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Artificial Intelligence (AI) implementation in the Design of Single Pilot Operations Commercial Airplanes

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ABSTRACT

Aviation is approaching a new historical milestone for the sector, the further decrewing in the flight decks of airliners four decades later. Technology enablers are considered inevitable on the future SiPO flight deck (Li and Harris, 2007). Upon the establishment of the SiPO ConOps a task redistribution between human and machine agents is anticipated which will necessitate further human system integration (HSI) considerations during the design of the futuristic SiPO cockpit (Bailey et al., 2011). Yet, the existing commercially available AI technology (e.g., direct voice inputs-DVI) may be ready to serve some low-impact or non-time-critical applications (e.g., weather in destination and alternate airports update during the cruise phase) in this transitional period to eMCOs and SiPOs (Ziakkas et al., 2022). Such AI integration could initially postpone the necessity for a complete flight deck redesign at this time (Stanton & Harris, 2015) and offer both the industry and users the necessary time to accept and adapt on the operational changes. Recent studies introduced more sophisticated forms of cognitive assistants (Katz, Ding and Doyle, 2018; Dormoy, Andre and Pagani, 2020; Simon, Brock and Causse, 2020; Wei, He and Liu, 2020). No matter the level of complexity of the introduced technology in SiPO sound human system integration (HSI) through a structured iterative approach for HSI could ensure reliability and enhance safety levels towards eMCO and SiPO. This research aimed to suggest a HSI framework and outline considerations regading the implementation of AI technology in aviation during the transition from multi-crew to eMCO and SiPO. The conceptual SiPO with AI supported flight deck presented through the AUTOS pyramid the potential AI role in the human-machine interaction (HMI) to the flight deck on the SiPO Commercial Airplanes.

Keywords: SiPO, Human systems integration, Artificial intelligence, AUTOS pyramid

INTRODUCTION

According to the industrial roadmaps, the first certification of assistance for pilots is anticipated to occur in the year 2025, and this will be followed by a gradual transition to full autonomy sometime around the year 2035 (EASA, 2020). The progression of events in the field of commercial air transport can be broken down into three distinct stages:

- First step: crew assistance/augmentation (2022–2025)
- Second step: human/machine collaboration (2025–2030)
- Third step: autonomous commercial air transport (2035+)

There have been identified two different operational concepts (EASA, 2020):

- Extended Minimum-Crew Operations (eMCOs), formerly known as "Reduced Crew Operations," in which single-pilot operations are permitted during the cruise phase of the flight with a level of safety similar to that of today's two-pilot operations (to be implemented beginning in the year 2025).
- Single-Pilot Operations (SiPOs), in which, at a later stage, end-to-end single-pilot operations might be allowed, also based on a level of safety equivalent to today's two-pilot operations, to be implemented as of the year 2030.

Among the concerns identified as a result of the absence of a second crew member were a lack of monitoring and the potential for unchallenged mental models to lead to poor decision making (Pechlivanis & Harris, 2022). Commercial single-pilot should be aided by cognitive assistance for effective workload (WL) management and improved safety (Estes et al., 2018). Promising large-scale progress in the field of AI and cognitive computing (CC) are expected to provide effective support to pilots in SiPO (Dormoy et al., 2021).

It was supported that pilots have a positive attitude towards technology; however, they are hesitant to welcome another agent in the form of digital flight assistants (DFA) in the aircraft's cockpit (Gosper et al., 2021). Pilots' expect AI to provide assistance in time-critical scenarios (e.g., information retrieval during diversions) and active monitoring to trap errors/mistakes (Gosper et al., 2021).

The AI in the commercial SiPO flight deck is imperative to be adaptive in the operational context to provide efficient and effective support (Gosper et al., 2021). Multimodal bidirectional communication is argued to be an added value within the human intelligent machine team (HiMT) on the future SiPO flight deck (Dormoy et al., 2021).

HUMAN SYSTEMS INTEGRATION (HSI) FRAMEWORK FOR SIPO

In particular, information technology advanced significantly over the latter three decades of the 20th century. Automation can be defined as the transfer of cognitive functions from individuals to machines (e.g., pilots were manually in charge of aircraft handling qualities; a task that has been recently transferred to computers). The research team's primary goal is to construct a topology that iteratively enables system science and its application in aviation through the developing of HSI tools and AI to support systems design for Single Pilot Operations Commercial Airplanes. Human-automation symbiosis will optimize the allocation of cognitive labour in the flight deck (Romero et al., 2020).

The AI applied technology could be considered as system within the system of SiPO cockpit (SoS) and altogether within the SiPO concept of operations

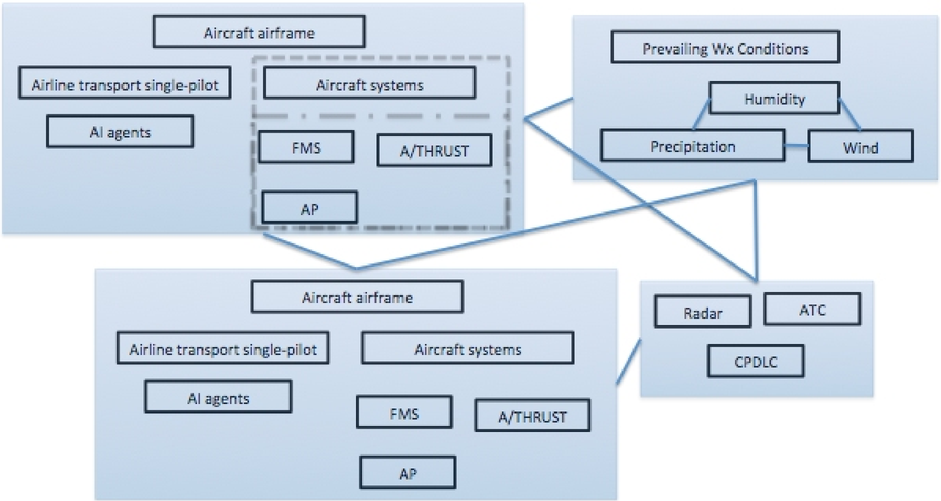

Figure 1: A SiPO system is a system of systems (i.e., a system includes an organized set of systems, and a system belongs to a bigger system).

(ConOps) (Figure 1) (Boy, 2021). The SoS notion is now commonly used to indicate sociotechnical interrelated systems. The research links the SiPO with the concept of SoS, delink them to the agents involved and relink them in the AUTOS pyramid.

A system can be either cognitive (or conceptual) in nature, physical, or both (Boy, 2017). Both humans and computers having cognitive capabilities. To date, autothrust, flight management systems (FMS), and autopilots meet the criteria those of cognitive agents within the sociotechnical environment of a commercial jet at present (Boy, 2021). The ongoing development of AI and CC will introduce more entities and functions to provide effective support to pilots in SiPO (Dormoy et al., 2021).

The term “system” is synonymous with “agent”. A system is a system of systems, just as an agent is a society of agents. The SiPO system is defined by structures and functions.

Lastly functions can differ depending on the context. The total single-piloting flight context, for instance, can be broken down into smaller contexts like as taxiing, takeoff, after-takeoff ascent, cruise, descent, approach, landing, and so forth. These settings can all be broken down into even more compact contexts. Context 1 may represent nominal operations, whereas Context 2 may, for example, be an abnormal one, as a system may develop from Context 1 to Context 2 (Figure 2).

Pilots need more autonomy and flexibility when operating outside of these settings since they must solve problems on their own when an unexpected circumstance arises. Once more, cooperation amongst knowledgeable agents is a very valuable resource. In addition, these agents—human or mechanical—need to be properly coordinated. Overall, designing for systemic flexibility is a matter of wisely allocating machine and human function. HSI experts contribute by ensuring that human capabilities and

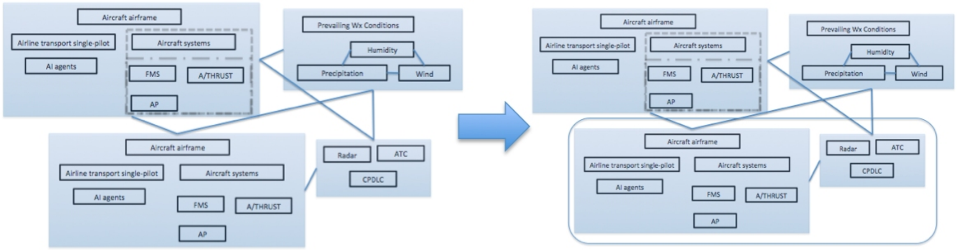

Figure 2: SiPO SoS evolution from nominal (context 1) to abnormal operations (context 2).

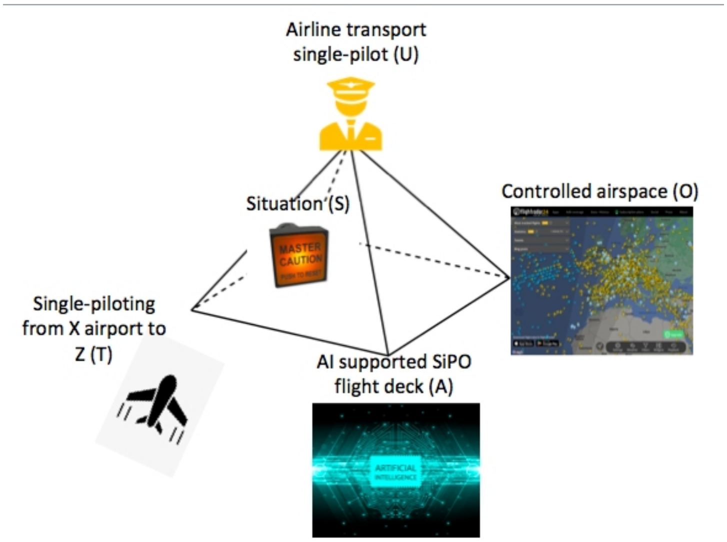

Figure 3: Recursive definition of a system, where resources are systems themselves.

limitations are considered. Purdue suggests the AUTOS pyramid (Boy, 2021) to be utilised to that end.

THE AI AUTOS PYRAMID FOR SIPO

The AUTOS pyramid concept was created as a useful and practical HSI guide (Boy, 2021). The letters "A" stands for Artifact (i.e., AI supported flight deck), "U" for User (i.e., airline single-pilot), "T" for Task (i.e., Commercial SiPO), "O" for Organization (i.e., controlled airspace), and "S" for Situation (i.e., normal operations).

To be more explicit, an airline transport single-pilot (U) who operates an aircraft with AI supported flight deck (A) is flying a commercial jet from X departure airport to Z destination airport is an example of a high-level task (T) in a controlled airspace (O). Whether this flight is a nominal operation or dealing with abnormal conditions (e.g., weather avoidance, aircraft malfunction, diversion) sets the situation (S). During the HSI iterative design particular considerations should be given to every agent in SoS based on the AUTOS pyramid (Figure 3).

The airline transport single-pilot (U) might range from experienced with SiPO (e.g., ex-military fighter or small business jet pilots) to cadet or to be prone to cultural or individual differences. The users might be also fatigued or stressed. Pilots representing the majority of potential influencing factors spectrum should be included in humans-in-the-loop simulations to find emergent features and functions. The AI supported flight deck (A) could be comprised by the already available technology (e.g., DVI) or more sophisticated intelligent assistants providings perhaps decision-making suggestions (e.g., suitable airports for diversion). The explanation of the AI supported flight deck complexity is directly related to system's complexity. The more complex the system is the more difficult a system is to operate and the more challenging testing it would be. The high-level task of single piloting a commercial jet with passengers (T) may be broken down into low-level tasks like taxiing, takeoff, climbout, cruise, and so on. The organisational context of controlled airspace (O) might consisted of other commercial or not aircrafts and air traffic controllers (ATC).

Interactions between the agents could explain (Boy, 2021):

- Single-piloting task and activity analysis (U-T)
- Information requirements, and AI technology requirements and restrictions for SiPO (T-A)
- Ergonomics and training/procedures for AI supported (T-U)
- Social issues between single-pilot, ground support (if any), ATC (U-O)
- Commercial single-pilot role and job analyses (T-O)
- Emergence and evolution (A-O)
- AI utilities usability/usefulness (A-S)
- Situation awareness (U-S)
- Single-piloting situated actions (T-S)
- Cooperation/coordination (O-S)

Moreover, the concepts of the A-factors and U-factors should be considered. The rules of ergonomics, information density, and content management within the SoS and the agent interactions and meet cognitive performance indicators such as option workability, cue prominence, direct comprehension, fine distinctions, transparency, enabling anticipation, historic information, situation assessment, directability, flexibility in procedures and adjustable settings (Billman et al., 2019).

CONCLUSION

Aviation is approaching a new historical milestone for the industry. Techological enablers are anticipated to provide further decrewing in the flight decks of airliners. The introduced technology in SiPO sound human system integration (HSI) through a structured iterative approach for HSI could ensure reliability and enhance safety levels towards eMCO and SiPO.

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