certain union legislative acts" has been recently issued by the European Commission. The proposal contains rules related to the use of AI in several domains, including aviation, on the basis of a risk-based approach (EU, 2021). These initiatives by the European Commission support the project assumption of more sophisticated automation being available in the future SPO.

3.2.2 Main legal issues: responsibility and liability

The main legal issues arising from the SAFELAND concept concerns the link between the allocation of roles and responsibilities in the SPO functions and the related set of legal liabilities arising from fault and/or harmful events in the course of operations. In SAFELAND deliverable D1.3 (SAFELAND, 2021b) section 2.4, we discussed the fundamental features of the legal concepts of responsibility and liability: aim, scope, forms, subjects, etc. Then we presented the features of legal liability (from now on simply "liability") in aviation with particular relation to the functions and actors involved in SAFELAND.

In order to establish a clear liability regime in SAFELAND, and thus avoid legal uncertainty and limit judicial burdening, it is essential to define the allocation of functions both in nominal flight conditions and in off-nominal conditions (i.e. single pilot incapacitaion) as clearly and precisely as possible, while on the other hand maintaining a certain degree of flexibility within the workflow, so that unexpected events can be better dealt with in consideration of the specific context. As it has been noted in deliverable D1.3 (SAFELAND, 2021b) and deliverable D3.2 (SAFELAND, 2021c), the design of the SAFELAND concept – through the evaluation of the three possible implementations - has already identified the key roles and interactions for each actor and each operational step. In D1.4 the further development of the SAFELAND concept addresses the allocation of functions at a greater detail (cf. chapter 4.5.1) and provides a sequence of processes for critical phases of the flight (cf. chapter 4.5.2). This will allow to analyse the concrete implications of the concept in the field of legal liability in D3.4 Final Evaluation Results.

The main actors involved in SAFELAND are the onboard single pilot, the GSO/remote pilot, the ATCO, the automated systems and AOCC operators (cf. chapter 3.3 and 4.3). As far as their liability is concerned, it is crucial to consider the role of the Pilot-in-Command (PIC), which has the ultimate responsibility for the operation of the aircraft (ICAO, 2015b). As far as civil liability is concerned, under the Montreal/Rome Convention system the air carrier (i.e. airline) bears liability for all harmful events concerning their aircraft and their employees. However, the personal liability of the employee (in this case, of the PIC) comes into play with regard to the compensation cap, as well as insurance issues. Furthermore, the organizational role of Air Navigation Service Providers (ANSP) is relevant in terms of administrative liability and compensation recovery.

In the SAFELAND concept it is the GSO who shall assume the role of PIC in case of pilot incapacitation, and therefore act as a remote PIC (RPIC). A "combined" GSO-RPIC role emerges thereby, which shall include both functions and responsibilities of a multi-flight monitoring entity (the GSO) which may – but only in rare cases – turn into a remote pilot of one of the monitored aircraft. This shall require a careful design of the specific features of the ground station, with regard to operations but also to training and licencing (incl. type rate) of the RPIC and cabin crew, and other personnel (e.g. ATCO). The process shall consider and integrate existing and forthcoming regulation concerning RPAS (e.g. ICAO, 2015a; EASA, 2016).

The liability regime of ATCOs is still lacking clear, general provisions at International and European level. Therefore, liability of Air Traffic Service (ATS) is linked to civil law provisions of single national states and encompasses personal liability of ATCOs as well as liability of providers. While the Montreal/Rome system absorbs much of the liability contention on the air carrier, the responsibilities of the ATCO are still relevant as far as the redress cap is concerned. Thus, a clear allocation of ATC tasks in the SAFELAND concept is advisable for liability purposes. As it has been emerging in the discussions on the concept implementations, the need for a PIC and the general civil liability of air carriers strongly discourage the adoption of the SAFELAND implementation option focusing on increasing the responsibilities of the ATCO in case of pilot incapacitation. This would in fact require piloting training and licencing for ATCOs, with subsequent burdensome regulatory requirements. Moreover, the responsibility of the ATCO would conflict with the liability of air carriers, since ATCOs are not employees of the latter.

The SAFELAND concept assumes that the automated system onboard will be able to conduct the flight with a high degree of automation. As already noted in deliverable D1.3 (SAFELAND, 2021b), a high degree of automation should comply with the principle of the Human-in-Control (EASA, 2020a). This balance can only be reached through a clear allocation of roles and responsibilities between the single pilot, the GSO and automation, which is also a focus of this deliverable (cf. chapters 3.3 and 4.3). This will in turn serve to determine the scope of the so-called product liability for failures of the automation systems in case of harmful events, and therefore the regulatory needs concerning certification of these systems. The respective roles of GSO and automation will be crucial in the phase of safe-landing due to the pilot's incapacitation (cf. section 4.2).

A final consideration on the main legal issues with regard to the location and employer of the GSO is provided in this paragraph. In the previous deliverables it was considered that, in order to keep the GSO as an employee of the airline, s/he could be located at AOCC. However, this may not be feasible for smaller airlines. It was suggested that these smaller airlines could be brought together in a "shared" facility (e.g. dedicated building for GSOs), with "shared" GSOs. This would require specific contractual agreements airlines and these GSOs, allowing to maintain a clear link between the GSO/PIC (and their liability) and the civil liability of the air carrier. However, for the purpose of this deliverable, it is assumed that the GSO will be located at AOCC.

3.3 Roles and responsibilities

This chapter describes the specific roles and responsibilities envisaged to be involved in future SPO for nominal flight condition. Hereby the descriptions rely on the operational concept proposed in chapter 3.1 and illustrates the responsibilities for each actor in detail, including those of the "new" roles such as *Departure GSO, Cruise GSO* and *Arrival GSO*. Specifically, the subsections below clarify the foreseen distribution of tasks between the involved actors, as well as addresses considerations regarding the training needs and competence requirements for each role.

The impact of the final SAFELAND concept on team composition is also examined, including, whenever possible, considerations on the appropriate allocation of tasks between human actors, such that there is no overlap of responsibilities. In addition, an initial assessment of the communication needs between team members is provided.

It is important to distinguish between tasks and responsibilities as defined by SESAR (SESAR, 2020). A task is a “set of actions/activities which can be performed alone, or together with other tasks, to achieve a goal”. Responsibility is the “obligation to conduct assigned tasks to a successful conclusion”. It follows that responsibilities lie with the human, but tasks can be performed with different levels of automation. Consequently, in SPO some responsibilities might not change compared to two-crew operations, but tasks might change drastically as will be clarified in sections 3.5 and 4.5.

3.3.1 Onboard Single Pilot (nominal flight conditions)

The text below is adapted from the description from EATMA (V14.0 Draft) for current operations with two pilots in the cockpit. Some of these responsibilities and the associated tasks will remain unchanged in SPO for commercial aviation, others might need to be shared with, or transferred to the ground. The specific distribution of tasks between the GSO and the single pilot (SP) might differ between airlines.

The SP remains ultimately responsible for the safe and orderly operation of the flight in compliance with the ICAO Rules of the Air (ICAO, 2005), other relevant ICAO and NSA/EASA provisions, and 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 SP is responsible and has authority for operational control of the flight delegated to him during the period he is in command. S/he is responsible for preparing, conducting and terminating a flight, and for having a good coordination with the Network Operations Control (NOC).

Responsibilities to assure airborne spacing with regard to another aircraft may be delegated by ATC to the SP under specific circumstances. The pilot will then be responsible for spacing using ASAS-Spacing (e.g. Sequencing and Merging). ATC will still retain responsibility for separation from other aircraft.

The key responsibilities of the onboard single pilot are comparable to the responsibilities in a “2-pilot cockpit” and include the following:

- Execute the flight according to the current flight plan.
- Comply with clearance/instructions given by ATC using voice or data link.
- Request deviations of agreed trajectory where appropriate, if deemed necessary mainly for safety, operational and/or economic reasons.
- Obtain information on landing conditions from the destination airport's information service (D-OTIS) and from the Arrival GSO.
- Assume responsibility to maintain own spacing from other airborne traffic (e.g. sequencing and merging) when temporarily delegated by ATC, with ATC still responsible for separation.
- Prior to take-off: Check NOTAM and METAR.
- Accept/reject ATC proposed alternative routings based on safety and feasibility.

- Obtain a clearance from ATC prior to deviating from the cleared flight plan route/trajectory. Inform GSO about the deviations (Cruise ATCO will be monitoring several a/c and will not be listening to all communications between the single pilots and ATCOs).
- When, for reasons of flight safety deviation from the cleared flight plan route/trajectory must be taken without clearance (e.g. following a TCAS advisory), inform ATC and Cruise GSO (when applicable) of actions taken as expeditiously as possible.
- Take over responsibility for the visual separation assurance on final approach on request of ATC.
- Provide ATC with mandatory information calls e.g. "on frequency, leaving frequency, leaving altitude, reaching altitude" etc.
- Request support from the GSO as needed.

It is thus expected that communication and coordination between the SP and ATC (cf. chapter 3.3.3), as well as between the SP and NOC (cf. chapter 3.3.4) will be mostly as today, with support from automation. The assessment of the level of automation required inside the cockpit that would allow the SP to perform all tasks and responsibilities is out of scope for SAFELAND. However, since some of these functionalities would need to be transferred to the ground station in case of pilot incapacitation, they will be discussed in section 3.4.

3.3.2 Ground Station Operators (GSO)/ (passive) Ground Remote Pilots

In general, in normal operations the Ground Remote Pilots are required to monitor the flight and assist the onboard SP upon their request. Note that whereas in current operations the two pilots are expected to cross-check each other's actions, in SPO only the GSO will be monitoring the actions of the SP. As already mentioned earlier, the definition of the specific procedures for team communication (ensuring mutual cross-checking, readback confirmations/monitoring, duplication of calculations) between the single pilot and the GSO, is out of scope for SAFELAND. Airlines might develop their own standard operating procedures detailing the task distribution between the two roles, and some might also be completely automated, for example:

- Equipment settings such as altimeter pressure settings, cleared altitude, frequency change and navigation routings, are set by the SP or even automated, and cross-checked by the GSO or by automation.
- Adherence by the SP to defined Stabilised Approach gates and to calculated Reference Speeds and Aircraft Flight Manual Limitations.

The airlines shall also define which of the flying tasks can be transferred from the SP to the GSO and under which conditions, and how the interaction with AOCC is envisaged.

The procedures governing the transfer of aircraft between the different GSO (departure -> cruise -> arrival) will be described in chapter 3.5.2.1. Hereby, the communication needs between the pilots and the GSO should be kept to a minimum, as most of the information about the flight should appear automatically in the GS entity. The different GSO teams should also be able to contact each other via telephone or electronic coordination, in case of loss of communication with the aircraft. However, in normal operations, communication between ATCO and SP should have priority over those between the GSO and the SP.

Good monitoring skills are not generally inherent in humans, therefore effective monitoring techniques for the GSO must be trained and rewarded. Monitoring is a tedious activity, generally associated with very low workload levels and low vigilance. However, GSO can significantly improve monitoring skills through SOP. Carefully developed procedures and guidelines can make a significant contribution to enhancing GSO monitoring skills.

3.3.2.1 Departure and Arrival GSO

As described in chapter 3.1, during the departure and arrival flight phases, one GSO will be appointed to one single piloted aircraft. The departure GSO will be responsible to monitor the flight for the entire departure process starting from gate until passing FL100. The exact upper limit will probably be defined in specific regulations to be followed by all airlines. Below FL100 there is usually more traffic, speed restriction (typically 250kts) and terrain issues (where applicable), which might be compounded by weather avoidance and icing issues. Due to vicinity of the airport, there is less time to react and correct deviations from the vertical/lateral profile. Pre-flight briefings might not require the input from the departure GSO and could be done with automation support. Therefore, his/her assistance in this flight phase is ensivaged. In addition, the Flight Dispatcher might be given more responsibilities (e.g. support SPO during aircraft inspection before take-off). The acceptability and operational feasibility of these procedures and tasks will not be investigated in SAFELAND and are thus out of scope. However, the core of the issue is that the departure GSO should be released as soon as it is safe, in order to assist other flights. The GSO will not be able to completely inherit all tasks of the pilot monitoring in a dual piloted aircraft.

The arrival GSO will be responsible to monitor the flight from Top of Descent until the aircraft reaches the gate at the destination airport, to allow both the single pilot and the arrival GSO to build team SA and share information regarding the aircraft and airport conditions. Hereby, the main tasks and responsibilities for both operators, the departure and the arrival GSO, will be to constantly maintain supervisory oversight of the flight and the aircraft.

The main responsibilities for the departure and arrival GSO in nominal conditions are:

- Departure and approach briefings together with SP to ensure shared SA and good monitoring. As an example, company standard configuration point for gear down could be 2nm before the FAF. However, it could be the case, that the SP in the briefing establishes that, due to expected high tailwind, s/he wants to put the gear down 4nm before the FAF. This has to be communicated to the GSO in the briefing, so that GSO understands why the gear is lowered at 4nm instead of 2nm. Conversely, the GSO could help the SP by making this suggestion regarding the gear to the pilot, enhancing safety. The GSO is in a position to greatly contribute to the safety of the flight, since s/he is most likely familiar with approaches in that airport and knows the threats present that day.
- Monitor the departure and arrival phases with regard to e.g. trajectory conformance, aircraft systems and pilot health state.
- Check (and inform the pilot) for potential hazardous weather along the planned flight route in the vicinity of the airport. Even though the pilot will most likely have an onboard weather radar and access to ground-based weather services like today, as already mentioned above, the GSO will have already supported several single pilots in the previous hour and can report on the difficulties experienced due to the weather conditions. The GSO might also have an actual satellite picture, which might provide a better overview than the WX-radar in the aircraft.

- Actively listen to the communication between single pilot and ATC. ATC clearances will normally be monitored by both, and consequent action including readback taken by the single pilot will be monitored by the GSO. The question of whether the single pilot is able to handle all communication tasks (including provide readback to ATCOs) in normal operations, or whether some of it has to be delegated to the GSO is out of scope for SAFELAND. But see section 3.4.3 for some potential support for automation.
- Inform the single pilot if there is anything unusual with the aircraft systems.
- Respond to requests for support by the single pilot.
- Take over responsibility if the pilot becomes unresponsive.

It is out of scope for SAFELAND to define and discuss in normal operations the operating procedures and technical requirements needed for the GSO to be able to communicate with ATC. In other words, the communication needs between ATCOs and GSO within nominal flight conditions will not be covered here.

3.3.2.2 Cruise GSO

During cruise, when workload is normally low, the GSO will be able to monitor the flights of more than one single piloted aircraft. As such, s/he could be responsible for example for five single pilots simultaneously. Hereby, her/his responsibility starts as soon as the aircraft FL100 and ends at Top of Descent. The tasks of the cruise GSO do not essentially differ from the tasks of the departure and arrival GSO. However, since s/he is monitoring multiple aircraft simultaneously, it will not be possible to follow the ATC communications for each aircraft, if the communication is based on voice. Multiple data link communications on the other hand can be monitored by one GSO.

As a result, the main responsibilities of the cruise GSO in nominal flight conditions are:

- Monitor the flight of multiple aircraft simultaneously with regard to e.g. trajectory conformance, aircraft systems and pilot health state
- Check (and inform the pilots) for potential hazardous weather along their planned flight route
- Monitor multiple voice and data link communications by changing frequencies as required.
- Monitor voice communications between ATCOs and the single pilots as needed. This will highly depend on the communication medium that will be used by the time SPO becomes operational.
- Inform the SP of a particular aircraft if there is anything unusual with the aircraft systems.
- Respond to requests for support by a single pilot.
- Take over responsibility if one pilot becomes unresponsive.

3.3.3 ATC

Providing ATC services in future SPO environment would require almost similar standards and recommended practices as well as operational procedures as they are adopted today. Therefore, we do not anticipate any significant changes in terms of the requirements for competency of air traffic controllers. In other words, most of specified requirements (currently in force) relating to professional competency and Class 3 Medical Assessment would most likely be applicable and remain unchanged. Similar assumptions also apply to ATC training and licensing. A decent level of knowledge in subjects, such as air law, air traffic control equipment, operational procedures and human performance, and a completion of an approved training course must be demonstrated and fulfilled (ICAO Annex 1, 2018).

In addition, competency in the use of English Language, which is already applicable and endorsed in the ATCO licence today, may remain in effect in future SPO context. It should, however, be mentioned that as of 3 November 2022, one must demonstrate general knowledge in principles of flight (i.e. knowledge in RPAS) before being issued a controller´s licence. This specific requirement is not currently in force. To summarise, the introduction of SPO is not expected to induce extensive training and licencing updates, as the main foreseen changes in nominal conditions are limited to information display (e.g. HMI identification of SPO aircraft on the radar screen, plus possibly additional information in the flight plan).

The following subsections will address roles, responsibilities and tasks of each relevant ATCO. The description applies to en-route and approach operations. In en-route, it applies to both conventional (i.e. sector-based) and flight centric (i.e. sectorless) operations, where although the team structure and organisation may vary (from 1 executive – 1 planner, to n executive – 1 planner), the fundamental roles and responsibilities of executive and planning controllers remain unchanged. In tower and airport operations, roles and responsibilities of the active controllers are close to the executive controllers' ones (although tasks will differ).

3.3.3.1 ATC Executive Controller

The Executive Controller (EC), in general, is responsible for providing Air Traffic Control (ATC) service within his/her area of responsibility (AoR), e.g. sector, in order to accomplish the objectives of preventing collisions between aircraft and expediting as well as maintaining an orderly flow of air traffic. Besides, the EC principal responsibilities are to comply with the ICAO Rules of the Air (Annex 2) (ICAO, 2005), other relevant ICAO (e.g. Doc. 4444 (ICAO, 2016)) and European/National provisions to separate known flights operating within his/her AoR and to issue instructions to pilots and remote pilots (if per pilot request or part of the SOP, the GSO takes over communication tasks) for conflict resolution and segregated airspace circumnavigation. SAFELAND does not anticipate any change in the roles and responsibilities of ATCOs in future SPO. Thus, most of the tasks executed by the EC in current operations will be managed in the same manner in future SPO in commercial aviation.

The Executive Controller responsible for TMA is called Approach Controller.

The main responsibilities of the EC are to:

- Issue appropriate ATC clearances/instructions (e.g. headings, speeds and levels) and, if necessary, holding instructions.
- Assign specified headings, speeds and levels suitable for the planned approach.
- Inform pilots about the intended approach procedures and determine (if not done by arrival management systems) the approach sequence.
- Issue approach clearance and, if necessary, holding instructions.
- Provide separation and sequencing between controlled flights.
- Identify conflict risks between aircraft.
- Communicate with onboard pilots and/or GSO by means of radiotelephony (RTF) or data link.
- Coordinate with the Planning Controller regarding planned conflict solution strategies based on system derived solution proposals, and their implementations.
- Inform onboard pilots and/or GSO of the intended approach procedures and determine (if not done by arrival management systems) the approach sequence.

- Transfer control of aircraft to an appropriate Executive Controller at previously agreed points and/or when traffic is well clear within his/her AoR.
- Monitor the weather conditions and the functionalities of ATC equipment/system.

In addition, the EC also monitors the trajectory (4D and 3D) of aircraft, according to the clearance they have received. Other responsibilities are focused on the traffic situation, as displayed at the integrated Controller Working Position (CWP), and are very much related to task sharing arrangements within the sector team. The wide use of data link helps to enhance the task sharing between the Executive and the Planning Controller, as both controllers are technically able to communicate with the single pilot and the GSO.

Additional implementations to some existing features in ATC system might be required. For instance, if pilot incapacitation is assigned (by ICAO) with a specific squawk code, the ATC system detects the code and presents the pilot incapacitation message (abbreviation) together with the aircraft label (similar to 7700, 7600, 7500). But this is not a challenge since the feature already exists. The scope of the technical changes will be evaluated during the planned SAFELAND exercise.

3.3.3.2 ATC Planning Controller

Depending on the ANSP local practice, operating methods and traffic environment, the Planning Controller could endorse responsibilities belonging to different roles. However, the Planning Controller (PC) is mainly responsible for planning and coordination of the traffic entering, exiting or flying within his/her AoR. In other words, the PC ensures “no surprises” to the EC and that the traffic enters/exits the sector in a well-organized way. Furthermore, the PC provides tactical flight control assistance to the EC. Similar to the principal responsibilities stated in subsection 3.3.3.1, the PC is also required to comply with the ICAO Rules of the Air (ICAO, 2015b) other relevant ICAO and European/National provisions to efficiently facilitate air traffic control service. It is foreseen that his/her tasks and basic responsibilities will not change in future SPO compared to today’s operations.

The responsibilities of the PC are to:

- Coordinate entry and exit conditions (if different from previously agreed procedures).
- Check flight plans/Reference Business Trajectory (RBT)/Reference Mission Trajectory (RMT) for possible conflicts and complexity issues within the AoR.
- Plan conflict-free flight path through his/her AoR and, in so far as practicable, plan taking into account if the aircraft is also subjected to other network constraints in order to facilitate the execution of the RBT/RMT.
- Coordinate with the Executive Controller about planned conflict solution strategies based on system derived solution proposals.
- Implement solution strategies by communicating trajectory changes to the aircraft through the concerned EC via data link.
- Monitor flights regarding adherence to flight plan/RBT/RMT.
- Coordinate with adjacent sectors/areas for e.g. the delegation of AoR or aircraft.
- Monitor the weather conditions and the functionalities of ATC equipment/system.

Internal coordination between EC/PC, as well as between the EC/PC team and other ATC roles is not expected to change in SPO. EC and PC will continue to exchange information mostly via elbow coordination, whereas they might coordinate with Supervisor via electronic coordination, hotline or elbow coordination. Coordination between sectors is also not expected to change. However, additional HMI features exclusive for SPO operations might be needed.

3.3.3.3 ATC Tower Controller

The Tower Runway 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 (unless transferred to Approach Control/ACC, or to the Tower Ground Controller), by issuing clearances, instructions and permission to aircraft, vehicles and persons as required for the safe and efficient flow of traffic. The Tower Runway Controller is assisted by arrival, departure and surface management systems, where available.

The main responsibilities of the Tower Runway Controller are listed as follows:

- Issue clearances to aircraft entering/leaving/crossing the control zone.
- Provide separation between landing and departing aircraft.
- Identify conflict risks between aircraft.
- Ensure the prescribed runway separation exists and is maintained at all times.
- Communicate with pilots by means of RTF or data link.
- Coordinate with other ATC units or agencies (e.g. airline operator, airport), when necessary.
- Transfer control of aircraft to an appropriate Executive Controller (next/adjacent unit) at previously agreed points and/or when traffic is well clear within his/her AoR.
- Monitor the weather conditions and the functionalities of ATC equipment/system.

Besides the responsibilities elaborated above, the Tower Runway Controller is also required to comply with the ICAO Rules of the Air (Annex 2), other relevant ICAO and European/National provisions to efficiently facilitate ATC services and meet its objectives. It is foreseen that his/her tasks and basic responsibilities will not change in future SPO compared to today's operations.

3.3.4 AOCC

As already mentioned, the GS would be located at the Airline Operations Control Center (AOCC). Note, however, that if the GSOs are commercial pilots flying for the airline, they would be part of the Airline Flight Operations Department, not part of the AOCC organization. Either way, for ease of reading and to allow a more in-depth discussion of the tasks of the ground remote pilot, in this document the GSO is addressed separately in dedicated chapters (3.3.2 and 4.3.1).

The AOCC of an airline represent a coordination hub responsible for monitoring and solving operational problems (Castro & Oliveira, 2011). The facilities and personnel may vary considerable depending on the type and size of the airline, ranging from a single dispatcher on duty to hundreds of personnel (Clarke & Naryadi, 1995). In larger airlines, the AOCC can be composed of teams that work under the control of an operations supervisor. Although each team has a specific goal (for example, the crew operations group is responsible for handling the crew), they all contribute to the more general objective of minimizing the effects of disruption in the airline operational plan (Castro & Oliveira, 2011). The information provided here is based on the standard practice of one legacy carrier in Europe.

AOCC are usually linked to the Aeronautical Radio Inc. (ARINC) and the Societe International Telecommunications Aeronautiques (SITA) networks, to send and receive messages. In some cases, the AOCC has communications systems connected to VHF, HF and SATCOM radio links, air traffic control centers, and other relevant locations, allowing them to effectively gather and disseminate information instantaneously (Clarke & Naryadi, 1995).

Most AOCC-floors are already fully utilized, therefore whether it is possible for the GSO to be on the AOCC floor will depend on the following:

- Size of Total Fleet
- Size of Sub-Fleet (how many a/c of each type)
- How many a/c can be monitored by one GSO
- If it is foreseen that the GSO also supports the pilot during take-off and landing then the number of GSOs increases and subsequently there will be more GSO stations
- How much space does each GS need

Therefore, the ground stations will most probably not be located directly in the AOCC floor, but in close proximity (on a different floor or away from AOCC on the same floor). If this is not possible, it makes no difference if the location of the GSO is in the next building to AOCC or some kilometres away. Communication could then be assured via a messenger service or Voice over IP (VoIP).

As in current operations, in SPO all non-critical flight tasks should be allocated to AOCC. Note that the flight dispatcher and the members of Network Operations Control (NOC) are not monitoring a/c systems.

Within the AOCC organization it is expected that the only relevant roles to be affected by SPO will be the NOC and, in a lesser degree, Flight Dispatcher.

3.3.4.1 Network Operations Control (NOC)

The Network Operations Control (NOC) is active once the aircraft is in flight, for example with Flight Following (Long-haul Flights only) or diversions. Nowadays, if the pilots have a problem or a request once in flight, they contact NOC. In addition, pilots are also expected to continuously check the weather (via Datalink) for airports close to the route, in order to be prepared for any kind of emergency. This could be an engine failure, fire in the aircraft, emergency descent, sick passenger, etc., so that the pilots know in advance where to go in case of an emergency. In SPO the onboard pilot might need to delegate this task to automation and/or to the GSO. Presumably the NOC could also cover this task, such that, in case of pilot incapacitation the information of an alternate airport is immediately shared with the GSO. Of course, if there are two airports in the same distance, and both are fine weather-wise, the pilots will choose the airports with better onward flight connections for the passengers, but this is not their primary goal. The exchange of information and distribution of tasks between the GSO and NOC during nominal SPO conditions needs to be clearly defined, however this is out of scope for SAFELAND.

AOCC works with all available weather information, which could be weather reports for en-route and airports, weather charts or live weather radar information. In addition, they take the actual and forecasted weather information (i.e. METAR and TAF) into account. The weather radar charts and displays portray all pertinent information concerning the intensity, configuration, coverage, type, and movement of precipitation. This information may, at times, supplement the radar information displayed on the weather radar in the cockpit. In SPO, the Pilot-In-Command (PIC) might work together with the GSO and the AOCC to collectively decide on a preferred route, or reroute, around significant weather. At times, the type of aircraft with its particular performance characteristics and limitations may be a critical factor in weather planning and en-route decision-making ("The Operations Control Center", n.d.).

NOC is responsible for supervising and initiating appropriate actions for any case of deviations caused by weather phenomena en-route and at destinations, unserviceable equipment or facilities on aerodromes and en-route, crew availability, incidents/accidents, among others. Note however, that the NOC does not have the authority to divert flights in-flight. This is the responsibility of the PIC. The NOC is expected to forward recommendations and analyses for change of route and/or destination aerodrome or alternate aerodrome as applicable.

NOC shall have the possibility to establish contact with the pilot by any available means of communication during the entire portion of the flight, and if required, NOC shall provide the pilot with any info that is relevant and important for the progress of the flight. This may include information about the weather, important aerodrome information, request to divert the flight (authority rests with PIC) and various recommendations, as applicable.

In current operations, if the pilots know that a diversion is likely (e.g., normal landing with bad weather) they will contact NOC to inform them, and ask about a preferred alternate airport. The final decision, however, lies with the PIC. In case of an emergency situation, there is no time and mental resources (very high workload) to wait for a reply from NOC. In this case the pilot(s) will only send a datalink message to NOC, to inform them about the situation, and where and when they are about to land. NOC will then inform Passenger Service Center (for onward travel), crew control, dispatch and other stakeholders. Dependent on the severity of the situation, the NOC or a superior will also call the "Crisis management team" (see section 4.3.3 for more details). The specific dedicated procedure depends on the different events. In SPO the pilot might inform the AOCC of an emergency via the GSO, but as explained above, the delegation of tasks between the single pilot, the GSO and the NOC might differ between airlines. Nevertheless, it shall be clearly defined in their standard operation procedures.

Regarding the competencies and training of the NOC, they are not expected to change in SPO.

3.3.4.2 Flight Dispatcher

Flight Dispatch is the partner of the PIC on ground for all flight planning matters. The flight dispatcher is responsible for the planning of an individual flight by assessing all boundary conditions (e.g. meteorological conditions, regulations, NOTAMs etc.) that impact the flight execution. The flight dispatcher plans the trajectory of the flight in accordance to all requirements for an orderly and safe flight. Furthermore, the flight dispatcher provides all briefing information to the flight crew (briefing). In SPO, the flight Dispatcher might also share that information with the GSO most probably by inserting the relevant data into system, which will be accessed by the GSO as needed.

The Dispatcher is more involved in the flight preparation, including preparing the Flight Plans and dealing with ATC-slots. S/he does the pre-flight planning, whereas the PIC or the GSO does the inflight re-planning (eventually with the help of NOC). Therefore, the changes to responsibilities would not change, and thus, competencies and training. However, as mentioned above in section 3.3.2.1, the flight dispatcher might be given more tasks in SPO, to support the pilot.

3.4 Technical challenges for SPO

This chapter describes the main technical challenges that will need to be addressed by any concept applicable to future SPO. It focuses on the key technical showstoppers, highlights possible solution strategies and clarifies the envisaged requirements for technical systems on high level in order to enable the implementation of the proposed SAFELAND concept.

3.4.1 Command and Control (C2) datalink

3.4.1.1 Latency and Radio Waves Propagation Method

In general, SPO concepts which include the use of ground station operators (as the concept proposed for SAFELAND does) are expected to be affected by the issue of latency in the datalink connection time. Round-trip latency is the most important parameter when it comes to command and control (C2) functions, as it represents the total time required for a two-way communication to take place. Round-trip is defined as the amount of time it takes for a signal to be sent and, in addition, the amount of time it takes for an acknowledgement of that signal to return.

Several factors affect the latency times between communications, including (TNO, 2015):

- Signal transport
- Datalink electronics
- Encryption
- Compression
- Error Correction
- Synchronization
- Computations

The overall latency of a communication system can be computed as the sum of the different latencies introduced by each of these factors, which change in function of physical parameters, the type of data to be transmitted and operational requirements.

Among those, “signal transport” represents the most interesting factor for SPO and SAFELAND, as the choices upon signal transport methodology not only influence the latency, but also have direct impact on the operational characteristics of the system, by defining communication ranges and structural requirements.

In this chapter a quick overview of RLOS (radio line of sight) and BRLOS (beyond radio line of sight) signal transport methods are given, with the aim of establishing their main potentials and limitations in SPO context.

Radio and data communications are achieved through the use of radio magnetic waves. Three methods can be employed to propagate radio magnetic waves and transport the signal in space: ground-wave propagation, sky-wave propagation and space-wave propagation. Space-wave propagation is commonly used for aviation purposes, as it is the most reliable. Signals transmitted this way have a very defined range, due to earth curvature, which varies depending on the height of the transmitter and the height of the receiver. As a result, these factors define a Radio Line Of Sight (RLOS) horizon.

RLOS distance can be simplistically calculated using the following formula (TNO, 20005):

$$D = \sqrt{(R + h_r)^2 - R^2} + \sqrt{(R + h_t)^2 - R^2}$$

R: radius earth, h_r: height receiver, h_t: height transmitter

While RLOS transport method allows for minimal latency and high reliability, the main obstacle for SPO utilizing a GSO is that the maximum range RLOS is usually very limited when the aircraft operates at low altitude.

As an example, assuming a ground station aerial with a height of 15m, RLOS maximum ranges will vary in this manner depending on aircraft altitude:

- On the ground: RLOS max range of about 15 km.
- Terminal area flying at 1000m of height: RLOS max range extends to approximately 100 km
- En-route, assuming a cruise altitude of 10.000 m: RLOS max range of 300 km and more.

The aforementioned maximum ranges were calculated using the formula described above.

It is therefore evident that while significant range values can be achieved for high altitude operations during cruise, approach and landing operations require the aircraft to be increasingly closer to the GS entity in order to remain in RLOS range. To overcame these limitations, relays are employed to further transport the signal, consequently transforming RLOS signals into Beyond RLOS signals (BRLOS). Possible relays are ground-based fixed repeaters and satellites.

Nowadays GEO SATCOM is normally used as relay for BRLOS communications in UAV operations, thanks to its high range potential (cf. Figure 2), reliability and predictability. Additionally, geostationary satellites are capable of relaying signals at great distances, with the relative position and height of the receiver and transmitter only minimally influencing range and latency levels.

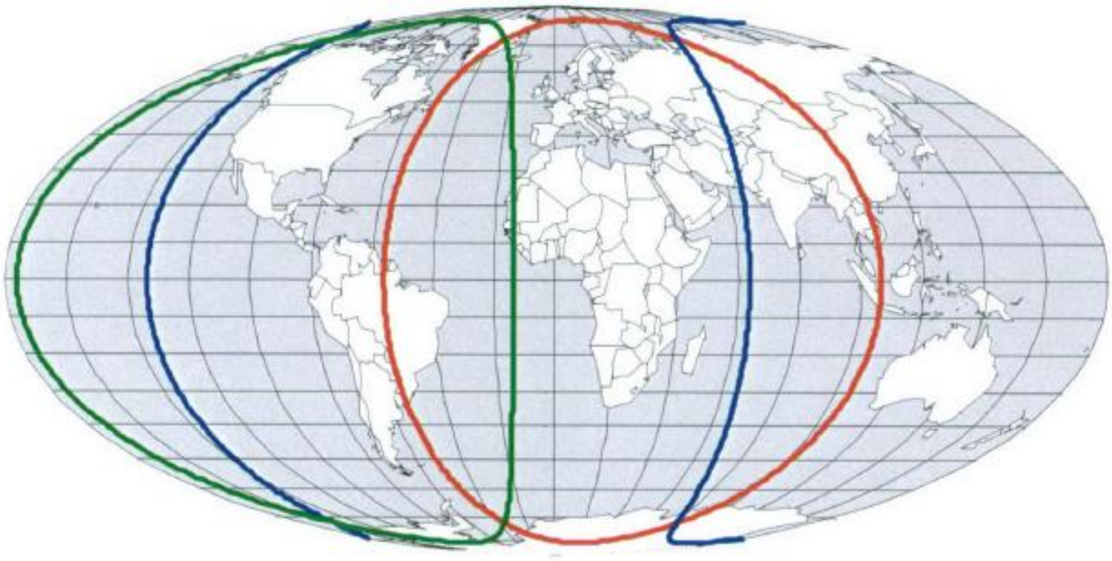


Figure 2. Cover ranges of three geostationary satellites (TNO, 2005). Each circle represents the area in RLOS of a GEO satellite. Generally, more than 3 GEO stationary satellites are needed to cover the earth.

However, these benefits come at a cost, as, due to the distance of their orbit, they add significant latency to the communication system (cf. Figure 3). An overall latency comparation between RLOS and BRLOS (using GEO satellites communication methods) can be seen in the figure. The minimum and maximum numbers reported account for possible different combinations of delays induced by the system components. Note that for GEO, maximum latency levels are difficult to estimate, and may be higher than the ones shown in Figure 3 (e.g. Global Hawks operators have reported maximum delays up to 3000 ms (EUROCONTROL, 2010)).

	GCS-UAV configuration			
	LOS		GEO	
	min	max	min	max
Tranceive	40.0	300.0	80.0	300.0
Transport	0.2	3.3	239.0	281.0
Encryption	0.0	4.0	0.0	4.0
Compression	0.0	375.0	0.0	375.0
Error correction	0.0	1.5	0.0	1.5
Synchronization	8.0	32.0	8.0	32.0
Computations	10.0	30.0	10.0	30.0
Uplink	58.2	370.8	337.0	648.5
Downlink	58.2	745.8	337.0	1023.5
Round trip total	116.4	1116.6	674.0	1672.0

Figure 3. Estimations for minimum and maximum latencies (in ms) for two types datalink: Radio Line-of-Sight (LOS) and geostationary satellite (GEO) (TNO, 2005).

For the calculation in Figure 3 it is assumed that for the lowest estimation of electronic latency (min. values) there are no encryption, compression or error correction required in the data transfer. For the calculation of the higher estimation of the latency the aforementioned factors are considered and additionally the presence of a Ground Data Terminals (GDT), relaying signals received from glass-fiber ground cables, are assumed. Although these numbers appear to be rather precise it is better to regard them as rough estimates. As the table reports, latency values can greatly vary depending on involved factors.

RLOS transmissions are able to provide a minimum latency at around 100 ms, which is approximately six times lower than the minimum latency level that can be granted by GEO SATCOM BRLOS. Due to this property and its reliability, RLOS is mostly used if a continuous transmission of large data is required with a minimal delay. When an UAV is controlled through RLOS connection, latency levels are low enough to allow manual control of the aircraft flight path from the ground (TNO, 2005).

In case of GEO BRLOS instead, high latency levels do not allow the performance of manual flight tasks or operations which may be susceptible to pilot induced oscillation (PIO), meaning the control of the aircraft from the ground can be performed solely through the use of commanding an autopilot. Additionally, high latency levels limit the GSO ability to respond to time critical tasks, such as visual traffic detection and avoidance, requiring the onboard system to satisfactorily respond automatically or specific procedures to be implemented.

While nowadays GEO SATCOM represents the only valid alternative for BRLOS operations, future SPO are foreseen to be implemented using emerging technologies, which may overcome GEO SATCOM latency limitations, while achieving similar range and reliability levels. For the purposes of this analysis, two possible future solutions are taken into consideration: Multi-hop SATCOM technology and 5G network usage.

Multi-hop communications are used to break down the link between the UAV and the satellites. This technology can drastically reduce the latency of SATCOM communications, by allowing the usage of LEO satellites constellation for command and control functions (Zolanvari et. al., 2020). The lowest altitude of these satellites represents their main advantage for latency, in comparison to GEO constellations. However, their closer position to earth means they are not geostationary and their cover range is significantly reduced. Multi-hop solutions, coupled with edge computing technology, allow the overcoming of these limitations, creating communication bridges between LEO satellites, able to relay signals at long distances in short times (Soret et. al., 2020).

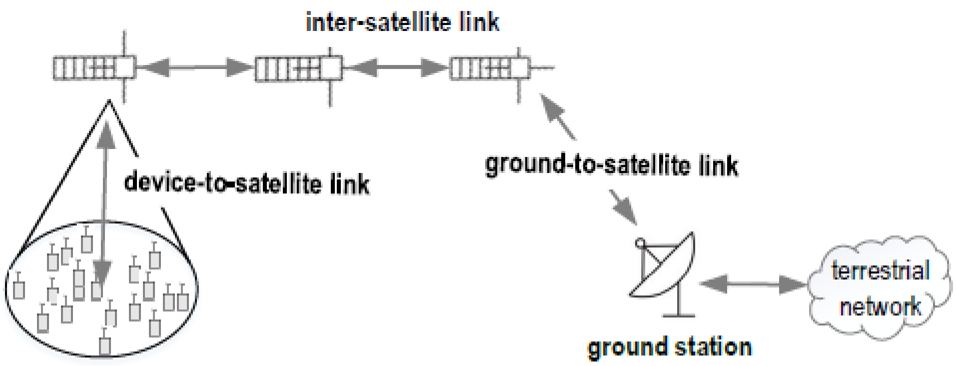


Figure 4. Example of Multi-hop relaying satellite network (Soret et.al., 2020)

On the other hand, 5G in use for cellular communications allows the transfer of large quantities of data with minimal latency at great distance, thanks to the high bandwidth capacity. The main obstacles for its usage in aviation are related to the already high congestion of the network, and the limited range of 5G antennas, requiring a large number of relays. In the future however, once separate channels are allocated for aviation purposes and special handover systems designed, this technology may represent a good alternative for low-latency BLROS C2 links architecture (Zolanvari, 2020).

In conclusion it is foreseen that, in years to come, technology development will let SPO to be conducted utilizing BLROS communications, thereby allowing the GSO operator to be remotely located at long distances from the SP aircraft. While BRLOS latency levels are foreseen to decrease enough to allow some time critical tasks to be performed, the GSO is not expected to be able to operate the aircraft under manual control from the GS, but only intervene through autopilot management.

3.4.1.2 SPO latency requirements and C2 link architecture

On the basis of the analysis made in chapter 3.4.1.1, it can be deduced that the main challenge for SPO using a GSO will be the achievement of appropriate levels of control and monitoring from the GSO, while maintaining flexibility in deciding its physical location.

Founding Members

Ideally, SPO should be designed to safely function in case only BRLOS GEO SATCOM C2 links are available. This would allow the GSO to be located at the AOCC and the tripartite concept requirements to be satisfied as they have been described in chapter 3.1.

As GEO SATCOM is affected by latency levels ranging between 0.6ms to 3s (and possibly more), high automation levels are foreseen to be required onboard the single piloted aircraft, accounting for GSO limitations due to delay. However, given the development of future technologies, as previously described, it is assumed that during the critical phases of flight, the GSO will have at their disposal a BRLOS connection (e.g. multi-hop communication) with lower latency levels, similar in performance to RLOS, which, thanks to system and automation design, can be backed up in case of failure utilizing SATCOM.

Additionally, as pointed out in the previous chapter, the GSO is not foreseen to be able to manually intervene on the flight path of the aircraft, but solely control its automation.

Table 3 summarizes SPO C2 link architecture and requirements:

Table 3. SPO C2 link architecture and requirements in SAFELAND

Flight phase	Take-off – Climb	Cruise	Descent - Landing
Datalink mode	BRLOS Primary: LEOSatcom/ 5G Backup: GEO Satcom	BRLOS GEO Satcom	BRLOS Primary: LEOSatcom/ 5G Backup: GEO Satcom
GSO: Aircraft ratio	1:1 (successively)	1 : n (parallel)	1:1 (successively)
Roundtrip Latency	Primary: close to RLOS Backup: 1-3 sec	1-3 sec.	Primary: close to RLOS Backup: 1-3 sec

The main advantages of such a design will be:

1) Flexibility in positioning of the GS entity
2) Backup possibility with SATCOM in case of primary C2 link failure during critical flight phases
3) High levels of automation reducing SP and GSO workload in particular during abnormal flight conditions and total loss of control link connection
4) Adequate safety maintained in case of total failure of C2 link thanks to high automation levels
5) High economic advantages
6) Automation support may simplify multi-type flying and reduce type ratings requirements

Issues and possible disadvantages include:

1) Technological feasibility of automation levels required

2) Performance and reliability of future C2 link technology

3) Optimize tasks allocation between human and automation

Drawing on these considerations, the SAFELAND concept assumes for the SAFELAND use case an SPO C2 link architecture as shown in Figure 4.

Automation and GS requirements for SAFELAND will be identified in chapter 4.4, taking into consideration the need for the system to function satisfactorily in case of GEO SATCOM is used as backup, during abnormal operations affecting C2 connection.

3.4.2 Automation functionalities

Within the proposed concept it is assumed that the aircraft is equipped with more sophisticated onboard automation compared to today´s CS-25 aircraft, which will support and assist the onboard single pilot in his/her piloting tasks. In this sunbsection potential automation systems wich could pave the way for SPO of CS-25 aircraft in commercial aviation, are discussed.

Future aircraft automation could be expected to be fitted with some degree of artificial intelligence (AI), allowing it to respond to complex scenarios and situations with automated decisions. In this regard it is important to notice that EASA already started to define guidelines for AI in aviation, in the view of upcoming applications (EASA, 2021b).

At the current status AI is configuring itself as based upon the technology of machine learning. This term refers to the automated detection of meaningful patterns in the data, and it is fundamental in the design of all sorts of new automated systems, from web applications (search engines or anti-spam software) to security (face recognition technology) and transportation (prevention algorithm for car accidents). For what concerns aviation, the developments of the following three companies can be used as examples:

ACubed, owned by Airbus, with the project “Wayfinder”, is exploring the potentials of AI technology for the phases of take-off, approach and landing. By carrying out large scale experiments and real-time simulations, the company is creating solutions to enable aircraft to intelligently react to visual clues concerning the airport environment, allowing automated take-off and landing capabilities.

Garmin, on the other side, under the project Autonomi, developed an “Emergency Autoland” tool allowing an aircraft to land in case in of pilot incapacitation. The system, currently operational on single piloted aircraft (in GA), such as the Cirrus Vision jet, is able to automatically decide where to land, communicate the decisions to ATC and passengers and, by calculating a 3D routing comprised of weather avoidance, safely bring the aircraft on the ground. This complex system is based upon an algorithm which, by assigning “merit values” to datasets, is able to take safe decisions on it´s own.

Finally, on the ATC side, machine learning has been extensively used by Thales in the creation of their ATCO station “Top-Sky”. This controller station integrates algorithms enabling traffic patterns prediction as well as tailored display of information depending on the situation, allowing the ATCO to easily manage large flows of traffic, while continuing to take optimal decisions. However, as mentioned earlier, the SAFELAND concept does not foresee significant changes in the roles and responsibility of ATC, and thus it could be assumed that the technical implications of the proposed concept on the Controller Working Posistion is limited.

The advancements in AI are going in the direction of developing what is being defined as a "Virtual Pilot Assistant" (Y. Lim et. Al, 2017), which will act as the fulcrum of the automation, and the main tool to support the SP, as well as to coordinate functions with all other actors of the system (ATCO, GSOs). The concept consists of an onboard system able of interfacing with various subsystems (including the flight control, FMS, sense-and-avoid and communications subsystems), providing intelligent support to the single pilot.

The high-level functionalities of such a concept would be:

1. Decrease pilot workload by assuming control of specific flight tasks, which include:
    a. Computing optimized flight plans through a Next-Generation FMS;
    b. Temporarily assuming control of the aircraft in the event of pilot incapacitation, with the capability to perform CAT II (< 200ft decision height) and CAT III (< 100ft decision height) landing;
    c. Systems monitoring through Integrated Vehicle Health Management (IVHM) and Avionics Based Integrity Augmentation (ABIA) systems to provide cautions/warnings to the pilot if required.
2. Decrease flight deck complexity through psychophysiological monitoring sensors that assess the pilot's cognitive state and trigger changes in adaptive interfaces to prompt appropriate automation modes to the pilot.
3. Increase aircraft surveillance capabilities through advanced avionics systems, including: a surveillance system for autonomous Separation Assurance and Collision Avoidance (SA&CA); a weather surveillance system augmented by ground forecasts; as well as automated strategic/tactical rerouting and deconfliction.
4. Facilitate collaborative work- and information-sharing through a combination of direct LOS and BLOS air-to-ground communication channels, supplemented by ground-to-ground channels between the ground support and ATM.

In conclusion, on the basis of these considerations, future SPO are foreseen to be supported by an automation capable of some of the aforementioned functionalities, assisting all actors involved in the operations.

3.4.3 Communication

It is expected that in SPO, the ATCOs might rely more on CPDLC to transmit non urgent messages to an aircraft as an alternative to voice communications, in order to reduce the impact of communication in the pilot's workload. In current operations, the CPDLC application provides air to ground data communication. It enables a number of data link services (DLS) that provide for the exchange of communication management (e.g. clearance/information/request messages). These messages correspond to voice phraseology employed by ATC procedures. ATCOs are provided with the capability to issue ATC clearances (e.g. level assignments, lateral deviations/vectoring, speed assignments, etc.), radio frequency assignments, and various requests for information. Currently, the CPDLC is being globally implemented. The global communication procedures are detailed in the ICAO Annex 10 (2004). The CPDLC message set is contained in ICAO Doc 4444 (ICAO, 2016).

In addition, through ADS-C the aircraft would be able to automatically send messages to ground ATC systems in case a specific reporting contract has been established. The contract would establish the conditions under which reports are sent and the information included, generally related to:

- Aircraft current situation: i.e., position (Lat/Lon, altitude), ground speed, gross mass, etc.
- Aircraft Flight Management System prediction: i.e., next fixpoints to be overflown, fixpoints expected overflying time and altitude, etc.
- Meteorological information

In case of pilot incapacitation, the aircraft can also broadcast the emergency to ATC and other aircraft through ADS-B.

Despite all these, radiotelephony will remain an important part of SPO for situations when faster reactions are required. Radio messages are expected to be exchanged between the SP and the ground, including ATC-related roles, the Remote Pilot and the NOC, as needed.

In current operations, the Pilot Monitoring handles all routine and emergency communication with ATC, Flight Dispatcher, AOCC's, and other aircraft. Tasks include configuring multiple radios to correct frequencies, and following frequency changes on appropriate radios, as well as monitoring party line communications, i.e., flight path clearances for potentially conflicting traffic (Norman, 2007). The single pilot will no longer be able to perform some or all of these tasks, which will need to be replaced or supported by automation. Workload reduction through enhanced automation could afford the Pilot Flying more time to devote to routine communications tasks. Norman (2007) suggested that Enhanced Data Link capabilities could potentially be used to receive clearances, translate their meaning, and transmit them to appropriate navigation systems onboard, for processing, analysis, and display to the Pilot Flying for approval, with minimum intervention. It could also be used to automate outgoing status related communication (i.e., planned arrival time coordination with AOCC or Flight Dispatcher, arrival at cleared altitudes or positions, missed approach, etc.).

3.4.4 Ground Station entity

One core element of future SPO, and of the SAFELAND concept presented here is the Ground Station (GS) entity enabling the Ground Station Operator (GSO) to monitor and supervise an aircraft remotely. These GSs should be designed in accordance to specific design standards for ground stations of remotely piloted aircraft, such as the *Minimum Aviation Systems Performance Specifications for Remote Pilot Stations Conducting IFR Operations In Controlled Airspace* (EUROCAE, 2019)

The GS could be envisaged to look very similar to the Ground Control Station (GCS) depicted in Figure 5 showing a GCS for a Sky Guardian UAS developed by General Atomics (Unmanned Aircraft News, 2019). The left side of Figure 5 illustrates one GS entity capable of monitoring and (if needed) controlling one RPAS at a time. One display depicts the aircraft system status including information typically shown on a Primary Flight Display (PFD). Via another display, the operator is able to observe the 4D flight trajectory and the Flight Plan stored in the FMS. Furthermore, another display is reserved for additional information concerning the flight or its surrounding (e.g. NOTAM, METAR information).

The display below shows a 3D map of the near vicinity of the aircraft. Note that apart from the square in the middle, the window view in the GCS is simulated. In the square the video stream from a camera installed in front and/ or in the tail of the aircraft is visible in a picture-in-picture like format. The depicted GCS provides the ability to takeover manual control by the operator via the presented side-sticks. However, as mentioned before, manual control, using throttle and stick to control the aircraft's control surfaces, is not foreseen in the SAFELAND concept. It is assumed that the aircraft first enters an automatic mode for 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 (cf. chapter 4.5.2). On the right side of Figure 5 two independent GS entities are depicted in order for the GSOs to interact with each other. The configuration and layout of both GS are identical.

During cruise, no video feed is necessary, since normally there are no time critical actions required by the GSO and thus a latency of 1-3 seconds would be acceptable. Nevertheless, if the GSO wishes to receive video data, the video would be available per request. The departure and arrival GSO could serve one aircraft after another, thus keeping the concept economically feasible. During departure and arrival phases, it is necessary for the GSO to have access to real-time aircraft data and maybe visual information from the video feed, since an emergency situation may require immediate action. One such situation would be the need for a go-around during final approach with an incapacitated pilot.

Figure 5. GCS of Sky Guardian UAS (developed by General Atomics)

Figure 6 shows another GS that was developed at the Institute of Flight Guidance of the German Aerospace Center (DLR). The GS enables a single pilot the ability to control and supervise (also referred to as supervisory control; Ferrell & Sheridan, 1967) multiple highly automated UASs in controlled airspace (Friedrich & Lieb, 2019). Figure 6 presents the GS, which is called U-FLY. Instead of relying on text-based presentation of safety critical information and warnings, the U-FLY utilizes hue changing icons to make the remote pilot aware of safety critical states of system functions at a glance. The icons, presented in the so-called Icon Widget, enable the GSO to quickly gain a comprehensive overview of the status of each aircraft system for the different aircraft, as each column in the Icon Widget represents one aircraft. The U-FLY is therefore especially suited for the high-level supervision of multiple aircraft, as would be required for the Cruise GSO in the SAFELAND Concept.

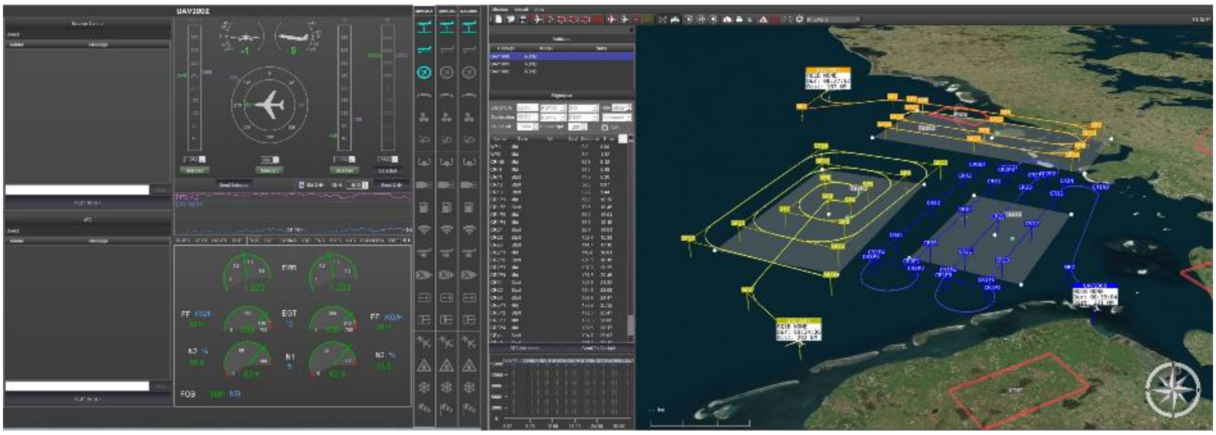


Figure 6. Layout of the U-FLY HMI. Picture from Friedrich & Lieb (2019).

3.5 Operating Method for specific phases

3.5.1 Function allocation diagram (SOCA-CAT)

Figure 7 presents the SOCA-CAT for visualizing the assumed function allocation in the SAFELAND concept for nominal conditions. The figure essentially depicts the same functions, as the SOCA-CATs in the SAFELAND deliverable D1.2 Initial Concept (SAFELAND, 2021a) with some minor changes. The function “system management & health monitoring” was divided into the two functions “system health monitoring” and “aircraft system management”. Further, the function “Aircraft transfer of control” was renamed to “aircraft handover” and the function “pilot health monitoring” was added. The actors, considered in the SOCA-CAT of Figure 7, are the single pilot, departure, cruise and arrival GSOs, the (optional) automation as well as ATC and AOCC.

Whereas the aviate and navigate functions are performed by the SP, the automation and ATC, all actors are involved in the communicate functions. The manage functions are performed by the SP, the respective GSOs and the automation and the control traffic functions are solely allocated to ATC. Further, the diagram visualizes the adapted tripartite concept of single pilot operations proposed by Schmid & Korn (2017). During the departure phases (i.e. flight preparation & on block to climb to CRZ ALT), the departure GSO is the responsible GSO, for the cruise phases (i.e. levelled flight to descent preparation) the cruise GSO is responsible for the aircraft and during the arrival phases (i.e. descent to on block) it is the arrival GSO. The handovers between the departure and cruise as well as cruise and arrival GSOs are performed in the climb to CRZ ALT and during the descent preparation phases (cf. Figure 7).

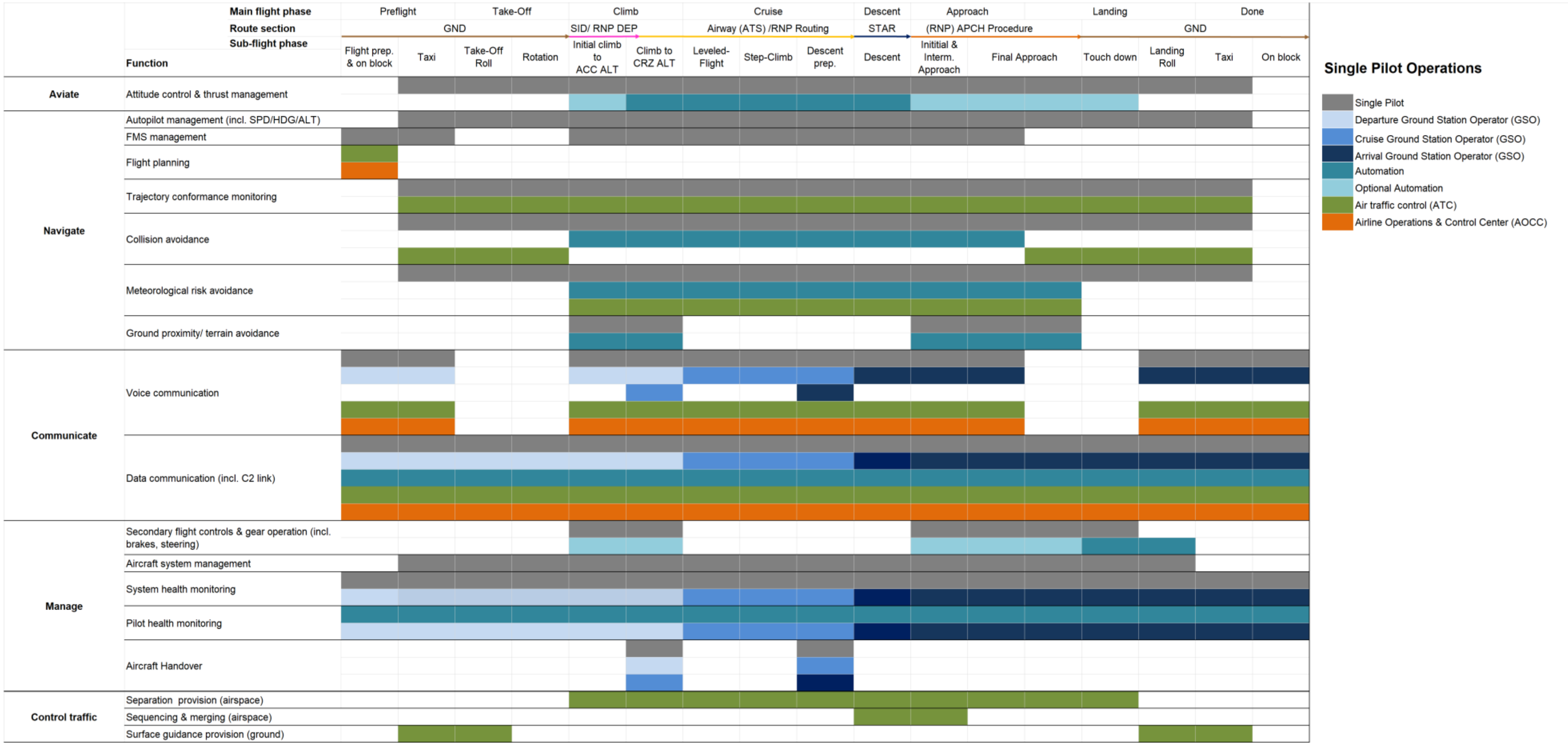


Figure 7. SOCA-CAT for the SAFELAND concept for nominal SPO operations.

3.5.2 Operational Event Sequence Diagram (OESD)

As described in chapter 3.1, the assumed operational concept for nominal conditions in SPO foresees the handover of monitoring and support tasks of the aircraft between three different ground stations, i.e., the departure, cruise and arrival GS. Handover phases were found to be particularly risky within the remotely piloted aircraft domain (Hobbs & Lyall, 2016). Differing configurations of the involved ground stations for example could lead to abrupt flight manoeuvres and eventually loss of control of the aircraft. Therefore, it is important to thoroughly plan and follow procedures for in-flight handover between two ground stations.

As a result, the here present OESDs are based on already existing literature found for handover process in the domain of RPAS operations, as described in chapter 2.3. It is worth noting, that the sequence of processes found in the referenced literature has been mapped to the SAFELAND use-case, in particular as for nominal flight condition in SAFELAND there is still a pilot onboard of the aircraft, which will have to be informed on the handover process.

3.5.2.1 Handover from transferring GSO to receiving GSO

As mentioned in chapter 3.1, even in nominal flight conditions it is assumed that for critical flight phases (i.e., departure and arrival) only one GSO will assist one aircraft. However, in less critical flight phases (i.e., during cruise) one GSO will monitor multiple aircraft simultaneously. In consequence, the monitoring responsibilities will have to be transferred from one GSO to another one when leaving the departure phase, and respectively when entering the approach flight phase. Therefore, a handover process from departure to cruise GSO, and from cruise GSO to arrival GSO will have to be established. Furthermore, the same handover process shall be used in cases there is a need to transfer the monitoring responsibilities from one cruise GSO to another cruise GSO.

Figure 8 illustrates the proposed handover process from one transferring GSO to a receiving GSO. Hereby, it is not foreseen that the proposed process has to be changed when transferring the monitoring responsibilities from departure GSO to cruise GSO or from cruise GSO to arrival GSO.

In total, five actors (i.e., SP, Transferring GSO, Receiving GSO, automation and EC) are involved and the entire handover process consists of 4 phases, namely:

- Handover initiation
- GS configuration and retrieval of aircraft data
- Handover execution
- Handover finalization

Within the **handover initiation** phase, first the SP informs the transferring and receiving GSO of the intention to handover the monitoring responsibilities between these via a verbal request, due to the change of the flight phase. Both GSOs will acknowledge this request and the transferring will start to initiate the handover process by e.g. a dedicated button on the GS entity. Hereby, a display notification (e.g. pop-up window) will appear on the GS entity of the receiving GSO. Moreover, as the handover process has been initiated by the transferring GSO by pressing a dedicated button, the aircraft automation will establish and test the C2 link availability and bandwidth to the receiving GSO. After the test has been successfully performed, the sufficient data and link performances will be reported by the receiving GSO to the transferring GSO, which will be acknowledged.

Hereafter, the **GS configuration and retrieval of aircraft data** phase starts. First, the receiving GSO initiates the retrieval of the aircraft parameters and settings by pushing a button on his/her GS entity. This request will appear in the cockpit of the aircraft, and the SP will confirm the request in order to start the process. The onboard automation will upload the aircraft parameters and setting to the receiving GSO. In consequence, two different GS entities receive the aircraft parameters simultaneously. As soon as the aircraft settings have been received by the receiving GS entity a display notification will inform the receiving GSO as well as the transferring GSO. In addition, the receiving GSO will inform the transferring GSO via voice that the aircraft settings have been received. As a result of this phase, the downlink capabilities from the aircraft to the receiving GSO has been established.

Within the **handover execution** phase, first the receiving GSO informs the transferring GSO that the aircraft settings have been received, which will be acknowledged by the transferring GSO. Hereafter, the transferring GSO enables the uplink capabilities of the receiving GSO. These new uplink capabilities of the receiving GSO will be tested. The SP receives a message that the uplink capabilities of the receiving GSO are tested. Via voice the SP confirms that the uplink test was successfully. After that, the responsibility to monitor the aircraft will be transferred from transferring GSO the receiving GSO. The receiving GSO acknowledges (e.g. by pushing a button) that the aircraft responsibilities have been transferred. In a next step, the aircraft automation disables the C2 link to the transferring GSO. Hereafter, all human actors receive a display message that the handover process is completed (e.g. via voice communication).

Finally, in the **handover finalization** phase, the receiving GSO informs the respective EC that a new GSO is monitoring the aircraft.

Arguably, with a healthy pilot onboard it could be possible to reduce the number of checks and confirmation tests depicted in Figure 8, and to follow the more stringent approach for the handover process only in case of pilot incapacitation. However, safety and risk assessments would be required before the final procedure can be defined. Because these are out of scope for SAFELAND, we have decided for a more conservative approach, which has been adopted from EUROCAE (2019).

Finally, it is worth mentioning, that the column “automation” refers to overall system automation (incl. aircraft automation and automation on ground), and not necessarily only onboard aircraft automation.

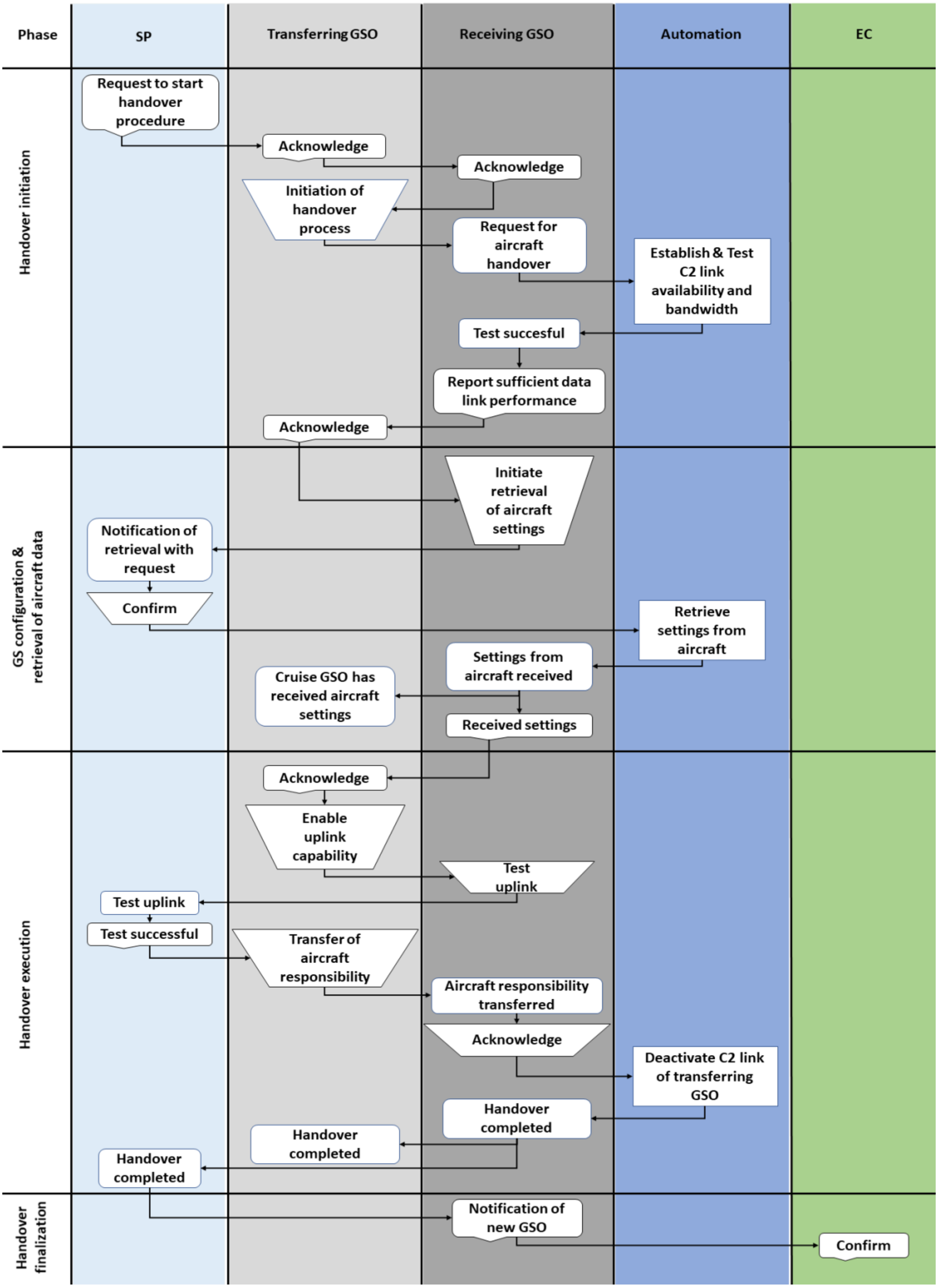


Figure 8. Handover process from a transferring GSO to a receiving GSO

4 SAFELAND use-case: Pilot Incapacitation in Single Pilot Operations

This chapter addresses the specific SAFELAND use-case in which the onboard single pilot is incapacitated (cf. chapter 4.1), and the transition from single piloted aircraft to remotely piloted aircraft has to be managed. In particular, this chapter covers the legal and regulatory implications of the proposed SAFELAND concept (cf. chapter 4.2), examines the impact of incapacitation on the different roles and responsibilities (cf. chapter 4.3) and describes the required technical characteristics (cf. chapter 4.4) within the ATM framework in order to enable the SAFELAND concept to be operational.

4.1 Operational concept

As described in chapter 3.1, during the departure and arrival flight phases one GSO will assist one aircraft, and during cruise one GSO will monitor multiple aircraft simultaneously. In case of pilot incapacitation, a stand-by GSO will take over control of the concerned aircraft (cf. chapter 4.3.1 and 4.5) and become the new PIC. In SAFELAND, it is assumed that first the aircraft enters an automatic mode for a very short period of time, in which it follows the approved flight plan automatically, and then 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 (cf. chapter 4.5.2). Manual control, using throttle and stick to control the aircraft's control surfaces is not foreseen in the concept. As such, 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.

As soon as the pilot incapacitation is detected by an onboard pilot health monitoring system, onboard automation disables the controls within the cockpit in order to prevent any accidental inputs by the incapacitated pilot. Hence, autopilot will be engaged, and the aircraft is flying according to the defined flight plan stored in the FMS. Simultaneously the onboard automation transmits notification of the pilot´s incapacitation to the cruise GSO. This actor will then attempt to confirm the incapacitation, and take over the control of the aircraft, while still being responsible to monitor other aircraft in normal flight condition. It is foreseen that the cruise GSO will immediately initiate the handover procedures to transfer the control of the concerned aircraft to a dedicated stand-by GSO (cf. chapter 4.3.1.2.1) responsible to land the aircraft safely, as soon as possible. Moreover, the remaining other actors (i.e. ATC and AOCC) will be informed about the incapacitation pilot.

If the incapacitation takes place during the departure or approach flight phases, the dedicated departure or arrival GSO, who at a time is only assisting this aircraft, will take over control. S/he will become the new PIC and land the aircraft safely.

A clear differentiation of the envisaged roles and responsibilities in this abnormal flight condition is provided in chapter 4.3.1.2. In addition, a description of the sequence of processes that will have to be undertaken for safely landing the concerned aircraft is provided in chapter 4.5.2.

4.2 Legal and Regulatory Characteristics

This section explores the legal and regulatory characteristics of SAFELAND which specifically concern the off-nominal flight conditions, i.e., the phase of safe-landing of the single-piloted aircraft in case of pilot incapacitation, which call for the consideration of the SPO flight as an "exceptional" RPAS.

4.2.1 Regulatory aspects: SAFELAND and RPAS

In this section, the regulatory framework involved in the SAFELAND concept is provided in case of single pilot incapacitation. SAFELAND works in the context of SPO and foresees the possibility of an abnormal operational phase (i.e., pilot incapacitation) in which the basic features of an RPAS are considered. Hence, it tackles a complex of regulatory issues both of manned and unmanned aircraft, of ordinary and abnormal operations (i.e., contingency/emergency situation). Its implementation shall then require tailoring a set of regulatory provisions which need to be adjusted accordingly.

The aircraft, with the single pilot fully incapacitated, changes its status from "onboard piloted aircraft" to "remotely piloted aircraft". The aircraft shall be certified for "manned" and "unmanned" operations involving airworthiness issues with effects on airspace and air traffic management.

Even the operator (i.e., airline) may be involved in different roles and responsibilities. The GSO and the "personnel" employed should know all the responsibilities and roles. The situation is very similar to what the ICAO RPAS Panel is working on, so it is possible to build on the experience gained with the ICAO work, i.e., "Remotely Piloted Aircraft System (RPAS) Concept of Operations for International IFR Operations" (ICAO, 2017) and ICAO Doc 10019 (ICAO, 2015a). Issues such as handover procedures and airworthiness are already addressed in these documents and will be mapped to the SAFELAND use-case in chapter 4.4.4.

An added issue to consider when the full incapacitation has been confirmed, is the identification of the diversion aerodrome. Depending on the circumstances there are different possibilities. For example, the landing airport in case of incapacitation could be the original destination, the alternative airport stated in the flight plan or a new destination. However, some specific aerodromes could be strategically identified along the planned route and indicated in the flight plan stored in the FMS, as well as available to the GSO and the NOC. Consequently, automation, on the basis of the aircraft position along the route, might display to the GSO the most feasible aerodrome and the GSO, as PIC, can accept or reject the option proposed. In any case, due to unexpected problems or conditions, the GSO may change the planned airport, conducting the aircraft to a different one that is not necessarily the nearest to the current position of the aircraft.

In the European context, regulation for "certified" operation is still lacking to some degree. Only very recently European regulatory documents, in particular Commission Implementing Regulation (EU) 2019/947 of 24th May 2019 (EU, 2019a) on the rules and procedures for the operation of unmanned aircraft and Commission Delegated Regulation (EU) 2019/945 of 12th March 2019 (EU, 2019b) on unmanned aircraft systems and on third-country operators of unmanned aircraft systems, were issued for UAS, even if aimed at operations with "low" or "medium" risk for third parties on the ground or in the airspace. As a fact, only for OPEN and SPECIFIC operation categories, detailed requirements are defined. These documents do not provide many indications for CERTIFIED operations, where the SAFELAND concept will be applied to.

The UAS regulatory updating process is consistent with the EASA Rule Making Task RMT.0230 "Regulatory framework to accommodate unmanned aircraft systems in the European aviation" (EASA, 2016).

For "CERTIFIED" operations, EASA has defined different steps of implementation of Certified operations. In the first phase, EASA will address three types of operations, as follows (EASA, 2019):

- **Operations type #1:** IFR operations of certified UAS cargo flying in airspace classes A-C and taking-off and landing at aerodromes under EASA's scope.
- **Operations type #2**: Operations of UAS in urban environment using scheduled/pre-defined routes in volume of airspaces where U-space services are provided. This includes operations of UAS (e)VTOL type carrying passengers (i.e. air taxis) and small UAS cargo providing delivery services. For operations of type #2, taking-off and landing could be at aerodromes under EASA's scope or in designated landing ports, vertiports or landing sites.
- **Operations type #3:** Piloted VTOL in urban environment. Actually, this is expected to cover the first type of air taxi operations, where the pilot will be on board. In a second phase the aircraft will become remotely piloted (operations type 2).

Operation type #1 is the most similar to the SAFELAND concept (i.e. IFR commercial flight in the European airspace) and, even if Operation type #1 is aimed at cargo drones while SAFELAND is considering commercial aviation transporting passengers, this type of operation is the "starting point" for the SAFELAND concept.

Lastly, the safety risk of an occurrence in the SAFELAND concept can be determined using the European Risk Classification Scheme (ERCS) set out by the Commission Delegated Regulation (EU) 2020/2034 of 6th October 2020 (EU, 2020). The ERCS does not provide the effective result of an event but its safety risk. For each occurrence, the assessment establishes the worst accident result that can be expected due to the event, and how close to that accident result the event was. A safety risk assessment on the proposed concept will be provided later in the project (in task T3.4).

4.2.2 Legal aspects: roles and responsibilities

From a study of the legal and regulatory framework in which SAFELAND is implemented, an agreement can be found on the possible implementation option as a blend of the GSO and automation original options as they were described in deliverable D1.2 (SAFELAND, 2021a). The ATCO option has been described as not feasible (cf. SAFELAND, 2021a), both for the difficult identification of liability, and the need for further training and certification of ATCOs.

The GSO and Automation options, as described in D1.2 (SAFELAND, 2021a), both have advantages and disadvantages, but most of the issues can be addressed by merging the two, with the GSO becoming the Pilot in Command (PIC) responsible (and liable, as part of the airline) for the safe conduct of the flight, and automation assisting the PIC more than today.

In the moment pilot incapacitation is confirmed, we can thus identify some critical aspects, related mostly to the transfer of responsibility and control. After the incapacitation has been detected, the automation would be responsible for disabling the onboard controls and stabilizing the aircraft (cf. chapter 4.5.2). The GSO has meanwhile had his controls enabled, and is verifying the correct execution of these function. He is now the PIC, and able to take control of the aircraft.

As already mentioned above (cf. chapter 3.2.2), a clearer allocation of the roles of the actors involved (i.e., ATCO, GSO, automation) is required and will be provided in chapter 4.3. When following the paradigm of the GSO becoming the PIC in case of onboard single pilot incapacitation, the role of the ATCO should not foreseeably entail serious modifications in order to avoid liability concerns. In this emergency situation, the ATCO should focus mainly on pathway clearance, separation provision and weather conditions. The crucial distribution of functions concerns the relations between the GSO (which becomes the remote PIC) and the automation systems. The main critical functions involved are the generation of a new flight plan to an alternate airport and autopilot management, collision avoidance as well as secondary flight controls.

In parallel with the role allocation, a safety analysis involving the main potentially harmful events (with special reference to the GSO-automation workflow) in the execution of the safe landing is desirable for the purposes of liability analysis. Moreover, while it is assumed that the automated system can effectively maintain the conduction of the flight, the consideration of possible system failures in these instances is likewise advisable from a legal perspective. However, these implications are out of scope for the SAFELAND project, as the project assumes nominal flight conditions apart from onboard single pilot incapacitation (cf. chapter 2.1.1).

4.3 Roles and Responsibilities

The following sections address the impact of pilot incapacitation on the roles and responsibilities of the actors first identified in chapter 3.3.

4.3.1 Ground Station Operators / (active) Ground Remote Pilots

Once pilot incapacitation is confirmed, the responsibility and authority for the operational control of the flight are transferred to the responsible Ground Station Operator, who becomes a Remote Pilot (i.e., Pilot in Command). The new PIC is responsible for conducting the flight and landing the aircraft safely, ensuring a good coordination with the other relevant actors such as Executive Controller, Planning Controller and Tower Controller, as well as the Network Operations Control (NOC).

It is expected that all responsibilities described in section 3.3.1 for the onboard single pilot will be transferred to the GSO in case of incapacitation. In some cases, however, the tasks associated with these responsibilities might need to become automated, as the GSO may not be able to manually perform them from the ground (cf. chapter 4.4 and 4.5).

Once incapacitation is confirmed and the takeover procedure to the GSO are completed (cf. section chapter 4.5 for more details on the procedure), the GSO will be responsible for controlling the aircraft including the communication with all relevant ground actors. This includes coordination with other GSO, with the ATC and AOCC.

4.3.1.1 Departure/Arrival Ground Remote Pilot

As described in chapter 4.1, during departure and arrival flight phases one GSO is monitoring one aircraft, also in nominal flight condition (i.e., onboard single pilot is available). In case of pilot incapacitation, the tasks and responsibilities for controlling the aircraft will be transferred to the departure and arrival GSO, respectively, who will become the new PIC. Hereby, the operator will change from a passive monitoring role to actively controlling the aircraft by being able to command the aircraft (e.g., heading changes). Furthermore, the responsibilities detailed in chapter 3.3.1 for the onboard single pilot will be transferred to the departure and arrival GSO, respectively, depending on the current flight phase (i.e., departure or arrival flight phase).

However, as the aircraft is in abnormal flight condition due to the pilot incapacitation, the GSO – who has become the new PIC - is expected to safely land the aircraft, as soon as possible. Hereby, the following main responsibilities are given to the new PIC:

- Take over control of the concerned aircraft including flight authority by becoming the new PIC;
- Stabilize the aircraft by uploading commands to the autopilot and FMS (if needed);
- Inform ATC about the confirmed pilot incapacitation via voice or data link;
- Request radar vectoring for emergency landing from ATC;
- Comply with clearance/instructions given by ATC using voice or data link;
- Accept/reject ATC proposed radar vectoring based on safety and feasibility;
- Command aircraft autopilot to comply with radar vectors;
- Provide ATC with mandatory information calls e.g. "on frequency”.

The envisaged sequence of processes for the take over and emergency landing phase is described in detail in chapter 4.5.2.1 and 4.5.2.2.

4.3.1.2 Cruise Ground Remote Pilot

As described in chapter 4.1, during cruise one GSO is responsible for monitoring several aircraft simultaneously. In case of pilot incapacitation, the responsibility for controlling the aircraft will be transferred to ground. In the first instance, the cruise GSO will become the new PIC. However, as this actor is already monitoring several aircraft simultaneously, the proposed SAFELAND concept envisages the handover of the concerned aircraft to a stand-by GSO (cf. chapter 4.1 and 4.3.1.2.1 for more details). In addition to the “normal” responsibilities applied to the other aircraft stated in chapter 3.3.2.2, in case of pilot incapacitation the cruise GSO is also responsible for:

- Take over control of the concerned aircraft including flight authority by becoming the new PIC;
- Stabilize the aircraft by uploading commands to the FMS and autopilot (if needed);
- Inform ATC about the confirmed pilot incapacitation via voice or data link;
- Comply with clearance/instructions given by ATC using voice or data link;
- Initiate the handover procedures to a stand-by GSO;
- Hand over the concerned aircraft to a stand-by GSO;
- Provide ATC with mandatory information calls e.g., "intended handover to stand-by GSO”.

The envisaged sequence of processes for the handover from cruise GSO to the stand-by GSO is not expected to differ from the sequence of processes described in chapter 3.5.2.1.

4.3.1.2.1 Stand-by GSO

In order to avoid multiple handovers of “healthy” aircraft from the cruise GSO to other GSO, the SAFELAND concept introduces a dedicated stand-by GSO who will take over the control of the concerned aircraft, and land it safely (cf. chapter 4.5.2.1 for more details on the process).

Since the aircraft is in abnormal flight condition due to the pilot incapacitation, the stand-by GSO – who becomes the new PIC - is expected to land the aircraft, as soon as possible. Hereby, the following main responsibilities are given to the new PIC:

- Take over control of the concerned aircraft including flight authority from the cruise GSO by becoming the new PIC;
- Request clearance for emergency landing from ATC;
- Comply with clearance/instructions given by ATC using voice or data link;
- Accept/reject ATC proposed radar vectoring based on safety and feasibility;
- Command aircraft by uploading new routing to FMS or, alternatively provide input to the autopilot system for radar vectors (heading);
- Provide ATC with mandatory information calls e.g. "on frequency”.

The envisaged sequence of processes for the takeover and emergency landing phase is described in detail in chapter 4.5.2.1.

4.3.2 ATC

SAFELAND considers pilot incapacitation as a MAYDAY call. The project, therefore, adopts the sets of rules or principles (considered as guidelines/checklists) that are already in place in today’s practices when dealing with any unusual or emergency situation. Incapacitation is handled as an emergency, and procedures as defined in the ICAO Doc 4444 (ICAO, 2016) chapter 15 may apply. Although detailed emergency procedures are local, differing from country to country (e.g., some countries involve military support in case of emergency while others do not), the ICAO Doc 4444 emergency general procedures (§15.1.1.2) are applicable, with the ATC responsible to:

- ascertain situation,
- decide upon assistance,
- enlist the aid of relevant support,
- provide relevant information,
- obtain relevant information and
- notify the appropriate authorities.

The general rule being that an aircraft known or believed to be in a state of emergency, including being subjected to unlawful interference, shall always be given priority over other aircraft.

Currently, there are some simple principles to be adhered to by ATCOs such as RISC, TAS, ATIS, and ASSIST (EUROCONTROL, 2003). However, the ASSIST principle appears to be successfully adopted by a number of European ANSPs. ASSIST is an acronym for:

- **A**cknowledge the call; get the squawk.
- **S**eparate the aircraft from other traffic. Give it room to manoeuvre.
- **S**ilence - on the frequency. Provide separate frequency where possible - this prevents unnecessary clutter for the pilots.
- **I**nform those who need to know and those who can help; inform others as appropriate.
- **S**upport the pilots in any way possible - Start to think of alternative routings, etc.
- **T**ime - Give the pilots time to collect their thoughts, don’t harass them for information. Time produces good decisions.

The above principle is a guideline/checklist on actions ATCOs (i.e., the EC, PC and Tower Runway Controller) should perform. The guidelines are explicit, concise and, thus, practical. It is worth emphasizing that although workload may increase quite rapidly, ATCOs shall handle the emergency and assist the concerned aircraft efficiently in order to ensure the safe continuation of flight operations and services in general. Thus, a guideline/checklist illustrating tasks to be done and, as far as practicable, steps to be taken by actors involved (i.e., the EC, PC, Tower Runway Controller and supervisor) would be beneficial to ensure proper handling of the situation which usually requires immediate actions from ATCOs. Below are a guideline/checklist derived from best practices (Skybrary, 2020a).

When pilot incapacitation has occurred and been positively identified (e.g., by automated message, the GSO report), ATCOs should take some (or all) of the following actions, as appropriate:

- Determine the GSO's intentions; most likely s/he would select to land at the nearest suitable aerodrome;
- Determine whether the GSO is in full control of the airplane;
- Give the concerned aircraft priority and provide room for manoeuvring (e.g. immediate descent, most appropriate route to the aerodrome chosen, etc.) by clearing the way of other aircraft;
- Inform the supervisor as soon as practicable as s/he is usually expected to notify other authorities and may assist in the coordination activities with other units concerned/the landing aerodrome/adjacent ATC units etc.;
- Inform other appropriate authorities/agencies, e.g. airport firefighting services, airline operations and its ground staff;
- Coordinate emergency response services at the landing aerodrome;
- Determine the GSO's intentions after landing; it is possible that the aircraft would remain on the runway;
- Stop any runway operations at a reasonable time before the expected landing; if there is only one runway at the aerodrome, cancelling the start-ups should be considered.

Note that although not described in detail here, an additional actor, the supervisor, will also be involved in informing and coordinating with appropriate authorities.

In addition to the variety of actions listed above, there are specific obligation that need to be executed by each ATCO which are described in the following subsections.

The impact on training is limited to learning the procedures to handle pilot incapacitation, including coordination with GSO, which should be part of the normal refresher training of ATCOs. No change in terms of licencing is expected.

In general, it is expected that the roles and responsibilities from the perspective of the ATCOs will not change much compared to normal SPO, as described in section 3.3.3. The specific procedures for emergency situations will also be similar to those in place today. The main difference will be the new communication means between ATCO and GSO. As will be described in 4.4.4, ATC will most likely be informed by the remote pilot once incapacitation has been confirmed. The remote pilot will also inform ATC about the situation and about the intentions. However, it is also possible that the ATCO might have already started to suspect they have a case of communication loss, if the pilot has not responded to ATC calls.

To account for the characteristics of the systems and the communication link, the ATC focus' should be on allowing the aircraft to follow the determined FMS 4D route, reducing as much as possible the requirement for radar vectors and changes in the vertical or lateral routing, thereby avoiding potential increase in workload levels due to inflight re-planning.

4.3.2.1 ATC Executive Controller

In the event of pilot incapacitation, ATC service and the basic tasks provided/performed by the Executive Controller (EC) are not deemed different from his/her tasks in current emergency situations apart from the fact that communication will be with a remote pilot instead of an onboard pilot. This means that the responsibilities for ATC EC do not change compared to other emergency situations in which an emergency landing is regarded as necessary.

The main responsibilities of the Executive Controller are to:

- Provide separation and sequencing between the affected aircraft and other controlled flights.
- Issue appropriate ATC clearances/instructions (e.g. direct routing, STAR/ approach clearances, headings, speeds and levels) and, if necessary, holding instructions to other flights operating within his/her AoR and the affected aircraft.
- Provide separation and sequencing between the affected aircraft and other controlled flights.
- Identify conflict risks between the affected aircraft and other controlled flights.
- Communicate with GSO (remote pilot) by means of RTF or data link.
- Coordinate with the Planning Controller regarding planned solution strategies.
- Coordinate with relevant actors e.g. AOCC, airport operator and firefighting unit. Even if the GSO is probably in close contact with AOCC, the GSO might be too busy to coordinate with AOCC the emergency assistance to be provided to the aircraft on arrival. In this case, one of the controllers or even the supervisor might establish this contact and share information with the AOCC. This particular aspect will be further discussed during the exercises planned in SAFELAND.
- Inform GSO (remote pilot) of necessary information e.g., re-routing, intended approach procedures and weather conditions.
- Transfer control of other controlled flights to another Executive Controller, if deemed necessary.
- Monitor flights regarding adherence to the issued clearances.
- Monitor the weather conditions and the functionalities of ATC equipment/system.

4.3.2.2 ATC Planning Controller

As for the roles and responsibilities of the Planning Controller (PC) when handling a single pilot incapacitation, SAFELAND does not anticipate any significant change from the descriptions in 3.3.3.2 (normal SPO). Nonetheless, 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 single-pilot incapacitated aircraft and, to the best of his/her ability, facilitate the EC in resolving the pilot incapacitation situation efficiently. It should be emphasized that the necessary and relevant information shall be collected and made available to the EC as soon as possible. Furthermore, the PC, at his/her ability, will perform any other tasks that are assigned to/requested by the EC and the supervisor.

In regard to means of communication between the EC and PC, we do not expect any changes from today’s method. The direct and verbal communications (i.e. face-to-face) would still substantially be utilised since the two (CWP) positions are traditionally located next to each other, meaning the EC and PC usually sit side-by-side.

The followings are responsibilities that should be performed by PC:

- Coordinate with the Executive Controller about optimal re-routing and solution strategies.
- Coordinate entry and exit conditions (if different from previously agreed procedures) for other controlled flights.
- Check flight plans/RBT/RMT for other possible conflicts and complexity issues.
- Plan conflict-free flight path for other controlled flights, in so far as practicable, plan taking into account if the flights are subjected to other network constraints in order to facilitate the execution of the RBT/RMT.
- Implement solution strategies by communicating trajectory changes to the aircraft through the concerned EC via data link.
- Monitor flights regarding adherence to flight plan/RBT/RMT.
- Coordinate with adjacent sectors/areas for e.g. the delegation of AoR or aircraft.
- Monitor the weather conditions and the functionalities of ATC equipment/system.

4.3.2.3 ATC Tower Runway Controller

Similar to the context addressed in previous subsections regarding the EC and PC, we do not expect any changes in roles and responsibilities of the Tower Runway Controller. S/he will, however, 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 Tower Runway Controller's main responsibilities when dealing with pilot incapacitation are listed below:

- Issue appropriate ATC clearances/instructions (e.g. landing clearance) to the concerned aircraft and, if necessary, holding instructions to other flights operating within his/her AoR.
- Provide separation between the concerned aircraft and other landing/departing aircraft and ensure the separation exists and is maintained at all times.
- Identify conflict risks between all controlled flights.
- Communicate with the GSO by means of RTF or data link and inform him/her of necessary information e.g. intended plans after landing and weather conditions.
- Coordinate with relevant ATC units (e.g. en-route, approach) regarding planned solution strategies.
- Coordinate with other units concerned, e.g. AOCC, airport/airline operator and firefighting unit, regarding the assistance to the concerned aircraft.
- Stop any runway operations at a reasonable time before the expected landing; if there is only one runway at the chosen aerodrome, cancelling the start-ups should be considered.
- Transfer control of other flights to another controller, if deemed necessary.
- Monitor the weather conditions and the functionalities of ATC equipment/system.

It is foreseen that once the landing airport has been selected, the Tower Runway Controller of that chosen airport will be included at early stage and, therefore, be actively involved in providing airport/airfield information (e.g., point for short-routing, runway conditions, after-landing procedures/plans) to all relevant actors. Moreover, we expect that the tower supervisor will be in the loop at early stage as well since s/he may also assist in coordination and information providing tasks, as well as notify his/her superiors and/or other authorities.

4.3.3 AOCC

4.3.3.1 Emergency Crisis Center

In current operations, in case of severe incidents, accidents, environmental hazards (e.g., volcano eruptions, etc.) a so called "Crisis Management Team" consisting of different experts, including flight operations managers, is called. There is a dedicated room in the operations center Emergency Crisis Center, which is fitted with telephones, screens and internet. This type of organization to handle an emergency would probably remain the same to handle pilot incapacitation in SPO.

Nowadays, in case of an incapacitated flight crew member, the remaining pilot will land the aircraft at the best suited airport, which is probably not the home base. To support the remaining pilot, the cabin crew and the passengers, the airline will send the "High Emotional Impact" team to the site of landing. This team will also deal with the ground staff after landing and debrief the healthy pilot. With the SAFELAND concept, the GSO will land the aircraft safely. Since s/he is located close to the operations center (probably even directly in the center) s/he is also directly available for a debriefing. On the one hand this is an advantage, but on the other hand we have to bear in mind that there isn't a healthy pilot in the aircraft anymore. Most probably the cabin crew members will be the ones dealing with the passengers and ground staff after landing. However, it is out of scope for SAFELAND to address the impact of pilot incapacitation on the tasks and responsibilities of the cabin crew.

The task of the Crisis Center is not to support pilots with the landing (whether in current operations with two pilots, with a single pilot or with a remote pilot). It usually takes at least 30 minutes until the Crisis Center is fully operational, as the staff have to receive all information and build situation awareness. Until then, the aircraft is already on the ground in most cases. Thus, they will take care of the crew, the passengers, deal with authorities, decide how to fly the aircraft back to the home base, deal with media inquiries, etc. But they do not actively intervene into the flight. Therefore, regarding the composition of the crisis center, we do not expect any difference between a landing by a single pilot nowadays or the landing by the GSO in the future.

With the current understanding of the final concept of SAFELAND, we do not see the need for AOCC to drastically change in this regard.

4.3.3.2 Network Operations Control (NOC)

In case of pilot incapacitation, the NOC should also 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. PAX service center). Pilots are used to work (semi-) independently and the GSO will also be expected to do so. Once the GSO takes over a flight with an incapacitated pilot, it is very important to ensure that the GSO is not flooded with (partly unnecessary) information from various stakeholders. The GSO should be allowed to concentrate exclusively on the task of safely landing the aircraft.

The NOC is expected to forward recommendations and analyses for change of route and/or destination aerodrome or alternate aerodrome as applicable. The following factors shall be considered to select the aerodrome for intended landing:

- Amount of fuel required;
- Meteorological conditions;
- Performance requirements;
- Aircraft configuration, mass and system status;
- Availability, location and condition of the diversion aerodrome including operational and passenger handling aspects;
- Minimum altitudes en-route to and terrain at the diversion aerodrome;
- Available runways, approach procedures and runway in use including landing aids, approach lights, lighting and runway surface conditions.

However, since most of this information is also available to the GSO, it should be possible for the remote pilot to start planning the landing at the new designated airport without waiting for the NOC to provide the required information. Communications between the NOC and the GSO at this stage (airport selection and decision) might be limited to a confirmation of the designated airport (not an actual discussion, with exchange of information, which would delay the emergency landing).

4.3.3.3 Flight Dispatcher

For the proposed SAFELAND concept, there are no relevant changes expected for the tasks of the Flight Dispatcher in case of pilot incapacitation. The information provided in section 3.3.4.2 is thus also applicable in case of pilot incapacitation.

4.4 Technical Characteristics

The information provided here and in particular in chapters 4.4.2 and 4.4.2, is based upon what is written in chapter 3.4 complemented by discussions between experts within SAFELAND. They detail the requirements we foreseen will be needed for the SAFELAND concept to work. They should be part of the innovative aspects of SAFELAND, and some will be corroborated by the evaluation activities in the project, namely: simulation, expert workshop feedback and safety assessment.

4.4.1 Command and Control (C2) datalink

The C2 datalink for SAFELAND is expected to provide the GSOs with enough flexibility and capability to intervene and monitor the aircraft flight path through all the phases of the operation. The system will be designed to guarantee that signal delay/latency and stability will remain in an acceptable range for safe operations. These acceptable limits have been addressed in chapter 3.4.1. Additionally, the C2 datalink will provide the GSOs with the possibility to interact with ATC, using the aircraft as a relay.

The C2 datalink is therefore foreseen to be structured and follow the requirements as detailed in Table 3, employing BRLOS through SATCOM during en-route phase and BRLOS with close to RLOS performance during critical phases of the flight (take-off, climb, descent and landing), with possibility of GEO SATCOM usage as a backup. For SAFELAND however nominal conditions are assumed, implying GEO SATCOM will not be used during take-off, climb, descent and landing phases. The main reasons for this choice are the benefits offered by this kind of architecture as stated in chapter 3.4.1.2.

4.4.2 Level of automation

For the SAFELAND concept, the SPO aircraft is foreseen to be operated with a more advanced automation than the one currently fitted onboard of a CS-25 commercial aircraft. This increased level of automation will allow for the aircraft to complete the flight highly automated, once GSO programming is performed following the landing airport selection phase, if no changes or additional contingencies or malfunctions require a modification to its programmed 3D route. Should the latter be required, the GSO will be able to intervene on the aircraft flight path through direct inputs to the onboard autopilot, FMC reprogramming. However, SAFELAND assumes nominal flight conditions apart from onboard pilot incapacitation (cf. chapter 2.1.1).

The advanced automation capabilities will reduce the need for the GSO to actively monitor the aircraft parameters for the basic aviate functions (i.e. speed, heading, vertical speed, altitude, attitude and thrust levels monitoring), as well as accounting for loss of datalink connection and guaranteeing flight safety in the event of situations or malfunctions requiring time-critical actions or manoeuvres to be performed. Additionally, automation specifics are foreseen to allow the SAFELAND concept to function satisfactorily during critical flight phases with high levels of latency, should SATCOM be used as backup for C2 datalink. However, as previously stated, nominal flight conditions apart from onboard pilot incapacitation are assumed (cf. chapter 2.1.1).

For the aforementioned reasons, in SAFELAND, a very reliable automation of (at least) LOAT Scale C4 and D5 or JARUS scale level 4 characteristics is foreseen.

Supported function

Level of automation	A INFORMATION ACQUISITION		B INFORMATION ANALYSIS		C DECISION AND ACTION SELECTION		D ACTION IMPLEMENTATION	
Done by humans	A0	Manually	B0	Manually	C0	Manually	D0	Manually
Done by humans	A1	Supported by artefact	B1	Supported by artefact	C1	Supported by artefact	D1	Supported by artefact
Supported by automation	A2	With user filtering and highlighting of relevant info	B2	On user request	C2	With user choice and acceptance among proposals	D2	With user activation & control on actions
Supported by automation	A3	With user control of filtering and highlighting criteria	B3	On user request with alerting mechanism	C3	With user acceptance of one proposal	D3	With user activation and control on action sequence
Supported by automation	A4	With user awareness of filtering and highlighting criteria	B4	With user setting of alerting parameters			D4	With user activation, monitoring and interruption of action sequence
Supported by automation	A5	With filtering and highlighting criteria not visible to the user	B5	With alerting parameters not visible to the user				
Done by automation					C4	With user Informed	D5	With user monitoring, modification or Interruption capabilities
Done by automation					C5*	With user informed on request	D6	With user monitoring and interruption capabilities
Done by automation					C6*	With user not informed	D7	With limited user monitoring and interruption capabilities
Done by automation						* Always connected to Action Implementation D5-D8	D8	With no user monitoring nor interruption capabilities

Figure 9. Levels of Automation Taxonomy (LOAT) from SESAR

The rationale for these automation levels can be summarized as follows:

- Reduce the requirement of monitoring and intervention of the GSO thereby reducing his workload
- Reducing latency issues requirements
- Increase predictability of the aircraft helping ATC coordination
- Account for possibility of loss of connection

The subsections following below (cf. 4.4.2.1, 4.4.2.2 and), illustrate a detailed list of required automation capabilities and functions.

4.4.2.1 Aviate Functions

A robust flight control algorithm will allow the airplane to remain in a safe flight envelope and provide the passengers with the required level of comfort. Therefore, the onboard aircraft automation should be capable of, and authorized to:

- Prevent the occurrence of Loss of Control In-flight (LOC-I) incidents/accidents by automatically avoid/recover upset flight events, as defined by EASA (EASA, 2015), and caused by asymmetric flight conditions and a number of aircraft-specific flight controls malfunctions.
- Control aircraft flight path and secondary flight controls to follow the determined 4D route to the landing airport.
- Carry out the landing by means of ILS, GPS-based required navigation performance (RNP) operations and visual sensors, respecting aircraft and automation performance limitations.
- Perform go-around manoeuvre until after landing gear touchdown (if needed).
- Promptly execute GSO direct control inputs, automatically re-updating the 4D route following GSO intervention.

4.4.2.2 Management Functions

A software based upon machine learning capabilities and predetermined algorithms will allow the automation to carry out manoeuvres to maintain flight path safety, support the GSO in the decision-making process, and account for the possibility of datalink failure and/or loss of connection. The onboard automation system will have access to update weather, NOTAMS, METAR/TAF information, as well as a detailed airport and terrain database for the area to be overflown. Therefore, the onboard aircraft automation should be capable of, and authorized to:

- In case of C2 datalink failure when pilot incapacitation happens: choose the landing airport on the basis of available data evaluation, automatically advise ATC of the emergency status and routing and initiate the descent and landing, following a self-calculated 4D route comprising terrain and weather avoidance.
- In case of C2 datalink failure following the diversion airport routing calculation: advise ATC, through automated voice messages or datalink, of loss connection with GSO and provide updates on status/route. Continue to follow determined 4D routing avoiding as necessary weather.
- Support the GSO in the decision-making process following pilot incapacitation and in case of Go-around, malfunctions or other contingencies (ex: weather), by providing the GSO with calculated solutions alternatives, when available.
- When SP incapacitated, respond autonomously to situations requiring immediate action to be performed to maintain appropriate levels of flight safety. Such situations may include: pilot

incapacitation in short final, windshear event, engine failure in final approach or other events as determined by safety considerations.

- Provide “Fail Operational” response to failures which affect air data systems and sensor units, such as an airspeed unreliable events, using failure discrimination algorithms and machine learning capabilities.
- Provide “Fail Operational” response to a number of selected system malfunctions through autonomous management.
- Provide “Fail Operational” response to failures not completely manageable autonomously, but requiring direct GSO inputs to be addressed.

4.4.2.3 Communication Functions

The onboard automation will be able to communicate and transmit the relevant data to all the parties involved in the management of the emergency. Therefore, the onboard aircraft automation shoud be capable of, and authorized to:

- Transmit aircraft health and detailed flight path parameters and updates to the GSO station.
- Transmit required info (including routing details) to ATCO through datalink and transponder, as well as have automated datalink/voice communication capabilities in case of contingencies (ex: automatic notification of Go-around inititation to ATC) or loss of connection with GSO.
- Communicate aircraft flight path and status, as required by the airline, to AOCC.

4.4.3 Ground Station entity

The GS will provide the GSO with all required information and capabilities to effectively monitor and intervene on the aircraft flight path. The GS will be adaptive and the type of information displayed may vary depending on whether the GSO is following many or one aircraft at a time. Furthermore, the GS shall allow the GSO to achieve and maintain the highest possible levels of situation awareness in relation to the emergency aircraft, also thanks to the support of advance tools and technological implementations. Two already existing GS entities have been described in chapter 3.4.4, and can been seen as possible options for the SAFELAND use-case.

Nevertheless, the following subsections below shall detail some of the required features, functionalities and capabilities of the GS entity in order to enable the proposed SAFELAND concept to become operational. It is worth mentioning, that these functionalities are based on the expertise and know-how within in the SAFELAND project.

4.4.3.1 Ground Station Features

4.4.3.1.1 Data Presentation to GSO

Within the GS entity, several instruments should provide the GSO with required data concerning the emergency aircraft:

Primary Flight Display (PFD): The GSO should have at his/her disposal a PFD (primary flight display) with continuously updated data from the aircraft sensors, to effectively monitor aircraft flight path status.

Navigation Display (ND): The GSO should have at his/her disposal a ND (navigation display) as installed in the aircraft, with continuously update data regarding the aircraft 4D route, and integrating ACARS display and Weather Radar display (directly controllable by the GSO).

Flight Management System (FMS) Display: The GSO should interact with aircraft Flight Management Computer (FMC) through an interactive FMC display unit.

Multi System Synoptic Display: The GSO should be able to monitor and intervene on aircraft system through an interactive display unit.

Automation Communication Unit: The GSO should receive communications and inputs, as well as non-normal checklist actions, from the onboard automation, on a display unit. Automation will advise of flight path modifications, manoeuvres activation, secondary flight controls movements and further contingencies as required.

Synthetic Vision Supplement (SVS): The GSO ND and PFD should be supplemented with Synthetic Vision Technology to enhance his/her situation awareness and management capabilities. SVS will be supported also by additional inputs, such as terrain information, weather updates, NOTAMs and "highway in the sky" 3D route display.

Video Feed: Upon request an on-demand video feed can be activated by the GSO to assess particular situations. Cameras should be positioned in critical internal and external areas of the aircraft, including a microphone for audio recording.

CPDLC: The GSO should be able to communicate with the ATCO through CPDLC, as required, as well as voice.

4.4.3.1.2 Intervention Capabilities of the GSO

Within the GS entity, the GSO should be able to intervene on the aircraft flight path and its system by utilizing different GS control channels:

MCP: The GSO should directly operate the autopilot through the Multi Control Panel (MCP) installed in the GS, allowing for direct inputs to the automation (if required). This will equal the intervention capabilities over automation of pilots of current CS-25 aircraft.

Alternate Secondary Flight Controls Operation: The GSO should be able to control through an alternate channel the secondary flight controls (e.g. speedbrakes, flaps, brakes, landing gear, etc.) of the aircraft, should it be required due to a malfunction and/or contingency.

Quick Action Buttons: Specific buttons should be installed on the GS to allow the GSO to rapidly instruct the aircraft to perform certain manoeuvres or routines. As an example, the prompting of the Go-around or the Emergency Descent (due to loss of pressurization) manoeuvres in cases in which automation cannot or is not programmed to initiate those manoeuvres autonomously could be envisaged.

Aircraft System Controls: The GSO should operate, when necessary, aircraft systems (e.g. inner tank balancing) through the specific controls as installed. The GS will control these systems through alternate channels, providing backup in case of automation failures.

FMS: The GSO should operate the aircraft FMC through the GS FMC display unit. The unit will be designed to allow the GSO to operate the FMC in a fast and efficient manner.

CPDLC and Voice Communication Relay: The GSO should interact with the ATCO as required, using either CPDLC or voice communications. The aircraft can be used as a relay for ATC communications and additional channels maybe available on backup.

4.4.4 Automation & Human Integration

In case of pilot incapacitation in SPO, the GSO will be the PIC, being responsible for the flight safety and integrity. As such, he needs to have the ability to be effective in exercised his allocated responsibility (decide and act in order to keep the flight safe regarding airplane, passengers and ground).

Because the GSO is allocated on the ground, several sensory data and cues will not be available to him or the information they contain will be delayed and intermediated – filtered and/or degraded - by intermediary systems. This will also impact his ability to translate decisions to action in time to achieve his goals. In that regard, the aim of the onboard (and ground station) automation, should be to complement and extend – augment – the capabilities of the GSO, allowing him to surpass the natural handicap due to his situation.

Taking the aforementioned into account, several factors should be considered. Among others, the availability of information at the ground station and the susceptibility to delays and failures in relaying this information. In addition, the time scales involved in the different stages of information collection, processing, decision and action for the different flight phases and situations (see section 3.4.1). For instance, if real time reactions are demanded, it should be assessed if the pilot at the GS is in fact able to be effective in taking them. This is a concrete example where automation should complement the GS capabilities to act.

Adding to the differences arising from the location of the pilot (onboard compared to on the ground) as mentioned above, the cognitive differences and abilities of humans and automation should be accounted for and exploited for best human-machine teaming. Quoting from *the INCOSE Systems Engineering Handbook on Human Systems Integration (V4)* (INCOSE, 2020):

"*HSI analyses allocate human-centered functions within the system and identify potential human (or system gaps). For example, humans excel at solving induction problems, and machines excel at deduction (Fitts, 1954). The requirement for inductive or deductive decision making is inherent in the structure of the system design*".

In addition, taken from the human-centered aircraft automation guidelines described as by Charles E. Billings (Billings, 1991),

"*Though humans are far from perfect sensors, decision-makers and controllers, they possess three invaluable attributes. They are excellent detectors of signals in the midst of noise, they can reason effectively in the face of uncertainty, and they are capable of abstraction and conceptual organization. Humans thus provide to the aviation system a degree of flexibility that cannot now, and may never, be attained by computational systems. They can cope with failures not envisioned by aircraft and aviation system designers. They are intelligent: they possess the ability to learn from experience and thus the* *ability to respond quickly and successfully to new situations. Computers cannot do this except in narrowly defined, well understood domains and situations (refs. 29 and 92)"*

One of the challenges is, of course, to keep the human able to use his innate abilities from a full system view.

Simple framework to address this is to explore which functions and capabilities to be automated (and in what level) in order to enable the role of the GSO.

- What resources become unavailable (in content or time) to the GSO
- For a specific type of action what are the time constraints to act
- What level of decision he must keep in order to comply with legal restrictions and ensure safety and productivity

These important points will be addressed during the SAFELAND exercise, currently being planned, and described in deliverable D3.1.

A key element in evaluating this concept is thus human performance. In that regard, the Human Performance Envelope (HPE) concept was developed by the project Future Sky Safety (Silvagni, 2015) to address the impact on human performance when subjected to mixed demands (e.g., workload, stress, fatigue, situation awareness). It provides a framework to explore and test concepts of automation allocation when coupled with a scenario tool centered in the work that the GSO must accomplish (cf. Figure 10). In an exploratory context, the HPE can provide a first direction regarding the design of scenarios and contexts to explore and test the GSO performance. At our level of maturity, SAFELAND will not be able to cover this extensively, but the demands on the GSO will be examined to the possible extent throughout the project.

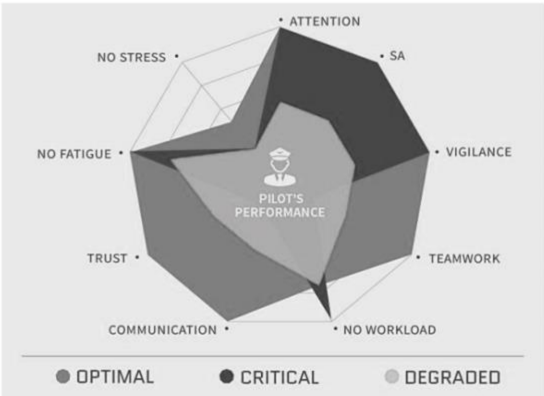


Figure 10. Human Performance Envelope concept

4.5 Operating method for specific phases

This chapter describes the operating method for the SAFELAND use-case. Specifically, it provides a clear allocation of function for different flight phases and illustrates the required sequences of processes in order to command the aircraft to safely land from the ground in case of pilot incapacitation.

4.5.1 Function allocation diagram (SOCA-CAT)

Figure 11 and Figure 13 illustrate the SOCA-CAT function allocation diagrams of the SAFELAND concept for the event of a single pilot incapacitation during cruise, departure and arrival. For the sake of clarity, the diagrams do not illustrate all the functions that would need to be executed, as presented in Figure 7 for the nominal case, but only the most important functions related to contingency management in case of single pilot incapacitation. These functions are (1) to manage the autopilot and the FMS from the ground, (2) decide on a suitable alternate airport, (3) coordinate with the other actors and (4) notifying them about the incapacitation, (5) handing over control of the aircraft to the ground station, (6) vectoring the aicraft to the next suitable airport and finally (7) clear the airspace around the aircraft. Following the timeline from left to right, the first active function is the “emergency notification & squawk” function, which is being performed by the respective GSO and the automation. During the whole process from the detection of the incapacitation to the safe landing, a great deal of coordination between all involved actors is indispensible, which is reflected in the “coordination between actors” function. The aircraft handover functions are solely performed by the GSOs and the automation, while all functions related to traffic control are allocated to ATC. Finally, the decision on the alternate airport is taken by the GSO with assistance of the automation and the autopilot and the FMS are managed by the respective GSO alone. The only differences between incapacitation in cruise and incapacitation during departure or arrival, are that during the latter, there is no aircraft handover between different GSOs and that the GSO does not need to decide on an alternate airport. Apart from these functions, the process is essentially the same. Section 4.5.2 depicts the processes and the foreseen interactions between the actors in more detail using OESDs.

Irrespective of the flight phase the incapacitation occurs in, the first action needed to be taken, is to notify all relevant stakeholders. As such, the automation will notify the GSO about the incapacitation, after which the emergency squawk is sent. If the incapacitation occurs during cruise, the Cruise GSO will immediately coordinate with ATC and the stand-by GSO and enable ground control of the aircraft (and thus become pilot in command), while ATC clears the airspace around the aircraft. After the Cruise GSO has enabled ground control, s/he notifies ATC and the stand-by GSO that s/he is pilot in command. Once the stand-by GSO has gained sufficient situation awareness of the aircraft and feels confortable to take over control, the Cruise GSO initiates the handover process of the aircraft to the stand-by GSO. Once the handover is completed and the stand-by GSO is the pilot in command of the aircraft, s/he needs to decide on an alternate airport. Automation will assist in this decision by providing a list of suitable alternate airports in the near vicinity of the aircraft, while considering infrastructural, meteorological and airline operational conditions. After the decision has been taken, the GSO needs to coordinate with ATC again and receive directions to the airport and ultimately the runway. The GSO will then merely be responsible to manage the autopilot and the FMS, while automation will fly the aircraft and maintain stable flight until touch-down.

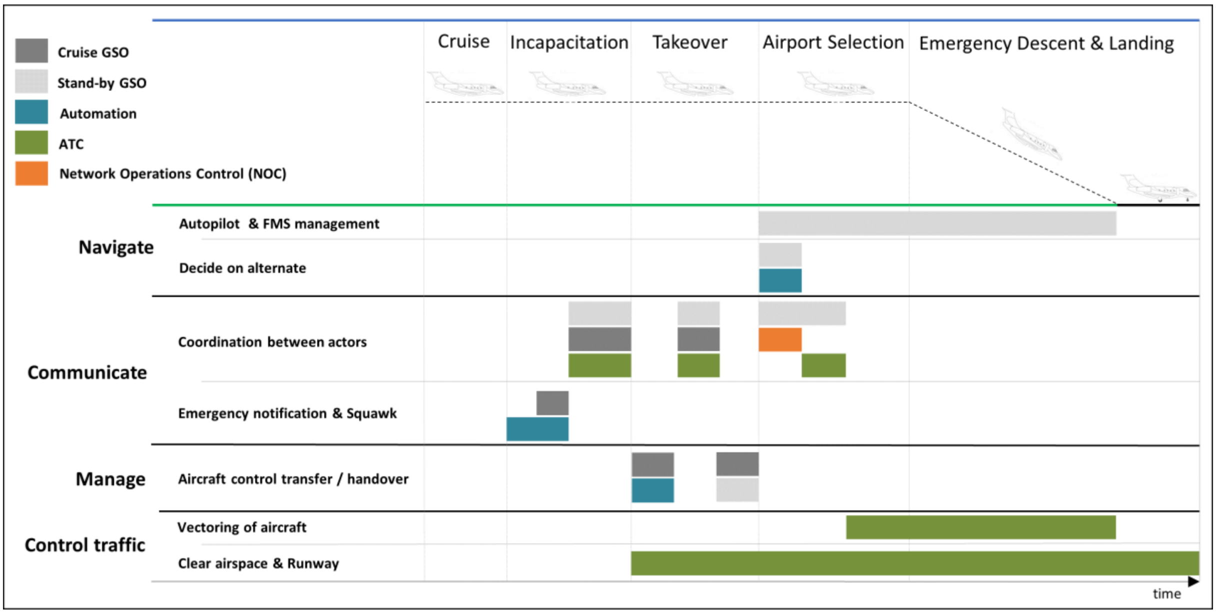


Figure 11. SOCA-CAT for the SAFELAND concept in case a pilot incapacitation occurs in cruise.

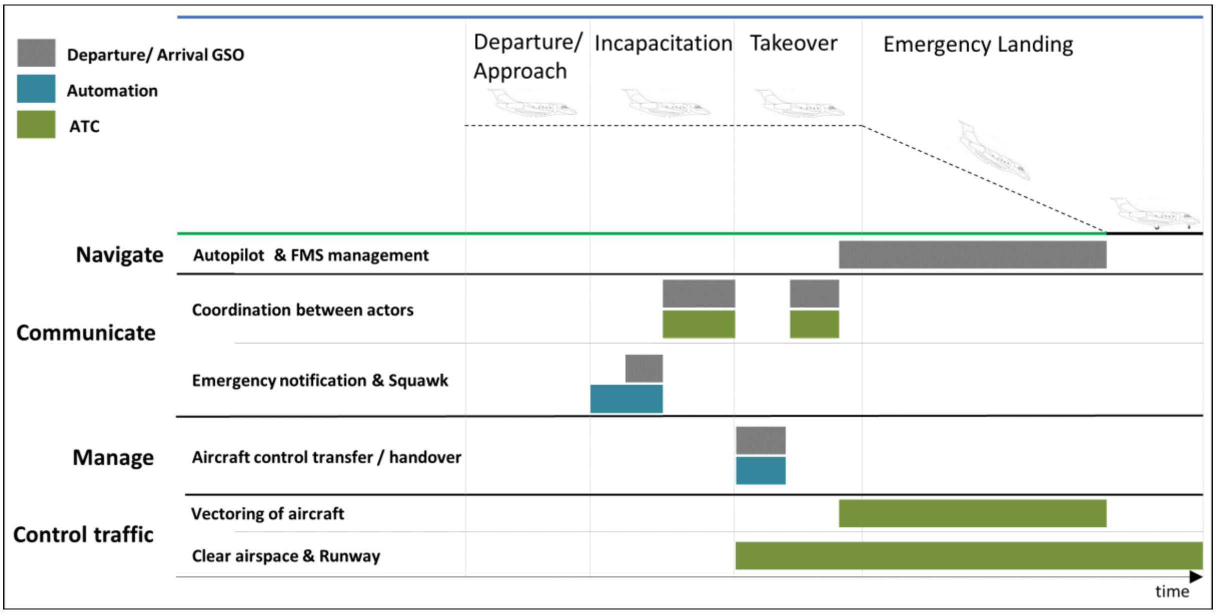


Figure 12. SOCA-CAT for the SAFELAND concept in case a pilot incapacitation occurs during approach.

4.5.2 Operational Event Sequence Diagram (OESD)

In the following sub-chapters (cf. chapters 4.5.2.1 and 4.5.2.2) the take over of aircraft control from the incapacitated SP to the GSO will be described in detail. Hereby, the take over process differs depending on the aircraft flight phase. In case the pilot incapacitation occurs during cruise a new stand-by GSO (cf. chapter 4.3.1.2.1) will, in consequence, take over the responsibility to land the aircraft safely (cf. chapter 4.5.2.1). In case the pilot incapacitation occurs during the departure or approach phases, the departure and arrival GSO, respectively, will change from his/her assisting role and take over the control of the aircraft, in order to land the aircraft safely (cf. chapter 4.5.2.2).

The OESDs presented here are based on already existing literature found for handover process in the domain of RPAS operations, as described in chapter 2.3. However, as the responsibilities for controlling the aircraft will be transferred from the air to the ground, the sequence of processes found in the referenced literature has been mapped to the SAFELAND use-case.

4.5.2.1 Takeover of control by the stand-by GSO in case of pilot incapacitation during cruise

Figure 13 depicts the foreseen sequence of processes in case the pilot incapacitation occurs during the cruise phase of the flight. In total, six actors (i.e. stand-by GSO, cruise GSO, automation, EC, PC and NOC) are involved in this process and the entire process is divided into three phases:

- Take over control from SP to GSO
- Airport Selection
- Emergency Landing

During the **take over control** phase from onboard the SP by the GSO, the onboard automation first detects the pilot incapacitation and disables the onboard controls in order to avoid any unintentional input from the cockpit. In addition, the autopilot is engaged and the aircraft will follow it´s intended flight plan (FPL). As a next step, the responsible cruise GSO will be visually notified on his/ her GS entity of the pilot incapacitation via e.g. a pop-up window. It is worth noting, that the cruise GSO is monitoring several aircraft simultaneously. The cruise GSO is obliged to reach out to the SP via voice communication. After having confirmed, that the detected incapacitation is not a false alarm (i.e. by having tried to get a verbal reply from the SP), the cruise GSO will enable a squawk notification (i.e. squawk 7700) on his/her GS entity. Hereby, all the relevant actors (i.e. stand-by GSO, EC, PC) will be informed of the pilot incapacitation. In addition to the squawk notification, the cruise GSO will inform the relevant actors of the incapacitated piloted aircraft via voice. This notification will be acknowledged by the actors, and the ATCOs will start to clear the airspace for the concerned aircraft. Moreover, the stand-by GSO will gain situation awareness by detecting the concerned aircraft on his map display. Within the SAFELAND concept, it is envisaged that the stand-by GSO has access to all relevant aircraft information via his/her GS entity without requiring support from other ground actors (e.g. ATCOs). Simultaneously when the stand-by GSO is gaining situation awareness, the cruise GSO enables the overwrite capabilities of his/her GS entity in order to be able to command the aircraft from ground. This could be foreseen to be done by pushing a specific button. Hereafter, the onboard automation enables these overwriting capabilities, and the cruise GSO is then in control of the aircraft. S/he becomes PIC. As an example, a display icon could illustrate to the cruise GSO that the control of the concerned aircraft is now established. The cruise GSO announce that s/he that the control has been established to the relevant actors. These actors acknowledge the verbal announcement. However, as mentioned above, the cruise GSO is still monitoring other aircraft simultaneously, therefore the proposed SAFELAND concept foresees to involve a stand-by GSO (cf. chapter 4.3.1.2.1), who will control the aircraft until landing.

The process for handing over the control from the cruise GSO to the stand-by GSO is not foreseen to be different from the handover process described in chapter 3.5.2.1. Here, the transferring GSO is the cruise GSO and the receiving GSO is the stand-by GSO.

Entering the **airport selection** phase, it is worth noting that the stand-by GSO is now in full control of the aircraft, and by definition the "new" PIC, whereas the cruise GSO continues his/her duty to monitor the other "healthy" aircraft. First, the stand-by GSO is obliged to decide if it is better to continue to follow the intended FPL or if the aircraft should enter a holding pattern. This decision is influenced by various factors (e.g. surrounding air traffic, weather in the near vicinity, aircraft parameters such as remaining fuel). If the GSO decides for a holding, s/he will request the coordinates of the holding fix from ATC and upload them to the FMS of the aircraft, which ensures a stabile flight path. After that, it is foreseen that the stand-by GSO requests a list of suitable airports in the near vicinity of the aircraft from automation. Hereby, it is assumed that in the future sophisticated onboard automation is able to provide a list of airports based on e.g. the current aircraft position, available runway length and weather conditions at the potential airport. However, this list could alos be already aviable within the GS entity, depending on the level maturity of the GS. Depending on the circumstances there are different possibilities. For example, the landing airport could be (i) the original destination, (ii) the alternative airport stated in the flight plan or (iii) a new destination. However, some specific aerodromes could be strategically identified along the planned route and indicated in the flight plan already stored in the FMS, and be avialable to the stand-by GSO on his/her GS entity. As a result, with the assistance of ATC as well as NOC the stand-by GSO decides for one of the airports to land.

After the decision has been taken where to land (i.e. airport selection) by the stand-by GSO the **Emergency Landing** phase starts. Within this phase, the stand-by GSO will first request clearance to the landing airport. The ATC EC will provide clearance (e.g. "direct to" clearance) and confirm e.g. STAR and approach procedures to the stand-by GSO, who will upload this data to the autopilot of the aircraft. Afterwards, within the SAFELAND concept it is envisaged that the concerned aircraft is able to land based on the uploaded route automatically.

Finally, it is worth mentioning, that the column "automation" refers to overall system automation (incl. aircraft automation and automation on ground), and not necessarily only onboard aircraft automation.

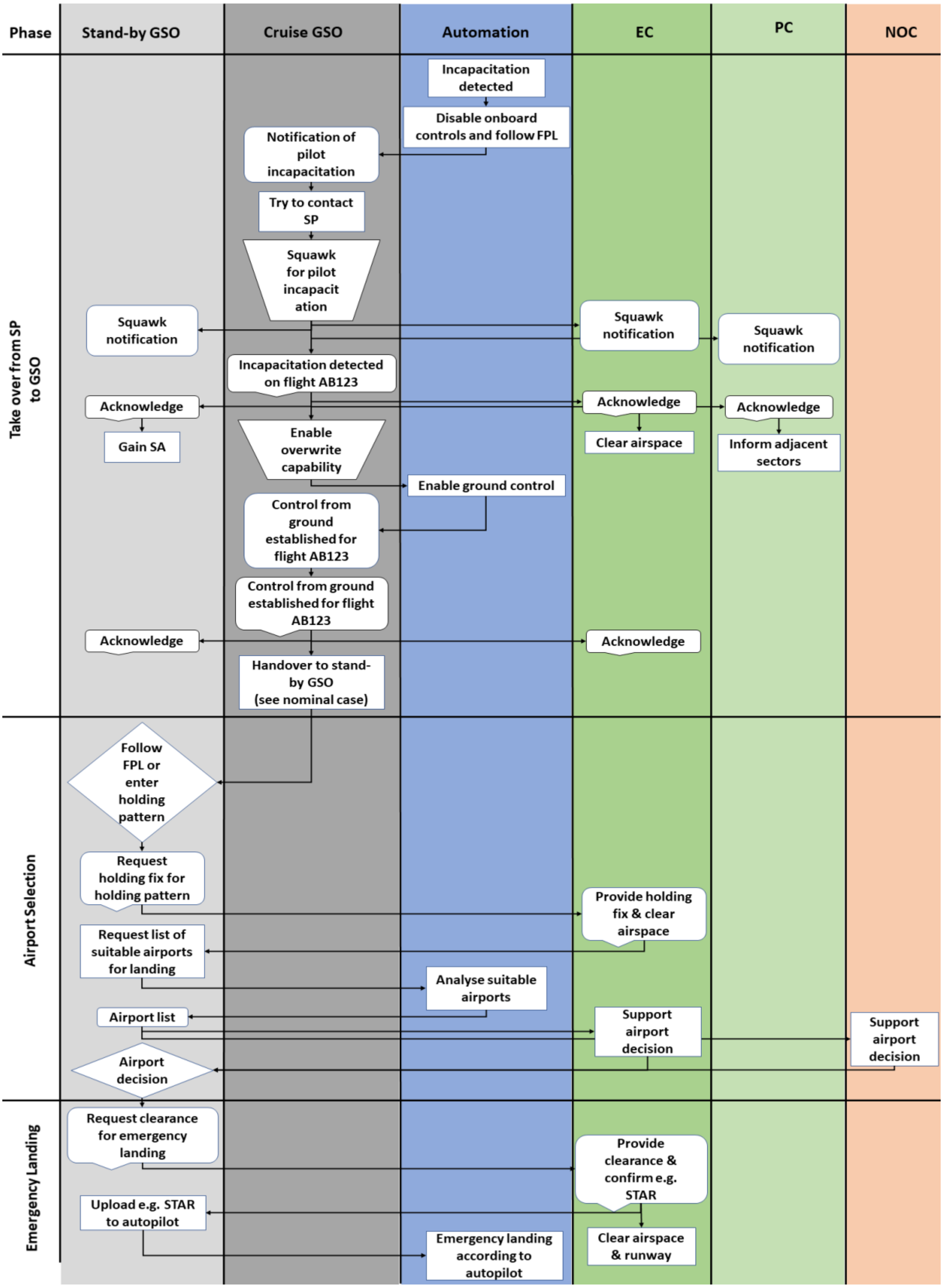


Figure 13. Takeover of control by stand-by GSO in case of pilot incapacitation during cruise.

4.5.2.2 Takeover of control by departure/arrival GSO

Figure 14 illustrates the foreseen sequence of processes in case the single pilot incapacitation occurs during the departure or arrival flight phases. As describe in chapter 3.1, within these flight phases the aircraft is exclusively monitoring by one GSO (i.e. departure or arrival GSO). In consequence, the need to involve a dedicated stand-by GSO for solely controlling the concerned aircraft is unnecessary.

Hereby, Figure 14 describes the take over of control from the SP by the departure, respectively the arrival GSO. Other phases of the emergency landing process are not described as these (i) do not exists (i.e. airport selection phase) or (ii) do not differ from the process described in chapter 4.5.2.1 (i.e. emergency landing).

In total, three actors (i.e. departure/ arrival GSO, automation, ATC) are involved in the process **of taking over from the SP by the departure or arrival GSO**. First, the onboard automation detects the pilot incapacitation and disable the onboard control in order to avoid unintended control inputs from the cockpit. Moreover, the aircraft autopilot is engaged and the aircraft follows it´s FPL. Hereafter, the monitoring GSO will receive a notification of the pilot incapacitation detections on his/her GS entity. The GSO is obliged to contact the SP via voice in order to confirm the pilot incapacitation. In case of no response from the SP, the incapacitation is confirmed and the GSO will initiate a squawk notification (i.e. squawk code 7700)for the concerned aircraft. As an example, it could be foreseen that the squawk notification is issued by pressing a dedicated button of the GS entity. The squawk notification will be received by ATC. In addition, the GSO will inform ATC of the pilot incapacitation in the concerned flight via voice communication. Hereafter, ATC acknowledges the information and will start to clear the airspace as well as the airport runways. In a next step, the GSO will enable overwriting capability of the GS entity in order to take over control of the concerned aircraft. The onboard automation will enable the control from ground for this aircraft, and a display notification (e.g. pop-up window) announces that control from ground is established to the GSO, who hereby becomes the “new” PIC. The GSO is now able to command the aircraft (e.g. heading changes). As a final step, the GSO informs ATC that ground control is established, which will be acknowledged by ATC.

Hereafter, two options could be envisaged, which are not depicted in Figure 14. On the one hand, the aircraft could enter a holding pattern in order to stabilize the flight and control the situation. In this case, the process for requesting a holding fix, and afterwards entering the emergency landing phase would remain as described in Figure 13. On the other hand, in case the aircraft was already in the final descent when the incapacitation occurred, the GSO might decide to follow the intended FPL and land the aircraft as planned. In this case, no additional sequence of process between the relevant actors is foreseen. The aircraft would land based on the already available FMS or autopilot data.

Finally, it is worth mentioning, that the column “automation” refers to overall system automation (incl. aircraft automation and automation on ground), and not necessarily only onboard aircraft automation.

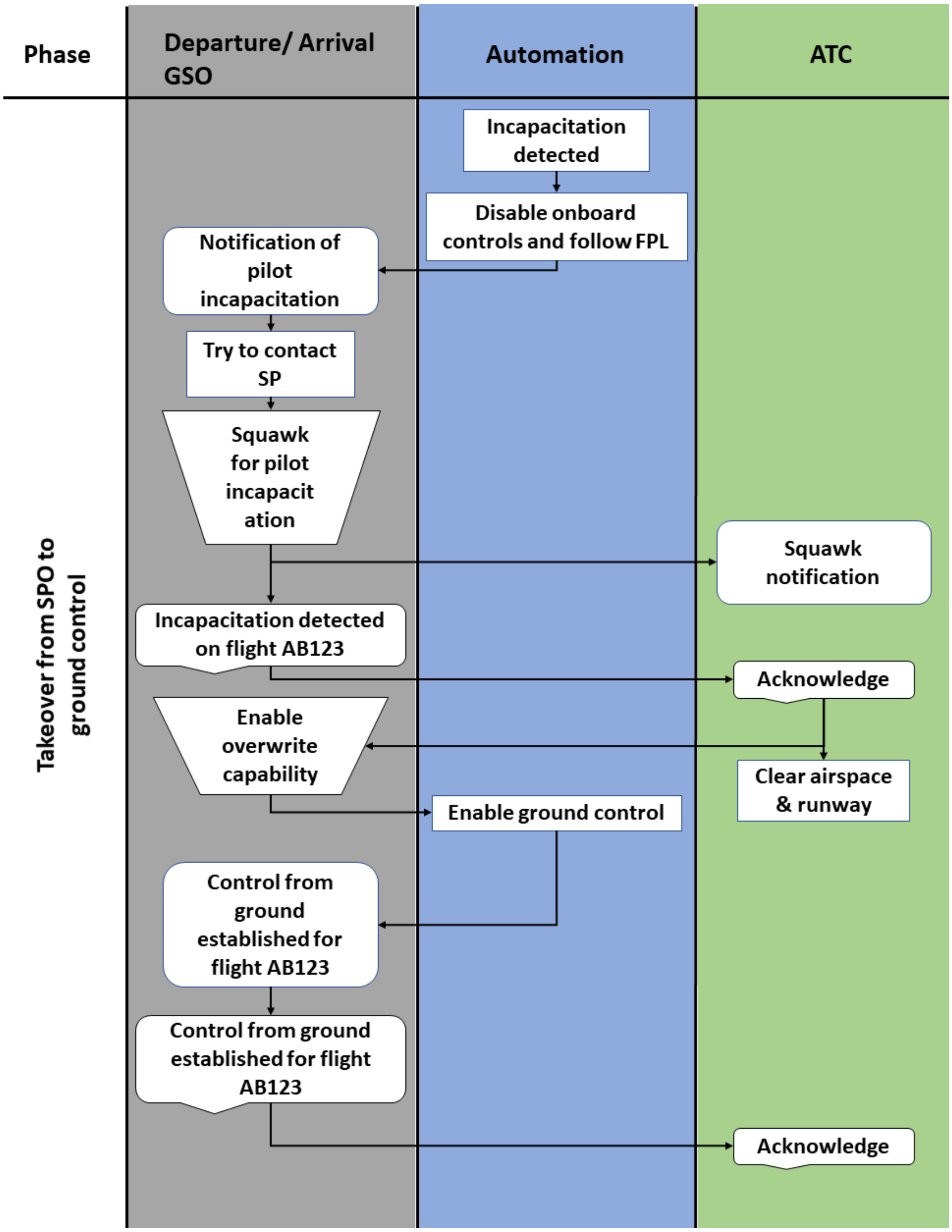


Figure 14. Take over control by departure/ arrival GSO in case of pilot incapacitation during departure/ arrival flight phase.

5 Conclusion

This chapter summarizes the key highlights of the proposed SAFELAND concept handling the event of pilot incapacitation in future commercial SPO. Especially, it describes the key principles of the proposed *Final Concept*. Even though SPO is already in operation for some business jets, operating procedures and regulations have not yet been defined nor implemented for large passenger commercial aircraft. Therefore, the project made several assumptions which are listed in chapter 2.1.1. In addition, the partners had to propose a definition of the expected roles, tasks, operating procedures and tools in normal operation (see chapter 3) before they could address how those would be affected in case of pilot incapacitation.

The SAFELAND concept presented here relies on three key principles developed on the basis of expertise and know-how of the SAFELAND partners in the project (T1.2). In addition, these principles were elaborated and discussed with the Advisory Board (AB) members in a dedicated workshop (T3.2.), and were subsequently further refined in order to take the recommendations and suggestions provided during the workshop into account (T1.4). In summary, the three key principles of the final SAFELAND concept are:

- First, it is worth noting that the SAFELAND project addresses single pilot incapacitation issue for future SPO of CS-25 aircraft operated in commercial aviation. Hereby, the proposed SAFELAND concept will most likely not be implemented before the year 2035, and therefore relies significantly on **more sophisticated onboard automation** to support the SP throughout the flight (also in nominal flight conditions) than the one available in CS-25 aircraft nowadays. Chapters 3.4 and 4.4 describe the technical challenges for SPO, and the technical characteristics for future SPO that need to be implemented in order to enable the SAFELAND concept, respectively. In particular, the first few moments after the pilot incapacitation has been detected are crucial, because onboard automation will become in control of the aircraft. Furthermore, highly automated landing procedures are foreseen in which neither the SP (in nominal flight condition) nor the GSO (in incapacitated flight conditions) is required to intervene in the final approach. However, it is worth noting, that the SP (in nominal flight conditions) is very well allowed to perform manual landing, in order to e.g. remain proficient in landing the aircraft.

- Second, as described in chapters 3.1 and 4.1, the SAFELAND concept has adopted parts of the Tripartite Concept proposed by Schmid & Korn (2017) to its use-case. In other words, it relies on the fact that a Ground Station Operator will be monitoring the flight at all times. Moreover, during critical flight phases (i.e. during departure and arrival) one GSO will monitor just one flight at a time, and support the SP. However, in order for the SAFELAND concept to bring some financial advantages compared to today´s operations, during cruise one GSO will monitor several aircraft simultaneously. As a result, the SAFELAND concept proposes **three different GSO roles**, namely departure GSO, cruise GSO and arrival GSO in nominal flight conditions. These roles and their responsibilities are described in chapter 3.3. Furthermore, 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. These roles and their responsibilities are described in chapter 4.3. In case the incapacitation takes place en-route, the stand-by GSO would take control of the concerned aircraft from the cruise

GSO in order to reduce the number of aircraft handovers. In other words, the en-route GSO would continue to monitor the remaining aircraft originally under his/her responsibility.

- Finally, in order to ease the way for the implementation of the SAFELAND concept into the existing ATM framework, and taking into account legal and regulatory aspects, the concept **does not require significant changes on the tasks and responsibilities of ATC and AOCC** (cf. chapters 3.3.3, 3.3.4 and 4.3.2, 4.3.3). Hereby, the SAFELAND partners based their approach on the expert knowledge in the ATC domain of the project participants, as well as on the recommendations received during the AB workshop. This resolution represents a development from the project proposal (SAFELAND Project, 2019), which stated that alternative assignments of piloting functions were to be considered, including the feasibility of ATC interacting directly with onboard automation. In fact, in deliverable D1.2 *Initial Concept* (SAFELAND Project, 2021a) one of the possibilities considered was the transfer of some of the onboard and remote piloting functions to air traffic controllers who would have the possibility to provide direct commands for speed, vertical rate, heading and altitude to the concerned aircraft. This would require access to the autopilot and the flight management system (FMS) from the ground. However, this variant of the SAFELAND concept was regarded as not feasible by most project partners, as well as by the AB members as described in chapter 2.1.2.

One core element of future SPO, and of the SAFELAND concept presented here, is a Ground Station (GS) entity enabling the Ground Station Operator (GSO) to monitor and supervise an aircraft remotely. Two types of GS entities were introduced and discussed. The first one is capable of monitoring and controlling one aircraft at a time, by allowing manual control by the operator via the presented side-sticks. However, as explained earlier, manual control, using throttle and sticks to control the aircraft's control surfaces, is not foreseen in the SAFELAND concept, mainly due to present latency issues (cf. chapter 3.4.1). Therefore, the second option considers a GS that would enable **a remote pilot to control and supervise multiple highly automated UASs** in controlled airspace (Friedrich & Lieb, 2019), with the possibility to switch to a single aircraft in case of pilot incapacitation.

One of the most important procedures to consider once the pilot is incapacitated and automation stabilizes the aircraft, is the takeover process of aircraft control from the cockpit to the GSO. The steps were described in detail in chapters 4.5.2.1 and 4.5.2.2, for cruise and departure/approach phases, respectively. The different steps of the handover procedures are closely aligned with current requirement and guidelines for remotely piloted aircraft handovers, such as EUCROCAE (2019) and ICAO (2015a). Between the cruise and departure/ approach phases, the handover procedure differs in one core aspect. During departure/approach, the GSO is responsible for one aircraft at a time, meaning that s/he should have an adequate mental picture of the current aircraft state and position, when the pilot incapacitation occurs. Once the incapacitation is confirmed, the GSO will enable the capability to control the aircraft from ground and land the aircraft. If the incapacitation occurs during cruise, the respective GSO will be monitoring several other aircraft at the same time. As described above and in chapter 4.3.1.2.1, SAFELAND introduces a stand-by GSO, to whom the concerned aircraft will be handed over, instead of the GSO handing over the non-concerned aircraft to other GSOs. Once the incapacitation is confirmed, the GSO and the stand-by GSO are notified. While the GSO arranges for taking over control of the aircraft and the handover to the stand-by GSO, the latter has time to acquire situation awareness regarding the concerned aircraft (i.e. its position, flight plan etc.). The GSO will enable ground control in a similar manner as would be done during the departure/ approach phase (to minimize the time during which no human is in control of the aircraft) and will shortly thereafter handover the aircraft to the stand-by GSO, who will the responsible GSO for the remainder of the flight.

From the list of all actors potentially affected by the incapacitation, it is clear that the most impacted role is that of the GSO. Therefore, some functionalities of possible **new additional systems with different levels of automation** that could help the GSO in their activity in supporting the flight management, were also discussed and addressed. Given that the GSO is allocated on the ground, several sensory data and cues will not be available or the information may be delayed and possibly degraded. This will impact the ability to translate decisions to action in due time to achieve the goals. In that regard, the aim of the onboard (and ground station) automation, should be to complement and extend – augment – the capabilities of the GSO, allowing him/her to surpass the natural limitations due to his/her situation and location.

The project has concluded that technology development will let SPO to be conducted utilizing **BRLOS communications**, thereby allowing the GSO operator to be remotely located at long distances from the aircraft. While BRLOS latency levels are foreseen to decrease enough to allow some time critical tasks to be performed and accomplished, the GSO is not expected to be able to operate the aircraft under manual control from the GS, but only intervene through autopilot management.

More specific changes to procedures, systems/displays, as well as communication and coordination needs between ATCOs and GSO will be assessed during the exercises being planned based on the concept depicted in this deliverable. In particular, the role that ATM could have in supporting the GSO in managing the transition from a single pilot operated flight to an absent onboard pilot until landing will also be assessed. Other aspects that will be covered are the acceptance by all stakeholders of the concept, and the impact that high levels of automation might have on human performance. In particular, how workload and situation awareness levels might be affected, and whether complacency and too much dependence on automation might become an issue.

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