EXPLORATORY RESEARCH

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Simulation Results

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SAFELAND

SAFE LANDING THROUGH ENHANCED GROUND SUPPORT

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Abstract

This document describes the Real Time Simulation (RTS) results conducted in the framework of the SAFELAND project aiming at addressing the pilot incapacitation issue for future Single Pilot Operations of CS-25 aircraft operated under IFR.

The Real Time Simulation focused on ground actors (mainly ATCO and pilots in the role of ground station operators - GSO) and aimed to assess the impact of the concept on feasibility/acceptability, Human Performance and Safety. The RTS took place in DLR premises for one week (2nd to 6th of May) and involved five pilots from SWISS and five Air Traffic Controllers from LFV. Each participant performed two runs under two simulated scenarios: incapacitation occurring either in Cruise (En-Route scenario) or in Approach (TMA scenario) phase. Considering the exploratory nature and the low maturity of the project (V1) the assessment was mainly done through qualitative measurements (questionnaires and debriefing) to collect feedback on the current level of maturity of the project, as well as suggestions and requirements for its further development towards the next steps.

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1 Introduction

1.1 Purpose and scope of the document

The purpose of the document is to report results, conclusions and recommendation of the SAFELAND Real Time Simulation.

The Simulation Results document is developed **within WP3 - Concept Evaluation, Task T3.3 - Simulations.** It will be used to feed the Final Evaluation report (D3.4), communication and dissemination activities (WP4) and will contribute to refine the SAFELAND concept developed in WP1 (Figure 1).

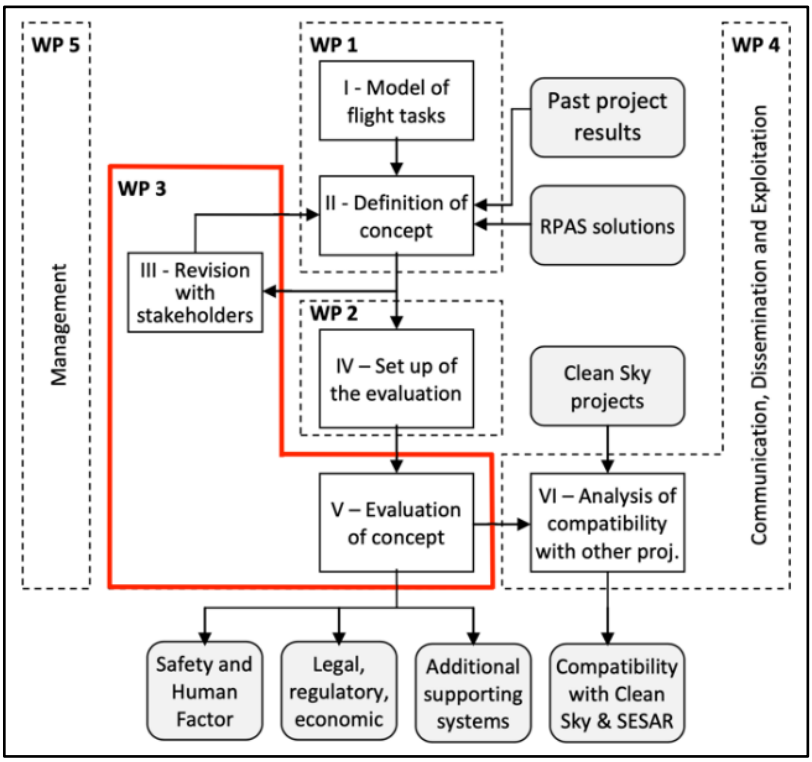

Figure 1: Relationship among WP3 Concept Evaluation (in red) and the other work packages of the project

1.2 Structure of the document

This deliverable presents the results of the SAFELAND Real Time Simulation conducted at DLR premises. It is structured as follows:

- Chapter 1 introduces the purpose of the document and its structure;
- Chapter 2 summarises the context of the SAFELAND Real Time Simulation, including the concept description and simulation plan (scope, objectives and scenario) and deviation from initial simulation plan;

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- Chapter 3 describes the simulation results detailed around defined objectives;
- Chapter 4 describes the conclusions and recommendations;
- Chapter 5 provides the references.

1.3 List of acronyms

Term	Definition
A/C	Aircraft
ACC	Area Control Center
ASV	Aircraft State Vector
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Services
CWP	Controller Working Position
FPL	Flight Plan
GS	Ground Station
GSO	Ground Station Operator
HMI	Human Machine Interface
NOC	Network Operations Control
PF	Pilot Flying
PIC	Pilot in Command
PM	Pilot Monitoring
PTT	Push-To-Talk
SJU	SESAR Joint Undertaking

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SP	Single Pilot
SPO	Single Pilot Operation
TMA	Terminal Manoeuvring Area
RTS	Real-time simulations
VoIP	Voice over Internet Protocol
WP	Work Package

Table 1: Acronyms

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2 Context of the simulation

2.1 Summary of the concept

The introduction of single pilot operations (SPO) in commercial aviation for large passenger aircraft will require new operational procedures and the implementation of technical innovations on the ground and in the cockpit. Most concepts under investigation assume ground support at all times to monitor and support the onboard single pilot (SP). The question remains on the level of involvement of the ground station operator (GSO) in nominal situations and, in particular, in the two phases of highest workload, departure and arrival. Current operational procedures of two-piloted aircraft assume a distribution of tasks and responsibilities between the pilot flying (PF) and the pilot monitoring (PM). In SPO the pilot will remain the pilot flying (arguably with more support from automation), but automation, the GSO or even the SP, will need to take over the tasks traditionally delegated to the PM. The extent of the support provided by the GSO depends on the chosen operational concept and the expected level of engagement.

In the SAFELAND concept, it is assumed that in future SPO the degree of automation in the cockpit will most likely be higher than in current aircraft [9]. In addition, a ground station would need to be introduced to support the single pilots mostly in non-nominal situations and to monitor their health. If necessary, the GSO would intervene and even take over control of the aircraft in case of pilot incapacitation [10].

2.1.1 Nominal case

Following the concept proposed by Schmid & Korn (2017) [11] , the SAFELAND concept assumes that SPO would be managed by involving three different ground stations: departure, cruise, and arrival ground station. During departure and arrival, one GSO would assist one single pilot at a time, whereas in cruise (when workload is normally relatively low) the GSO would support several single pilots simultaneously (see Figure 2). In nominal situations, some of the tasks that could be transferred to the GSO include flight planning, navigation, and communication in order to support the single pilot as needed.

In the SAFELAND concept, the handover phase is of particular concern and is closely aligned with current requirements and guidelines for RPA handovers, such as EUROCAE (2020) [12] and ICAO (2015) [13]. A handover between ground stations will have to take place each time a single-piloted aircraft enters the cruise phase after departure and prior to the descent phase. The same handover process would also be used whenever there is a transfer of the monitoring responsibilities from one cruise GSO to another. The handover procedures involve the single pilot, the transferring and the receiving GSO, the system automation (i.e., aircraft automation and GS automation). ATC might also be involved during this procedure.

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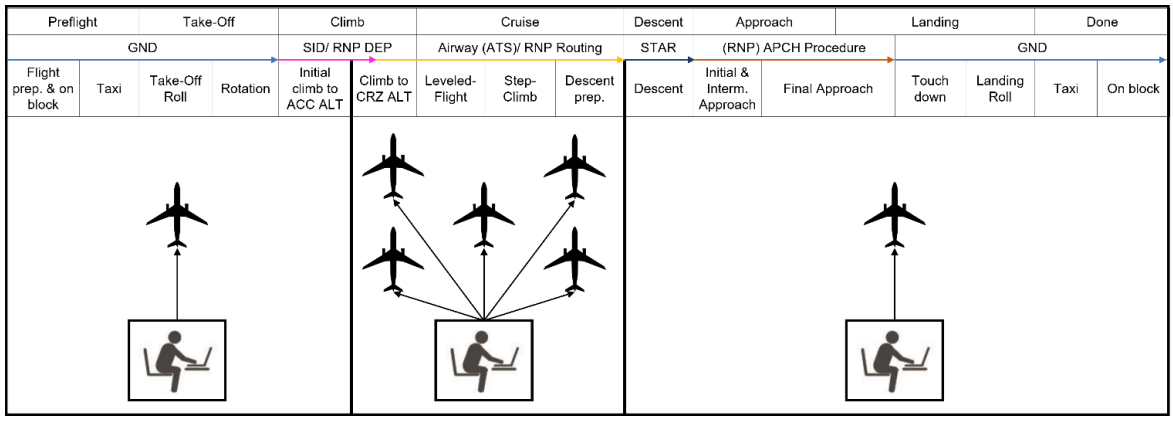

Figure 2: SAFELAND operational concept in nominal situation

2.1.2 Pilot incapacitation management

One of the key issues for the implementation of SPO is managing in-flight pilot incapacitation, defined as "any physiological or psychological state or situation that adversely affects (pilot) performance" [14].

In the SAFELAND concept, an additional actor has been introduced in cruise operations, namely a stand-by GSO. The stand-by GSO would be appointed as responsible for a single aircraft in case of an emergency during cruise (on-board pilot incapacitation). In case of single pilot incapacitation, the responsibilities to control the aircraft will have to be transferred from air to ground. First, the cruise GSO will take over the control of the aircraft for a short period of time. However, as this actor is also monitoring other aircraft, s/he will hand over the concerned aircraft to a stand-by GSO. The stand-by GSO will handle the incapacitated aircraft and land it safely becoming thus the "Pilot In Command"

Depending on the flight phase, the SAFELAND concept envisions slightly different procedures in the event of pilot incapacitation.

2.1.2.1 Cruise phase

When the incapacitation occurs during cruise, the responsibility of "aviating" the aircraft is transferred from air to ground, whereby the cruise GSO becomes the new Pilot-In-Command (PIC). Then, this responsibility is handed over to the stand-by GSO who will be the dedicated actors (1 GSO for 1 emergency aircraft) to manage aviate and navigate on board functions. To do so, the SAFELAND concept assumes high level of automation and advanced on board system (e.g., Advanced Landing System actuates the Autopilot and FM, enabling control of the aircraft flight path (primary controls), attitude (primary controls), and speed (thrust) and Manage/control secondary flight controls (such as flaps and landing gear).

Figure 3 below detailed the eight steps considered in the SAFELAND Concept, from the detection of the single pilot incapacitation to landing the aircraft safely.

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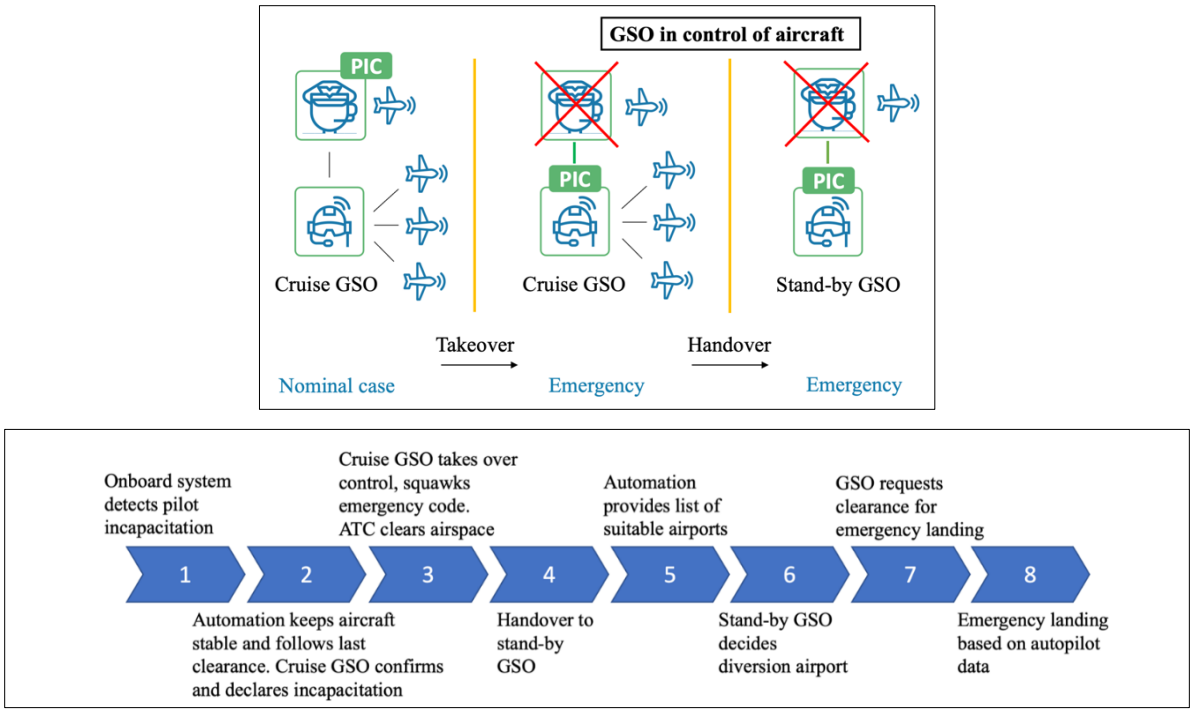

Figure 3: SAFELAND operational concept: pilot incapacitation management in cruise phase.

Note that during the RTS, the GSO did not squawk the emergency code (7700). This was automatically done by the onboard automation (crew monitoring system).

2.1.2.2 Departure/approach phases

As illustrated in Figure 4, the takeover procedures in cruise and in departure/approach phases differ in one core aspect. During departure/arrival, the GSO already supports one aircraft at a time, meaning that s/he should already have an adequate mental picture of the current aircraft state and position at the moment of incapacitation. Hence, if pilot incapacitation occurs during these flight phases, the aircraft is already being monitored by the appointed GSO and there is no transfer of responsibility to a stand-by GSO (i.e., no handover between GSOs).

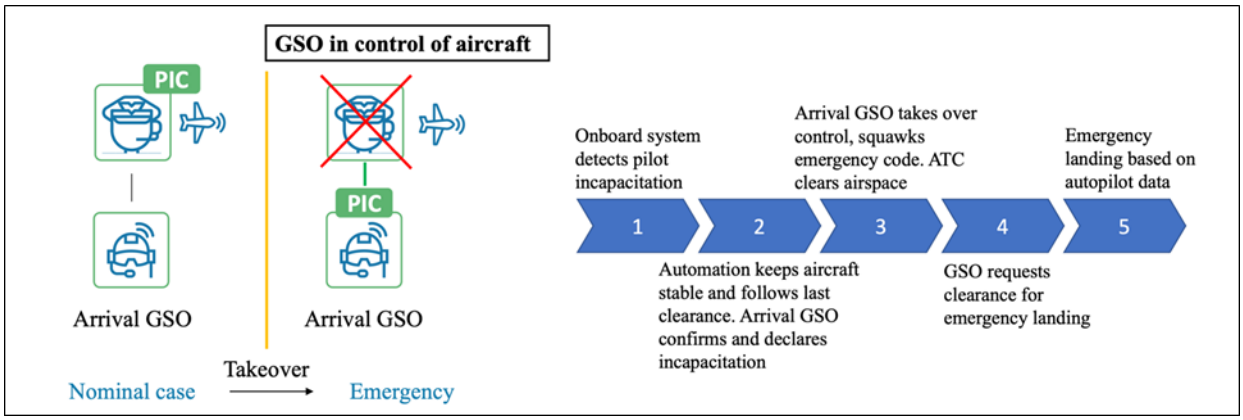

Figure 4: SAFELAND operational concept: pilot incapacitation management in departure/approach phases.

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Note that during the RTS, the GSO did not squawk the emergency code (7700). This was automatically done by the onboard automation (crew monitoring system).

2.2 Summary of the simulation plan

2.2.1 Simulation description and scope

The SAFELAND RTS addresses Single Pilot Operations in the event of on-board Pilot Incapacitation with focus on the ground side, i.e., how the incapacitation is managed by the ATCOs and Ground Station Operators (GSO). The RTS is a part of wider validations activities conducted within the SAFELAND project described in SAFELAND D3.1 [2].

The objective of the Human in the loop simulation is to have **relevant stakeholders experiencing the SAFELAND concept in a realistic situation,** in order to get their feedback on the current level of maturity of the project, as well as suggestions and requirements for its further development towards the next levels of maturity.

To do so, two different scenarios were simulated in a **Real Time Simulation (RTS)**, to test the concept under different operational constraints, and collect data about how the different actors interact with the system and with each other, as well as their expert feedback on the different aspects to improve or change.

The focus of this RTS is on:

- Emergency Operating Procedure for pilot incapacitation (normal operations are out of scope)
- Roles and responsibilities of the different participants
- Task allocation (including between human and automation)
- Communication and Coordination between participants

The RTS took place in DLR – Institute of Flight Guidance premises and involved 10 participants: 5 ATCOs from LFV and 5 pilots from SWISS (performing GSO role) from the 2nd to 6th of May 2022. Each day, one ATCO and one pilot performed 2 runs:

- 1 with pilot incapacitation occurring in Approach phase (**TMA scenario**) and;
- 1 with pilot incapacitation occurring in Cruise phase (**EN-ROUTE scenario**).

Depending on the scenario, the following roles were involved (as detailed in 2.2.3.2.2):

TMA scenario:

- 1 Approach Ground station operator (Approach GSO) played by the pilot participant
- 1 Onboard single pilot
- 1 approach ATCO played by the ATCO participant
- 1 ATCO (supervisor, tower)

EN-ROUTE scenario:

- 1 Stand-by Ground station operator (Stand-by GSO) played by the pilot participant
- 1 Cruise Ground station operator (Cruise GSO)
- 1 Onboard single pilot

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- 1 en-route ATCO played by the ATCO participant
- 1 ATCO supervisor
- 1 Network Operations Control (NOC)

The following Figure 5 depicts the overall simulation set up, in terms of roles and related simulator platforms.

Note that more detailed on platform descriptions and adaptations made are provided in the SAFELAND deliverables ([6], [7], [8]).

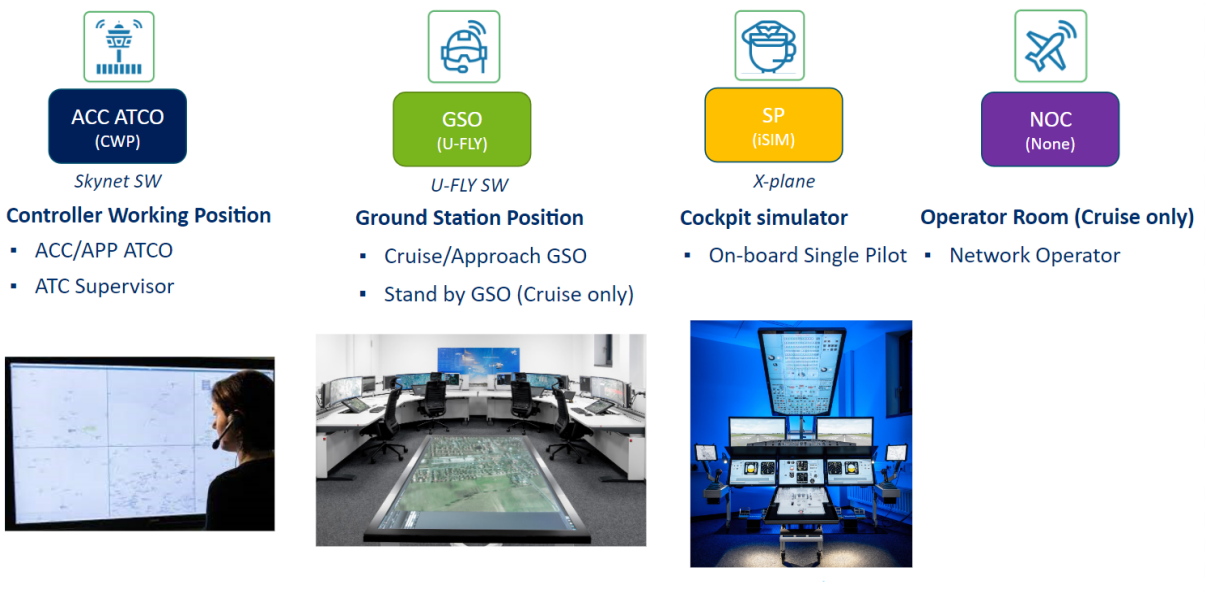

Figure 5: Overall simulation set-up.

2.2.2 Summary of validation objectives and success criteria

Considering the low level of maturity of the concept and the exploratory nature of the project, the Real Time Simulation will focus on Operational feasibility (VO1), Human Performances (VO2) and Safety (VO3) aspects (Table 2). Validation objectives were addressed through qualitative measurements: questionnaires, debriefings and experts' observation.

For each aspect, the SAFELAND simulation results document will provide:

- Assessment of the concept as experienced in the simulation
- Collection of:
    - Potential showstoppers/issues
    - Proposed mitigations/requirements

	Validation Objectives title	Success criteria	Investigated areas
VO1	Operational feasibility	The concept is considered	• Feasibility

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		feasible from the operational point of view	• Acceptability
VO2	Human Performances	The concept enables proper human performance levels, and is considered acceptable by the involved actors	• Roles, responsibility and tasks allocation • Operating Procedures • Team structure and communication • System performance • Workload • Situation Awareness • HMI usability • Competence/training needs
VO3	Safety	The concept contributes to SPO safety compared with operations currently conducted with two pilots	• Safety hazards • Comparison with current operations • Mitigation solutions

Table 2: Validation objectives and success criteria

2.2.3 Summary of validation scenarios

2.2.3.1 Reference scenario

Although some types of operations are conducted today with only one pilot on board (e.g., general aviation) and some solutions to pilot incapacitation problem have been proposed, the concept of SPO for commercial aviation is still a draft and different options are under evaluation. Considering the low level of maturity of the SAFELAND concept and main objectives, no reference scenario was performed, i.e., neither SPO without incapacitation scenario nor Dual Pilots operation with incapacitation.

However, to fulfil the requirements of the safety validation objective, post-simulations feedback from experts regarding safety addressed comparison between current baselines for dual pilot operation and SAFELAND concept.

2.2.3.2 Simulation scenario

The simulation scenario focuses on Single Pilot incapacitation management as described in SAFELAND Final Concept D1.4 [3] and followed the step summarised in 2.1.2.1 and 2.1.2.2, with the GSO taking over responsibility of the flight as a Pilot in Command once the single pilot is fully incapacitated.

As mentioned earlier, two scenarios were performed: one in Approach (in TMA) and one in Cruise (in EN-ROUTE/ACC). In both scenarios, the pilot incapacitation occurred a few minutes after the beginning of the run.

2.2.3.2.1 Operational description

The operational description of both scenarios are illustrated in Table 3.

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	Scenario 1 (TMA)	Scenario 2 (En Route)
Aircraft type	A321	A321
Callsign	SWR1026	SWR1026
ADEP / ADES	Zürich (LSZH) – Düsseldorf (EDDL)	Zürich (LSZH) – Kiev (UKBB)
Flight Level	120	330
Flight Phase	About to enter TMA	About to enter a new sector
PAX	150	146
Dangerous good	No	No

Table 3: Operational description of the simulation scenarios

2.2.3.2.2 Participants' roles, responsibilities, and tasks

According to the simulated roles, the participants were asked to follow the responsibilities and tasks defined by the SAFELAND concept. The following were proposed according to the actors (Table 4).

Roles	Responsibilities	Tasks before incapacitation	Tasks after incapacitation
Onboard Single Pilot	Pilot in Command (PIC), responsible for flight safety and thus decision-maker	• Manage flight until incapacitation • Communication and coordination with ATC and GSO as needed	• N/A
Approach GSO	Support the PIC, contributing to a safe and efficient flight. Act as PIC after pilot becomes incapacitated	• Monitor aircraft systems and flight • Monitor pilot's health • Support the PIC upon request • Cross-check and monitor SP actions • Listen to communication between pilot and ATC •	• Confirm pilot incapacitation • Takeover control of the aircraft • Declare MAYDAY • Communicate control from ground • Manage flight via high-level commands (HEAD, ALT, SPEED) or FPL changes • Communications with ATC
Cruise GSO	Support several single pilots, contributing to a safe and efficient flight. Act as PIC after SP becomes incapacitated until a/c is transferred to stand-by GSO.	• Monitor several aircraft systems and flights • Monitor pilots' health • Support the PICs upon request • Cross-check and monitor SP actions • Listen to communication between pilot and ATC	• Confirm pilot incapacitation • Takeover control of the aircraft • Declare MAYDAY • Communicate control from ground • Manage flight via high-level commands (HEAD, ALT, SPEED) or FPL changes (if needed) • Hand over control to stand-by GSO

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			• Communications with ATC and stand-by GSO
Stand by GSO	Become PIC after pilot incapacitation, responsible for flight safety and thus decision maker (note that the handover from GSO to the stand by GSO may take some time).	• Monitor several A/C	• Receive control of aircraft from Cruise GSO • Decide for suitable alternate airport with NOC support • Manage flight via high-level commands (HEAD, ALT, SPEED) or FPL changes • Monitor aircraft automation • Manage communications with ATC
ATCO	Ensures air traffic operation and management. Responsibilities are not expected to change compared to current operations.	• Issue clearances and instructions (if needed) • Provide separation between controlled aircraft • Communicate with SP • Coordinate with surrounded sectors/ATS units	• Same as before incapacitation but considering the emergency situation • Clear the airspace to 'isolate' the A/C in emergency (e.g. double separation) • Communicate with GSO • Support GSO as needed • Coordinate with ground services
ATCO Supervisor	Monitor the operations. Assisting in emergency situations.	• Monitor operations • Assisting upon request	• Supporting the ATCO to handle the emergency situation
NOC	Supporting all SWISS operations in the region	N/A	• Coordinate and support the Stand-by GSO with alternate airport decision

Table 4: SAFELAND roles, responsibilities and task proposed during simulated runs. Roles played by the invited participants are underlined.

2.2.3.2.3 Communication and phraseology

The following Figure 6 depicts simulated communication interactions and means between various roles. As in the current operations, the communication between ATCO and Pilots/GSO were made via radio. Communication between the different GSOs and between any GSO and any aircraft would be done through dedicated lines not shared by others (in the RTS, phone lines were used). For practical reasons during the simulation, communication between the GSO and the NOC, as well as between the ATS Units was done in person. To summarise, the following communication interaction/means were used:

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- Communication in person
    - between ATS Units and
    - between Approach/cruise GSO and NOC
- Communication by phone
    - Between GSOs and single pilot and
    - between Cruise and Stand by GSOs
- Communication via radio
    - between GSO and ATS Units
    - between pilots and ATS Units

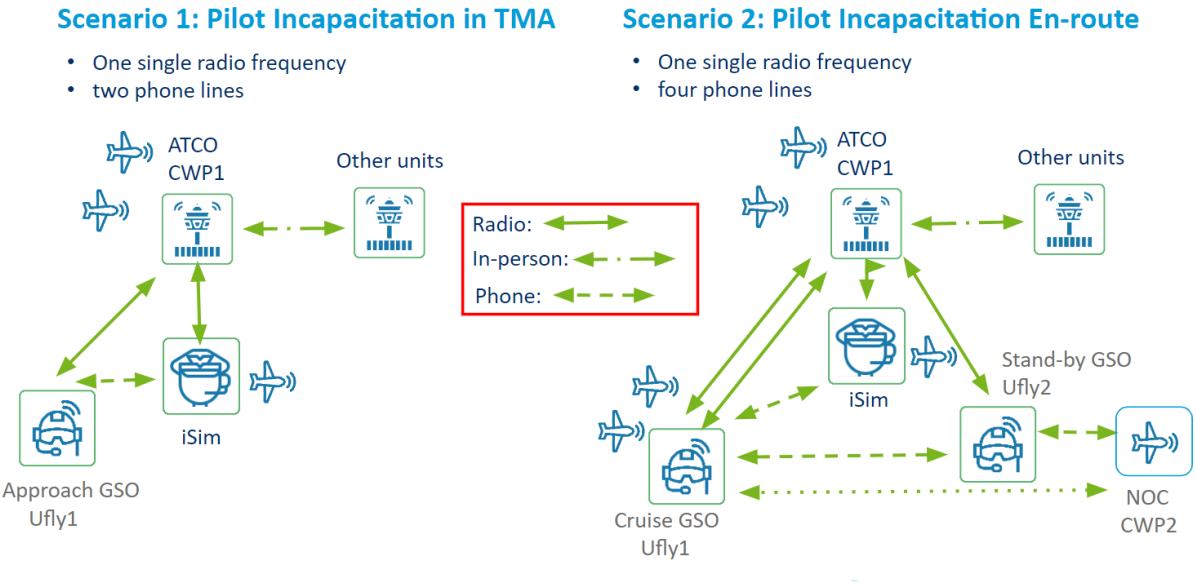

Figure 6: Simulated voice communication interaction for scenario 1 (left) and scenario 2 (right)

In terms of phraseology, the participants were tasked to use the current/standard phraseology between pilots and ATC whenever possible. However, some slight adaptations were proposed in the context of SPO, e.g., using "**remote**" by the GSO to remind the ATCO that the a/c is controlled from the ground.

As an example:

- **Stand-by GSO to Cruise GSO**: "SWISS 1026 remote, this is your stand-by GSO speaking. Ready to initiate handover procedure."
- **Cruise GSO to Stand-by GSO**: "Roger stand-by GSO. SWISS 1026 remote, ready for handover."
- **Stand-by GSO**: "Roger. Requesting control of SWISS 1026."
- **Cruise GSO**: "Request control accepted. You have control of SWISS 1026."
- **Stand-by GSO**: "Acknowledged. I have control of SWISS 1026"

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2.2.4 Summary of validation assumptions

The following general validation assumptions were defined and could be investigated in future validation activities:

- Operational
    - Full incapacitation: Partial incapacitation would be hard to simulate and would complicate the concept analysis
    - Nominal flight conditions apart from full pilot incapacitation (e.g. no adverse weather, no go around): SAFELAND is a V1 project so focuses in nominal scenario
    - Surrounding traffic is datalink equipped (no pilots or read backs)
- Technical
    - Malfunction of the systems and of the communication channels not investigated
    - Data link will be assumed to be adequate in terms of bandwidth and availability/stability

In addition, more detailed assumptions were defined in the context of the Real Time Simulation in terms of technical support/automation and communication means (Table 5).

Identifier	Title	Description	Justification	Impact on Assessment
SA01	Advanced technical support/automation on Air and Ground	• Onboard pilot health monitoring system capable of detecting incapacitation and automatically informing the GSO • After incapacitation, autopilot will be engaged automatically (i.e. A/C flies according to FPL) • Manual control from ground is not foreseen (i.e. only high-level commands from ground to A/C, such as HDG) • Advanced Landing System is engaged during arrival • If not given any further inputs, A/C will land according to the last FMS entry • Secondary flight controls and the landing gear are operated automatically	The objective of the simulation is to have experts experiencing the concept and applying the envisaged procedures.	No technical assessment

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SA02	Communication	• No delay (in C2 link or communication) • ATC provides clearances (via voice) only to EMERG A/C • CPDLC is advanced and can be used in any environment (incl. TMA) • All A/C being monitored by Cruise GSO share the same ATC frequency	The objective of the simulation is to have experts experiencing the concept and applying the envisaged procedures.	No technical assessment

Table 5: Validation assumptions for the simulation

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2.3 Data gathering

The methods chosen to carry out the data gathering process included: observations, questionnaires, and semi-structured interviews. Questionnaire and debriefing items were derived by the specific validation objectives generated for the RTS (see 2.2.2).

Questionnaires and debriefings' items are reported in Appendix A.

2.3.1 Observations

During the simulation session, researchers were observing participants' behaviour to register any relevant aspects relative to their performance and any deviations from expected behaviour. The motivation was to mark any point of discussion useful for the debriefing session.

2.3.2 Questionnaire

At the end of each experimental scenario, and at the end of the simulation session, participants were asked to fill in a questionnaire. This resulted in 3 questionnaires per participant, namely a TMA Scenario Post-run Questionnaire, an EN-ROUTE Scenario Post-run Questionnaire, and a Post-session Questionnaire. The questionnaires consisted of close-ended statements that participants were asked to rate on a 1 to 5 scale of agreement, where 1 corresponded to "*Strongly disagree*" and 5 to "*Strongly agree*". After expressing their rating for each item, participants had the chance to write some notes explaining their choice and elaborating on that topic.

2.3.3 Debriefing

The debriefing session consisted of a semi-structured part, where participants were invited to elaborate on different topics based on a prepared interview guideline, followed by a discussion session. Topics were related to the specific validation objectives investigated within the RTS and included a set of questions on safety aspects. The discussion session allowed participants to share any thoughts and opinions with the researchers, raise new topics of discussion not already covered within the questionnaire and the interview, and clarify possible ambiguities about the simulation and the concept experienced.

2.4 Deviations from the simulation plan

The COVID and related travelling constraints had a big impact on the Real Time Simulation planning and conduct. Initially planned in February, the RTS was postponed to the beginning of May 2022. This shift of schedule had also an impact in terms of participants' availability and led project members to "play" the NOC role during the RTS.

In addition, due to the mostly qualitative nature of the simulation's objectives (feasibility, human performances and safety), it was not found relevant to use quantitative indicators derived from platform logs.

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3 Simulation results

Written and oral feedback derived from questionnaires and debriefings were collected, integrated, and summarised. Results have been structured as follow:

A first section (3.1 - Concept Evaluation) reports the main findings related to concept evaluation. Results are divided into three categories that follow three of the four arguments from the HP Assessment Process in SESAR. (i.e., Arg. 1 Roles, Responsibilities, Operating Methods and Human Tasks, Arg. 2 Technical Support Systems and Human-Machine Interface, Arg. 3 Team Structures and Team Communication).

A second section (3.2 - Hazards identification) reports participants' feedback on safety and security aspects

Results include plots and a textual part. The plots have been derived from the rating answers provided by participants in the questionnaires (i.e., TMA Scenario Post-run Questionnaire, EN-ROUTE Scenario Post-run Questionnaire, and Post-session Questionnaire). The text combines the questionnaires' open-ended answers related to that rating and feedback on that topic collected during the debriefing. Each subsection includes plots and feedback from the pilots (in the role of GSO) and ATCOs participants. Note that not every topic of discussion covered during debriefing was associated with a rating item in the questionnaire. Each subsection includes a summary of these considerations as well.

Raw data from questionnaires and debriefings are reported in Appendix B.

3.1 Concept Evaluation

Note that in the following figures/graphs, the following colour coding and representations were used:

- Blue bar: Average ratings
- Black dots: Min and Max ratings

3.1.1 Roles, responsibilities, operating method and human tasks

Figure 7 and Figure 8 below describe pilot and ATCO participants' evaluation on some key aspects of the SAFELAND Concept of Operation experienced in the two scenarios, namely: participants' acceptability of their role and responsibilities, clarity and acceptability of the operating procedures, perceived level of safety and trust in the concept.

As a first consideration, it is immediately visible from the graphs that the ATCOs' results returned a generally positive opinion on these aspects with a low variability between participants. On the contrary, pilots' assessment returned more mixed results, with a positive trend for the first three items, and a negative trend for the last two (i.e., perceived safety and trust).

Before describing in detail each of these elements and analysing the rationale behind participants' ratings (see following subsections), it is important to highlight some general considerations in terms of

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participants' overall response to the concept, the concept's points of strength and weakness, and the key issues encountered during the simulation exercise.

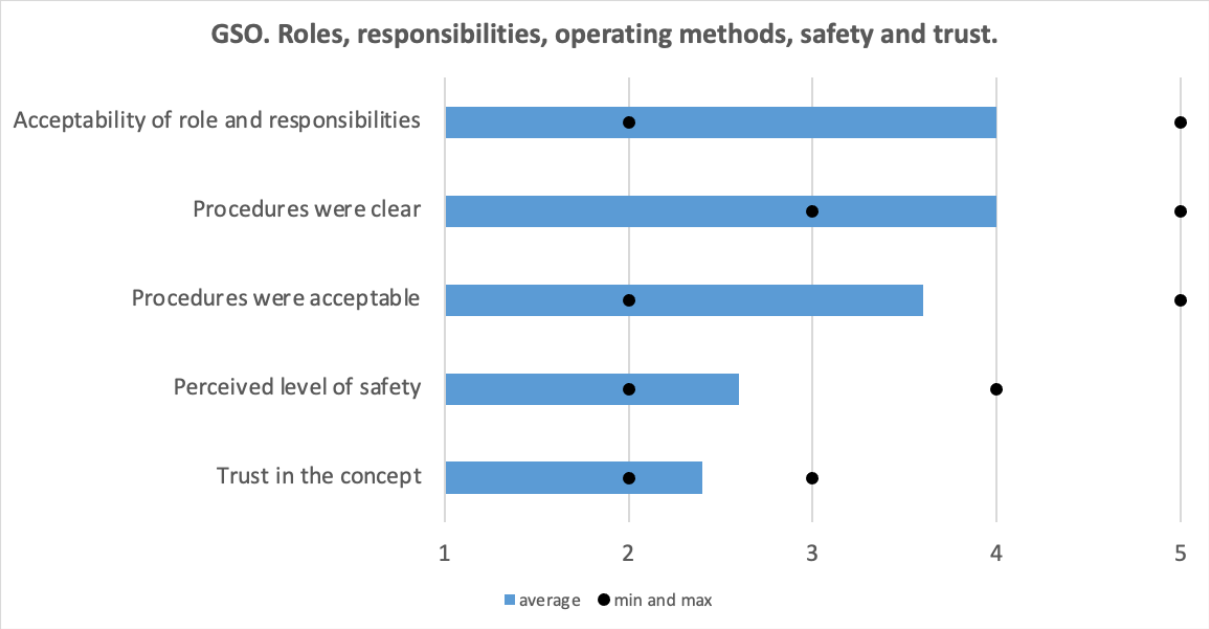

Figure 7: Pilots rating on some key aspects of the SAFELAND CONOPS

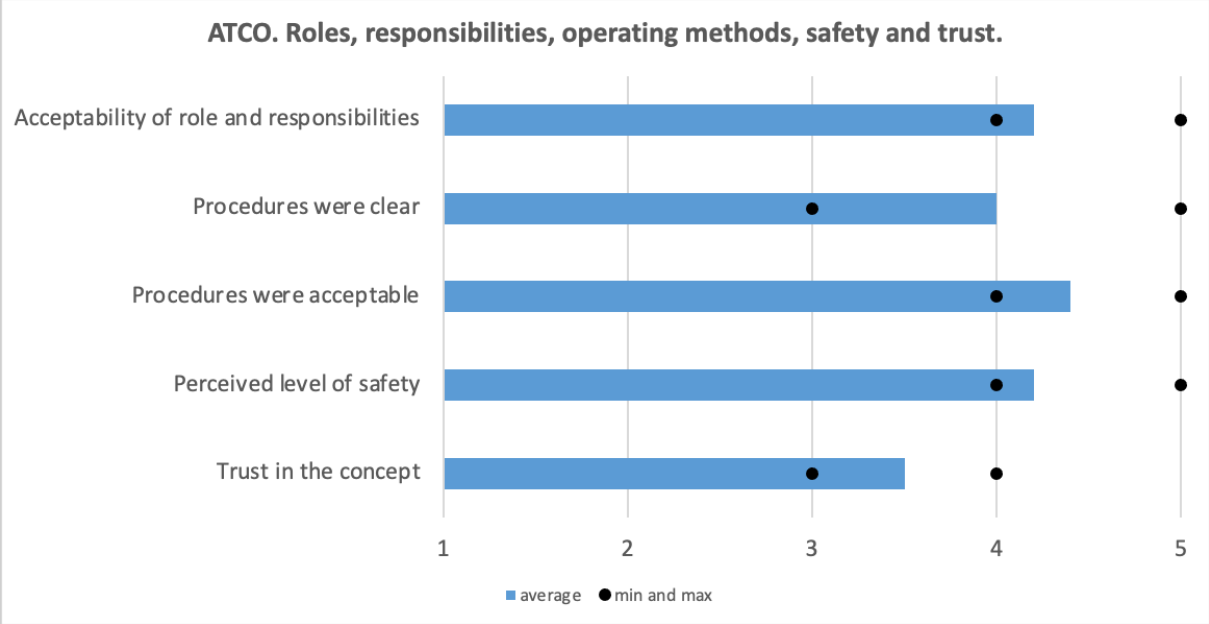

Figure 8: ATCOs rating on some key aspects of the SAFELAND CONOPS

Considering ATCOs role and responsibilities, and the procedures in place to handle the single-pilot incapacitation, the SAFELAND CONOPS (as described in D1.4 [3] and briefly summarised in Table 4) did not introduce many differences compared to current operations. The ATCOs tasks after incapacitation

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are quite similar to those envisioned for the management of other types of emergency, with the only difference that, after the incapacitation, the ATCO is required to interact with a remote pilot (the GSO) operating from a ground station position. Therefore, no substantial changes in ATCOs' knowledge, skills and experience are required, apart from the introduction of a standard phraseology needed to communicate with the GSO and, possibly, some adaptation of the CWP labels to indicate the SPO aircraft and the incapacitation (see Technical support systems and Human-Machine Interface section). The conservative approach adopted by the SAFELAND concept toward the ATCO role reflected on the general positive assessment provided by participants. Among the issues, in fact, the most cited was not directly connected to the concept itself, but to the technical issues experienced during the simulation exercise (e.g., software instability and malfunctions that in some cases affected ATCOs' situational awareness, workload, and ability to manage their tasks).

A completely different picture arises considering the role of the pilots (i.e., GSO) in the SAFELAND concept. In their case, not only participants had to deal with the big amount of changes (both procedural and technical) introduced by the SAFELAND Concept, but also with the fact that such changes in many cases were still presented at a conceptual level (i.e., not implemented in the simulation). Specifically, pilots faced the following challenges. First, they were invited to experience and evaluate a non-nominal case (single-pilot incapacitation) of a still not adopted concept of operations (i.e., SPO in commercial aviation). Second, from the technical point of view, they were asked to rely on new systems and technologies not fully implemented in the simulation itself (e.g., some of the GS capabilities, the Pilot Incapacitation Detection System, the Advanced Landing System), and on assumptions (e.g., reliability and redundancy of the datalink, no other failures). Third, at the operational level, pilots were introduced to a new environment (the GS) and to a completely different modality of operation (no manual control of the aircraft). Finally, the same technical issues experienced by the ATCOs affected pilots as well.

All these aspects had a major impact on pilots' assessment, especially considering the evaluation of the technology in place in relation to the tasks to be accomplished, safety aspects and a general trust in the concept. On the other hand, other procedural aspects were positively evaluated by pilot participants, especially those implying interaction between human actors. The following subsection will analyse in detail all elements of participants' assessment.

3.1.1.1 Clarity of roles and responsibilities

In both post-run questionnaires, participants were asked to rate whether the roles and responsibilities of all human actors involved in the SAFELAND CONOPS ([3]) were clearly defined.

As shown in Figure 9 below, pilots' evaluation over the clarity of their role and responsibilities as GSO, and of the other actors' roles (i.e., ATCO in both TMA and En-Route scenarios, NOC and Cruise-GSO in the En-Route scenario) returned positive results, with a slight difference between the two runs experienced. During the debriefing, the pilots affirmed that, overall, their role as GSO was clear. However, some uncertainty during the exercise still occurred, due to the lack of familiarity with some details of the SAFELAND procedures, and with the capabilities of the GS interface. Such unfamiliarity affected the perception of their role and, in turn, the decision making process, meaning that the pilots were not always sure of which actions and decisions were within their range of possibility. Regarding other actors' roles, pilots expressed some concerns about the NOC. In fact in the En-Route scenario, where the GSO and NOC were asked to cooperate on the diversion airport decision, some pilots

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affirmed that the NOC behaviour deviated too much from current operations (i.e., in some cases, the pilots reported a lack of real cooperation, in others the pilots felt that the decision was too much driven by the NOC).

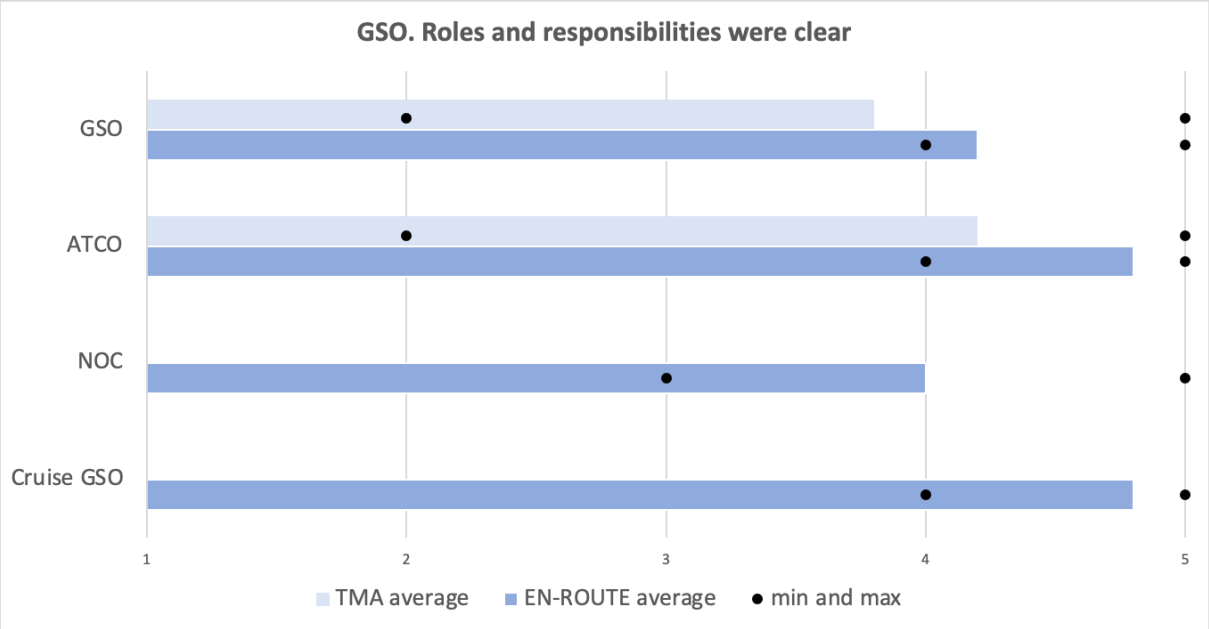

Figure 9: Pilots rating on clarity of roles and responsibilities divided per scenario

Figure 10 below reports ATCOs' evaluation on the clarity of their role and responsibilities, as well as the clarity of other actors' roles (i.e., GSO in both the TMA and the En-Route scenarios, and Cruise-GSO in the En-Route scenario only). As shown, all ATCOs participants expressed positive evaluations, with no differences between scenarios and low variability in the scores.

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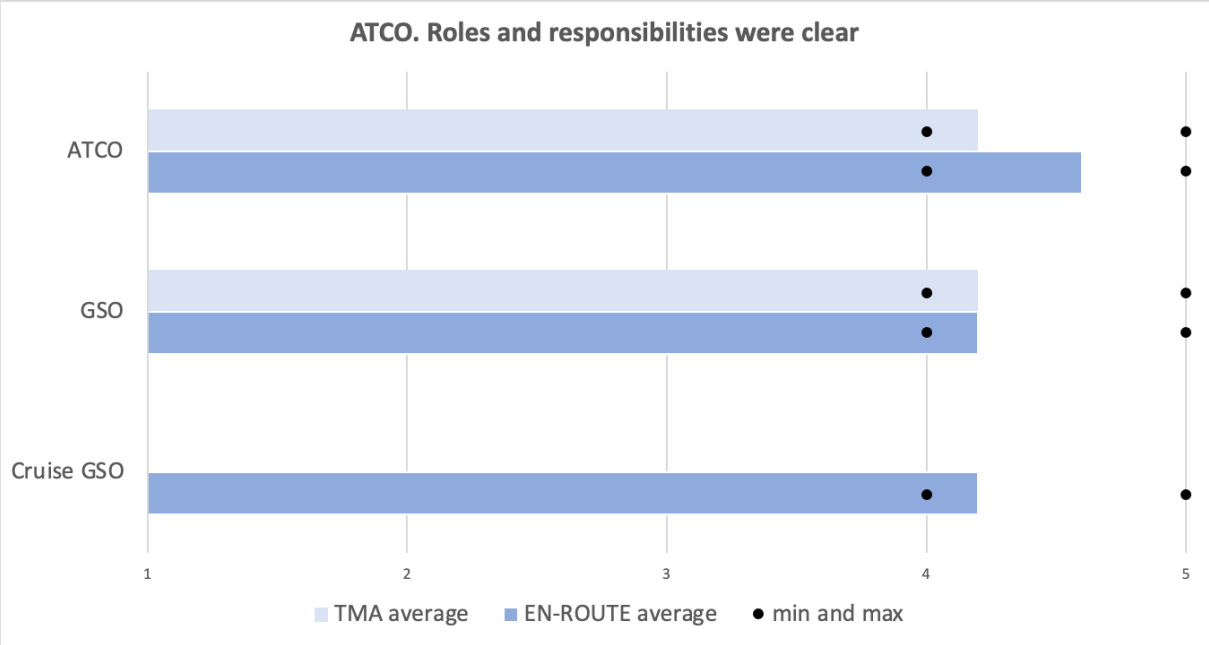

Figure 10: ATCO rating on clarity of roles and responsibilities divided per scenario

3.1.1.2 Acceptability of roles and responsibilities

Regarding pilots' acceptability of their role and responsibilities (see Figure 7), questionnaire results returned a positive evaluation, but the scores variability was high, ranging from a minimum of 2 (i.e., Disagree) to a maximum of 5 (i.e., Totally agree).

During the debriefing, all participants affirmed that they would not be comfortable to be responsible for the flight safety operating from a ground station position. Different reasons were identified, including the limited action possibilities of the GSO and the impossibility to control the aircraft automation. Moreover, pilots were concerned about other possible hazards that could arise apart from pilot incapacitation, and would be difficult to handle from the ground (e.g., serious weather conditions, engine or automation failure, fire on-board). Security issues (e.g., hacking) were mentioned as well. As emerged from the debriefing, and already pointed out previously, such considerations were highly affected by the limitations of the GS interface and of the simulation exercise itself, and on the difficulty to rely on systems, technologies and procedures (SPO) still not implemented.

By contrast, since the SAFELAND concept did not envision new or different ATCO responsibilities compared to current operations, all ATCO participants returned a positive evaluation as shown in Fig. bb.

Pilot participants were also asked to imagine what should be the **role of a Stand-by GSO in nominal conditions**, before incapacitation. As already explained, the SAFELAND concept envisions a team of Cruise GSOs, each monitoring more than one flight in the En-Route phase. When incapacitation occurs, a Stand-by GSO is assigned to handle the emergency, and the aircraft is transferred from the Cruise to the Stand-by GSO. Almost all participants answered that the Stand-by GSO should have an active role during the operations, sitting in the same room of the Cruise-GSOs and covering, for example, the role

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of a supervisor, or a Datalink supervisor. This condition would enhance the Stand-by GSO readiness to deal with the critical situation.

3.1.1.3 GSO: Skills and training required

Both pilot and ATCO participants agreed that, to ensure a high level of safety, the **GSO knowledge, skills and operational experience** should be similar to those required for a pilot. Such expertise would be obviously combined with the specific training needed to operate remotely from a ground station position. Among the GSO competences, some participants pointed out the need for well trained monitoring skills, necessary to accomplish a role that, apart from rare cases of active intervention, would be mostly passive.

3.1.1.4 Procedures

As already shown in Figure 7, pilots' evaluation on the clarity and acceptability of the new procedures envisioned by the SAFELAND concept was generally positive, but the variability was high between participants.

The **operating procedures** were defined by the pilots as straightforward, with some uncertainty due to the lack of familiarity with the GS interface and not enough training. Four pilots affirmed that the ability to manage their tasks during operations was good. A pilot commented that the efficiency of navigating (e.g., efficiency of routing determination) and managing tasks was highly dependent on the effectiveness of the automation, both ground and airborne. Another pilot expressed some concerns on the effectiveness of the pilot incapacitation detection, as not every occurrence of incapacitation can be easily detected via physiological parameters. This very interesting topic, as was explained to participants, was however out of the scope of the SAFELAND project.

Regarding **pilots' acceptability of the new procedures** envisioned by the concept, it emerged that the acceptability might be enhanced by future technological implementations and by their redundancy and reliability (e.g., incapacitation detection system, automation and datalink).

Overall, the **effectiveness of the decision making process** was considered good by the pilots. Nevertheless, some of them specified that, since in SAFELAND the decision making process also relies on the automated systems in place, such systems should be more transparent and understandable. Moreover, some pilots lamented that their decision making ability was affected by the limited possibilities to control the aircraft automation from the GS, and by the lack of information displayed on the GS interface (e.g., speed and distance from the airport). These aspects will be extensively discussed in following sections (Technical support systems and Human-Machine Interface).

Considering the **decision on the new destination airpor**t (En-Route scenario), some pilots claimed that the options provided by the NOC were limited and that the coordination NOC-GSO was too different from current operations. This aspect, in turn, limited the effectiveness of the decision making process. Despite the uncertainty on this procedure, both pilot and ATCO participants agreed that the decision on the new destination airport was made within an acceptable time frame, with questionnaire results returning positive scores (average GSO:4.4 min:3 max:5), (average ATCO:4.4 min:4 max:5).

In the questionnaires and debriefings, pilots were also asked to compare their **ability to manage their tasks during the experienced scenarios versus current operations**. Such a question required a big

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imaginative effort, considering the intrinsic differences between a cockpit and a GS, the constraints of the GS imposed by design, and the limitations of a simulation exercise.

On pilot's side, Figure 11 below shows that navigating and managing were the functions more affected by the SAFELAND system, while communication was perceived as effective, and not much different from current operations. Different points that affected pilots' performances were identified including:

- Lack of manual control from the GS;
- Technical issues experienced during the simulation (i.e., technical issues inserting new flight plans, software instability);
- Usability of the HMI;
- Lack of information displayed on the GS (i.e., classical IFR information), and
- General concern regarding not being part of a crew and sharing a mental model with a second pilot, which increases the likelihood of errors.

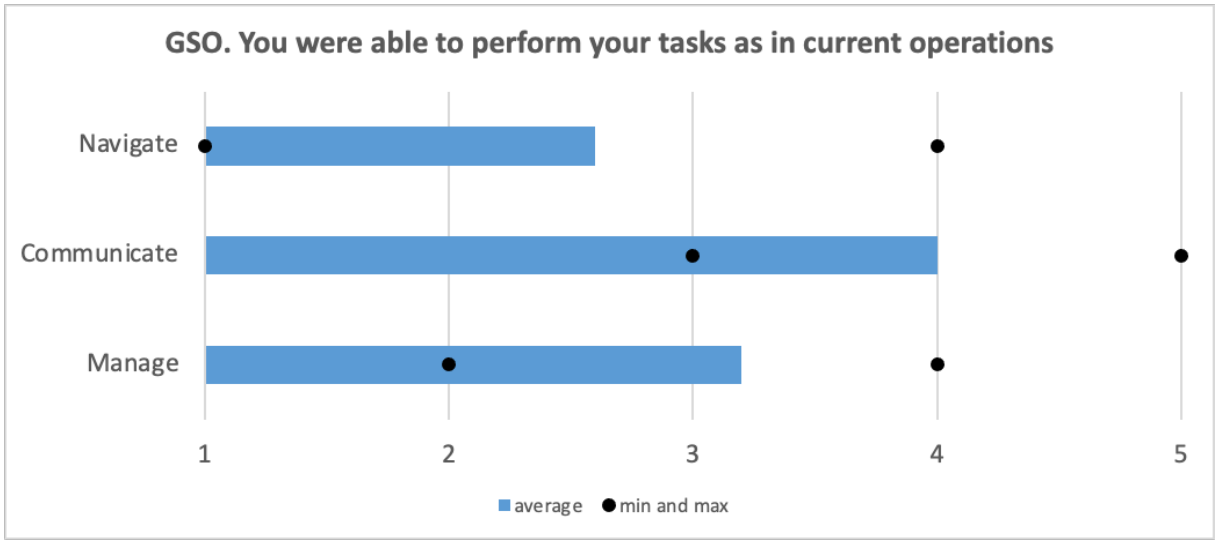

Figure 11: Pilots rating on "perform as in current operations"

On ATCOs' side, the operating procedures experienced during the RTS campaign were considered clear (Figure 8).

When asked to compare their performance with current operations, answers returned a positive evaluation for the Monitoring, Conflict detection and resolution and Coordination tasks, with low variability among participants (Figure 12). However, Managing traffic was considered more problematic by the involved participants.

From the post-run questionnaires results to the question "Rate your ability to handle the other traffic in an effective and safe way while managing the emergency aircraft" it emerged that in the first scenario (TMA), ATCOs experienced much more difficulties in managing traffic due to their unfamiliarity with the approach procedures for the Düsseldorf airport, and to the instability of the software (average:2.8 min:2 max:4).

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On the contrary, results from the En-Route scenario returned a more positive evaluation (average: 4.2 min:3 max:5).

Apart from the technical issues experienced, the successful management of the emergency translated also in a global acceptability of the operating procedures envisioned by SAFELAND (Figure 8), since, as affirmed by one ATCO during the debriefing, "*there is a very little difference from what we do on a daily basis*".

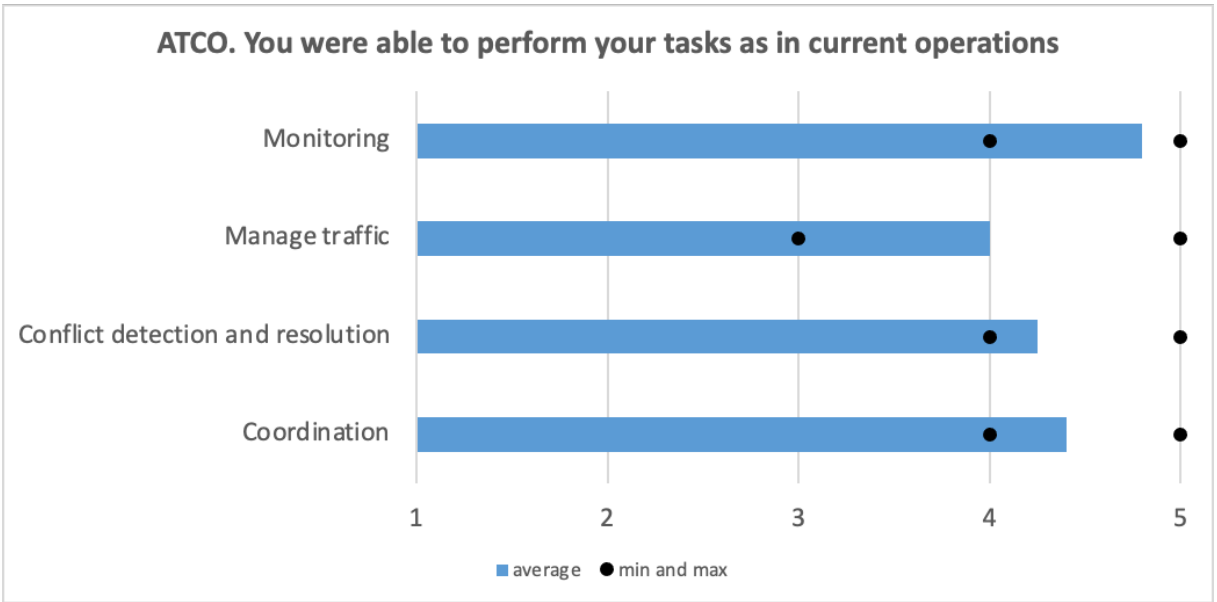

Figure 12: ATCOs rating on "perform as in current operations"

In the development process of the SAFELAND concept, different options for **specific operating procedures** were taken into consideration and discussed, each one of them implying different pros and cons. Due to resource constraints, during the RTS campaign only one option was chosen to be experienced by participants, whereas the others might have been still valid. During debriefing, participants were therefore informed about these different options and asked to analyse and comment on them. In particular, the procedures under analysis concerned the ***Incapacitation Alert Procedure*** and the ***Handover Procedure*** between the Cruise GSO and the Stand-by GSO, in the En-Route Scenario.

Regarding the ***Incapacitation Alert Procedure***, the option experienced by participants entailed an automatic alert sent by the onboard pilot health monitoring system simultaneously to the GSO (i.e., a red heart blinking on the GS screen) and the ATCO (i.e., 7700 Squawk shown on the aircraft label) as soon as incapacitation is detected. This option was evaluated against a second option entailing only the GSO to be informed by the incapacitation detection system. After the confirmation of the incapacitation, the ATCO is also informed by the GSO (i.e., the GSO squawks the 7700 from the GS and contacts ATC via radio). Participants did not express a common agreement over one of the two options. For instance, two pilots and two ATCOs preferred the first option claiming that the ATCO should receive the information as soon as the incapacitation occurs to be better prepared to handle the emergency. Another pilot and one ATCO preferred the second option instead, affirming that it creates less

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problems of communication overlap (in option 1 the ATCO might interrupt the GSO while he/she is still contacting the onboard pilot to verify the incapacitation) and in turn, reduces workload. Finally, an ATCO suggested a hybrid option between the two: both GSO and ATCO receive the alert and then (as standard procedure) the ATCO waits for the GSO to call. This option necessarily entails a specific Squawk for pilot incapacitation different from the 7700 or, at least, the indication that the aircraft is single-piloted.

Another procedural aspect addressed during the RTS campaign was the **Handover procedure** occurring between the Cruise and the Stand-By GSO when pilot incapacitation happens in cruise. In the SAFELAND concept, the Cruise GSO hands over the emergency aircraft to the Stand-By GSO, while keeping monitoring the other flights. The opposite option consists in the Cruise GSO remaining with the emergency aircraft, while the other flights are transferred to a Stand-By GSO. Again, no common agreement was achieved by the pilots involved in the RTS campaign. Three out of five pilots preferred the second option arguing that the Cruise GSO is already aware of the emergency aircraft status, and better fit to handle the situation. Moreover, since the emergency aircraft has the highest priority, this option would be less time consuming. However, another pilot commented that transferring several aircraft at the same time to the Stand-by GSO would be time consuming as well and it could create problems if, for example, the GSO was in the process of giving clearances to some of them.

Pilots were also asked who, among Cruise- and the Stand-by GSO, should initiate the handover procedure. Most of them claimed that, being the Cruise GSO the PIC at the moment of the handover, he/she should decide when to start the procedure.

Although different opinions were expressed on the procedural aspects of the Handover process, all pilots agreed, in the post-run questionnaire, that the procedure was performed within an acceptable time frame (average:4.2 min:3 max:5).

3.1.1.5 Situational Awareness

As shown in Figure 13 below, the level of situational awareness experienced in both scenarios was not positively evaluated by the involved pilots. Overall, participants did not feel they had all the necessary information needed to perform their tasks and they were not aware of the aircraft status. The variability of the scores was however high, with some pilots returning positive ratings.

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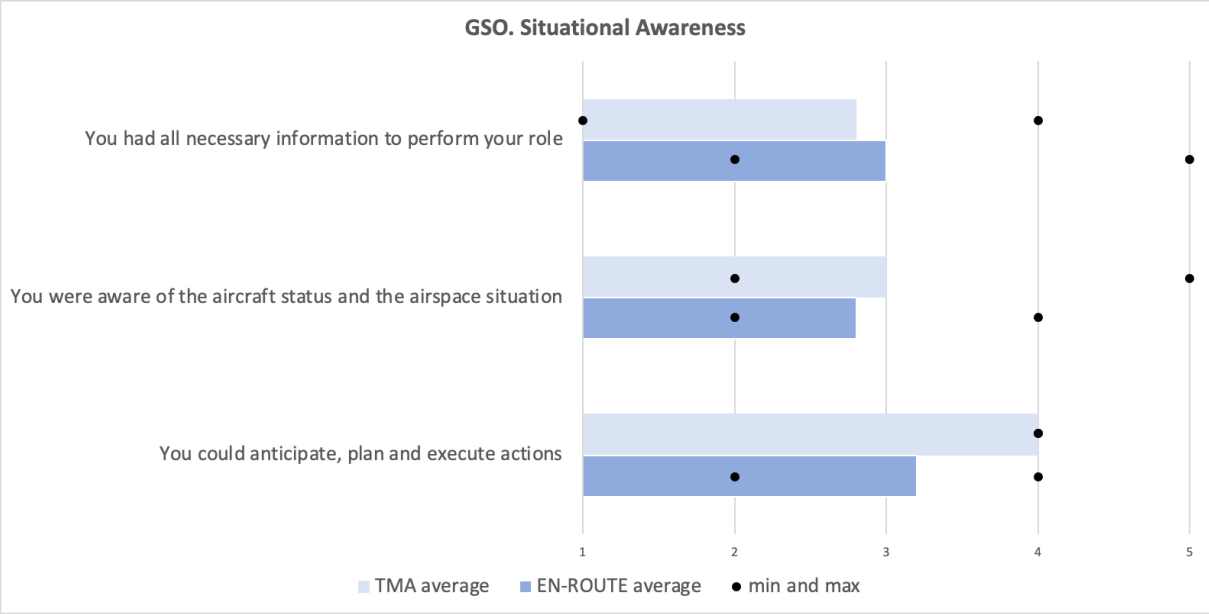

Figure 13: Pilots Situational awareness level in the two scenarios

Situational awareness level was further explored during the post-session questionnaire, where participants were asked to rate the type and quality of information received from all the actors involved, and from the HMI.

As immediately visible from Figure 14, the poor evaluation on SA mostly depended on the limited and missing information provided by the GS interface (e.g.,), and on the unfamiliarity with the GS itself. This topic will be further discussed in the Technical support systems and Human-Machine Interface section. On the contrary, the type and quality of the information provided by the human actors (i.e., ATCO, Cruise-GSO and NOC) was positively evaluated by the pilots involved. As said, looking at the (remote) pilot-ATCO relationship, the SAFELAND concept did not introduce many differences compared to the actual emergency procedures, therefore the information received from ATC corresponded to pilots' expectations. Considering the exchange between GSOs (En-Route scenario), this consisted in the handover procedure, where the Cruise-GSO transfers the emergency aircraft to the Stand-by GSO. Despite the novelty of the process, all pilot participants agreed that the information exchange was satisfactory for them to perform their tasks. The topic of coordination and communication between human actors will be further discussed in the Team structure and Team communication section.

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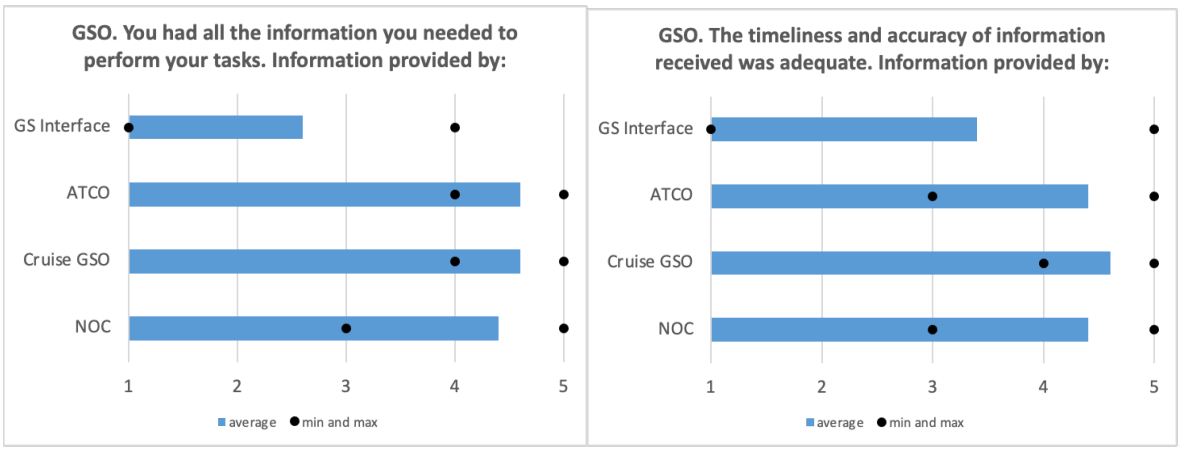

Figure 14: Pilots rating on information type (left) and information quality (right)

Looking at the ATCOs' feedback, the rating on situational awareness also returned mixed results, but the trend was positive as shown Figure 15.

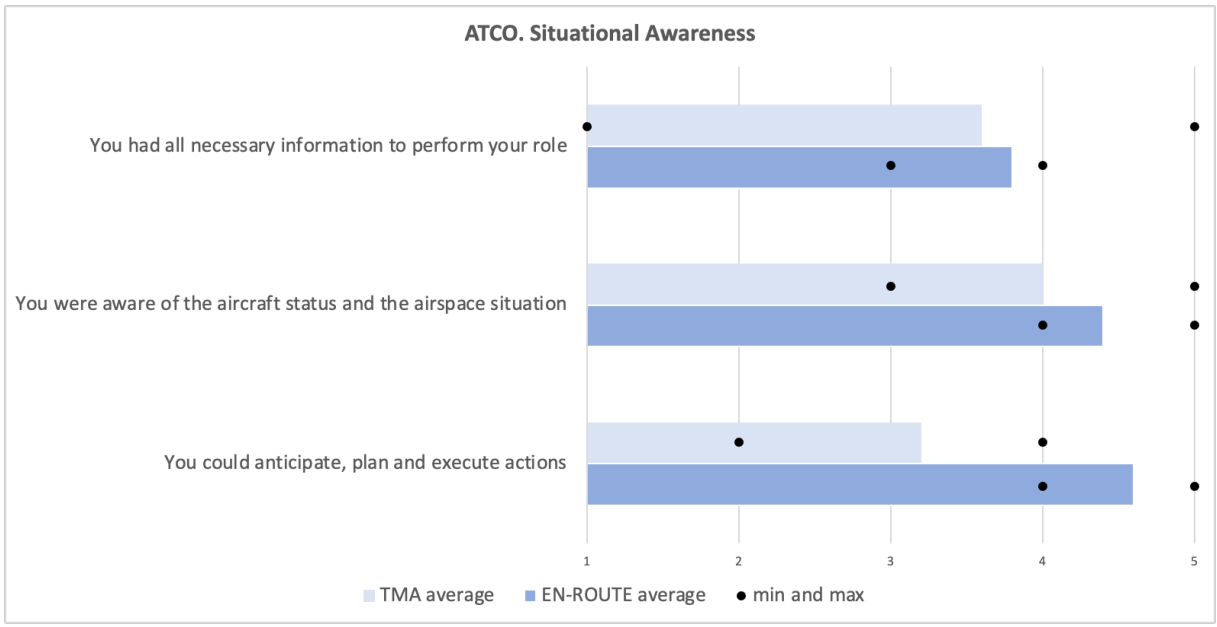

Figure 15: ATCO Situational awareness level in the two scenarios

Similarly to pilots, the majority of ATCO participants explained that low ratings depended on the limitations of the CWP used for the RTS (Figure 16) (e.g., missing labels on some aircrafts, limited input possibilities on the CWP, lags, bugs). Nevertheless, one ATCO affirmed that the current CWP was good enough to create adequate Situation Awareness to address the emergency of single pilot incapacitation. New technical support systems that can enhance SA were identified by the ATCOs during the debriefing and they will be further discussed in the Technical support systems and Human-Machine Interface section. Regarding information quantity and quality provided by the GSO and how those influenced the ATCOs' SA, results returned good ratings (Figure 16).

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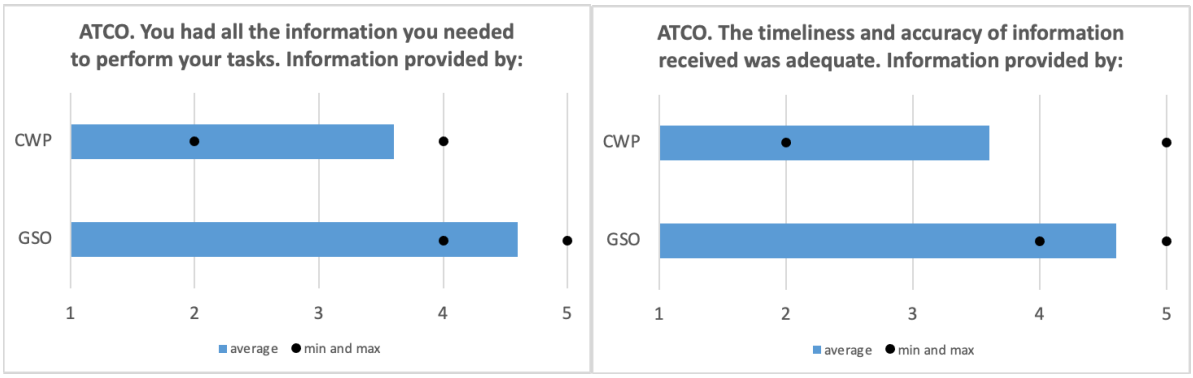

Figure 16: ATCO rating on information type (left) and information quality (right)

3.1.1.6 Workload

Pilots' concerns regarding their high level of workload (Figure 17) mostly depended on the missing and limited information provided by the GS, together with the perceived limited capabilities of the GS itself (i.e., lack of manual control possibilities). A pilot specified that, during initial approach on high altitude, workload was high due to the GSO inability to keep the planned flight path. Such an issue was related to the aircraft speed and to the slow aircraft reaction to pilot's inputs. Also, the unfamiliarity with some procedures and with the HMI played a role, being the remote station a completely new environment for the pilots.

Another contributing factor invoked by some participants to affect workload level was strictly related with the characteristics of the GSO role and the related responsibilities. As a pilot affirmed, the level of workload was in fact too high due to the GSO being the "*only pilot having to generate the information, rate the information, take the decision and then execute those decisions all by himself, with no possibility to cross-check the decisions with a second pilot*".

Some participants mentioned that during the following phases they experienced peaks of higher workload: handover between Cruise- and Stand-by GSO; the new destination airport selection phase; the insertion of a new flight plan on the GS.

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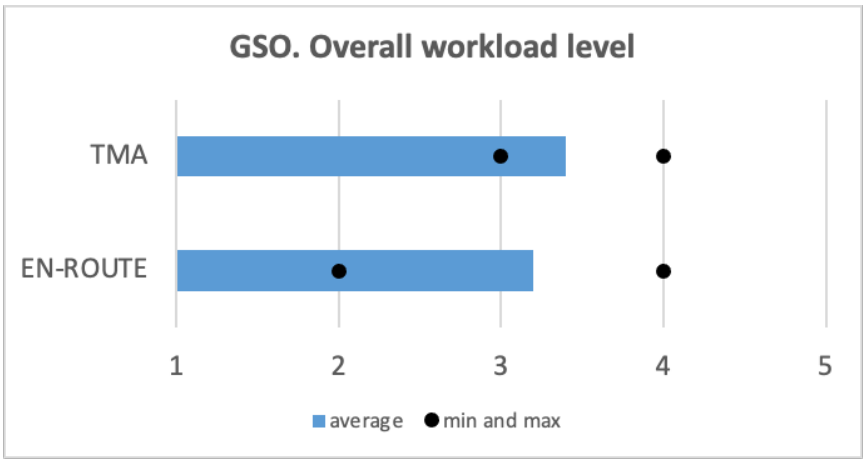

Figure 17: Pilots workload level in the two scenarios. 1= low WL, 5= high WL

As described by the plot above (Figure 18), ATCOs' level of workload remained low during the En-Route scenario, while higher workload was experienced during the TMA scenario. These results have been explained by mentioning the following aspects: the TMA was the first scenario experienced, so participants were less familiar with the procedures; in the TMA scenario incapacitation occurs in a time-critical phase; participants were not familiar with the approach procedures for Düsseldorf. All ATCOs also mentioned the software instability as a major contributing factor to the high workload level.

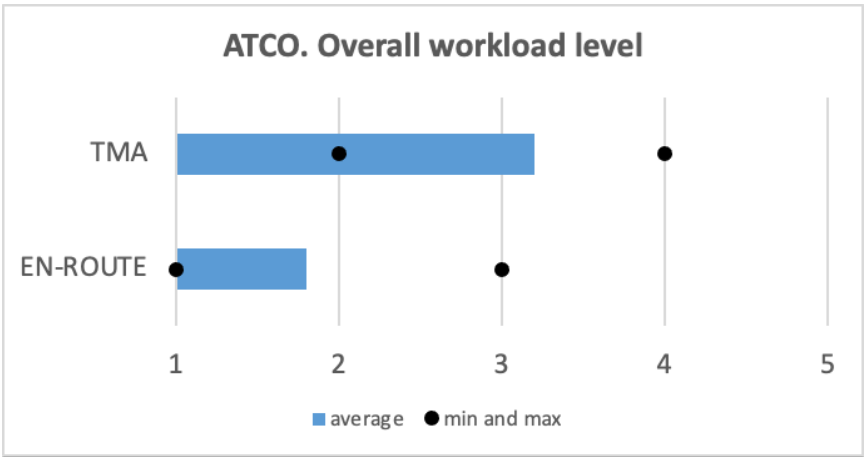

Figure 18: ATCO workload level in the two scenarios. 1= low WL, 5= high WL

3.1.2 Technical support systems and Human-Machine Interface

Regarding technical support systems and Human-Machine Interface, both pilots and ATCOs expressed some concerns.

Those concerns cover both the limitations of the prototype used to simulate the GS (limitation of the RTS) together with the new operation modalities envisioned by the SAFELAND concept which were

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seen as a limitation by some of the pilots (i.e., advanced use of automation despite using manual controls).

Regarding the GS, most of the pilots commented that ideally the GS should replicate what there is in the real cockpit. All pilots lamented a lack of information provided by the GS prototype used for this RTS campaign. The following is a list of items mentioned by the pilots, including:

- A very low Roll Rate/Bank of the A/C;
- No indication of LOC/GS (ILS) on the PFD (Primary Flight Display);
- No clear, separate indication of status of Flaps and Gear-Position;
- No indication about the distance/Time to the airport;
- No indication of distance/Time to be flown between the waypoints;
- Database of the Simulator was old (Charts provided to the pilots did not match the routing in the FMS);
- After selecting a "Direct To" Waypoint in the FMS the speed reverted to managed mode although it was selected to manual before, which resulted in unexpected speed changes;
- It was hard to spot the A/C on the Moving Map, as it was almost fully blocked by the tag with the information about the A/C;
- The Flight Director on the PFD showed wrongly, or moved very time-delayed to the correct position.

This lack of information negatively affected pilots' situational awareness during the simulation exercise (see Situational Awareness section), sometimes resulting in higher workload.

Pilots were also asked to identify possible **additional technical support systems** which might be included in the SAFELAND concept in order to enhance remote pilots' situational awareness. A system often mentioned was a **camera** inside the cockpit. This would be beneficial to confirm the on board pilot incapacitation, retrieve more information on the actual status of the on board pilot and, possibly, uncover the reasons for the incapacitation. Moreover, a camera could support the operations in the nominal case as well, giving the two pilots (on board and on the ground) the possibility to see each other and the feeling of being a crew. Nevertheless, not every participant was comfortable with the idea of having a camera always on, suggesting a system that could be switched on "on request".

Additionally, a pilot mentioned the possibility to have a **shared audio** environment between the GS and the cockpit (i.e., auto-microphone switched "on" when the incapacitation happens). This would enhance the GSO awareness of both the on board pilot conditions and the aircraft status.

Two pilots also suggested that an on-request **outside camera** system might also be useful to check weather conditions. Nevertheless, no one mentioned this as a strict requisite to operate an aircraft from the ground.

During debriefing, pilots also expressed some concerns on the transparency and explainability of the automation. They pointed out the lack of real-time feedback from the aircraft automation "*Also to have a visual indication when the autopilot changes its modes, also the speed modes and so on… like indication that the autopilot is changing the modes in the time it gives the indication*". Moreover, pilots mistrusted the system's redundancy and reliability and lamented the lack of manual control possibilities, with *most of the tasks* of the pilots being replaced by automation. Such concerns reflect

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the low rating given by pilots to the acceptability of task allocation between the GSO and the automation, as shown in Figure 19 below. The graph also shows pilots' evaluation on the usability of the user interface (input devices, visual displays/output devices, alarm & alerts). Similarly, results returned low ratings mostly due to the limitation of the GS (e.g., use of the mouse to insert inputs, latency issues in updating flight plans and visualisation of aircraft status, slow upon changes inserted, malfunction/instability of the software).

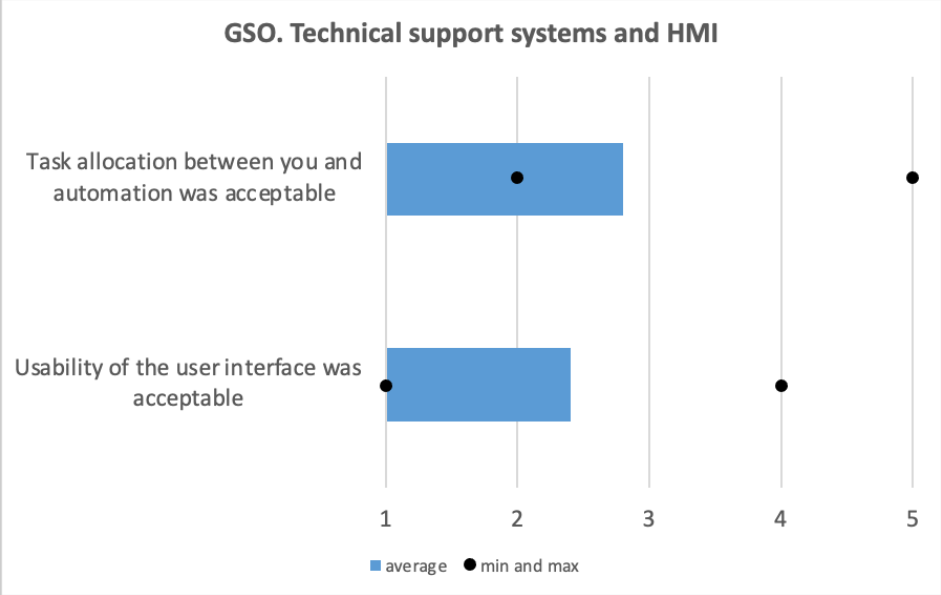

Figure 19: Pilots ratings on task allocation between GSO and automation and Usability of the HMI

From the ATCOs' side, comments regarding the technical support systems and HMI were all about the limitations of the CWP used during the RTS which affected ATCOs' SA during the simulation (see also Situational Awareness subsection).

Some ATCOs also specified new possible technical support systems that might be introduced in the future CWPs to improve ATCOs' SA in the event of single pilot incapacitation. An ATCO suggested labels of different colours to underline the type of operations (i.e., dual-piloted vs single-piloted aircraft). An ATCO suggested that other operational information (e.g., remaining fuel, number of people on board) might be sent automatically by the aircraft and displayed on the CWP with special labels (e.g., "*expanded labels*"). This, in turn, would reduce both GSO and ATCO's workload.

3.1.3 Team structure and Team communication

3.1.3.1 Communication

As already described in the Situational Awareness subsection, all pilot and ATCO participants positively evaluated the exchange of information that occurred between all the human actors involved in the simulation exercise. As said, both the type and quality of information received were perceived as adequate to perform the assigned tasks and handle the emergency (see Figure 14 and Figure 16).

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The Figure 20 below describes in detail how pilots rated the effectiveness and efficiency of the communication between them and the other actors involved in the two scenarios, namely the ATCO in both the TMA and En-Route scenarios, the NOC and the Cruise-GSO in the En-Route one.

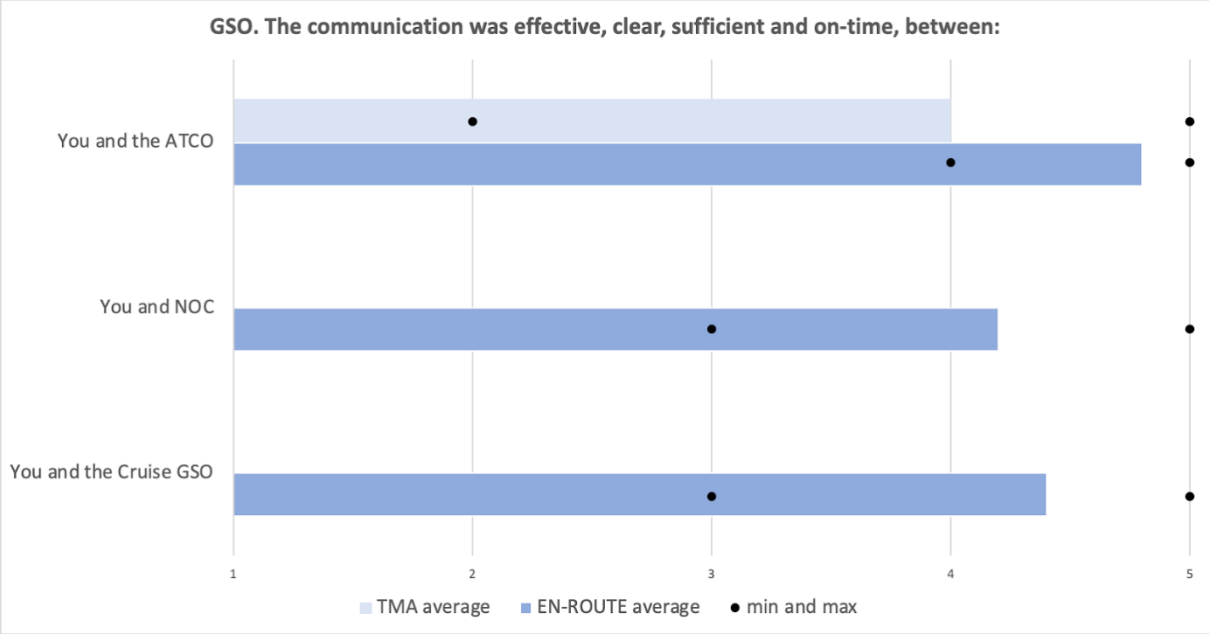

Figure 20: Pilots rating on effectiveness and efficiency of the communication between them and the other actors involved in the two scenarios

During the debriefing, pilots defined the communication and coordination with the other actors as straightforward. Specifically, the communication and interaction with the ATCO was considered good, and very similar to current operations. The communication with the Cruise GSO during the handover process was defined as clear, short and efficient. Finally, some concerns were expressed regarding the communication with the NOC. As already mentioned, in fact, some pilots affirmed that the role of the NOC during the simulation was not clear, and the interactions in some cases were judged as too different from reality.

In terms of phraseology, the participants were tasked to use the current/standard phraseology between pilots and ATC whenever possible. However, some slight adaptations were proposed in the context of SPO, e.g using "**remote**" by the GSO to remind the ATCO that the a/c is controlled from the ground.

As said in section 2.2.3.2.3, during the simulation exercise, participants were not required to use a specific phraseology to communicate with the other actors involved apart from some slight adaptations (i.e., while communicating with the ATCO, GSOs were asked to identify themselves as "remote" to remind the ATCO that the a/c was controlled from the ground). However, during debriefing a pilot reported the need for more precise communication procedures and standard phraseology in the context of SPO operations and its abnormal or degraded modes.

All ATCO participants agreed that the communication flow and the coordination with the other actors was very good, in both the scenarios executed during the simulation (Figure 21). During the debriefing,

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all ATCOs affirmed that the communication was as in current operations (timely, clear, and sufficient). The main difference compared to current operations was the new communication interaction between ATCO and GSO. An ATCO specified that, as in every emergency situation, even during the single pilot incapacitation communication should be the least priority. In this regard, another ATCO confirmed that his approach consisted in not interfering with the GSO decision making process, but waiting to be contacted by the GSO in order to give all the necessary information, when needed. Communication during the simulation was also influenced by timing, since according to the ATCOs the simulation was much faster than real life operations. Some participants mentioned possible delays in communication as an important factor to be taken into account in real life operations.

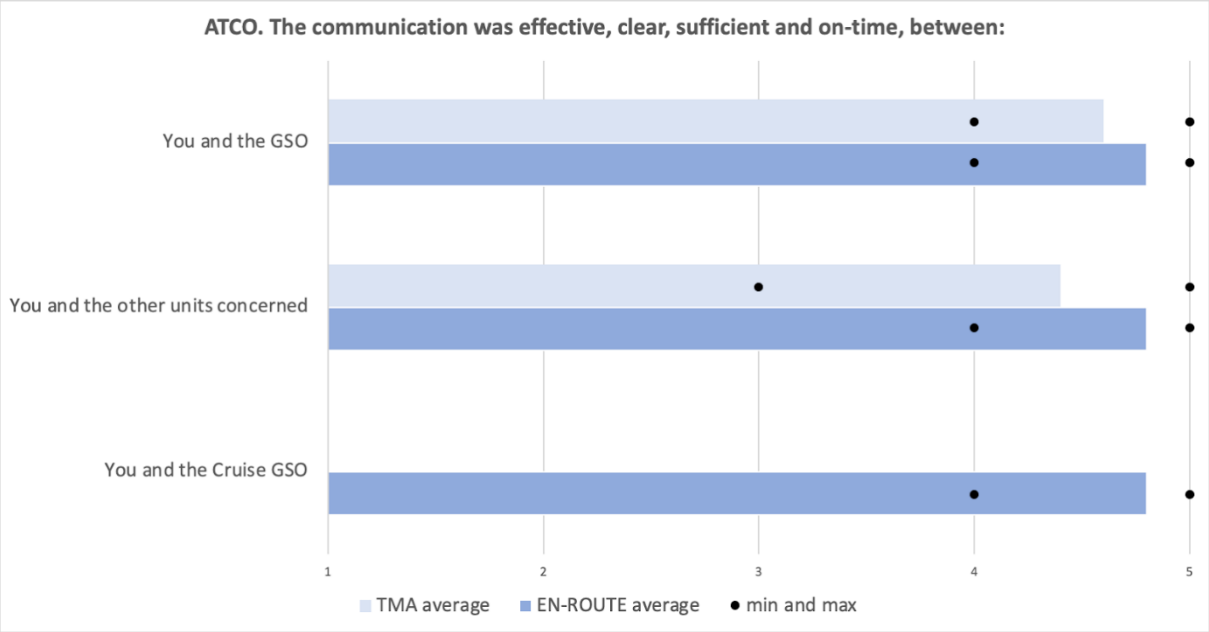

Figure 21: ATCOs rating on effectiveness and efficacy of the communication between them and the other actors involved in the two scenarios

3.1.3.1.1 Task allocation

Overall, task allocation between the GSO and the other human actors involved in the simulation was considered good by all pilot participants, with some concerns regarding the NOC role (see Clarity of roles and responsibilities and Communication sections). Pilots were also asked to evaluate if any extra help would be needed to handle the emergency from the GS. Three pilots affirmed that having a second person on the ground would be beneficial to better manage the situation. As already mentioned, in fact, pilots suffered for not being able to share a mental model with another crew member, as in current dual pilot operations. An additional person would allow an improved and more effective decision making process, and it would help in better monitoring the aircraft and managing possible high workload situations (see also Hazards identification section).

Regarding ATCOs' task allocation, no specific matters arose during the debriefing, since no changes were made on ATCOs' side regarding this aspect.

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3.2 Hazards identification

As already pointed out at the beginning of this chapter, participants' rating on the perceived level of safety during the two scenarios returned mixed results, with a negative trend for pilot participants (average:2,6, min:2, max:4 - See Figure 7), and a positive trend for the ATCOs (average:4,2, min:4, max:5 - see Figure 8).

- During the debriefing, pilots argued that their perceived level of safety was affected by:
- Limited amount of information available in the GS prototype (see Technical support systems and Human-Machine Interface section);
- Lack of manual control possibilities;
- Mistrust in the reliability and effectiveness of the automated system, and
- Possibility of other hazardous situation that might occur during the emergency, especially those that can not be addressed from the ground (e.g., severe weather conditions or technical failures) and therefore would require additional automation.

In this regard, an ATCO affirmed that *"in the approach phase there are quick decisions that the pilot should take as for example land or go around. Is the automation able to make these quick decisions to avoid wind shears for example? "*. Finally, some pilots were concerned regarding the conditions of the incapacitated pilot. The impossibility to retrieve additional information on his/her health status and possibly know the causes of the incapacitation, affected participants' level of perceived safety.

Participants were also asked to compare their perceived level of safety of the SAFELAND concept with current operations, in case of pilot incapacitation. According to one pilot, the perceived level of safety was mostly affected by the feeling of not being aware and in complete control of the aircraft. Accordingly he specified that he "would have been more comfortable being alone in the cockpit compared to being alone as GSO on the ground". Another pilot affirmed that the feasibility of the SAFELAND concept strictly depends on the future implementation of safety procedures and mitigation measures that can guarantee the same (or higher) safety levels, together with a system that in the future should be redundant.

Although the RTS participants did not experience any other emergency or failures apart from the incapacitation event, at the end of the debriefing they were asked to identify any other potential hazards for the concept and propose possible mitigation solutions.

Among technical hazards, participants mentioned engine failure, automation failure, and other technical failures that currently cannot be addressed from the ground since they need a physical intervention on the aircraft. Regarding communication, the main risks addressed were the loss of data link between the GSO and the aircraft, or the failure of other communication means. Communication latency was also considered as a potential risk factor. Other hazards pointed out were adverse weather (e.g., windshear, severe turbulence) and fire on board ("*Worse case scenario is if the pilot incapacitation is caused by fire on board. How to check if the fire is extinguished?*").

Regarding mitigations, according to both groups, pilots and ATCOs, advanced automation capabilities should cover the majority of the hazards that might happen during single pilot incapacitation. The communication failure between the aircraft and the GS would require systems in place to make the aircraft able to autonomously follow the flight plan and land automatically without any input from

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ground. Having multiple data link connections available would also create redundancy, helping to mitigate the risk.

An additional threat mentioned by some participants was connected to the capabilities of the pilot incapacitation detection system. In fact, it was argued that not every type of incapacitation can be detected through the monitoring of physiological parameters, and a non-detected subtle incapacitation might jeopardise the flight as well. To mitigate this, participants highlighted the importance of being able to communicate with the on-board pilot during the flight, and with the cabin crew members. It was also mentioned that having cameras on board would be beneficial to monitor the health status of the pilot.

Cyber security risks were also mentioned by a participant as a source of possible hazard. The main concern regarded the risk of a possible external hostile takeover of the aircraft through the GS. To mitigate this, multiple stable connections are required between the GS and the aircraft.

Participants also identified situations that might induce human errors. The main concern relied on the GSO being alone while handling the emergency situation. Not sharing the mental model with a second person might indeed affect the effectiveness of the decision-making process, and this can lead to human errors and hazardous situations. Specifically, participants were concerned regarding the missing cross-check of information between crew members (as in current dual-pilot operations) while making decisions in time-critical situations. As a mitigation, participants suggested that having a second person on the ground supporting the GSO could limit the possibility for human errors. In general, it was argued that working in a team with other actors would definitely increase the safety of the flight.

Other possibilities for human errors can result from the GSO not being physically located inside the aircraft. Being on the ground, the GSO lacks the sensory cues that normally improve the pilot awareness of the aircraft status and of the operating environment. Possible mitigations include additional technological systems (e.g., cameras and microphones onboard allowing to share the cockpit environment with the GS) and operational aspects (e.g., the introduction of a second GSO to better monitor the aircraft parameters during an emergency).

In terms of GSO competencies, it was broadly recognized that having a GSO who is a certified pilot would highly increase the safety of operations.

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4 Conclusions and recommendations

4.1 Unexpected Behaviours

During the 5 days of RTS conducted at DLR there were no unexpected behaviours from both pilots and ATCOs. The briefing carried out at the beginning of each RTS helped to minimise the risk of having participants who were not confident with the concept, with their role and responsibilities and with the different procedures envisioned by the SAFELAND concept (i.e., handover process, incapacitation detection, airport diversion…). Moreover, all the participants were trained over the simulation platforms constraints and adaptations.

4.2 Confidence in the Results

Due to the limited number of participants involved in the RTS campaign (5 pilots and 5 ATCOs), most of the data collected during the RTS were qualitative ones. To carry out the Human Performance assessment and concept evaluation, 3 Human Factors experts were involved during the RTS campaign to perform observations of participants behaviours, carry out the debriefing (using a semi-structured form), and administer questionnaires. After the RTS campaign, the qualitative data collected were systematically merged, synthesised, and analysed using standard research practices to improve data reliability (i.e., *Thematic Analysis Methodology*). The quantitative data collected through the questionnaire (ratings from the post-run questionnaires after each run and the post-session questionnaires at the end of the simulation session) were analysed using simple data visualisation techniques and were used in combination with the qualitative ones to constitute compelling arguments over the research findings and objectives. This mixed approach helped to overcome the limitations of having a low number of participants for the experiment, enhancing at the same time the reliability of the data collected during the test campaign.

4.3 Summary of the findings

Below is reported a summary of the findings per validation objectives.

4.3.1 Operational Feasibility (V01)

All the participants reported a good evaluation of the SAFELAND concept, especially considering the operating methods and the dynamics between actors. However, it was identified that the concept acceptability and feasibility mostly depend on future technological implementations, on the technical features and equipment rate reliability, and on the implementation of safety procedures and mitigation measures. All these aspects are strictly connected to the implementation of SPO for commercial aviation that will constitute the framework on which the development of the SAFELAND Concept is based.

4.3.2 Human Performances (V02)

Roles and responsibilities (Clarity and Acceptability)

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All ATCOs participants understood their role and the roles of the other actors involved in the concept. ATCOs acceptability over their role and responsibilities returned positive opinions. These results mostly depended on the SAFELAND concept not envisioning new or different ATCO responsibilities compared to current operations.

Regarding pilots' acceptability of their role and responsibilities, results were generally positive, with however high variability in the answers. Negative evaluations mostly referred to the limitations imposed by the experiment to the GS capabilities (see section Roles, responsibilities, operating method and human tasks). In this regard, new requirements for the technical support systems were identified by the participants to improve the GS (see section Technical support systems and Human-Machine Interface). Positive results were obtained regarding pilots' clarity of roles and responsibilities, with some concerns regarding NOC's role (see also section Procedures).

Operating procedures

Pilots' evaluation of the operating procedures returned mixed results, with a positive trend. During the debriefing, pilots defined the operating procedures as straightforward, including the handover process between the Cruise and the Stand-By GSOs (EN-ROUTE scenario). From the evaluation, it emerged that the efficiency of carrying out their tasks, and the acceptability of the new procedures envisioned depended on the technical support systems provided to the GSO, including higher levels of automation, further technological implementations, their redundancy and reliability. Pilots concerns over the technical support systems and the HMI provided to them during the simulation also affected their ability to accomplish tasks such as navigating and managing, compared to current operations. On the contrary, pilots reported a good evaluation over communication, which was considered as effective. The decision-making process was also considered effective. Nevertheless, pilots suffered for not being able to share a mental model with another crew member, as in current dual pilot operations.

The SAFELAND concept did not envision many changes in the ATCOs' tasks, therefore the operating procedures experienced during the RTS were defined as clear.

Situation Awareness and Workload

The information type and quality provided to pilot participants by the other human actors involved in the concept was considered adequate to accomplish their tasks. Nevertheless, the level of situational awareness experienced was negatively affected by the limitation of the GS, specifically by the lack of information provided. As a consequence of this, and in combination with the perceived limited capabilities of the GS itself (i.e., lack of manual control possibilities), pilots' workload level was also affected.

ATCO's level of SA was generally good, with most of the negative comments focused on the limitations of the CWP used for the simulation. In general, ATCOs considered the information provided by the CWP and by the other actors involved sufficient to handle the emergency. Some improvements to the HMI and new possible support systems were also identified to increase the quantity/quality of the information provided (see section Technical support systems and Human-Machine Interface).

Finally, ATCOs perceived their workload level as acceptable, lower in the EN-ROUTE scenario than in the TMA scenario. This result mostly depended on the unfamiliarity with the approach procedures for

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Düsseldorf airport, and on the higher time criticality of the Approach phase compared to the Cruise one.

Technical support systems and Human-Machine Interface

As pointed out before, both ATCOs and pilots expressed concerns on the systems experienced during the RTS. This aspect affected participants evaluation of some key aspects of the SAFELAND concept (i.e., acceptability of their role and responsibilities, SA, workload). Nevertheless, requirements for both the GS and the CWP were identified, together with new technologies that could be implemented to enhance SA and improve workload (see section Technical support systems and Human-Machine Interface).

Team structure and communication

All pilot and ATCO participants defined communication as timely, clear, sufficient, and straightforward during all the flight phases and with most of the human actors involved. The dynamic of interactions and the coordination between team members were considered adequate to accomplish the assigned tasks.

Regarding team structure, ATCO participants did not express any concerns. By contrast, some pilots were uncomfortable by not having the support of a second pilot on which to rely to make decisions and share the same mental model.

Tasks allocation

Overall, tasks allocation was considered adequate by all the involved participants (both ATCOs and pilots). As said, some pilots suggested that having an additional person supporting their tasks from the ground would improve the safety of the operations.

4.3.3 Safety (V03)

ATCOs were more confident on the safety level of the system than pilots. Again, pilots' evaluation was affected by the limitations imposed to the GS by the experiment, by their feeling not to be in full control of the aircraft, and by not being part of a two-pilot crew. Possible hazards were identified that could affect the safety of operations and would require the presence of new additional systems to be mitigated (see section Hazards identification).

4.4 Insights and recommendations

Overall, the RTS campaign returned a positive evaluation of the SAFELAND CONOPS, with some issues mostly related to the technology in place.

Most importantly, the involved participants positively evaluated the operating procedures implied by the concept, especially referring to the dynamic of interactions between team members, and to the coordination and communication flow.

However, as already mentioned at the beginning of the Results chapter, pilot participants faced several challenges while experiencing the SAFELAND Concept. First, they were asked to rely on systems and

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technologies still not implemented in civil aviation. Second, they were introduced to a new environment (the GS) with a completely different modality of operation (no manual control). Finally, after the on-board pilot incapacitation, they were asked to handle the emergency alone, as *single remote pilots*, a condition unfamiliar to them used to work in a team of two.

These aspects had a major impact on pilots' assessment, especially considering the evaluation of the technology in place in relation to the tasks to be accomplished, safety aspects and a general trust in the concept. However, some of these aspects are only partially connected with the SAFELAND Concept itself, being in fact much more related to the implementation of SPO for commercial aviation. Future research will uncover whether the procedures envisioned by SAFELAND will be compatible and applicable to the broader SPO CONOPS and to what extent improvement in technology will support our Concept.

From the ATC perspective, the SAFELAND concept was built "on purpose" to minimise the impact on ATC. By design, since the GSO acts as an RPAS pilot, the SAFELAND concept was globally found acceptable and feasible by the five the ATCOs participating in the simulation.

However, only full incapacitation in “nominal cases'' was tested (e.g., no additional failures, no partial incapacitation assessment) and assuming strong requirements in terms of technical features and equipment rate (e.g., 100% datalink, no delay in C2link communication). Therefore, additional use cases need to be assessed for further maturing the concept, such as:

- latency of communication (even more if the Approach GSO is located far away from destination airport).
- Unexpected events: late go around, change of destination airport, possible failure induced by the new systems.

Moreover, the SAFELAND project only focuses on a limited scope: i.e., from incapacitation confirmation until landing. Further assessment may be needed to address larger scope, such as:

- Transition period from nominal case (SPO without incapacitation) and incapacitation confirmation. Indeed, within this “grey area” a lot of events could happen (depending on the duration) that could severely impact safety (e.g., what if a depressurization leads to pilot incapacitation, how to limit this time period?).
- Ground handling: how to free the runway up once the aircraft has landed not to block/stop airport operations?
- Partial and temporary incapacitation.
- Role of the cabin crew.

4.5 Next steps

The RTS campaign is inscribed in a broader evaluation process that is also including the following activities:

- Low-fidelity simulation (already described in D2.4 - *Integration Report [15]*)

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- Workshops with internal SMEs aiming at further assessing the safety, cyber security, legal, regulatory, and economic aspects related to the SAFELAND concept
- Workshop with internal and external SMEs (i.e., the SAFELAND Advisory Board) aiming at discussing the results of the evaluation activities and collecting final feedback and next steps towards implementation.

A comprehensive description of all findings will be included in deliverable D3.4 – *Final Evaluation Results*, to be delivered at the end of July 2022.

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5 References

[1]. SAFELAND Project (2019). SAFELAND Proposal.

[2]. SAFELAND Project (2021a). Evaluation Plan Part 1 & Part 2. SAFELAND D3.1.

[3]. SAFELAND Project (2020). Final Concept. SAFELAND D1.4.

[4]. SAFELAND Project (2021b). Legal, Regulatory and Economy constraints. SAFELAND D1.3.

[5]. SAFELAND Project (2021c). Preliminary Results. SAFELAND D3.2.

[6]. SAFELAND Project (2022a). Adaptation of Controller Working Position. SAFELAND D2.1.

[7]. SAFELAND Project (2022b). Adaptation of Cockpit simulator. SAFELAND D2.2.

[8]. SAFELAND Project (2022c). Adaptation of Remote Cockpit simulator SAFELAND D2.3

[9]. Stanton, N. A., Harris, D., & Starr, A. (2016). The future flight deck: Modelling dual, single and distributed crewing options. Applied Ergonomics, 53, 331-342.

[10]. Lim, Y., Bassien-Capsa, V., Ramasamy, S., Lui, J. & Sabatini , R. (2017). Commercial Airline Single-Pilot Operations: System Design and Pathways to Certification, IEEE Aerospace and Electronic Systems Magazine. vol. 32, pp. 4-21. DOI: 10.1109/MAES.2017.160175

[11]. Schmid D., Korn B., A tripartite concept of a remote-copilot center for commercial single-pilot operations, AIAA Information Systems-AIAA, Infotech@ Aerospace, 2017

[12]. EUROCAE (2020). Minimum Aviation Systems Performance Specifications for Remote Pilot Stations Conducting IFR Operations In Controlled Airspace

[13]. International Civil Aviation Organization (ICAO) (2015). ICAO Doc 10019 Manual on Remotely Piloted Aircraft Systems (RPAS). 1st Edition. ISBN 978-92-9249-718-7

[14]. ICAO, Manual of Civil Aviation Medicine, DOC 8984, 2012

[15]. SAFELAND Project (2022d). Integration Report SAFELAND D2.4

Appendix A Data gathering

A.1 Questionnaire items

POST-RUN TMA GSO	POST-RUN TMA ATCO	POST-RUN EN-ROUTE GSO	POST-RUN EN-ROUTE ATCO	POST-SESSION GSO	POST-SESSION ATCO
1. Your role and responsibilities were clear	1. Your role and responsibilities were clear	1. Your role and responsibilities were clear	1. Your role and responsibilities were clear	1. The training received before the runs was sufficient to understand the procedures and perform your role	1. The training received before the runs was sufficient to understand the procedures and perform your role
2. The responsibilities of the other roles were clear: [ATCO]	2. The responsibilities of the Approach GSO were clear to you	2. The responsibilities of the other roles were clear: [Cruise GSO]	2. The responsibilities of the other roles were clear: [Cruise GSO]	2. Your role and responsibilities were acceptable	2. Your role and responsibilities were acceptable
2. The responsibilities of the other roles were clear: [NOC]		2. The responsibilities of the other roles were clear: [ATCO]	2. The responsibilities of the other roles were clear: [Stand-by GSO]		
	3. You were able to handle the other traffic in an effective and safe way while managing the emergency aircraft	2. The responsibilities of the other roles were clear: [NOC]		3. The task allocation between you and automation was acceptable [Rate]	
3. The communication			3. The decision on new		

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was effective, clear, sufficient and on-time, between: [You and the ATCO]			destination airport was made within an acceptable timeframe		
3. The communication was effective, clear, sufficient and on-time, between: [You and NOC]	4. The communication was effective, clear, sufficient and on-time, between: [You and the Approach GSO]	3. The handover between Cruise GSO and Stand-by GSO was performed within an acceptable timeframe		4. The procedures were clear	3. The procedures were clear
	4. The communication was effective, clear, sufficient and on-time, between: [You and the other units concerned]		4. You were able to handle the other traffic in a effective and safe way while managing the emergency aircraft		
4. Rate your overall level of Situational Awareness during the scenario: [You had all necessary information to perform your role]		4. The decision on new destination airport was made within an acceptable timeframe		5. The procedures were acceptable	4. The procedures were acceptable
4. Rate your overall level of Situational Awareness during the scenario: [You were aware of the aircraft status and the	5. Rate your overall level of Situational Awareness during the scenario: [You had all necessary information to perform		5. The communication was effective, clear, sufficient and on-time, between: [You and the Cruise GSO]		5. You were able to perform your tasks as in current operations [Monitoring]

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airspace situation]	your role]				
4. Rate your overall level of Situational Awareness during the scenario: [You could anticipate, plan and execute actions]	5. Rate your overall level of Situational Awareness during the scenario: [You were aware of the airspace situation]	5. The communication was effective, clear, sufficient and on-time, between: [You and the Cruise GSO]	5. The communication was effective, clear, sufficient and on-time, between: [You and the Stand-by GSO]	6. You were able to perform your tasks as in current operations [Navigate]	5. You were able to perform your tasks as in current operations [Manage traffic]
	5. Rate your overall level of Situational Awareness during the scenario: [You could anticipate, plan and execute actions]	5. The communication was effective, clear, sufficient and on-time, between: [You and the ATCO]	5. The communication was effective, clear, sufficient and on-time, between: [You and the other units concerned]	6. You were able to perform your tasks as in current operations [Communicate]	5. You were able to perform your tasks as in current operations [Conflict detection and resolution]
5. Rate your overall level of Workload:		5. The communication was effective, clear, sufficient and on-time, between: [You and NOC]		6. You were able to perform your tasks as in current operations [Manage]	5. You were able to perform your tasks as in current operations [Coordination]
	6. Rate your overall level of Workload:		6. Rate your overall level of Situational Awareness during the scenario: [You had all necessary information to perform your role]		
		6. Rate your overall level of Situational Awareness during the scenario: [You had all necessary information to perform	6. Rate your overall level of Situational Awareness during the scenario: [You were aware of the airspace situation]	11. Rate your overall level of trust in the concept	9. Rate your overall level of trust in the concept [Rate]

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		your role]			
		6. Rate your overall level of Situational Awareness during the scenario: [You were aware of the aircraft status and the airspace situation]	6. Rate your overall level of Situational Awareness during the scenario: [You could anticipate, plan and execute actions]		
		6. Rate your overall level of Situational Awareness during the scenario: [You could anticipate, plan and execute actions]		7. You had all the information you needed to perform your tasks [Information provided by the ground station interface]	6. You had all the information you needed to perfom your tasks [Information provided by controller working position]
			7. Rate your overall level of Workload:	7. You had all the information you needed to perform your tasks [Information provided by the ATCO]	6. You had all the information you needed to perfom your tasks [Information provided by the GSO]
		7. Rate your overall level of Workload:		7. You had all the information you needed to perform your tasks [Information provided by Cruise GSO]	
				7. You had all the information you needed to perform your tasks	

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				[Information provided by NOC]	
				8. The timeliness and accuracy of information received was adequate to perform your tasks [Information provided by the ground station]	7. The timeliness and accuracy of information received was adequate to perform your tasks [Information provided by controller working position]
				8. The timeliness and accuracy of information received was adequate to perform your tasks [Information provided by the ATCO]	7. The timeliness and accuracy of information received was adequate to perform your tasks [Information provided by GSO]
				8. The timeliness and accuracy of information received was adequate to perform your tasks [Information provided by Cruise GSO]	
				8. The timeliness and accuracy of information received was adequate to perform your tasks [Information provided by	

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				NOC]	
				9. The usability of the user interface (input devices, visual displays/output devices, alarm & alerts) was acceptable.	
				10. Your perceived level of safety during the scenarios was acceptable	8. Your perceived level of safety during the scenarios was acceptable

Table 6: Post run and Post session questionnaires' items

A.2 Debriefing items

Areas / Sub-areas	N°	GSO	ATCO
Opening question	1	Do you think that the operational concept experienced during the simulation is acceptable? Do you think it is feasible?	SAME QUESTION FOR ATCO
Roles / Responsibilities	2	Were you comfortable in being responsible for the flight safety?	NO
Task allocation	3	Task allocation was okay (take into consideration different tasks for example landing, airport decision)? Extra help needed?	NO

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Operating procedures	4	Regarding navigate and manage the flight: - How was your ability to manage your tasks? - How was the effectiveness of decision making procedures? - Were there any issues navigate and manage the aircraft?	NO
Operating procedures	5	NO	Did you perceive any changes in your role and responsibilities? If yes, are these changes in your responsibilities acceptable?
Team structure and communication	6	How was coordination and communication between you and the other actors? Was it timely, clear, sufficient? Information flow and synchronization? Were there overload problems?	SAME QUESTION FOR ATCO
Situational Awareness	7	Regarding Situational Awareness: what other information (from HMI, from other actors) do you need? What other tool (e.g., cameras) do you need? Do you have any suggestions to improve the system? (e.g., how info is displayed, timing of info) What info should be shared between cruise and stand-by GSO to increase levels of SA for the stand-by GSO?	SAME QUESTION FOR ATCO
Workload	8	Overall, how was your level of Workload?	SAME QUESTION FOR ATCO
Workload	9	Specifically, how was your level of workload during: - Handover from aircraft to Arrival GSO, handover from Cruise to Stand-by GSO, Airport selection phase, Emergency descent and landing.	NO
Human Error	10	IDENTIFY possible weak aspects that can lead to human error, special focus on team tasks (CRM - communication, WL management, shared SA, leadership).	SAME QUESTION FOR ATCO
Competence / Training needs	11	TRAINING NEEDED: What kind of training is needed to be a GSO? (e.g., experience as a captain?)	SAME QUESTION FOR ATCO
Operating procedures	12	Consider these two options:	SAME QUESTION FOR ATCO

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		1. Aircraft squawks 7700 -> GSO and ATCO receive squawk -> GSO confirms incapacitation. -> ATCO is informed 2. Aircraft transmit incapacitation notification -> GSO is informed through red alert on console and must confirms incapacitation-> GSO squawks 7700 -> ATCO is informed. Which option would you prefer and why? What are the advantages and disadvantages of each?	
Roles/Responsibilities	13	What do you think should be the tasks of the stand-by GSO in nominal operations (e.g., a supervisor of all ground station operators currently working on that shift or a GSO on a break, etc.)	NO

Table 7: Debriefings' items

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Appendix B Result data (raw)

B.1 Questionnaire results

POST-RUN TMA GSO															
Role	N	1. Your role and respons	2. The respo	2. The respo	3. The comm	3. The comm	4. Rate your	4. Rate your	4. Rate your	5. Rate your overall level of Workload: [Rate:]					
GSO	1	Disagree	Disagree	N/A	Disagree	N/A	Disagree	Neither Agre	Agree	Neither Low nor High					
GSO	2	Agree	Agree	N/A	Agree	N/A	Neither Agre	Neither Agre	Agree	High					
GSO	3	Agree	Strongly Agre	N/A	Agree	N/A	Agree	Strongly Agre	Agree	Neither Low nor High					
GSO	4	Strongly Agree	Strongly Agre	N/A	Strongly Agre	N/A	Agree	Disagree	Agree	Neither Low nor High					
GSO	5	Agree	Strongly Agre	N/A	Strongly Agre	N/A	Strongly Disa	Disagree	Agree	High					
POST-RUN TMA ATCO															
Role	N	1. Your role and respons	2. The respo	3. You were	4. The comm	4. The comm	5. Rate your	5. Rate your	5. Rate your	6. Rate your overall level of Workload: [Rate:]					
ATCO	1	Agree	Agree	Neither Agre	Agree	Neither Agre	Disagree	Neither Agre	Neither Agre	High					
ATCO	2	Strongly Agree	Agree	Disagree	Strongly Agre	Strongly Agre	Agree	Agree	Agree	High					
ATCO	3	Agree	Agree	Disagree	Strongly Agre	Strongly Agre	Agree	Agree	Disagree	Neither Low nor High					
ATCO	4	Agree	Agree	Neither Agre	Agree	Agree	Agree	Agree	Neither Agre	Low					
ATCO	5	Agree	Strongly Agre	Agree	Strongly Agre	Strongly Agre	Strongly Agre	Strongly Agre	Agree	Neither Low nor High					
POST-RUN EN-ROUTE GSO															
Role	N	1. Your role and respons	2. The respo	2. The respo	2. The respo	3. The hando	4. The decisi	5. The comm	5. The comm	5. The communicati	6. Rate your	6. Rate your overall	6. Rate your	7. Rate your overall level of Workload: [Rate:]	
GSO	1	Agree	Strongly Agre	Strongly Agre	Agree	Agree	Strongly Agre	Neither Agre	Strongly Agre	Strongly Agree	Disagree	Neither Agree nor D	Agree	High	
GSO	2	Agree	Agree	Agree	Neither Agre	Agree	Neither Agre	Agree	Agree	Neither Agree nor D	Disagree	Disagree	Neither Agre	High	
GSO	3	Strongly Agree	Strongly Agre	Strongly Agre	Strongly Agre	Strongly Agre	Strongly Agre	Strongly Agre	Strongly Agre	Strongly Agree	Agree	Neither Agree nor D	Neither Agre	Low	
GSO	4	Agree	Strongly Agre	Strongly Agre	Neither Agre	Strongly Agre	Strongly Agre	Strongly Agre	Strongly Agre	Neither Agree nor D	Strongly Agre	Agree	Disagree	Neither Low nor High	
GSO	5	Agree	Strongly Agre	Strongly Agre	Strongly Agre	Neither Agre	Agree	Strongly Agre	Strongly Agre	Strongly Agree	Disagree	Disagree	Agree	Neither Low nor High	
POST-RUN EN-ROUTE ATCO															
Role	N	1. Your role and respons	2. The respo	2. The respo	3. The decisi	4. You were	5. The comm	5. The comm	5. The comm	6. Rate your overall	6. Rate your	6. Rate your overall	7. Rate your overall level of Workload: [Rate:]		
ATCO	1	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Neither Agree nor D	Agree	Agree	Neither Low nor High		
ATCO	2	Strongly Agree	Agree	Agree	Strongly Agre	Agree	Strongly Agre	Strongly Agre	Strongly Agre	Agree	Strongly Agre	Strongly Agree	Neither Low nor High		
ATCO	3	Agree	Agree	Agree	Agree	Strongly Agre	Strongly Agre	Strongly Agre	Strongly Agre	Agree	Agree	Strongly Agree	Very Low		
ATCO	4	Strongly Agree	Agree	Agree	Strongly Agre	Neither Agre	Strongly Agre	Strongly Agre	Strongly Agre	Agree	Agree	Agree	Very Low		
ATCO	5	Strongly Agree	Strongly Agre	Strongly Agre	Agree	Strongly Agre	Strongly Agre	Strongly Agre	Strongly Agre	Agree	Strongly Agre	Strongly Agree	Very Low		

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POST-SESS GSO																				
Role	N	1. The training received l	2. Your role a	3. The task a	4. The proce	5. The proce	6. You were	6. You were	6. You were	7. You had all the ir	7. You had a	7. You had all the in	7. You had a	8. The timeliness ar	8. The timelir	8. The timelir	8. The timelir	9. The usabil	10. Your per	11. Rate you
GSO	1	Disagree	Agree	Neither Agre	Neither Agre	Agree	Neither Agre	Neither Agre	Agree	Agree	Agree	Agree	Agree	Neither Agre	Agree	Agree	Agree	Disagree	Agree	Low
GSO	2	Neither Agree nor Disagr	Disagree	Disagree	Agree	Neither Agre	Strongly Disa	Neither Agre	Disagree	Strongly Disagree	Agree	Agree	Neither Agre	Neither Agree nor D	Agree	Agree	Neither Agre	Strongly Disa	Disagree	Low
GSO	3	Strongly Agree	Strongly Agre	Strongly Agre	Agree	Strongly Agre	Agree	Strongly Agre	Agree	Agree	Strongly Agre	Strongly Agree	Strongly Agre	Strongly Agree	Strongly Agre	Strongly Agre	Strongly Agre	Neither Agre	Neither Disag	nor High
GSO	4	Strongly Agree	Strongly Agre	Disagree	Agree	Agree	Disagree	Strongly Agre	Agree	Neither Agree nor D	Strongly Agre	Strongly Agree	Strongly Agre	Agree	Strongly Agre	Strongly Agre	Strongly Agre	Agree	Disagree	nor High
GSO	5	Strongly Agree	Agree	Disagree	Strongly Agre	Disagree	Neither Agre	Agree	Disagree	Strongly Disagree	Strongly Agre	Strongly Agree	Strongly Agre	Strongly Disagree	Strongly Agre	Strongly Agre	Strongly Agre	Disagree	Disagree	Low
POST-SESS ATCO																				
Role	N	1. The training received l	2. Your role a	3. The proce	4. The proce	5. You were	5. You were	5. You were	5. You were	6. You had all the ir	6. You had a	7. The timeliness an	7. The timelir	8. Your perceived le	9. Rate your overall level of trust in the concept [Rate]					
ATCO	1	Agree	Agree	Agree	Agree	Strongly Agre	Agree	N/A	Agree	Disagree	Strongly Agre	Disagree	Strongly Agre	Agree	nor High					
ATCO	2	Agree	Strongly Agre	Agree	Agree	Strongly Agre	Neither Agre	Agree	Agree	Agree	Agree	Strongly Agree	Agree	Agree	High					
ATCO	3	Neither Agree nor Disagr	Agree	Agree	Agree	Strongly Agre	Agree	Agree	Agree	Agree	Agree	Disagree	Strongly Agre	Agree	nor High					
ATCO	4	Neither Agree nor Disagr	Agree	Strongly Agre	Strongly Agre	Agree	Strongly Disa	Agree	Strongly Agre	Agree	Strongly Agre	Agree	Agree	Strongly Agree	N/A					
ATCO	5	Agree	Agree	Neither Agre	Strongly Agre	Strongly Agre	Agree	Strongly Agre	Strongly Agre	Agree	Strongly Agre	Strongly Agree	Strongly Agre	Agree	High					

B.2 Debriefing results

SESSION 1	Pilot 1	ATCO 1

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Do you think that the operational concept experienced during the simulation is acceptable? Do you think it is feasible?	< The only indication that I had about the pilot incapacitation was the red icon and that he was not answering the phone. But nowadays I would like to see what the OBP is doing and how he/she is doing… communication with the cabin crew would help to be informed on the health status of the OBP < Pilot answered yes if there will be "Redundancy" of the whole system and "relationship" with the cabin crew. For the concept to work the system must be redundant and stable. *Non flexible: missing options to get more info (bearing info, no ILS, no speed breaks; MODES: different from real plane The first was easier	There was not much difference from current operations. < ATCO would like to know if they have to treat a single pilot incapacitation differently from other kind of emergency situations. ATCO would like to know if the GSO needs more information or not… which are the information that he/she needs. < ATCO suggested that maybe a solution could be to provide a new checklist for the ATCO. If new procedures are envisioned to manage this type of emergency, the ATCO shall be provided with a checklist. *HMI needs further development. Special callsign ok.

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Were you comfortable in being responsible for the flight safety?	< The pilot was only able to do limited actions during the simulation… this restriction in his action made the pilot less comfortable with the concept and his responsibilities. Not completely comfortable in being responsible for the flight due to the feeling of being only partially in control of the aircraft.	
Task allocation was okay (take into consideration different tasks for example landing, airport decision)? Extra help needed?	< It was ok for the pilot.	

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Operating procedures, regarding navigate and mange the flight:	< Not considering the technical malfunctions, the pilot affirmed that the operating procedures were quite straightforward. < The pilot also affirmed that he did not trained so much before the RTS (to answer this question?). More training needed. < Good ability to manage the tasks as well easiness for decisions making procedures.	
Any issue in navigate and manage the aircraft?	< Again, apart from the technical issues of the simulator… no.	
Did you perceive any changes in your role and responsibilities? If yes, are these changes in your responsibilities acceptable?		< ATCO affirms that it is acceptable have the same role and responsibilities. Role and responsibilities same as current operations.

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Team structure and communication: how was the coordination and communication between you and the other actors?	< For the pilot it was more or less similar to today. (apart from the technical malfunctions of the simulation together with the simulation's adaptations).	< For the ATCO was waiting and waiting when the incapacitation happened.
Reagarding Situation Awareness: additional information that could help you? Extra info?	< Pilot mentioned that it would help to have a tool that measure the distances from the runaway in order to plan the descent accordingly. The pilot did not have any info regarding the ILS during the simulation but he would like to have those kind of information. Regarding the camera the pilot affirmed that he would like to have a camera inside the cockpit to see what happens inside + camera for the weather outside ("why not"?).	
Overall, how was your level of Workload?	< The Pilot commented that the situation in the second run where he had to change the flight plan or when he received the "new" ATC instructions were the moments in which the workload was a little bit higher than usual.	< For the ATCO, since what experienced was an emergency situation the workload was a little bit higher than usual. < The ATCO also commented that the workload was influenced by the technical malfunctions happened during the simulation.

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Specifically, how was your level of workload during: - Handover from aircraft to Arrival GSO, handover from Cruise to Stand-by GSO, Airport selection phase, Emergency descent and landing. "	< The pilot affirmed that in the first run there wasn't a real handover so not high workload. < During the second run and the handover process everything was more or less straightforward, so no workload peak.	
Human errors?	< According to the pilot, there might be situations that can induce to human errors. These situation might depend by a combination of hazard situations (e.g., bad weather) together with a lack of information that are available to the GSO in the current GS. For instance, the pilot affirmed that if there will be bad weather from the current GS he cannot see the vertical speed and this situation might induce to human errors.	

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TRAINING NEEDED: What kind of training is needed to be a GSO? (e.g., experience as a captain?)	< The pilot did not know how to answer to this question. He just affirmed that to be a GSO the operator must be trained on the interface. Moreover, he affirmed that on the GS there should be a proper way to scan (meaning to see at the same time?) all the flights that a GSO is monitoring at the same time.	
Consider these two options: 1. Aircraft squawks 7700 -> GSO and ATCO receive squawk -> GSO confirms incapacitation. -> ATCO is informed 2. Aircraft transmit incapacitation notification -> GSO is informed through red alert on console and must confirms incapacitation-> GSO squawks 7700 -> ATCO is informed. Which option would you prefer and why? What are the advantages and disadvantages of each?	< The pilot affirmed that he would prefer the second option ("easier and maybe with less workload?").	

Time to come to a decision?	< The pilot affirmed that in real life it might be necessary more time to take decisions (however, no a precise time has been specified). In the simulation everything was much fast according to him.	
SAFETY: can you imagine hazards situations in addition to pilot incapacitation? For which situation do you think that our system is not ready to cope with those other situations?	< Fire on board?; How to check if the fire is extinguished?; Engine failure; Mitigations could be cameras to check inside the aircraft + communicate with the cabin crew also when the incapacitation happens.	
SAFETY as in current operation?	"Assuming that the system itself is running smooth, with redundancy and so on… I think that maybe there would not be a big difference… but as it is today for example I do not know why the pilot got incapacitated (e.g., food poisoning?)… all this thing would increase my workload and also the perception that the concept is not safe as the current operations".	
SESSION 2	**Pilot 2**	**ATCO 2**

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Do you think that this operational concept is acceptable (in the way we handle the incapacitation problem) and feasible?	< I felt it was a little too inflexible… I wrote in the questionnaire already that I was missing some option to have additional information (as the info of the ILS)… it was difficult because I did not have options to change the trajectory for instance, or the "speed breaks"… I had the feeling that TMA scenario was much easier (no plans to change, so it was easier to take over the flight).	< Apart from the HMI of the platform that should be fully developed also the learning curve and so on (meaning that it has been difficult to learn that specific CWP), but regarding the concept itself it could work, I felt quite comfortable during the simulation … it worked quite good. It is up to the pilot give us information about the flight and what is happening…so we as ATCOs can help to solve the problem.
Were you comfortable in being responsible for the flight safety? (being the PIC from a GS)	< I would not feel comfortable being responsible for flight safety as it is the concept. From the GS I missed the ability to use the speed brakes, to have all the FMS with me to put the headings and see where the airport is…. I would like to have the speed brakes, the FMS, instruments to check the flight height and so on... also to help me to plan in advance in order to enhance the SA. Also the map used for the simulation was difficult… I was not used to it.	
Task allocation was okay (take into consideration different tasks for example landing, airport decision)? Extra help needed?	It worked well. It was just one situation in the second run (airport to land) was a little bit strange because usually I'm in the cockpit and we discuss with NOC… and in this scenario the NOC helped for the list of airports, but it was quite strange during the simulation so at the end I felt that the decision was only on me...	

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Regarding navigate and manage the flight: How was the efficiency of routing determination and upload process?	It worked quite well. But the aircraft did not always do what I was expecting that it would have been doing. Sometimes the modes /routes of the autopilot changed without giving me any visual feedback in real-time.	
How was your ability to manage your tasks?	The pilot affirmed that when talking with the NOC and taking instruction from him/her in order to make a decision as a GSO (PIC) has been challenging. (During the scenario there has been also an overlapping with the ATCO while the GSO was talking with the NOC).	
How was the effectiveness of decision making procedures?	< The effectiveness of decision making procedures depended by the information that the GSO received during the RTS. During the simulation, indeed, the GSO affirmed that he had only the weather information instead of also the airport information. This limited the decision making, inducing to an error and to extra workload.	

Other issues regarding navigate and manage?	< Limited controllability of the aircraft.	
Did you perceive any changes in your role and responsibilities? If yes, are these changes in your responsibilities acceptable?		The ATCO did not perceive any changes in roles and responsibilities even if the SP aircraft had an incapacitated pilot ("so it was basically a drone").

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How was coordination and communication between you and the other actors? Was it timely, clear, sufficient? Information flow and synchronization? Were there overload problems?	< Communication with the ATCO was very clear. No changes compared to current operations. However, the pilot affirmed that it has been a little bit challenging being the only one controlling the aircraft and carrying out the communications with the ATCO and the NOC. The pilot affirmed that when there are two pilot the control of the aircraft and the communication are more effective, together with the fact that in two there might be a better decision making process. The pilot affirmed that in this case of single pilot incapacitation it might be helpful have a second GSO. < The communication with the Cruise GSO were defined as clear, short and efficient.	< I was waiting for info from the GSO, supporting, trying to be my best, preparing my colleagues (the "rest of the world").

Regarding Situational Awareness: what other information (from HMI, from other actors) do you need? What other tool (e.g., cameras) do you need? Do you have any suggestions to improve the system? (e.g., how info is displayed, timing of info) What info should be shared between cruise and stand-by GSO to increase levels of SA for the stand-by GSO?	1. The charts with the layouts as in current operations; 2. Cameras depend on the situation. Cameras for the outside view only in specific occasions ("when I flight I don't look outside very often I look at the instruments instead to create SA"). 3. The layout of the autopilot also in the GS with informative feedback in real-time ("Also to have a visual indication when the autopilots changes it is modes, also the speed modes and so on… like indication that the autopilot is changing the modes in the time it gives the indication"); 4. FMS; 5. Sharing audio in the cockpit to check the situation of the onboard pilot (e.g., auto-microphone switched "on" when the incapacitation happens to hear the audio from the cockpit on the GS to enhance the SA). 6. Also video feedback of what is happening inside the cockpit. The pilot affirmed that the focus should not too much on the use of the automation but on "check and verify" the automation. According to the pilot, it would be important to see what the automation is doing (also with informative feedback in real-time).	< The SA was influenced by the limitation of the CWP used for the simulation. A good feature to have in the CWP would have labels of different colours to underline the aircrafts.

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Overall, how was your level of Workload?	< The pilot affirmed that he experienced higher workload during the single pilot incapacitation. This higher workload depended by the fact that the pilot had no information from the cabin side. Moreover, the pilot could not have the possibility to communicate with the cabin crew. The pilot affirmed that he was uncomfortable to being the only person to make decisions. Since the GSO was the only pilot that had to generate the information, rate the information, take the decision and then executing those decisions all by itself, it impacted on the level of workload. < Moreover, the pilot affirmed that he would be comfortable to have the responsibilities of the decisions if he would have more information (the missing information aforementioned) and more support from the ground to make the final decision.	< The ATCO did not experience any difference in WL compared to current operations when there are emergency situations.

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Where the level of workload was higher? "Specifically, how was your level of workload during: - Handover from aircraft to Arrival GSO, handover from Cruise to Stand-by GSO, Airport selection phase, Emergency descent and landing. "	< During the airport selection phase… This is because the airport selection phase (cruise scenario) has been considered as a time-critical situation. The pilot lamented that in this phase he did not have the opportunity to speak with the cabin crew. For instance, he would have liked the opportunity to call the cabin crew to have the information about the incapacitated pilot in order to give this information to ATC so that they would have called the ambulance (if needed).	
IDENTIFY possible weak aspects that can lead to human error, special focus on team tasks (CRM - communication, wl management, shared SA, leadership).	< The pilot affirmed that in time and safety critical situations (as the single pilot incapacitation) the GSO should work as a "team" to avoid human errors. For instance, not having cross-checks at all (as during the simulation) might induce to human errors. A mitigation might be having the NOC nearby (or in constant contact) the GSO.	
TRAINING NEEDED: What kind of training is needed to be a GSO? (e.g., experience as a captain?)	< The pilot affirmed that the GSO should have "piloting skills", including decision making skills and some "ATCO" skills as well (monitoring an aircraft from a display of a GS). The pilot affirmed that a specific training for the GS working environment is necessary (stay in the GS, use and understand the HMI, specific training to develop monitoring skills).	

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Consider these two options: 1. Aircraft squawks 7700 -> GSO and ATCO receive squawk -> GSO confirms incapacitation. -> ATCO is informed 2. Aircraft transmit incapacitation notification -> GSO is informed through red alert on console and must confirms incapacitation-> GSO squawks 7700 -> ATCO is informed. Which option would you prefer and why? What are the advantages and disadvantages of each?	< The pilot prefers the option 1.	< The ATCO prefers the first option. This is because the ATCO affirmed that he would like to know about the incapacitation as soon as possible, taking into account that there might be hazard situations where the GSO might not be ready to answer to the incapacitation, and this might be dangerous especially in TMA.

What do you think should be the tasks of the stand-by GSO in normal, real life operations (e.g., a supervisor of all ground station operators currently working on that shift or a GSO on a break, etc.)		
In the scenario you've just experienced, the cruise GSO transfers the emergency a/c to the stand-by GSO. A different option could be that the Cruise GSO transfers all a/c to the Stand-by GSO except the emergency one. What option do you think is the safest one? Can you identify pros and cons of both options?	< He would prefer to stay with the incapacitation in the route scenario and gives the other aircraft to the stand-by GSO.	

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Who should initiate the exchange between GSOs?	< No difference according to this pilot (?)	
Can you imagine other hazard situations in addition to pilot incapacitation that may be critical for safety of operations?	< With the actually generation of aircraft, there are some functions in the cockpit that are mechanics. It might be possible that the incapacitated pilot pushes those functions that can be controlled only from the aircraft, so the GSO cannot intervene remotely.	
CONSIDER THIS HAZARD: unforeseen technical malfunctions - ENGINE FAILURE?	< It depends by the automation of the aircraft. If the aircraft is able to handle an engine failure by itself it is fine.	
How do you consider safety levels of experienced scenarios compared to nowadays dual pilot operations in case of pilot incapacitation?	< The pilot affirmed that this concept might be less safe than the current two-pilot operations. < According to the pilot, he would have been more comfortable and with a higher perception of safety being alone in the cockpit compared to being alone as GSO on the ground (this depended by a lack of information and SA, as well as by a lack of perception to be in a team - CRM).	

	< The pilot also affirmed that his perceived level of safety would be higher if he would have been some support from the ground during the decision making processes, as well as for other operations (monitoring specific aspects, cross-check information between each other...).	
SESSION 3	**Pilot 3**	**ATCO 3**
Do you think that this operational concept is acceptable (in the way we handle the incapacitation problem) and feasible?	< The pilot affirmed that the operational concept (at is early stages) it feasible. However, its feasibility depends on the functionalities of the GS, and how the safety issues related to the concept will be mitigated.	< Same for the ATCO.
Were you comfortable in being responsible for the flight safety? (being the PIC from a GS)	< The pilot affirmed that he would be comfortable if he knows that the automation and the system is working fine in order to carry out a safe landing. However, the pilot is concerned about the fact to not be on the aircraft to act immediately if other emergency situations come up due the fact that the pilot is remote (GSO).	

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Task allocation was okay (take into consideration different tasks for example landing, airport decision)? Extra help needed?	< The tasks allocation was fine for the pilot. He affirmed that IRL the communication with the NOC would have been more time consuming. The pilot affirmed that two people in the ground managing the single pilot incapacitation might be better to let the pilot sharing the same mental model and opinions in order to carry out effective decisions. In case of only one GSO, the GSO should be trained to make good decisions during single pilot incapacitation.	
Regarding navigate and manage the flight: How was the efficiency of routing determination and upload process?	< Apart from the difficulties due to the simulator, it was ok.	
How was your ability to manage your tasks?		

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How was the effectiveness of decision making procedures?	< Good effectiveness of decision making procedures.	
Other issues regarding navigate and manage?	> Issues regarding navigate and manage depended by the constraints and limitations of the GS used for the simulation (display waypoint, map with different scale compared to what the pilot was used to). > The pilot lamented a lack of information regarding the speed and the distance from the airport. > The pilot affirmed that he would like to have control of the aircraft, at least influencing the autopilot and the advanced landing system.	

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Did you perceive any changes in your role and responsibilities? If yes, are these changes in your responsibilities acceptable?		> No. Same emergency procedures (1 pilot incapacitation in current operations) could apply also for single pilot incapacitation. From ATCO point of view not a big impact.
How was coordination and communication between you and the other actors? Was it timely, clear, sufficient? Information flow and synchronization? Were there overload problems?	Yes, not considered the simulated environment that limited the simulation.	According to the ATCO, communication was as in current operations, so yes (timely, clear, sufficient). The ATCO affirmed that the communication was influenced by the timing of the simulation that was much faster that IRL. In IRL the ATCO would have given more time to the pilot in order to cope with the emergency situation.

Regarding Situational Awareness: what other information (from HMI, from other actors) do you need? What other tool (e.g., cameras) do you need? Do you have any suggestions to improve the system? (e.g., how info is displayed, timing of info) What info should be shared between cruise and stand-by GSO to increase levels of SA for the stand-by GSO?	The pilot affirmed that in order to enhance his SA from the GS he would like to see the FMS as well as have real-time and step-by-step information about what the aircraft is doing and why. He would also like to have information about the pilot heath status with specific health systems or also cameras, since he would like to know why the pilot is incapacitated. However the pilot also affirmed that as pilot onboard he would not like to have a camera in the cockpit always on, but on the other side, it would be good see what is happening onboard from the GS. Ideally, the GS should replicate what there is in the real cockpit, with also other tools to improve the SA (cameras, health systems information…).	The ATCO asked if there would be cameras for the GSO in order to enhance SA. The ATCO also asked if the GSO might have the information about what is happening to the onboard pilot ("why the GSO is incapacitated?"). The ATCO affirmed that he would like to have direct information from the aircraft regarding the fuel onboard, the number of passengers and other operational information. All those operational information can be send automatically by the aircraft itself, so that the ATCO can avoid to ask those information to the GSO reducing the overall level of workload. The ATCO affirmed that those information might be displayed automatically on the CWP with special labels (e.g., "expanded labels").

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Overall, how was your level of Workload?	Same as for the ATCO. The pilot affirmed that the only situation in which he might have experienced a higher level of workload was the handover phase.	All the workload issues were with the simulator itself. Maybe IRL there would be a raise of the level of workload due to the emergency situation.
Where the level of workload was higher? "Specifically, how was your level of workload during: - Handover from aircraft to Arrival GSO, handover from Cruise to Stand-by GSO, Airport selection phase, Emergency descent and landing. "		

HUMAN ERROR - Identify possible weak aspects that can lead to human error, special focus on team tasks (CRM - communication, wl management, shared SA, leadership).	The pilot affirmed that since he is not in the cockpit, he would like to have all the information that he has in the cockpit also on the ground. According to the pilot, this might decrease the likelihood of human errors. For instance, what happens if there is wind shear during the landing? According to the pilot, the GSO needs to know this information as soon as possible in order to act accordingly. "Which are the info that are in the cockpit that you don't have on ground? Specifically, sensory information? (e.g., vibration, audio…)" o Engine sounds o Birds coming o Flaps sounds o Those information might be helpful. The pilot also affirmed that from the GS on ground it might be difficult have the same SA because the lack of sensory cues and information, and this can lead to possible human errors.	

TRAINING NEEDED: What kind of training is needed to be a GSO? (e.g., experience as a captain?)	The pilot affirmed that the GSO should be a pilot. This would be important because he/her need to understand the aircraft and how to fly from A to B. For instance, the pilot affirmed that having a GSO as a pilot in the ground also with manual control can help to cope with those hazard situations that there might be if the autopilot (or the advanced landing system) does not work anymore.	Also for the ATCO the GSO should be a pilot.
Consider these two options: 1. Aircraft squawks 7700 -> GSO and ATCO receive squawk -> GSO confirms incapacitation. -> ATCO is informed 2. Aircraft transmit incapacitation notification -> GSO is informed through red alert on console and must confirms incapacitation-> GSO squawks 7700 -> ATCO is informed. Which option would you prefer and why? What are the advantages and disadvantages of each?	The pilot affirmed that he would like that the ATCO receives the information as soon as the situation happens.	By contrast to what the pilot affirmed, the ATCO the first option might cause some problems regarding the interaction and communication between the GSO and the onboard pilot (e.g., the ATCO might interrupt the GSO while he/her is still contacting the onboard pilot to verify the incapacitation).

What do you think should be the tasks of the stand-by GSO in normal, real life operations (e.g., a supervisor of all ground station operators currently working on that shift or a GSO on a break, etc.)	As in the organization of the ATC, there might be a supervisor and some GSO… Since the stand-by is just a remote case, it might be that a stand-by GSO would be a GSO under break (for example).	
In the scenario you've just experienced, the cruise GSO transfers the emergency a/c to the stand-by GSO. A different option could be that the Cruise GSO transfers all a/c to the Stand-by GSO except the emergency one. What option do you think is the safest one? Can you identify pros and cons of both options?	In the moment when the cruise GSO detects the emergency for pilot incapacitation, he/she would be really focused to handle the a/c with the pilot incapacitation. For this reason since he/she would be really focus on that, it would be better if he/she would stay with that aircraft (option 2).	Also the ATCO prefers the second option.

Who should initiate the exchange between GSOs?	The first option (cruise GSO contacts the stand-by GSO to initiate the handover procedure).	
Can you imagine other hazard situations in addition to pilot incapacitation that may be critical for safety of operations?	The most critical part for me is departure and arrival. If the ATCO can help the GSO to vector the a/c around the bad weather would be a good help according to the pilot (assuming that in the GS there would be an option to control manually the aircraft). Time would be really important. Time-critical situations would be much difficult to handle from the GS. Moreover, the GSO should trust the automation since in the current SAFELAND concept there aren't manual controls in the GS.	In the approach phase there are quick decisions that the pilot should take as for example land or go around. Is it the automation able to make this quick decisions to avoid wind sheers for example? Those quick decisions must be taken in these emergency situations.
CONSIDER THIS HAZARD: unforeseen technical malfunctions - LOSS OF COMMUNICATION WITH THE A/C?	Everything would be up to the automation and what the automation can do to solve the emergency situation (in this case a complete loss of communication between the a/c and the GSO). So, for instance, if the a/c is fully automated it can land by itself.	

How do you consider safety levels of experienced scenarios compared to nowadays dual pilot operations in case of pilot incapacitation?	The level of perceive safety drops down in SPO with pilot incapacitation because in the SAFELAND concept there are not cross-checks with a "crew". This limits the sharing of the GSO mental model and the decisions that the GSO has to take. Being alone without cross-checking might induce to higher probability of human errors so the perceived level of safety goes down. Support from another GSO might help for these concerns, also replicating the task divisions that pilots' have in current operations.	
SESSION 4	**Pilot 4**	**ATCO 4**

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Do you think that this operational concept is acceptable (in the way we handle the incapacitation problem) and feasible?	Regarding the procedures, as for example the handover, the pilot affirmed that they were good and feasible. The pilot also affirmed that from the technical point of view nobody would trust a system as the one experienced during the simulation. This is due the lack of information displayed on the GS, especially on the navigation part. In an emergency such as single pilot incapacitation there should be the need to go down as soon as possible. The GSOs need a great SA to handle the emergency situation. For this reason, the information that have been presented to the the pilot during the simulation from the GS were insufficient. The pilot affirmed that if the automation can land the a/c automatically there is not the need to have manual controls from the ground (assuming that there would not be another emergency on top of the single pilot incapacitation). If the advanced landing system will be certified, the level of trust in the concept would be enhanced.	It easier for the ATCO because the concept doesn't change so much how the ATCO relates with the aircraft. It does change from current operations as for example with drones.

Were you comfortable in being responsible for the flight safety? (being the PIC from a GS)	Difficult answer. Since the automation would not be under control of the GSO, the pilot affirmed that he would not be comfortable to be the PIC. The pilot would not be comfortable to be responsible for what the automation is doing. The pilot affirmed that flying from the ground would be feasible. Regarding the autopilot, it should be 4 or 5 times more reliable than current operations. In current operations there are errors in the autopilot and for this reason there are two pilots in the cockpit. Moreover, the pilot affirmed that if the GSO would have the possibility to handle the aircraft from the ground in manual in the way it is certified, as GSO he would be ready to take responsibility of the aircraft. He would take responsibility if he knows that the system is redundant and if he knows that there is the same system of the a/c on ground.	

Task allocation was okay (take into consideration different tasks for example landing, airport decision)? Extra help needed?	Tasks allocation was okay. IRL the GSO would have more time also to think and act.	
Regarding navigate and manage the flight: How was the efficiency of routing determination and upload process?	As far as the automation was effective, the pilot as GSO was comfortable of the efficiency of routing determination.	
How was your ability to manage your tasks?		

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How was the effectiveness of decision making procedures?	Good. Operationally it would be better to work as a "Crew" on the ground with the NOC in order to make more effective decisions. The pilot affirmed that he would be comfortable to being in charge for the final decision.	
Other issues regarding navigate and manage?	The pilot mentioned some problems with the GS that was used during the simulation. Those problems were connected with the design choice to use the mouse to interact with the HMI. The pilot affirmed that he would have preferred to use some "switch" on the GS to change the headings, altitude speed, and interact in general with the HMI. This is because changing the headings (for example) with the mouse it would be too long.	

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Did you perceive any changes in your role and responsibilities? If yes, are these changes in your responsibilities acceptable?		No specific differences. But a good idea would have be a specific squawk number for the single pilot incapacitation.
How was coordination and communication between you and the other actors? Was it timely, clear, sufficient? Information flow and synchronization? Were there overload problems?	Good communication and coordination. Straightforward.	Communication and coordination was not a problem. The ATCO affirmed that for her would have been important know that the pilot calling was the remote pilot or not (this, generally, as soon as the incapacitation happens).

Regarding Situational Awareness: what other information (from HMI, from other actors) do you need? What other tool (e.g., cameras) do you need? Do you have any suggestions to improve the system? (e.g., how info is displayed, timing of info) What info should be shared between cruise and stand-by GSO to increase levels of SA for the stand-by GSO?	What is missing on the GS to create a good SA: 1) Navigation display with the nose of the aircraft pointing up a. Navigation information and terrain information b. Moving map 2) FMS 3) Moving map 4) Radar 5) Altitude 6) Approach charter 7) Controls for the approach configuration (flaps and so on…) to take over manually the approach from the automation; What can be added to improve the SA: 1) See with camera inside the cockpit to confirm the incapacitation with a visual cue 2) Camera would be beneficial also in nominal operations to increase the feeling of being a crew also on ground.	The systems that there are in current operations are enough to have a good SA. As long as there is communication between ATCO and GSO, the SA is good, since it would be the same as in current operations with an emergency situation. If the GSO can cross-checks all the information would be really good for safety… not having it, it would be less safe.

Overall, how was your level of Workload?	Acceptable workload for this emergency situation.	Low workload during the simulation… just communication all the time.
Where the level of workload was higher? "Specifically, how was your level of workload during: - Handover from aircraft to Arrival GSO, handover from Cruise to Stand-by GSO, Airport selection phase, Emergency descent and landing. "	No	

HUMAN ERROR - Identify possible weak aspects that can lead to human error, special focus on team tasks (CRM - communication, wl management, shared SA, leadership).	For instance, the situation in which the GSO is cross-checking and monitoring a lot of flights... this situation might lead to human errors. Also not having the cross-checks with a second pilot might enhance the probability of human errors.	
TRAINING NEEDED: What kind of training is needed to be a GSO? (e.g., experience as a captain?)	Her/he should be a pilot.	I hope her/he would be a pilot.

Consider these two options: 1. Aircraft squawks 7700 -> GSO and ATCO receive squawk -> GSO confirms incapacitation. -> ATCO is informed 2. Aircraft transmit incapacitation notification -> GSO is informed through red alert on console and must confirms incapacitation-> GSO squawks 7700 -> ATCO is informed. Which option would you prefer and why? What are the advantages and disadvantages of each?		According to the ATCO, a pilot incapacitation would be a time-critical phase. For this reason, it would be better have squawk 7700 in real-time as for the GSO, and then wait for the call with the GSO (OPTION 3!).

What do you think should be the tasks of the stand-by GSO in normal, real life operations (e.g., a supervisor of all ground station operators currently working on that shift or a GSO on a break, etc.)	It should be an active actor because otherwise would be difficult to be active and create SA for the emergency situation. So maybe it would be a supervisor because supervisors have active roles during the shifts. Maybe can be the supervisors of the datalink (data-link is a big issue in this concept).	
In the scenario you've just experienced, the cruise GSO transfers the emergency a/c to the stand-by GSO. A different option could be that the Cruise GSO transfers all a/c to the Stand-by GSO except the emergency one. What option do you think is the safest one? Can you identify pros and cons of both options?	Better option 1 (the one experienced). Transfer a lot of aircraft at the same time might be a problem if the GSO is giving clearances to some aircraft. For thins reason, it would be better give the incapacitated a/c to the stand-by GSO.	

Who should initiate the exchange between GSOs?	The pilot affirms that since the Cruise GSO in that moment is the PIC, the Cruise GSO should initiate the exchange with the stand-by GSO.	
Can you imagine other hazard situations in addition to pilot incapacitation that may be critical for safety of operations?	WHO IS GONNA CROSS CHECK THE INFORMATION GIVEN BY THE ATCO TO THE PILOT? This is a major problem in SPO according to the pilot. --> Autopilot failure and automation failure --> Loss of data link --> Worse case scenario is if the pilot incapacitation is caused by a fire on the a/c.	The ATCO affirms that a possible hazard could be taking away from SPO the cross-checking between the pilots… this might led to hazard situations. --> No cross-checks between onboard pilot and the different GSOs --> Loss of data links --> All kinds of loss of communication --> The problem to being alone is that it would be much difficult to be alert and awake… stay alone inside in a cockpit for hours (OUT OF TOPIC).
CONSIDER THIS HAZARD: unforeseen technical malfunctions - LOSS OF COMMUNICATION WITH THE A/C?		

How do you consider safety levels of experienced scenarios compared to nowadays dual pilot operations in case of pilot incapacitation?	The pilot affirmed that the safety of operations with a pilot incapacitation in SPO would not be a big issue also compared with current operations if technically everything works fine (no other issues in addition to pilot incapacitation).	
SESSION 5	**Pilot 5**	**ATCO 5**
Do you think that this operational concept is acceptable (in the way we handle the incapacitation problem) and feasible?	The concept was defined as clear and straightforward (communication, interaction, GSOs roles...).	Yes, since there are not big differences on how the ATCOs operate compared to current operations.

Were you comfortable in being responsible for the flight safety? (being the PIC from a GS)	The pilot was not comfortable to answer this question "I cannot answer this...". This comment mostly depended by the fact that the pilot didn't have the opportunity to "influence" what the aircraft was doing. The would not be comfortable to rely on the advanced automation since something might go wrong. The pilot also affirmed that with the incapacitation of a single pilot the a/c should be on ground as soon as possible, and a fast landing might be carried out only with manual controls on the GS. Not flying manually (also influencing the automation from the ground) was seen as a limitation by the pilot. The pilot would like to be the decision maker: not really fly the aircraft from the GS, but handle the decisions of what the aircraft is doing.	
Task allocation was okay (take into consideration different tasks for example landing, airport decision)? Extra help needed?	Good tasks allocation. However, in case of emergency situation would be beneficial have a second GSO on the side to better monitor the a/c.	

Regarding navigate and manage the flight: How was the efficiency of routing determination and upload process?	No information in real-time (no real-time feedback) when the system does flaps, gears and so on. Moreover, the pilot lamented that he did not have the possibility from the GS to influence this "management parts" of the a/c.	
How was your ability to manage your tasks?		
How was the effectiveness of decision making procedures?	No much decision making in the scenario (limited option for the decision of the landing airport).	

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Other issues regarding navigate and manage?	The lack of information provided by the GS already mentioned.	
Did you perceive any changes in your role and responsibilities? If yes, are these changes in your responsibilities acceptable?		
How was coordination and communication between you and the other actors? Was it timely, clear, sufficient? Information flow and synchronization? Were there overload problems?	Good communication and coordination with the ATCO. Also good handover and communication with the Cruise GSO and stand-by GSO. However, the pilot lamented a lack of sharing of the mental status with the onboard pilot. This can led to hazardous situations.	Communication was considered goo. Good and realistic coordination with the supervisor. As ATCO you are trained to make the aircraft alone as much as possible in order to let the pilot to make the decisions in their time and then let the pilot return to the ATCO with all the information the pilot can provide to the ATCO: "don't communicate asap with the incapacitated aircraft, but wait for the GSO to contact ATC" (communicate is less priority also in emergency situation).

Regarding Situational Awareness: what other information (from HMI, from other actors) do you need? What other tool (e.g., cameras) do you need? Do you have any suggestions to improve the system? (e.g., how info is displayed, timing of info) What info should be shared between cruise and stand-by GSO to increase levels of SA for the stand-by GSO?	Camera views (outside and inside) and pictures of the cockpit; Primary flight display; Sound (so to share the sound environment with the cockpit); Nose? (other sensory information if possible).	The ATCO had on the CWP the emergency message. However in the real word there would be some delay in communication and this is something that must be taken into account. Also would be beneficial inform the traffic that there is a remote flight in that area. Regarding labels, he would prefer a different colour coding to highlight the remote piloted aircraft. Moreover, the ATCO affirmed that according to him there is no need for specific squawk code for the single pilot incapacitation.
Overall, how was your level of Workload?	Workload in the first scenario was a little bit higher than usual because he was not used to the HMI and to what the advanced landing system was doing. In the second scenario the workload was indeed a little bit lower because the pilot was more used to the HMI.	High workload derived from the HMI of the CWP because the ATCO was not used to it.

Where the level of workload was higher? "Specifically, how was your level of workload during: - Handover from aircraft to Arrival GSO, handover from Cruise to Stand-by GSO, Airport selection phase, Emergency descent and landing. "		
HUMAN ERROR - Identify possible weak aspects that can lead to human error, special focus on team tasks (CRM - communication, wl management, shared SA, leadership).	Information sharing between actors (especially the GSO and the onboard pilot) and sharing the same mental model in SPO might be hard.	

TRAINING NEEDED: What kind of training is needed to be a GSO? (e.g., experience as a captain?)	According to the pilot, the GSO should be a pilot and it should be even more skilled than a pilot. Him/her has to take in care of the aircraft from another perspective (the GS). Him/her must be someone who knows how to fly.	Also the ATCO says that it should be a pilot, otherwise it would be impossible to deal with the situation and also with the current operations.
Consider these two options: 1. Aircraft squawks 7700 -> GSO and ATCO receive squawk -> GSO confirms incapacitation. -> ATCO is informed 2. Aircraft transmit incapacitation notification -> GSO is informed through red alert on console and must confirms incapacitation-> GSO squawks 7700 -> ATCO is informed. Which option would you prefer and why? What are the advantages and disadvantages of each?		better first option. ATCO knows about the emergency situation asap but wait for the GSO to confirms the incapacitations.

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What do you think should be the tasks of the stand-by GSO in normal, real life operations (e.g., a supervisor of all ground station operators currently working on that shift or a GSO on a break, etc.)	The stand-by GSO needs to be in the same room with the GSO, because him/her needs to create a good SA as soon as possible. Him/her should be actively sitting in the same room (so he/she cannot be in break for example). According to the pilot, the most important thing is that the stand-by GSO will be "active", otherwise a lot of time would be lost in a time-critical situation.	
In the scenario you've just experienced, the cruise GSO transfers the emergency a/c to the stand-by GSO. A different option could be that the Cruise GSO transfers all a/c to the Stand-by GSO except the emergency one. What option do you think is the safest one? Can you identify pros and cons of both options?	Since the emergency aircraft has the highest priority, according to the pilot the a/c with the pilot incapacitation should stay with the cruise GSO, and the other aircrafts should be transferred to the stand-by GSO.	

Who should initiate the exchange between GSOs?	It is good that the cruise GSO contact him at the beginning.	
Can you imagine other hazard situations in addition to pilot incapacitation that may be critical for safety of operations?	There are more advances that disadvantages to have two people in the cockpit instead of one…. You can deal with all those emergency situations that can be added to pilot incapacitation (incapacitation + bad weather etc…).	Cybersecurity; experience turbulence even severe but as GSO he/she would not have a clue about that.
CONSIDER THIS HAZARD: unforeseen technical malfunctions - LOSS OF COMMUNICATION WITH THE A/C?	The automation should land the aircraft as soon as possible by itself.	From the ATCO point of view there is no difference if you flight in communication failure so it would be fine.

How do you consider safety levels of experienced scenarios compared to nowadays dual pilot operations in case of pilot incapacitation?	It depends from the safety procedures that will be implemented in the future that can guarantee the same (or higher) safety levels. The pilot affirmed that in the future this kind of system should be redundant.	The ATCO did not answer this question ("I cannot answer this question").

Table 8: Debriefing results

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