Towards single pilot operations: A review of cockpit interaction concepts

Arijit Gupta
RWTH Aachen Univeristy
Aachen, Germany
arijit.gupta@rwth-aachen.de

ABSTRACT

Number of crew members in commercial flight cockpits has seen a steady decrease since 1950s. While in the 1950s, a commercial aircraft cockpit featured 5 persons, currently a two pilot system is common for large wide-body aircrafts. There is an interest from NASA, airline companies and aircraft manufacturers to look into the potential of a future cockpit featuring only one pilot. A single pilot operation will be fundamentally different than the current two pilot setup. Thus, it is necessary to conceptualize tomorrow's cockpits, today.This paper presents a review of current and novel interaction strategies that could influence tomorrow's single pilot operations.

Author Keywords

explainable AI, human machine interaction, human in-the-loop, situation awareness, trust building, human-centered method

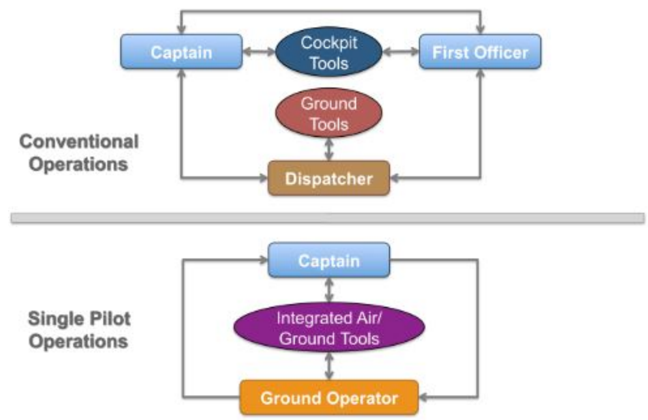

Figure 1. Conventional vs. single-pilot operations [1]

INTRODUCTION

Cost of on board flight personnel represents the highest percentage (typically 10-15%) of operating cost of an aircraft. From a five member cockpit in the 1950s, airline companies have been consistently "de-crewing" [5] to today's two-member cockpit. The reduction of a single cockpit member could further save up to 50 % cost in salary with additional savings on licensing, training etc. [12]. Consequently, from a purely economic perspective, it is in the benefit of airlines to make the move towards Single Pilot Operations (SPO). In addition, SPOs might provide a solution to the global pilot shortage and increase flexibility in crew scheduling. In 2012, a technical interchange meeting [3] held at NASA Ames Research Center focused on five major research areas: automation, operations, communications/social interactions, pilot incapacitation and certification. In recent years, research on SPO has focused on remote pilots or Ground Operators (GO) and automation [14]. With the massive progress in the field of Artificial Intelligence (AI) technology, there is a push towards researching new concepts for SPOs (Fig. 1). The removal of the first officer from the cockpit and reduction of crew member calls for new control devices and interactions.

CHI'20, April 25–30, 2020, Honolulu, HI, USA

ISBN 978-1-4503-6708-0/20/04…$15.00

DOI: https://doi.org/10.1145/3313831.XXXXXXX

Thanks to technological advancement and increased automation in flights, today's cockpits are based on a two-pilot safety critical system. Modern aircrafts are able to take-off, cruise and even auto land without major intervention from pilots. One might ask, what is the need of two pilots. The pilots' presence in the cockpit is necessary for monitoring and in case of an emergency, to take over control. The need for safety is paramount and redundancy is necessary. While autonomy in flights have decreased pilot's physical workload, cognitive workload has increased over the years [10].

A single pilot operation will fundamentally be different than a two pilot operation. Also, future pilot's of the year of 2045 are 5 year old today and are exposed to different technology, interaction paradigms than there predecessors born in the 1980s. Thus, it is necessary to conceptualize tomorrow's cockpit today. This article provides an overview of interaction concepts, as present in existing research and summarizes strategies for designing cockpit for SPOs.

SINGLE PILOT OPERATIONS

Steady advancement of design and technology systems in the last decades allowed the reduction in number of crew members

Figure 2. From left to right: Concorde's analog cockpit; glass cockpit in the A320; interactive cockpit in the A380 [4]

to two. For example, Inertial Navigation Systems/Global Positioning Systems (INS/GPS) and Flight Management Systems (FMS) have replaced tasks performed by an on-board navigator. There is an interest in such a move to SPO for future aircrafts [14, 2].

In a two pilot setup, the first officer helps in flying the airplane by following captain's orders and is also capable of taking control in case of an unfortunate event of incapicitation of the captain. Researcher propose, any functions currently performed by the first officer can be absorbed by an air-ground based approach [6, 7] or an automation-centric approach [12].

Air-ground based approach
An air-ground approach is thought of as an improved version of air traffic control that is able to serve multiple aircrafts. According to Lachter et al. [7] a two pilot crew, separated in flight and ground, is a feasible solution. Although, common issues with this approach are lack of awareness between two pilots [6], missing non verbal cues [13] and pilots' general subjective dislike [7] .

Automation-centric approach
Unlike the air-ground based approach discussed above, in the automation-centric approach, automation in the cockpit needs to be developed so that a single pilot can fly the aircraft without receiving aid of a second human operator [13]. Human interaction with automation has both benefits and pitfalls. Automation can reduce physical workload but increase cognitive workload, leading to problems associated with vigilance or complacency [8]. Automation-centric operational concepts must overcome these pitfalls. Shively et al. [11] highlighted the notion of human-autonomy teaming (HAT), where humans and automation work together. HAT marks a significant shift from the notion that automation simply replace human functions.

In the cntext of reduced-crew operations, Shively et al. further argued that human understanding of automation's intent and reasoning as well as automation's understanding of human preferences, attitudes and states is crucial for HAT.

Trust plays an important role in success of using automation. While low levels of trust can lead to disuse, very high level of trust in automation system can lead to over reliance and therefore complacency [8].

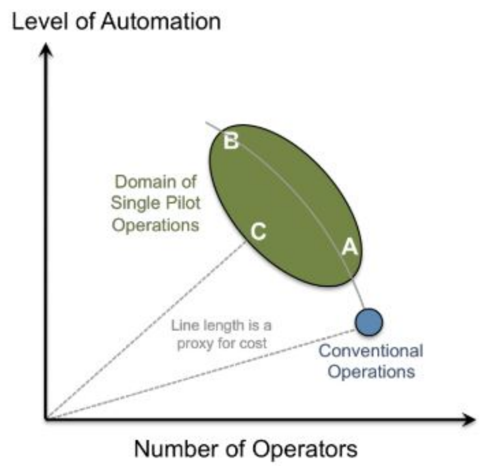

Figure 3. Options space for implementation of SPO [1]

ENTER EXPLAINABLE AI
In recent years, performance of AI based systems have exceeded human level for not only simplistic but complex tasks (e.g. sentiment analysis, speech understanding or strategic game playing [9]). However, these highly optimized AI models usually work in a black box manner. This has been a concern for number of application areas (e.g. medicine, law, self-driving cars) due to the inherent non-transparency of these models. There is a need of explainable and human interpretable AI for trust building. This is particularly necessary for human centered design that result from the AI model is validated by a human expert. In SPO context, the pilot.

COCKPIT DESIGN
In the last sixty years, manufacturers have grouped related functions into common displays and increased the number of functions and information available to pilots [4]. Also, cockpit of the aircraft has gone through a massive evolution from Steam or analogue cockpit (Concorde) to "glass" cockpit (Airbus A320) to interactive cockpit (Airbus A380) (Fig. 2).

Future visions for SPOs have to face increasing complexity of cockpit visualization environments, aiming at the optimisation of pilot's performance. Indeed, pilots must maintain a high level of situation awareness during all phases of the flight in order to match the unprecedented level of safety seen in current two-pilot-automation based systems.

Researcher have shown an interest in keeping humans in-the-loop and proposed various new interaction concepts:

1. "Tangibilisation of the cockpit" by Castillo et al. [4]
2. Additional assistant system with AR-Glasses by Tran et al. [12]

While there is no single solution for SPO interaction concept, it is likely that the future cockpits will feature multi-modal interaction with increased autonomy and multiple communication channel. Meanwhile, incremental changes with a mix of interaction paradigms must find a way to co-exist together till the change to a new concept for SPO is designed and validated.

CONCLUSION

A single pilot operation would mean less cost to employ pilots, less time spent on training and there is definitely an interest from the aviation industry. However, major hurdles exist in terms of technology (automation, connectivity, communication security), regulations (certifications on an aircraft) and social acceptance of an one-pilot system. Lack of trust in automation and AI based system is also a major issue and hence we propose more transparency through the use of explainable AI models. Pilots, passengers and all stakeholders must be kept in the loop at all stages to realize the vision of cockpit of the future for a single pilot operation.

REFERENCES

[1] Karl D. Bilimoria, Walter W. Johnson, and Paul C. Schutte. 2014. Conceptual framework for single pilot operations. *HCI-Aero 2014 - Proceedings of the International Conference on Human-Computer Interaction in Aerospace* (2014), 1–8. DOI: http://dx.doi.org/10.1145/2669592.2669647

[2] Summer L. Brandt, Joel Lachter, Vernol Battiste, and Walter Johnson. 2015. Pilot Situation Awareness and its Implications for Single Pilot Operations: Analysis of a Human-in-the-Loop Study. *Procedia Manufacturing* (2015). DOI: http://dx.doi.org/10.1016/j.promfg.2015.07.846

[3] Doreen Comerford, Summer L Brandt, and Richard Mogford. 2019. NASA / CP — 2013 – 216513 NASA ' s Single -Pilot Operations Technical Interchange Meeting : Proceedings and Findings. April 2013 (2019).

[4] Nadine Couture, Nadine Couture, The Aircraft, Future Towards, Juan Angel, Nadine Couture, and U Bordeaux. 2016. The Aircraft of the Future : Towards the Tangible Cockpit To cite this version : The Aircraft of the Future : Towards the Tangible Cockpit. *Proceedings HCI-Aero '16* (2016). DOI: http://dx.doi.org/10.1145/2950112.2964582

[5] Don Harris, Neville A. Stanton, and Alison Starr. 2015. Spot the difference: Operational event sequence diagrams as a formal method for work allocation in the development of single-pilot operations for commercial aircraft. *Ergonomics* 58, 11 (nov 2015), 1773–1791. DOI: http://dx.doi.org/10.1080/00140139.2015.1044574

[6] Joel Lachter, Quang V. Dao, Vernol Battiste, Robert Koteskey, Michael Matessa, and Walter W. Johnson. 2014a. Toward single pilot operations: The impact of the loss of non-verbal communication on the flight deck. In *HCI-Aero 2014 - Proceedings of the International Conference on Human-Computer Interaction in Aerospace*. Association for Computing Machinery, Inc. DOI: http://dx.doi.org/10.1145/2669592.2669695

[7] Joel Lachter, Sarah V. Ligda, Summer L. Brandt, Michael Matessa, Vernol Battiste, and Walter W. Johnson. 2014b. Toward single pilot operations: Developing a ground station. In *HCI-Aero 2014 - Proceedings of the International Conference on Human-Computer Interaction in Aerospace*. Association for Computing Machinery, Inc. DOI: http://dx.doi.org/10.1145/2669592.2669685

[8] Raja Parasuraman, Thomas B. Sheridan, and Christopher D. Wickens. 2008. Situation Awareness, Mental Workload, and Trust in Automation: Viable, Empirically Supported Cognitive Engineering Constructs. *Journal of Cognitive Engineering and Decision Making* 2, 2 (2008), 140–160. DOI: http://dx.doi.org/10.1518/155534308X284417

[9] Wojciech Samek and Thomas Wiegand. 2017. EXPLAINABLE ARTIFICIAL INTELLIGENCE : UNDERSTANDING , VISUALIZING AND INTERPRETING DEEP LEARNING MODELS Dept . of Video Coding & Analytics , Fraunhofer Heinrich Hertz Institute , 10587 Berlin , Germany Dept . of Computer Science , Technische Universit ¨ D. (2017).

[10] Lance Sherry, Peter Polson, and Michael Feary. 2001. Designing User-Interfaces for the Cockpit :. *Society* 2 (2001).

[11] R. Shively, Joel Lachter, Summer Brandt, Michael Matessa, Vernol Battiste, and Walter Johnson. 2018. Why Human-Autonomy Teaming? 3–11. DOI: http://dx.doi.org/10.1007/978-3-319-60642-2_1

[12] The Tran, Ferdinand Behrend, Niels Funning, and Andres Arango. 2018. Single Pilot Operations with AR-Glasses using Microsoft HoloLens. 1–7. DOI: http://dx.doi.org/10.1109/DASC.2018.8569261

[13] Kim Phuong L. Vu, Joel Lachter, Vernol Battiste, and Thomas Z. Strybel. 2018. Single Pilot Operations in Domestic Commercial Aviation. *Human Factors* 60, 6 (sep 2018), 755–762. DOI: http://dx.doi.org/10.1177/0018720818791372

[14] Cynthia A Wolter and Brian F Gore. 2015. A {Validated} {Task} {Analysis} of the {Single} {Pilot} {Operations} {Concept}. January 2015 (2015), 60.