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D-8 REPORT ON THE PRELIMINARY SAFETY RISK IDENTIFICATION FOR SIPOS

eMCO-SiPO – Extended Minimum Crew Operations-Single Pilot Operations

An Agency of the European Union

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SUMMARY

This report of the Extended Minimum Crew Operations-Single Pilot Operations (eMCO-SiPO) project of EASA focusses on Single Pilot Operations (SiPO), whereas the project covers both extended minimum crew and single pilot operations. The risk assessment for eMCO is described in a separate project deliverable: D-9. While single pilot operations are considered novel in commercial air transport, in other sub-domains of aviation, such as general aviation and the military domain, single pilot operations are common. An overview of the type of aircraft involved, the training, the certification aspects, standards and regulations is given in this report. The safety considerations of single pilot operations are also described. Finally, different interpretations of how the concept of single pilot operations can be implemented are considered.

Problem area

During normal crew operations in commercial air transport there are always two pilots flying the aircraft together. For single pilot operations just one pilot is in control throughout the whole flight from take-off to landing, and no other pilot is present in the cockpit. This raises the question of whether single pilot operations achieve an equivalent level of safety as normal crew operations.

Description of work

This report builds further upon other work executed as part of the overall eMCO SiPO study in combination with a review of literature on SiPO and an analysis of current commercial single pilot operations.

Application

The factual findings of this study are relevant for EASA as input for their Rulemaking Task RMT.0739, and any associated regulatory efforts within the agency. They can also be used in the discussion that is taking place in society regarding the impact of single pilot operations. The scientific findings from the current study can serve as stated facts in that discussion, such that less speculation will emerge when analysing the impact of single pilot operations. It will facilitate a balanced discussion of the technological advancements and operational efficiency of single pilot operations on the one hand and with uncompromised operational safety standards.

This report examined SiPO risk aspects, while a similar analysis of eMCO risk assessment aspects can be found in project report D-9.

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ABBREVIATIONS

ACRONYM	DESCRIPTION
AFM	Aircraft Flight Manual
AMC	Acceptable Means of Compliance
ATC	Air Traffic Control
CAT	Commercial Air Transport
CONOPS	Concept of Operations
CRM	Crew Resource Management
CS	Certification Specification
DBL	Deep Blue
DLR	German Aerospace Centre
EASA	European Union Aviation Safety Agency
EFIS	Electronic Flight Instrument System
EU	European Union
eMCO	Extended Minimum Crew Operations
FAA	Federal Aviation Administration
FCL	Flight Crew Licencing
GNSS	Global Navigation Satellite System
GM	Guidance Material
HF	Human Factors
HMI	Human Machine Interface
HPA	High Performance Aircraft
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
MEL	Minimum Equipment List
MMEL	Master Minimum Equipment List
MPA	Motor-Powered Aircraft
MTOM	Maximum Take-Off Mass
NLR	Royal Netherlands Aerospace Centre
NTSB	National Transportation Safety Board
OEM	Original Equipment Manufacturer
ORO	Organisation Requirements for air Operations
PNT	Positioning, Navigation, and Timing
RVR	Runway Visual range
SiPO	Single Pilot Operations
TCAS	Traffic Collision Avoidance System
TCDS	Type Certification Data Sheets
TCH	Type Certificate Holder
VFR	Visual Flight Rules

1. Context

1.1 Objective

The objective of this report is to provide preliminary risk identification for the Single Pilot Operations (SiPO) generic concept of operations for commercial air transport.

1.2 Methodology

The analysis is based on the results obtained in the previous tasks for eMCO in combination with a review of literature on SiPO and information on current commercial single pilot operations in small (less than 5700 kg MTOM) aircraft. The literature review followed a mixed method approach, which included organic searches in popular media via Google, as well as keyword searches in academic literature databases and the NLR reports database. Only relevant reports, publications or websites were stored and used in this review. The following topics were explored: existing SiPO operations, safety implications and incidents, (automated) support systems, including future concept of operation and other mitigation measures.

2. Existing Single Pilot Operations

2.1 Aircraft

EASA has a Class and Type Ratings and Licence Endorsement List which constitutes the class and type of aircraft categorisations in accordance with FCL.0.10 and FCL.700 of Annex I (Part-FCL) to Commission Regulation (EU) No 1178/2011 of 3 November 2011 as well as in accordance with GM1 FCL.700, including the minimum number of flight crew for which the aircraft is certified: single-pilot, single-pilot high-performance and multiple pilots. A study on behalf of EASA by van Birgelen et al. (2016) on high-performance aircraft proposed a definition for the term "high-performance" based on aircraft performance threshold values above which the risk of incidents becomes substantial for pilots who are not used to this kind of performance. Performance values include service ceiling, maximum operating speed, approach speeds, maximum climb rate and descent rate. EASA also makes a distinction between complex and non-complex aircraft, with a complex motor-powered aeroplane having either of the following characteristics:

- Having a maximum certified take-off mass exceeding 5700 kg, or
- Being certified for a maximum passenger seating configuration of more than nineteen, or
- Being certified for operation with a minimum crew of at least two pilots, or
- Being equipped with (a) turbojet engine(s) or more than one turboprop engine.

Thus, by definition, all non-complex aircraft are certified for single pilot operations. However, several of complex aircraft can be flown by a single pilot with most models being additionally defined as "high-performance" aircraft. Most of these complex aircraft are turboprop, with about a third being jet aircraft. The largest of these complex aircraft (in terms of capacity) can carry up to nineteen passengers. A full list of all complex aircraft that are certified by EASA to be operated with a single pilot can be found in Annex A .

2.2 Training

Commission Regulation (EU) No 1178/2011 lays down the technical requirements and administrative procedures related to civil aviation aircrew. It covers areas such as pilot licensing, training and medical certification, including those for single-pilot operations. In 2014 EASA proposed to incorporate CRM training for single-pilot operations and make it distinct from multi-pilot operations. The two types of training would differ in several aspects. For single-pilot operations, the initial training for complex motor-powered aircraft would be a minimum of 8 hours (or left to be determined by the operator in case of non-complex aircraft) compared to 24 hours for the initial training for multi-pilot operations. CRM training for single-pilot operations should focus on the relevant aspects to those operations and should therefore include, according to EASA, among others:

- Situation awareness;
- Workload management;
- Decision-making;
- Resilience development;
- Surprise and startle effect; and
- Effective communication and coordination with other operational personnel and ground services.

2.3 Certification standards for Single Pilot Operations in small aeroplanes

The design and certification standards for small aeroplanes are established under Certification Specification 23 (CS-23), which applies to aeroplanes with a maximum seating capacity of nineteen passengers. For aeroplanes with nine or fewer passenger seats or those equipped with non-turbojet engines, the alleviation provided in ORO.FC.200(a)(2) allows for single-pilot operations, subject to compliance with operational requirements. Consequently, current single-pilot operations must be considered within the CS-23 certification process for such aeroplanes.

Notably, certain CS-23-certified aeroplanes equipped with turbojet engines have been approved for single-pilot operations under specific conditions. Examples include:

- Cessna Citation 525,
- Pilatus PC-24, and
- Honda Aircraft HA-420.

The Type Certification Data Sheets (TCDS) for these aircraft provide some details on the operational limitations and requirements associated with their approval for single-pilot operations. These documents specify the minimum flight crew configurations, which are defined as follows:

Minimum Flight Crew:

- One pilot (in the left pilot seat) plus additional equipment as specified in the Limitations Section of the EASA Approved Airplane Flight Manual, or
- One pilot and one copilot.

NOTE**:**

Approval for operation with a minimum crew of one pilot (in the left pilot seat) is based upon the cockpit equipment installation and arrangement evaluated during EASA certification testing. No significant changes may be made to the installed cockpit equipment or arrangement (EFIS, autopilot, avionics, etc.), except as permitted by the approved MMEL/MEL, without prior approval from the appropriate Competent Authority.

This requirement underscores that specific equipment must be installed and that the cockpit layout must remain unchanged to ensure compliance with single-pilot operational standards. Certification Specification CS 23.1523 (Minimum Flight Crew) mandates that the designated minimum crew must be sufficient to ensure safe operation. This assessment considers factors such as workload management, ease of control operation, and the nature of authorized operations (e.g., Visual Flight Rules (VFR), Instrument Flight Rules (IFR), day and night operations, and meteorological conditions, including icing). The outcome of this certification process is typically reflected in the operational documentation of the aircraft.

For example, in the case of the Honda Aircraft HA-420, the following equipment must be operational and available to support single-pilot operations (source: Honda Aircraft HA-420 AFM):

- Autopilot
- Quick Reference Handbook – Normal Procedures
- Quick Reference Handbook – Emergency / Abnormal Procedures

2.4 Operational standards for Single-Pilot Operations in small aeroplanes

Beyond certification requirements, several operational considerations apply to single-pilot operations in CS-23 aeroplanes, as outlined in ORO.FC.202 and related regulatory provisions:

- **Training requirements**:
  Pilots must demonstrate proficiency in departure and approach procedures, engine management, emergency handling, and single-pilot CRM [ORO.FC.202(a)].
- **Minimum flight time experience**:
  Commanders are required to meet specific flight time experience thresholds for IFR and night operations [ORO.FC.202(c)/(d)].
- **Autopilot requirements**:
  IFR operations conducted by a single pilot must be supported by an autopilot system capable of at least altitude hold and heading mode [CAT.IDE.A.135].
- **Crosswind limitations**:
  Certain operational restrictions may apply to crosswind conditions, particularly in cases where the pilot occupies the left seat.
- **Visibility and Runway Visual Range (RVR) limits**:
  Minimum RVR or visibility requirements may be imposed depending on the availability of visual aids and onboard equipment [AMC5 CAT.OP.MPA.110].
- **Limits on Single-Pilot endorsements**:
  To mitigate operational errors, training deficiencies, and human factor risks, pilots may be restricted in the number of single-pilot endorsements they can hold [AMC1 ORO.FC.240].
- **National regulations**:
  Additional flight time limitation regulations for single-pilot operations may be enforced at the national level [Regulation (EU) 2018/394, Article 8.2].

Additionally, in some cases, passengers may be permitted to occupy the unoccupied flight crew seat during single-pilot operations. However, they must not interfere with the pilot's duties and should be familiar with relevant safety procedures and restrictions [AMC1 CAT.GEN.MPA.135(a)(3)].

2.4.1 Transposing the single pilot requirements of small aeroplanes to large aeroplanes

Implementation of SiPO for large aeroplanes would require a revision of ORO.FC.200 to allow single-pilot operations for all aeroplanes, irrespective of engine type or passenger capacity.

In alignment with the requirements outlined in CS-23, CS-25 also mandates the establishment of a minimum flight crew (CS 25.1523). If the current restriction in ORO.FC.200 were removed, SiPO could, in principle, be permitted - provided it can be demonstrated that safe operations are ensured by addressing the following key factors:

- **Workload on individual crew members:**
  It must be demonstrated that a single pilot can manage all operational tasks during all phases of flight without compromising safety. This includes:
  - Flight path control.

- Collision avoidance.
  - Navigation.
  - Communications.
  - Operation and monitoring of aircraft engines and systems. [Note: In CS-23, this requirement is stated as: *"Operation and monitoring of all essential aeroplane systems."*]
  - Command decision-making.
- **The accessibility and ease of operation of necessary controls by the appropriate crew member.**
  It must be demonstrated that essential controls can be accessed and operated effectively by the flight crew in all expected flight scenarios. This ensures that flight crew workload, aircraft control, and CRM are not adversely affected.
  [Note: In CS-23, this consideration is phrased as: "*The accessibility and ease of operation of necessary controls by the appropriate crew member during all normal and emergency operations when at the crew member flight station.*"]
- **The kind of operation authorised:**
  Any limitations on single-pilot operations should be based on the Type Certificate Holder (TCH)'s technical assessment. Operations beyond those explicitly authorised for single-pilot flights should be strictly avoided. The TCH would be responsible for conducting this assessment as part of the certification process. This evaluation should:
  - Incorporate lessons learned from single-pilot operations in CS-23 aeroplanes.
  - Address the increased complexity of CS-25 operations.

One of the primary reasons for ORO.FC.200's requirement for two pilots in large aeroplanes is the significantly higher fatality risk associated with commercial transport operations. In small aeroplanes, such as those certified under CS-23, single-pilot operations are permissible partly because the potential loss of life is lower due to the limited number of occupants. However, in large transport-category aeroplanes (CS-25), the number of passengers can be one to two orders of magnitude higher, meaning that a catastrophic event involves significantly more casualties.

3. Safety considerations

3.1 Pilot incapacitation and impairment

Pilot incapacitation refers to a pilot becoming unable to adequately control an aircraft due to physical, physiological and/or psychological issues (Somerville et al., 2023), for instance because of acute illness, unconsciousness, sleep, drug intoxication, and death (Comerford et al., 2013). This also includes impairment of higher-level cognitive states, such as decision-making, which impacts pilots' ability to perform (Somerville et al., 2023). Incapacitation can be total or partial and subtle or obvious, see also project deliverable D-5). In cases of partial incapacitation, the pilot may be able to self-declare the incapacitation. In-flight incapacitation because of medical problems is a rare event occurring with a frequency of to 0.45 times per 10 million flight hours (DeJohn et al 2004). There are no reliable data on partial incapacitation or impairment available because it is not systematically reported. Partial incapacitation or impairment could pose a safety risk in the case of SiPO. Based on a survey (with 6300 respondents of which 4161 provided information on incapacitation or impairment, see project deliverable D-5) it was found that on average approximately two times per 1000 flight hours a flight crew member identified subtle incapacitation of their colleague crew member. The survey did not define subtle incapacitation or explain the difference between subtle and partial incapacitation. It is therefore assumed that responses for subtle incapacitation include occurrences of both subtle and partial incapacitation and also includes impairment due to excessive fatigue. The actual number on subtle/partial incapacitation could also be higher as the number found based on the survey only relates to the cases where a crew member was able to identify the incapacitation.

The catastrophic effect of pilot incapacitation in current single pilot operations is demonstrated by FAA Advisory Circular 25.1523 (published in 1993) that provides information on NTSB accident data from 1980-1989 regarding occurrences of pilot incapacitation. The data includes 32 occurrences of pilot incapacitation in on-demand commercial operations, such as charter flights, resulting in 32 fatalities. All fatalities were attributed to single pilot operations. In contrast, during scheduled commercial airline operations over the same time period, 51 pilot incapacitation occurrences were recorded but these resulted in a safe recovery of the aircraft by the other pilot.

The times during which the aircraft is closest to the ground (i.e., take-off and initial climb, and approach and landing) are the most critical phases, as during these periods a slow or incomplete transfer of control from the incapacitated pilot to an automated system is most likely to result in an accident. This forms the basis of the "1% rule" that is used for setting limits for aircrew incapacitation risk (Mitchell & Evans, 2004). During these flight phases incapacitation detection must be almost instantaneous, and/or the aircraft should be equipped with some form of envelope protection during take-off and landing.

However, it is not yet clear how (partial) incapacitation can be timely detected or predicted. Body worn devices that measure physiological parameters and camera systems to observe pilot's posture, facial features and eye parameters have been proposed for incapacitation detection. The performance of these systems is not yet sufficient. An additional issue is the fact that the use of personal data is restricted under Regulation (EU) 2016/679 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data. A pilot activity monitoring system that is based on expected pilot control input (maybe augmented with a system that periodically requires activation akin to a “dead man’s switch” as used in, among others, the railway industry) has also been proposed for pilot incapacitation detection. In any case, when a valid and reliable incapacitation detection technique would become available, there also must be some process to keep the aircraft safe after incapacitation has been detected. This process may include automatic take-off abortion, automatic take-off and automatic landing, including selecting and navigating to a suitable aerodrome.

3.2 Cognitive and psychological impact

In the survey that was done as part of project deliverable D-5, pilots outed their concern that SiPO could pose increased risks for pilots in terms of adverse cognitive and psychological effects. These effects include increased feelings of loneliness, boredom, and fatigue, particularly during monotonous tasks. The scarce literature that was found on boredom is based on subjective ratings only. Boredom has been associated with a higher frequency of attention lapses (Bhana, 2009) and there is evidence that alertness decreases the most during the monotonous part of the cruise flight (Airbus, 2004). Therefore, both monotony and boredom can be considered as a potential problem during the cruise phase of single pilot operations as they could “*impair the crew member’s alertness and ability to safely operate an aircraft or perform safety related duties*” (ICAO, 2011). Furthermore, in the survey results it was found that there is concern amongst pilots that during high-workload flight phases, such as take-off and landing, or in non-nominal conditions, the workload for a single pilot would become unsustainable, whereas it is currently manageable with a multi-person flight crew. It is known that high workload may contribute to fatigue, in turn affecting performance.

3.3 Cross-checking

Cross checking of the activities of one pilot by another pilot is one of the cornerstones of the multi-crew principle. For several predictable tasks, it is envisioned that an aircraft system will be able to perform a form of cross checking, but this will not be possible in all relevant situations. Therefore, the SiPO pilot must perform a self-check of tasks and procedures. While there are some tasks and decisions for which effective self-checking might be feasible, an individual performing self-checks is a common cause for errors.

3.4 Impact of increased automation

The implementation of SiPO will likely require additional automated functions in order to reduce pilot workload. The associated human-automation interaction issues should require attention. Based on scientific literature and operational experience, possible automation interaction problems including complacency, a lack of knowledge of advanced automation systems, not fully understanding what the automation is doing and lack of situational awareness which may result in error when pilots need to take over from automated systems have been identified (Hancke, 2020). The degradation of pilot manual flying skills is a concern that has been highlighted in literature as well (Comerford et al., 2012). As automation assumes more tasks, pilots may have fewer opportunities to practice manual flying, potentially impacting their proficiency in safely controlling the aircraft in the event of automation failure. Studies have also suggested that increased reliance on automation can lead to decreased situational awareness, which may result in errors when pilots need to take over from automated systems.

Current automation systems are not yet advanced enough to fully replicate the complex decision-making capabilities of a human pilot, particularly in emergency scenarios where situations can be highly dynamic and unpredictable. While automation has made significant progress, it still lacks the nuance, critical thinking, and contextual understanding that a trained pilot possesses.

However, advanced autoflight systems that can assist single pilots are already in use in some aircraft. These systems are able to provide (one or more of) the following functions:

- Automatic emergency descent in case of loss of cabin pressure.
- Automatic landing. The system automatically engages when it determines the pilot is unable to fly (it is unclear how the system determines this) or passengers can press an activation button.
- Automatic navigation to nearest suitable airfield: in the event of loss of engine power in a single-engine aircraft, the pilot can activate the system which helps the pilot efficiently navigate to an airport in range.
- Automatic TCAS response.

Several studies have investigated new support systems for single pilot operations, yet no research or detailed system descriptions were found from companies with practical experience in the industry. Many of the researched support systems were very similar to the already existing Emergency Descent and Autoland systems. Furthermore, new automation support functions (Airbus, 2025a and b), like automated taxiing and take-off functions, are still under research in the two men cockpit. Also, research on remotely-controlled aircraft (for instance as a backup) function, or remotely pilot-assisted functionalities are still in research in the civil aviation industry.

Robust safety measures will need to provide protection against security threats such as jamming and spoofing. Recent occurrences of GNSS jamming and spoofing demonstrate the vulnerability of the aviation system to these forms of cyber-attacks (Aireon, 2024, Spirent 2024). OEMs are developing anti-jamming and spoofing systems. Due to the nature of the issue, information on those systems is not publicly available. Positioning, navigation, and timing (PNT) resilience may require changes to the PNT infrastructure that need technological developments as well as policies and decisions at a State or even international level (Critchley-Marrows and Verspieren, 2024).

4. SiPO Concept of Operations

Different configurations of SiPO concept of operations (CONOPS) were found in the literature (Comerford et al., 2013; Lim Y. , Ramasamy, Gardi, & Sabatini, 2017):

1. Single pilot operations with no changes to current aircraft

In this CONOPS, single pilot operations of current CS-25 aircraft are allowed similar to the existing single pilot operations of CS-23 aircraft. This would require a change of regulation, and most likely a change the flight crew training programme. However, this is not a viable option because it will not result in an equivalent level of safety; the level of safety of CS-23 aircraft is accepted to be less than that of CS-25 aircraft (as for instance expressed in system failure requirements).

2. One pilot on board with onboard personnel as a back-up pilot

This CONOPS includes the replacement of the second pilot with a back-up airline staff member on-board for relief when required. This could be e.g. a flight attendant, commuting pilot or air marshal. The back-up pilot is supposed to (assist in) control the aircraft to a safe landing when the pilot is impaired or incapacitated.

However. there are several issues with this concept. A trained back-up pilot needs to be on-board at all times. This will offset some of the benefits gained by SiPO, for instance in the case of cargo aircraft. Furthermore, maintaining proficiency of the back-up pilot may be an issue.

3. One pilot on board with automation replacing the second pilot

In this concept the second pilot is replaced by automation. Autoflight systems of modern aircraft such as the Airbus A350 and Boeing 787 already provide much support to the flight crew in nominal and non-nominal situations. With automation at this level, the pilot's role is that of a systems manager/decision-maker.

4. One pilot on board with a ground operator replacing the second pilot

Two subtypes have been described for this CONOPS

a. One-on-one support when needed

A ground operator function supervises several flights and provides dedicated one-on-one support when needed. It is unclear how shift changes will work in this concept but these will likely be similar to current ATC shift transitions, with some overlap so that the incoming operator can understand the traffic situation. The new ground operator joins the last 5-10 minutes of the current ground operator's shift to monitor the traffic. The current ground operator also provides a transition briefing to the incoming ground operator.

b. Continuous one-on-one support

The pilot onboard has the help from a ground operator who takes over the duties of the second pilot throughout the entire flight. This is not considered to be a realistic option however because this concept does not seem to have any benefits relative to existing two-crew operations, with the additional drawback of more complicated inter crew communication.

The proposed design of the ground stations has not been specified, but will be a critical element for ensuring safety and efficiency of the single pilot flight operation. Training of the ground-operator has also not been specified in detail in any publication. Another critical element of this CONOPS is the security and reliability of the communication link between the aircraft and the ground station.

Regardless of the details of the CONOPS described above, flight safety must be ensured for various scenarios as presented in Figure 1 (Johnson, 2015) which combines pilot condition and flight condition classes. Off nominal flight conditions include technical issues (on-board or on ground) and environmental issues (weather) and operational issues (e.g. airport closure).

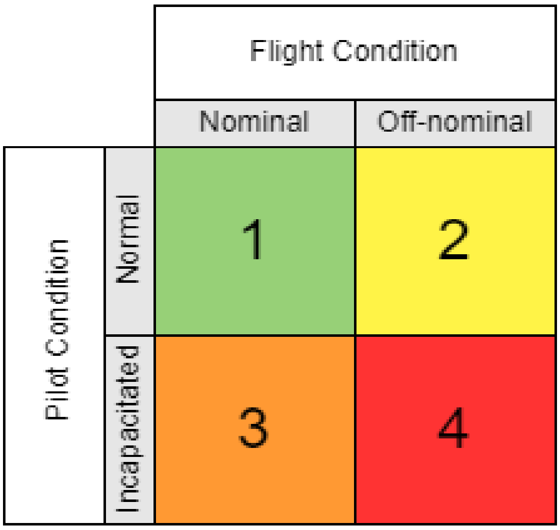

Figure 1: SiPO scenarios based on pilot and flight condition

Flight safety solutions that are proposed to allow eMCO (Airbus, 2022) may also be applicable to SiPO. This means that the aircraft design should aim to: 1) manage incapacitation and drowsiness, 2) simplify cockpit interaction and reduce workload, 3) improve support to the pilot for aircraft system failure management, 4) enhance aircraft resilience in abnormal events, 5) mitigate the risk of error, 6) preserve pilot's role and responsibilities, and 7) allow a safe lavatory break during long haul flights. However, OEMs have not provided details on how these objectives will be achieved in eMCO scenarios. Therefore, conclusions on the effectivity and applicability of these measures in achieving an equivalent level of safety of SiPO operations cannot be drawn either.

5. Conclusion

The primary question that this report investigates is whether single-pilot operations (SiPO) can be executed within larger commercial air transport operations with an equivalent level of safety compared to the current operations. SiPO are already utilized in complex, high-performance aircraft with an MTOM below 5,700 kg, highlighting the feasibility of this concept in certain contexts. However, as the industry considers adapting larger commercial aircraft to SiPO, several challenges and uncertainties arise. This project identified that there are still several significant issues which need to be resolved before SiPO can be considered to achieve an equivalent level of safety to the current commercial air transport operations with large aircraft.

Pilot incapacitation

A robust and reliable system for pilot incapacitation should be available. This should be capable of detecting not only pilot incapacitation but also impairment and drowsiness. The detection of incapacitation should be virtually instantaneous, since any delay can have catastrophic consequences if the pilot is actively controlling the aircraft. Once incapacitation is detected, a process must be in place to ensure the aircraft's safety. This may involve automatic functions such as take-off, including the ability to abort if needed, and landing, including selection and navigation to a suitable aerodrome. In practice, this means that the aircraft must be capable of autonomous flight. The added value of the single pilot would then lie in decision-making during unforeseen events or circumstances. Due to the requirement for (almost full) autonomous flight capability, the role of the SiPO pilot will primarily be monitoring, but the SiPO pilot must also be prepared for decision-making, which can be unpredictable in terms of the timing and type. As a result, workload could increase suddenly while the effects of such abrupt increases in workload on performance and the quality of subsequent decision-making are still not yet fully understood.

Pilot inactivity

The monitoring role of the SiPO pilot may lead to uneventful flights being perceived as boring, particularly during long-haul flights. The current literature on the effects of boredom on performance, including drowsiness, is scarce. Further, the potential long-term effects on the psychological well-being of individuals is unknown.

Cross-checking

As an alternative to cross-checking by the second pilot, the SiPO pilot must perform self-checks of task execution and decision-making. While there are some tasks and decisions for which effective self-checking might be feasible, the individual performing the self-check could be the common cause for errors.

Ground station augmentation

Augmenting the SiPO pilot with a ground station operator to perform cross-check functions or take over the flight in case of pilot incapacitation poses two main issues: security and reliability of the aircraft-ground station link, and the performance of the ground pilot. In this CONOPS the ground pilot will monitor one or more flights and only intervene in unforeseen or abnormal conditions. However, the effects of boredom and sudden increases in workload on performance of the ground operator are not sufficiently understood.

Therefore, the conclusion of the project is that at least these significant issues need to be addressed in order for SiPO to achieve an equivalent level of safety.

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Annex A Appendix EASA Class and Type Rating & License Endorsement List – Aeroplanes Complex Single Pilot Aircraft

A.1 Single pilot aircraft

Aircraft	Manufacturer	Type
AP68TP-600 Viator	Vulcanair S.p.A	Jet
AP68TP-300 "Spartacus"	Vulcanair S.p.A	Jet
SF600	Vulcanair S.p.A	Jet
SF600A	Vulcanair S.p.A	Jet
SC7 Skyvan	Bombardier	Turboprop
BN2T Turbine Islander	Brittan-Norman Aircraft LTD	Turboprop
BN2T-4R MSSA	Brittan-Norman Aircraft LTD	Turboprop
BN2T-4S Defender	Brittan-Norman Aircraft LTD	Turboprop
DO 128-6	Dornier	Turboprop
DO 28-G92	Dornier	Turboprop
Dornier 228-100	Dornier	Turboprop
Dornier 228-200	Dornier	Turboprop
Dornier 228-101	Dornier	Turboprop
Dornier 228-201	Dornier	Turboprop
Dornier 228-202	Dornier	Turboprop
Dornier 228-212	Dornier	Turboprop
Bandeirante EMB 110	Embraer	Turboprop
Nomad 22B	Nomad TC PTY LTD	Turboprop
Nomad 24A	Nomad TC PTY LTD	Turboprop
P166	Piaggio	Turboprop
DHC-6 (Twin Otter) **Series 400**	Viking Air	Turboprop
DHC-6 (Twin Otter) **Series 300**	Viking Air	Turboprop
DHC-6 (Twin Otter) **Series 200**	Viking Air	Turboprop

DHC-6 (Twin Otter) **Series 100**	Viking Air	Turboprop
SC7 Skyvan	Viking Air Limited	Turboprop

A.2 Single pilot high performance aircraft

Aircraft	Manufacturer	Type
C501/500SP	Cessna	Jet
C551/550SP	Cessna	Jet
C510 Citation Mustang	Cessna	Jet
C525 – CJ C525	Cessna	Jet
C 525 – CJ1	Cessna	Jet
C 525A – CJ2	Cessna	Jet
C 525 – CJ1+	Cessna	Jet
C 525A – CJ2+	Cessna	Jet
C 525B – CJ3	Cessna	Jet
C 525B – CJ3+	Cessna	Jet
C 525C – CJ4	Cessna	Jet
C 525 – M2	Cessna	Jet
SF50 Vision Jet	Cirrus Aircraft Company	Jet
Eclipse 500	Eclipse Aerospace	Jet
Eclipse 550	Eclipse Aerospace	Jet
EMB-500 Phenom 100	Embraer	Jet
EMB-505 Phenom 300	Embraer	Jet
HA-420 HondaJet	Honda Aircraft Company	Jet
HA-420 HondaJet Elite	Honda Aircraft Company	Jet
PC-24	Pilatus	Jet
PC-24 TF	Pilatus	Jet
PC-24 AYT	Pilatus	Jet
PC-24 AYT/TF	Pilatus	Jet
BE-200/B200	Beechcraft	Turboprop

BE-C90A/B/GT	Beechcraft	Turboprop
BE-C90/90-1	Beechcraft	Turboprop
BE-E90	Beechcraft	Turboprop
BE-F90/F90-1	Beechcraft	Turboprop
BE-90/A90/B90	Beechcraft	Turboprop
BE-200PL21/B200GT/250	Beechcraft	Turboprop
BE-C90GTi/C90GTx	Beechcraft	Turboprop
B1900	Beechcraft	Turboprop
1900 C	Beechcraft	Turboprop
1900 D	Beechcraft	Turboprop
300	Beechcraft	Turboprop
300LW	Beechcraft	Turboprop
B300/B300C (except with ProLine 21)	Beechcraft	Turboprop
B300/B300C (with ProLine 21)	Beechcraft	Turboprop
300 (FF serial with ProLine 21)	Beechcraft	Turboprop
RA-390	Beechcraft Raytheon	Turboprop
C406/425	Cessna	Turboprop
C441	Cessna	Turboprop
MU 2B series	Mitsubishi Heavy Industries	Turboprop
226 T	Ontic	Turboprop
226 T(B)	Ontic	Turboprop
226 AT	Ontic	Turboprop
226 TC	Ontic	Turboprop
227 TT	Ontic	Turboprop
227 AC	Ontic	Turboprop
227 AT	Ontic	Turboprop
227 BC	Ontic	Turboprop
227 DC	Ontic	Turboprop

P180 Avanti	Piaggio	Turboprop
P180 Avanti II	Piaggio	Turboprop
P180 Avanti EVO	Piaggio	Turboprop
PA-31T series Cheyenne	Piper	Turboprop
PA-42 series Cheyenne	Piper	Turboprop
AC 680T	Rockwell-Twin Commander	Turboprop
AC 690 series	Rockwell-Twin Commander	Turboprop
AC 900 series	Rockwell-Twin Commander	Turboprop

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