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Title

Enabling Single-Pilot Operations technological and operative scenarios: a state-of-the-art review with possible cues

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Abstract
Since the 50s, commercial aviation flights have progressively been changing alongside to the on-board automated systems' technological improvements, moving from up to five members populated crews to the current two. To date, a flying pilot (PF) and a non-flying pilot (PNF) are both responsible for the tasks of piloting, navigation, communication, and management of flight. However, no further enhancing and cost-reducing modification could be applied with the actual cockpit configuration, except through persisting in the trend of de-crewing and replacing the copilot with trustworthy automated subsystems or supporting ground stations. Enabling the so-called Single-Pilot Operations (SPO) is seen as one way of saving airliners' money and eventually facing with the future flights increase and lack of commercial pilots [1]. That associated with crews is, in fact, a significant fraction of aircrafts operating costs, especially for regional operators. Therefore, as the automation capability is rising, an exploration of SPO feasibility shall be conducted. Manufacturers such as Airbus [2] and Boeing are evaluating this concept for long-haul routes, paving the way for deeper implementation of AI-based technologies [3], [4] in avionics systems to supplant the copilot loss of redundancy with continuous assistance to the single PF. Nonetheless, mixed opinions about SPO arise, with many claims about safety risks and possible conflict with public opinion [5]. The purpose of this paper is to gather a review of the state of the art regarding Single-Pilot-Operations, with a focus on the topic of digital assistants in commercial aviation. In particular, the collected publications were classified into five specific headings, each one reporting theoretical discussions and practical cues to address possible future research activities. Regarding Operations, several SPO high-level architectures have been proposed with different function and task allocation between the agents, most of them involving a ground support, too, which is specifically addressed [6] to provide remote assistance in case of high-workload or pilot incapacitation. Communications refers to the necessary improvements which are required to remotely control the aircraft and cope with new potential cyber vulnerabilities. Also, Pilot Monitoring concerns with the need to characterize pilot performance during complex and/or emergency scenarios by defining human performance inference techniques from a set of automated, remote-sensed, psychophysiological measurements [7]. Certifications heading is then aimed to collect and identify regulatory aspects requirements for SPO [8] among institutions, creating standards and recommended practices to fill the lack of shared guidelines. Lastly, Cognitive Human-Aircraft Interface will be the key for enabling the transition to SPO, as the potential advantages to incorporating intelligent systems into the cockpit could take the shape of Digital Flight Assistants (DFAs). Regarding this, expert pilots' opinion is generally collected [9] as a support for these systems assessment, also by means of Human-In-The-Loop simulations (HITL). This review is also intended to give a brief recap of Machine Learning (ML) based applications [10], as well as Computer Vision (CV) algorithms candidates for implementation in more-autonomous

flights. Besides, establishing the potential interrelationships among all these subtopics can be helpful in improving SPO complexity managing, by trying to gain insight into topics that are mostly fragmented at the subsystem-level.

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