Pre-study Walkthrough with a Commercial Pilot for a Preliminary Single Pilot Operations Experiment

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Abstract. The number of crew members in commercial flights has decreased to two members, down from the five-member crew required 50 years ago. One question of interest is whether the crew should be reduced to one pilot. In order to determine the critical factors involved in safely transitioning to a single pilot, research must examine whether any performance deficits arise with the loss of a crew member. With a concrete understanding of the cognitive and behavioral role of a co-pilot, aeronautical technologies and procedures can be developed that make up for the removal of the second aircrew member. The current project describes a pre-study walkthrough process that can be used to help in the development of scenarios for testing future concepts and technologies for single pilot operations. Qualitative information regarding the tasks performed by the pilots can be extracted with this technique and adapted for future investigations of single pilot operations.

1 Introduction

Technology is currently available that assists pilots with take-off and landing, parking at airport terminals, en-route navigation, and various other operations. Many other forms of advanced technologies and concepts of operations are currently being developed and evaluated for possible implementation over the next few decades [1]. Within the Next Generation Air Transportation (NextGen) system [2], it is assumed that the adoption of advanced aeronautics technologies will alter the role and responsibilities of the operators in the system. This paper will focus on one potential change to flight deck operations, called single pilot operations (SPO), which is not presently envisioned in the NextGen initiatives.

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Fifty years ago, flight decks had up to a five person crew, a number that has steadily decreased over time. Currently, commercial aircraft have two flight deck crew members: a captain and a co-pilot. Either the captain or the co-pilot may perform the duties of pilot flying (PF) and pilot monitoring (PM). According to Hutchins [3], the pilot flying is concerned with controlling the aircraft, while the pilot not flying (or pilot monitoring) communicates with air traffic controllers (ATCos), operates aircraft systems, accomplishes checklists, and attends to other duties in the cockpit. While the captain always retains command and leadership of the flight, the duties of PF and PM typically are traded back and forth from one leg to the next leg. In order to successfully reduce the number of crew members from two to one for single pilot operations (SPO), the tasks of one pilot must be transferred to automated systems or otherwise replaced.

The benefits of transferring tasks to automation have been demonstrated in the past. Automation typically lowers operators' overall workload [4], and in mundane conditions, automation can maintain more consistent and accurate performance than that obtained by human operators. However, the drawbacks of automation are well documented. Automation leads to operators to becoming complacent [5], and to "out-of-the-loop" syndrome, which can cause a decrease in operator situation awareness [6]. "Out-of-the loop" syndrome occurs when an operator is less involved in and therefore less aware of the state of a system. The reduction in operator involvement is usually a result of more advanced technology that performs actions in place of the operator. Moreover, the modern cockpit is already highly automated. Pilots now supervise and monitor aircraft systems and automation tools [7]. To increase the level of automation that is required for single pilot operations would mean that the pilot's role will evolve more towards the title of 'flight manager' than actual 'flyer' of an aircraft. Thus, the benefits and costs associated with SPO must be evaluated.

The major benefit of SPO is probably reduced cost of operations through reduction of crew costs (i.e. one less pilot to pay per flight). In addition, Norman [8] proposes that the benefits of SPO would include more efficient crew scheduling and better aircraft availability. Also, with one less crew member, the size of the cockpit could be reduced, leading to lighter aircraft. Moving to SPO is also practical because current regulations specify that all aircraft must be capable of being operated by one pilot from either seat. This means that much of the infrastructure already exists for SPO [7] for commercial flight. For general aviation, the concept of a single pilot is not new, so air traffic controllers already have experience interacting with single pilot flight decks.

The main question of interest in any move to SPO is "what is being lost when transitioning from a two-pilot crew to a single pilot?" According to Harris [7], de-crewing has not affected flight safety when paired with appropriate technology available on a flight deck. Therefore, it is expected that automation will be an important aspect of SPO. But to adequately answer "what is lost", and therefore what needs to be made up for with automation or other procedures, research must aim to fully understand the perceptual, cognitive, and social aspects of current, dual-crew flight operations. With a more complete knowledge of the factors that drive pilot and co-pilot interactions, SPO flight decks can be designed to ensure that SPO will achieve safe and efficient flight operations. Factors involved in crew resource management (CRM) such as operator decision making, adaptability, communication, situation awareness, workload, and expertise, among others, must be understood to develop automation tools and flight deck procedures that will accommodate the loss of the second crew member on the flight deck. The goal of the present study is to illustrate the use of using a pre-study walkthrough of a pilot task to gather the information about the flight deck processes and interactions occurring during dual-crew operations. Findings from such a walkthrough would allow researchers to create a generic task flow. This task flow, in turn, can serve as a basic template for designing experimental flight scenarios to be used in simulation evaluations of SPO concepts and technologies. In the following sections we describe how, for one pilot (among several which we examined), we used a pre-study walkthrough to uncover issues and problems that should be addressed in evaluating SPO. It is not our purpose in this report to propose solutions for these issues. Also, the ultimate simulation evaluations that grew out of this process are not described here, but will be reported in later publications.

2 Method

2.1 Participant

Commercial pilots served as subject matter experts (SMEs) for the pre-study walkthroughs. The process for one of these pilots is described below.

2.2 Apparatus

A generic flight scenario was drafted in Microsoft PowerPoint with an arrival path illustrating a descent into Denver International Airport (DEN) (Figure 1). The placement of weather cells in the scenario was intended to interfere with nominal procedures associated with flying the arrival route. This scenario was used to guide the walkthrough along with a semi-structured interview that was developed to guide the pilot through the flight scenario. Fig. 2 includes sample questions that were used in the interview. The questions were selected to elicit detailed information regarding the communication, cognitive decision making, and physical actions that the pilot would experience during the flight. In particular, the pilot was questioned about his goals during a typical flight, the time pressure present, errors that he might expect to occur, his decision process, and from what displays he would expect to retrieve specific information in the cockpit.

A laptop computer using Camtasia Studio was used to record the interview as the pilot performed the walkthrough. Camtasia Studio is an audio/video recording and editing software. Audio input was received from a microphone built into the laptop. Recordings were reviewed and any information that was overlooked during the live walkthrough was noted.

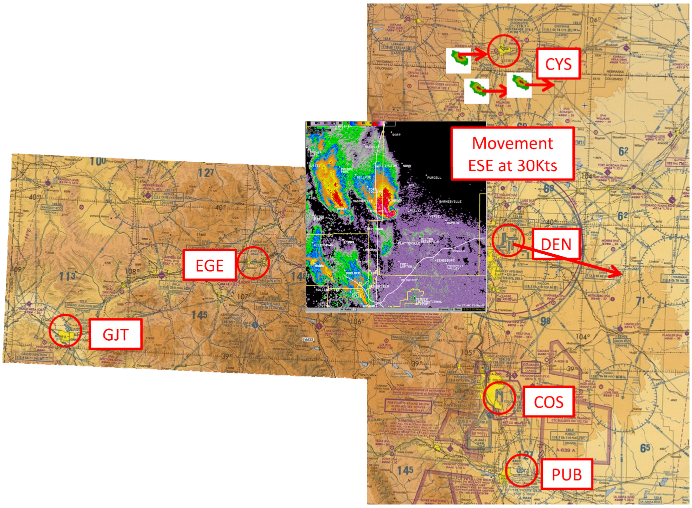

Fig. 1. The generic flight scenario generated in Microsoft PowerPoint. A convective weather cell headed SE towards DEN. The pilot attempted to fly in to DEN from the Northeast. A color version of the figure is available in the electronic copy of this paper.

Cognitive Walkthrough/Scenario Evaluation Questions

- When would you begin to calculate how long you could stay in a holding pattern?
- When receiving the holding instructions, what would be the first thing you would think to do?
- For what would you rely on your co-pilot before and after receiving the holding instructions?
- How long would you wait in holding before diverting to another airport?
- When heading to CYS, would you notice the weather cells before the airborne weather failure? If so, what would be your next decision?
- What would be the first thing you would do when the airborne weather system fails?
- What would be your expectations of the ATCs during each phase of flight?
- Difficulty questions?

Fig. 2. Examples of questions that the pilot was asked. These questions were designed to extract cognitive decision making, communication, and timing information from the pilot.

2.3 Procedure

The pilot arrived at the test area and was given a brief introduction to the study. The researchers explained what types of questions would be asked (questions related to cognitive, behavioral, and communicative decision making). Using the PowerPoint scenario described above, the pilot was asked to imagine that he was flying into Denver International Airport. He was told that he was at the top of descent point, planned to perform the arrival procedure, and then planned to land at the airport. Subsequently, the pilot was told that air traffic control issued a warning that holding might be expected during the arrival. The pilot was then given instructions to initiate a holding pattern due to potential weather disruption at the airport. The aircraft had enough fuel to enter the holding pattern for 5 minutes. Once 5 minutes passed, the pilot had to make a decision to fly to another airport if he could not land at the Denver airport.

The generic scenario described above was then walked through, step-by-step and with no interruptions, by the pilot. The pilot performed a think aloud protocol, describing his actions, thoughts, behaviors, and potential communication that would occur between him and a co-pilot, and/or between him and an air traffic controller. The pilot was asked to tell a story of the potential flight from beginning to end with as much detail as possible. After the first walkthrough of the scenario, the researchers took the pilot back through the scenario again, asking numerous pre-determined questions relating to his prior responses, as well as follow-up questions to clarify any concerns.

During and after the walkthrough process, the researchers took notes on a printout of the PowerPoint scenario slides, and provided alternative indicators in the scenario to improve its usefulness in future studies. Improvements in the scenario design were changes that would make the scenario more realistic while still requiring actions to be made by the pilot that would reflect critical underlying factors that would influence the pilot's decision making, communication, and behaviors. In terms of SPO, it was essential to obtain all information that reflected pilot and co-pilot decision making, communication, and interactions. This information was intended to be of use in future investigations of concepts of operations involving remote crew members or automated systems that would take over the co-pilot's role.

3 Data Collection

The information gathered was qualitative, retrieved from a think aloud protocol and semi-structured interview questions captured during the walkthrough. Results were organized and summarized using flow charts designed in Microsoft Visio (see Figure 3). From the information and insights gathered from the pre-study walkthrough, a prototypical scenario and flowchart of events were created. These two items provided a basic template for future SPO experimental scenario development.

3.1 Prototype Scenario

The generic scenario created after the cognitive walkthrough takes pilots on an arrival path to Denver International airport. At a specific time during descent, the pilot was asked to enter into a holding pattern due to weather complications at Denver. The pilot has limited fuel, enough for 5 minutes in the holding pattern. After this critical time period, the pilot must make a decision to divert safely to one of a few nearby airports. The scenario exercises the communications that would be involved between the pilot and his/her co-pilot, communication between the pilot and air traffic control, the mental computations require for determining how long to stay in the holding pattern, and the time-sensitive decision-making points involved in determining an alternative airport and route to that airport

3.2 Temporal Flow Chart

Events during which potential verbal and nonverbal communication between the pilot and co-pilot were identified. The events that required communication between the pilot and co-pilot were flagged as critical events that should be evaluated during the subsequent SPO experiments. Events requiring decision-making (or giving insights into pilot decision-making) were also identified and flagged. Fig. 3 provides an illustration of the scenario, with the critical communication slot between a pilot and co-pilot during a holding pattern flagged in red (bottom left box of Figure 3).

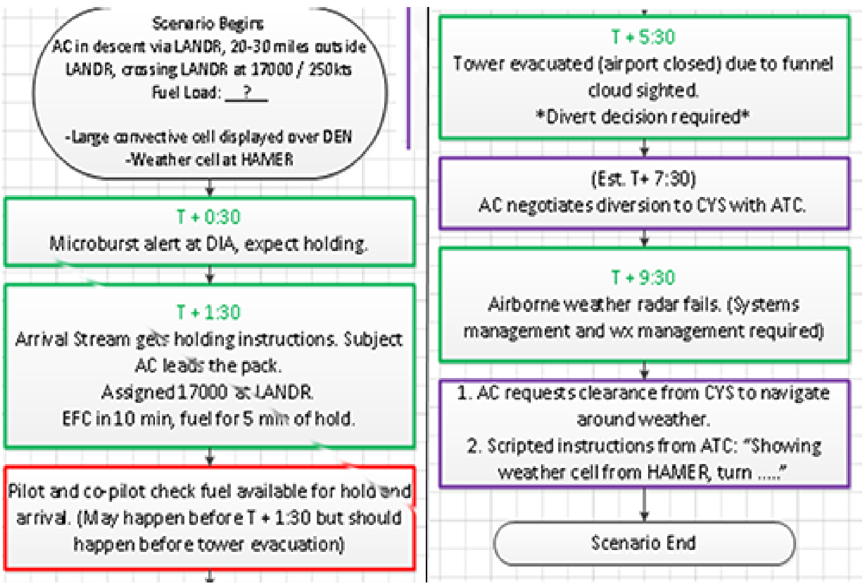

Fig. 3. Snippet of a flowchart of the prototype scenario that was generated after the cognitive walkthrough. The red box (bottom box on the left) flagged a critical communication slot that should occur between a pilot and co-pilot during a holding pattern. During single pilot operations experimentation, this time slot will need to be closely examined. A color version of the figure is available in the electronic copy of this paper.

4 Discussion

This example case illustrates how findings from a pre-study walkthrough could be used to assist the development of scenarios for SPO investigations. Although this paper only provided one example case, it is recommended that cognitive walkthroughs of this type be performed for a variety of scenarios to form a database of template scenarios that can be used in future evaluations of SPO concepts of operations and/or in the evaluation of alternative displays and technologies designed to support SPO. The detailed knowledge of when to look for critical decision-making points, and where essential communication between pilots are likely to occur, should help researchers to better design SPO experiments to test specific concepts and technologies. Researchers can also use this information to pinpoint when errors, faulty decision-making, and poor communication may arise during SPO.

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