Towards single pilot operations: A review of cockpit interaction concepts

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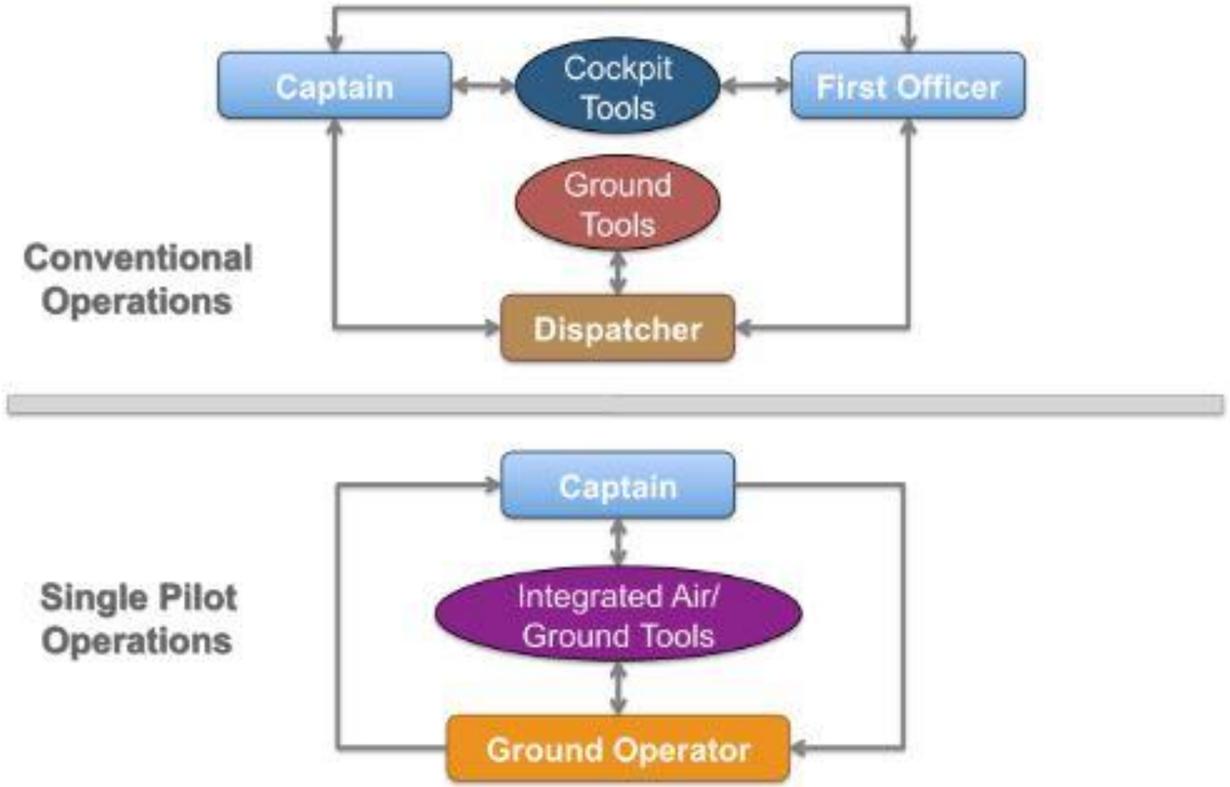
Introduction

What is Single Pilot Operation?

- Currently, a two pilot system is common for large wide-body aircrafts
- The potential of a future cockpit featuring only one pilot
- Interest from NASA, airline companies and aircraft manufacturers

Introduction

What is Single Pilot Operation?



Karl D. Bilimoria, Walter W. Johnson, and Paul C. Schutte. 2014. Conceptual framework for single pilot operations. HCI-Aero 2014

Introduction

In What context?

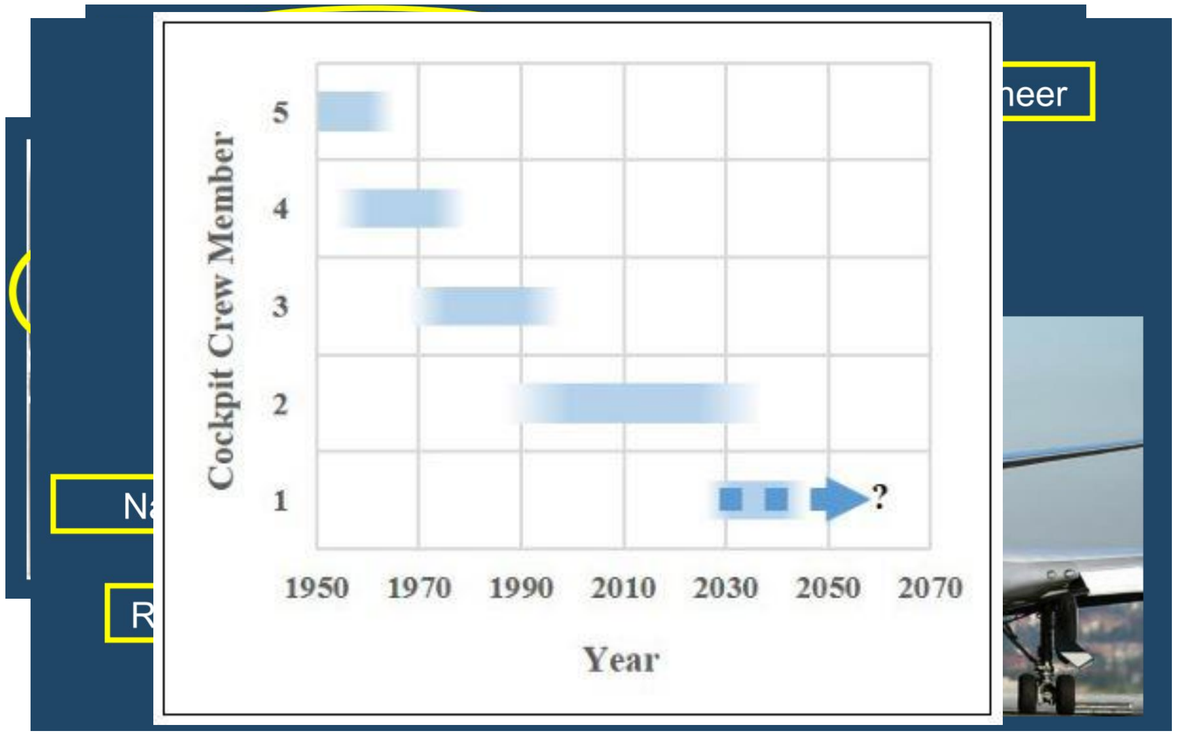
- Commercial
- Wide Body
- Long-haul

From left to right: Concorde's analog cockpit; glass cockpit in the A320; interactive cockpit in the A380

Nadine Couture, Nadine Couture, The Aircraft of the Future : Towards the Tangible Cockpit. Proceedings HCI-Aero '16 (2016)

A brief history

of “de-crewing” in the cockpit



1950s

Captain, First Officer, Flight Engineer, Navigator, Radio Operator

1970s

Crew size of four

1980s

Crew size of three

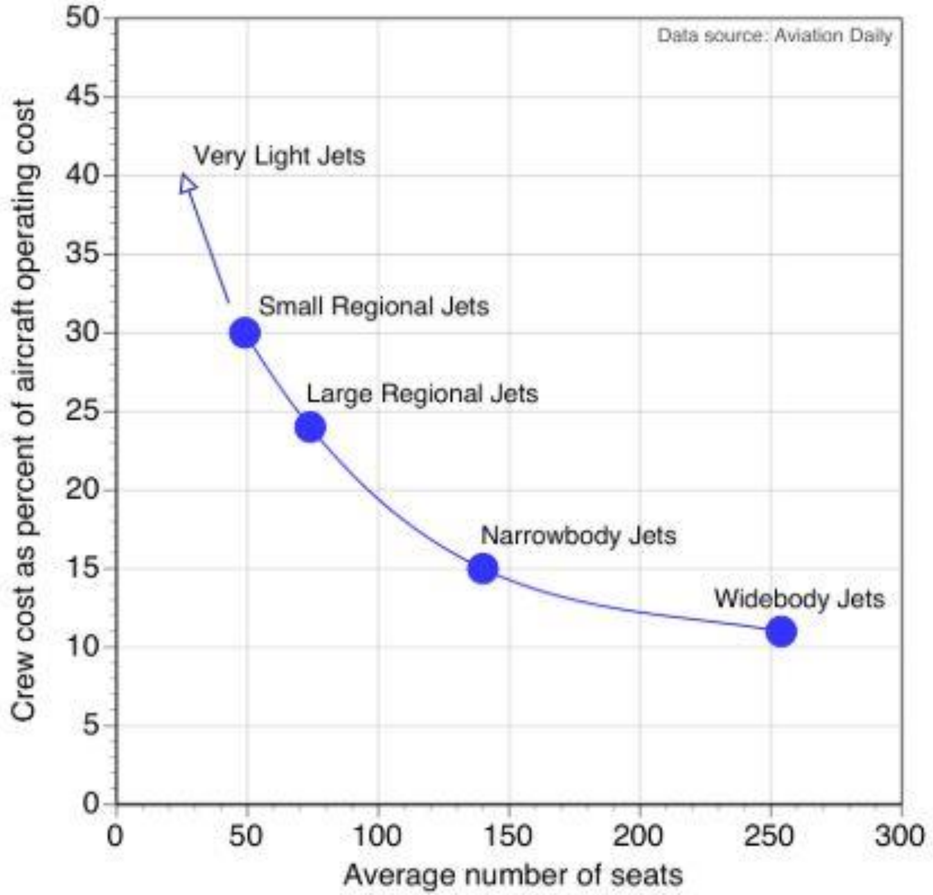
2019

Captain, First Officer

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),

Motivation

for Single Pilot Operations



- Cost of on board flight personnel represents the highest percentage (typically 10-15%) of operating cost of an aircraft
- The reduction of a single cockpit member could further save up to 50 % cost in salary cost in salary with additional savings on licensing, training etc.
- SPOs might provide a solution to the global pilot shortage and increase flexibility in crew scheduling

The Tran, Ferdinand Behrend, Niels Funning, and Andres Arango. 2018. Single Pilot Operations with AR-Glasses using Microsoft HoloLens

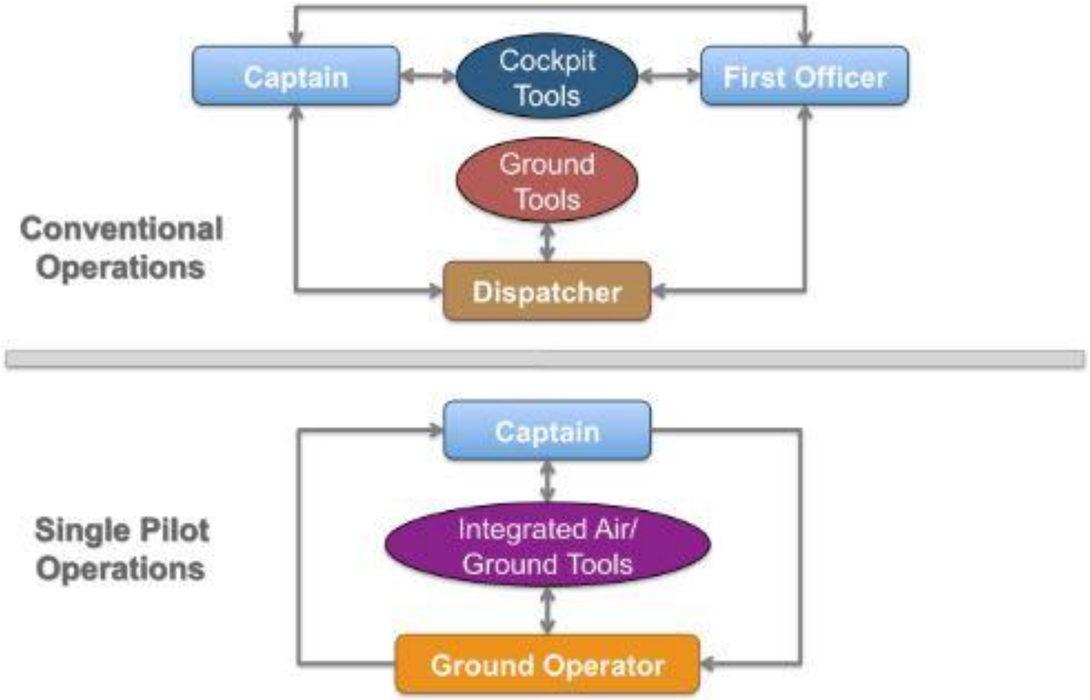
Single Pilot Operations

Two potential paths

- **Ground-Based Support:** In the future we will be relying much more extensively on air-ground collaboration, with many of the First Officer functions being handled remotely

- **Flight Deck Automation:** In the future we will have a flight deck with very intelligent automation that can effectively replace the functions of the First Officer

Ground-Based Support



- Today's cockpits are based on a two-pilot safety critical system
- An air-ground approach is thought of as an improved version of air traffic control that is able to serve multiple aircrafts
- Common issues with this approach are lack of awareness between two pilots, missing non verbal cues and pilots' general subjective dislike.

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

Ground-Based Support

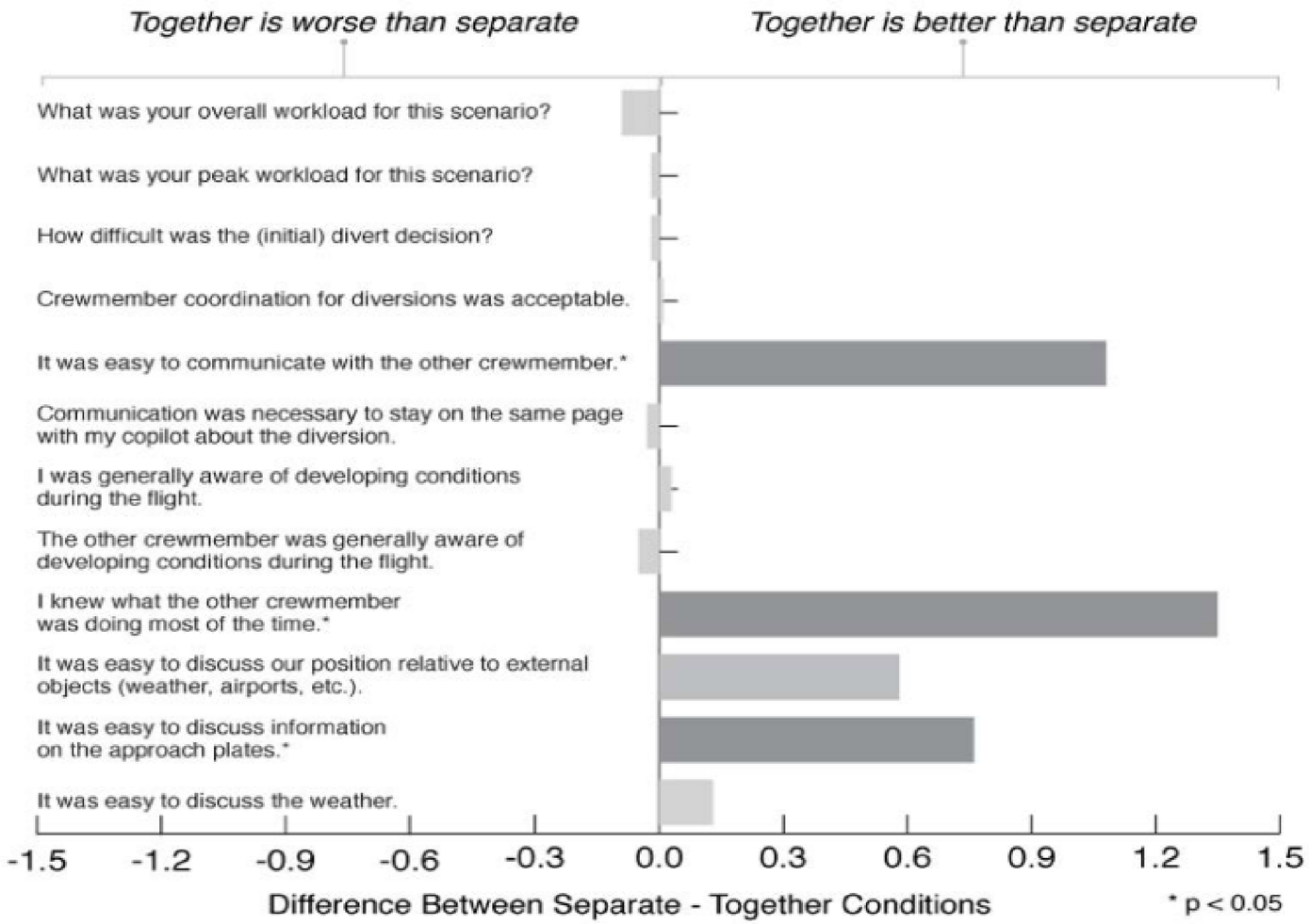
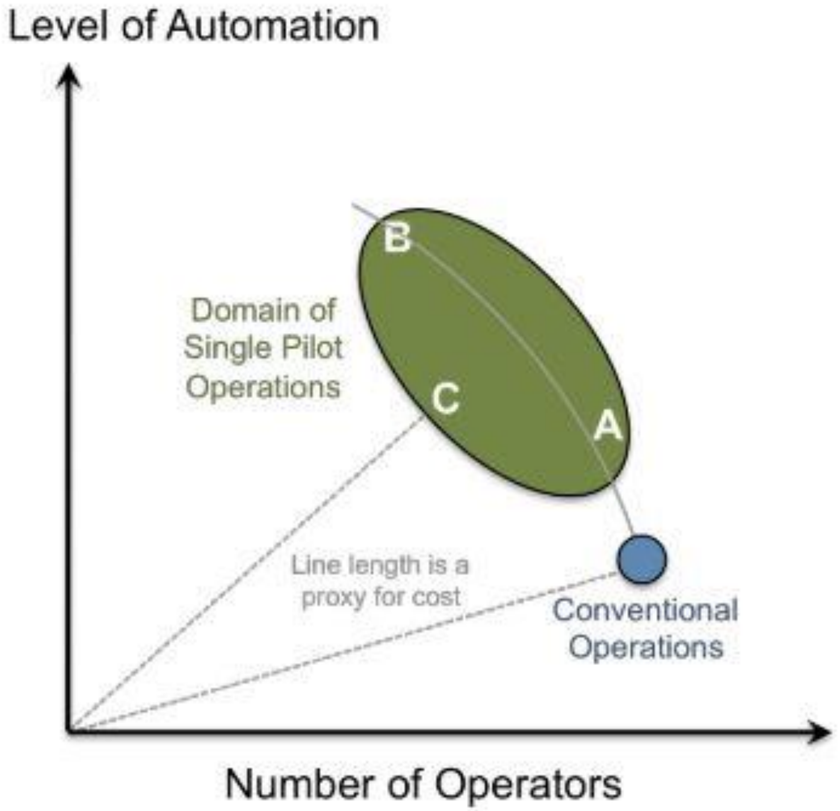


Figure 4. Differences between Together and Separate in response to post-trial questionnaire. Dark shaded bars indicated significant differences.

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

Flight Deck Automation



- In the automation-centric approach, a single pilot can fly the aircraft without receiving aid of a second human operator
- 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
- Common issues with this approach are lack of awareness between two pilots, missing non verbal cues and pilots' general subjective dislike.

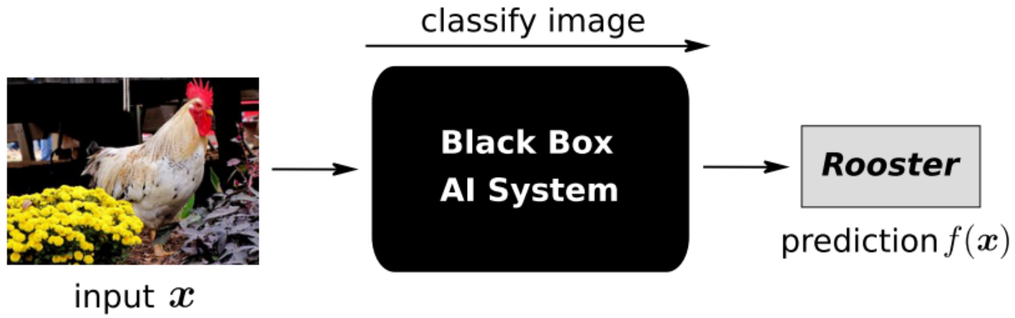
Kim Phuong L. Vu, Joel Lachter, Vernol Battiste, and Thomas Z. Strybel. 2018. Single Pilot Operations in Domestic Commercial Aviation. Human Factors 60, 6 (sep 2018)

Human-Autonomy Teaming (HAT)

- Shively et al. 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
- Human understanding of automation's intent and reasoning as well as automation's understanding of human preferences, attitudes and states is crucial for HAT.

R. Shively, Joel Lachter, Summer Brandt, Michael Matessa, Vernol Battiste, and Walter Johnson. 2018. Why Human-Autonomy Teaming?

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)
- 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)
- There is a need of explainable and human interpretable AI for trust building.

Cockpit Design

Two potential concepts

- **Tangible cockpit:** identify criteria and properties within the cockpit's user interfaces that can facilitate the coexistence between its tactile and physical actuators.

- **Augmented Reality:** to discover how an AR-device can be integrated on board the human-machine system and to define the pilot-cockpit interaction, to improve the overall performance of the SPO if ground support is not possible

Cockpit Design

Tangible cockpit

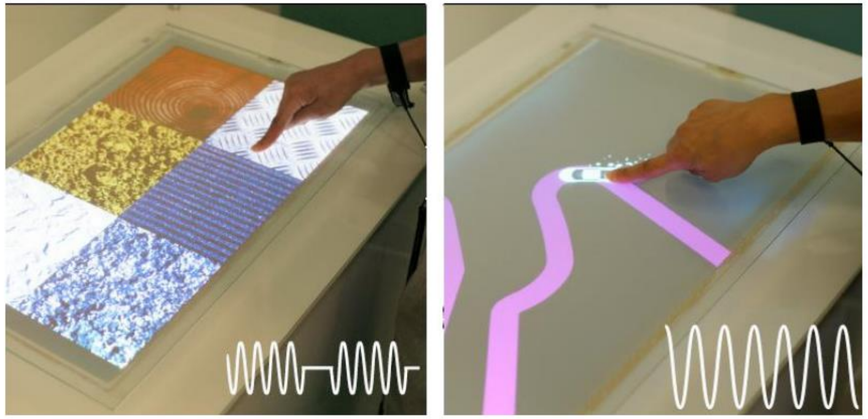


Figure 3: Tesla touch [10].

Figure 6: Ultrahaptics [13].

- Input equals output: The display is also the input device. The same continuous surface that provides information to the pilots will be used to introduce commands and control the aircraft.
- Function equals Form: The shape of the display equals its function. Applied to the cockpit, it means that the shapes of its devices afford their function.
- Form follows flow: The display can take different shapes. Triggered by events like the context or the flight stage, sections of the cockpit will be capable of showing up or modifying their shape to adapt accordingly

Nadine Couture, Nadine Couture, The Aircraft of the Future : Towards the Tangible Cockpit. Proceedings HCI-Aero '16 (2016)

Cockpit Design

AR Glasses

Fig. 2. Airbus A320 Simulator

Fig. 3. AR-Pilots Point of View

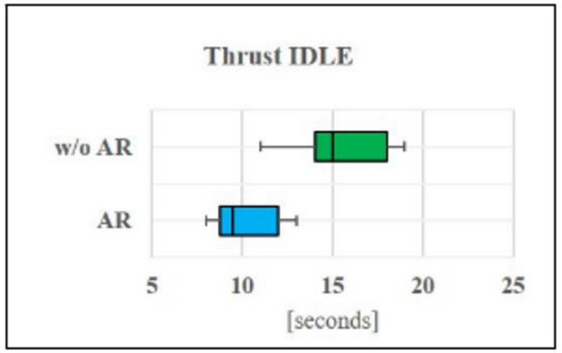


Fig. 5. Idle the thrust lever – 1st Action

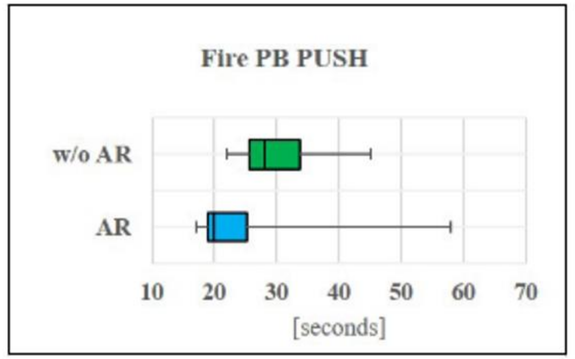


Fig. 7. Push the fire pushbutton - 3rd Action

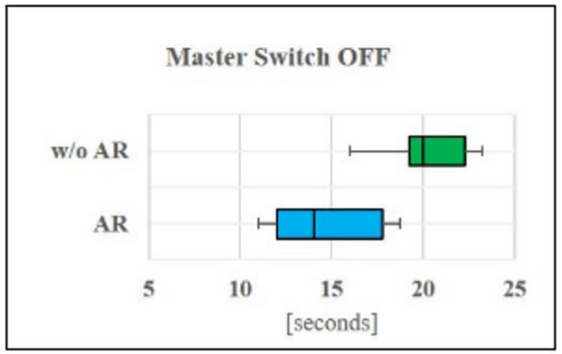


Fig. 6. Switch off the engine - 2nd Action

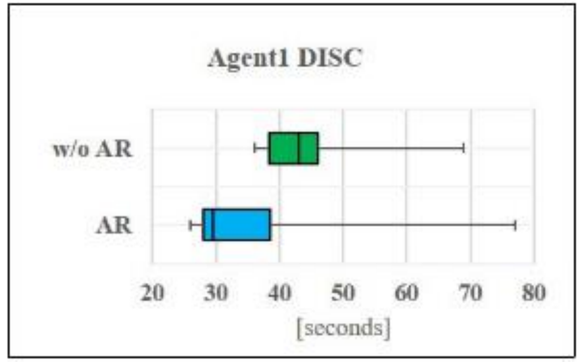


Fig. 8. Discharge Agent1 - Last Action

The Tran, Ferdinand Behrend, Niels Funning, and Andres Arango. 2018. Single Pilot Operations with AR-Glasses using Microsoft HoloLens

Barriers to SPO

Barriers:
- Perceived and actual reduction in safety
- Increased pilot workload
- Reduced ability to handle off-nominal events

New Requirements:
- Smarter advanced automation
- Improved coordination/collaboration
    - With both remote people and automation

Arguments against SPO

- Unacceptable to flying public?
- Too much faith in automation and communication reliability?
- Won’t save money, just moves people to the ground?

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 SPO
- Lack of trust in automation and AI based system is also a major issue and hence transparency through the use of explainable AI models is proposed
- 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