

# HCI Aero 2012

## Task Allocation for Single Pilot Operations: A Role for the Ground

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### ABSTRACT

Researchers at the United States National Aeronautics and Space Administration (NASA) are jointly investigating issues associated with an environment in which a single pilot, or reduced crew, might operate transport category aircraft. In this paper we initially, and very briefly, summarize selected findings of a technical interchange meeting (TIM) coordinated and hosted by NASA. This meeting of a cross section of the aviation community addressed issues involved with a move from two pilot to single pilot operations for transport category aircraft. Following this, and based in part on these findings, we espouse a position that such an endeavor will require development of air-ground teaming, where a ground-based operator will have to be able to support many of the traditional roles of the copilot.

### Keywords

Single pilot operations (SPO), reduced-crew operations, Next Generation Air Transportation System (NextGen).

### BACKGROUND: WHY CONSIDER SINGLE PILOT OPERATIONS?

Starting in the 1950s, commercial aviation began experiencing what Harris called, “de-crewing” [1]. Historically, a five-person flight crew has been gradually reduced to today’s two-person crew. This de-crewing has been gradual rather than the result of some radical, one-time

change in required crew size. With technological developments, one-by-one, the need for humans to perform three roles, flight engineer, navigator, and radio operator, disappeared. Because technological advancements continue, it is not a surprise that some in the aviation community are currently considering further crew reduction. Specifically, some are questioning whether a two-person crew continues to be necessary in commercial aviation.

Harris reported that the historic crew reduction events in commercial aviation have not posed threats to flight safety [1], and now some in the aviation community believe that the concept of single pilot operations (SPO) (or a similar de-crewing strategy) warrants serious consideration and exploration. In fact, researchers began addressing SPO as early as 2005 [2], and others have since addressed SPO [1, 3]. In 2010, a Brazilian aircraft manufacturer (Embraer) announced that it planned to provide single-pilot capabilities by approximately 2020 [4]. Such announcements from industry further suggest that some are taking the idea of reduced crew operations quite seriously. Of course, the current conference provides additional, clear evidence that the aviation community has interest in exploring the potential for another phase in the de-crewing trend.

## INVESTIGATING SPO

Researchers at the United States National Aeronautics and Space Administration (NASA) Ames Research Center (ARC) and Langley Research Center (LaRC) are jointly investigating issues associated with various potential concepts, or configurations, in which a single pilot, or reduced crew, might operate. As part of their early efforts, these NASA researchers hosted an SPO TIM in order to gain insight from members of the aviation community. The meeting was held on April 10-12, 2012 at NASA Ames Research Center. Professionals in the aviation domain were invited because their areas of expertise were deemed to be directly related to an exploration of SPO. NASA, in selecting prospective participants, attempted to represent various relevant sectors within the aviation domain. Approximately 70 people representing government, academia, and industry attended.

A primary focus of this gathering was to consider how tasks and responsibilities might be re-allocated to allow for SPO. In this paper we highlight some of the considerations discussed at the meeting. In particular, we take the position that ground personnel can have a significant role in enabling SPO.

### Preliminary Findings from the SPO TIM

General Reaction of Meeting Participants. Overall, but not without exception, the meeting participants seemed to believe that the industry was moving toward SPO. Several possible configurations were mentioned. The most frequently suggested concept was where a “pilot” on the ground served as a second pilot for several flights simultaneously. However, some participants and workgroups also suggested that simply doing without the second person assisting the pilot (pure single pilot) or a configuration with a non-pilot (e.g., dispatcher or a member of the cabin crew) supporting the flight operation was either more desirable or more likely to be adopted. Participants also mentioned unmanned aerial systems (UASs) periodically in the context of comparing single pilot operations to the situation in which no pilot was present. On several occasions, they pondered whether or not UASs might represent some future state in which we may find airspace operations.

General Issues Relevant to Any SPO Configuration. Issues raised were plentiful and diverse. One way to conceptualize the results of the meeting is to present five areas the participants felt should be addressed in relation to SPO: (1) automation issues, (2) operational issues, (3) pilot incapacitation, (4) communication/social issues, and (5) certification and approval issues.

Participants frequently voiced concerns regarding automation issues in SPO. First, they strongly suggested that legal responsibilities must be seriously considered in designing automated systems for SPO. Pilots are accountable for a range of tasks that may be assigned to automation on an SPO flight deck. This raises questions regarding how much legal responsibility can be reasonably

placed on the single pilot if something goes wrong. If an automated system fails and this leads to an incident or accident, how would fault be assigned (pilot, aircraft manufacturer, or software engineers)? Second, participants expressed concern regarding the use of adaptive automation. They suggested that unless great care is taken to ensure that the pilot is informed as to what the automation is or is not doing, the pilot may lose overall situation awareness of different automation states. However, such feedback and need for monitoring the automation might yield unnecessary workload. Participants suggested that, to be safe, several taxonomies should be considered when developing automation (e.g., various levels of automation, the sharing and blending of automation, adaptive and adaptable automation, etc.). Third, participants voiced concerns that a probable increase in automation use under SPO will lead to skill degradation. Finally, they suggested that we “step back” and ask ourselves, “What can single pilots do without more automation?” Only after this question is answered should we determine whether or not more automation is needed.

Trajectory based operations and pilot workload. The evolution of air traffic management towards the Next Generation Air Transportation System (NextGen) in the United States, and the Single European Sky Air Traffic Management Research vision in Europe, raises a number of operational issues for SPO. It is generally thought that under future air traffic management concepts, significant responsibilities will be given to the flight deck. One example is trajectory based operations (TBO) where aircraft will be expected to fly precise 4D trajectories and to keep their routes synchronized with computers on the ground. Today, when making a weather deviation, the flight crew must only request a new heading and can determine when to return to their previous path at a later time. Under TBO the flight crew must develop an entirely new flight plan, potentially increasing workload. Will future single pilots be able to manage their single pilot task with the addition of these new TBO requirements?

The issue of pilot incapacitation surfaced quite frequently in discussions of SPO. A few participants suggested that SPO would not be feasible due to the possibility that the single pilot could become incapacitated, while others felt the issue was being overemphasized. The majority of attendees seemed to believe the issue was an extremely important one but that it could be effectively addressed. For example, the use of proactive approaches, such as requiring more sophisticated or frequent medical examinations for the single pilot, or actively monitoring pilot health during flight were mentioned on several occasions. Real-time monitoring of pilots could incorporate measures that assume incapacitation is often a progressive state, and early symptoms might assist in identifying less than optimal conditions. Such monitoring also could be in the form of assessing the physical state and/or mental state of the pilot, with the latter being relatively more difficult to achieve. Several participants felt that state-of-the-art equipment is

not currently able to handle such monitoring, and, even if it was, some suggested that the decision as to whether or not a pilot is incapacitated should be reserved for another human.

Pilot incapacitation was considered to be the issue that might be most detrimental with regard to the acceptance of SPO. Several participants suggested that the pilot community, the general public, insurance companies, and unions be polled to learn of their willingness to accept SPO, given the possibility of pilot incapacitation in a single pilot environment.

Communication and social issues were identified by attendees. They pondered whether the lack of social pressure from a second pilot to “stay on the ball” might have detrimental effects. Furthermore, under normal circumstances, the lack of informal social interactions may result in boredom, especially given that increases in automation use are likely. Such boredom is known to lead to a lack of situation awareness and an over reliance on automation.

Certification and approval of SPO for part 121 operations. Participants discussed how SPO operations would be approved for part 121 (Air Carrier) operations. A focus of the discussion was evaluating the impact of new task allocations strategies on many different aspects of part 121 operations. These topics included, the regulation of new training paradigms as pilot responsibilities change, changes to procedures in a distributed system, and the adequacy of methods for evaluating increasingly complex hardware and software systems. Concern was expressed that it will be difficult to show equivalent levels of safety for reduced crew in the presence of failures, and that if task allocation strategies employed rely on the automation having authority over control of the airplane that the evaluation may require processes and standards equivalent to a UAS.

### **Air-Ground Teaming for SPO**

One factor in previous crew reductions was the increased availability of ground personnel. Directed communications such as the Aircraft Communications Addressing and Reporting System (ACARS) meant that pilots could offload high workload strategic tasks such as planning for diversions and strategic weather re-routes to an Airline Operations Center (AOC) without clogging the radio party line communications. This was considered critical in the move from the three pilot flight deck to the two pilot flight deck. One presenter reported that the Federal Aviation Administration would not certify Piedmont Airlines for two-man operations in 1978 unless the airline demonstrated continuous “reliable and rapid communications” in FAR 121.99, that is, ACARS. The increased communication bandwidth available with current technologies will enable ground personnel to play an even greater role in reducing pilot workload, especially peak workload.

Based on the presentations and discussions of attendees, and above summary, we take the position that there will be a need for air-ground teams in which single pilots are supported by ground-based operators who will assume

some, if not all, of the roles and responsibilities of the second on-board pilot. We can imagine a variety of specific implementations of this approach from a single operator acting as a remote co-pilot for a single plane to a remote follower working a group of planes to a ground based team of experts who are called in on an ad hoc basis. Of course, we also expect onboard automation to play a critical role in any move to SPO; however, a human ground-based operator is able to bring unique capabilities. First, ground-based team members can help handle workload problems associated with unexpected and challenging situations for which the automation may not be designed, and where human problem solving is a critical activity. For example, systems failures, especially failures of the automation itself, may require human problem solving abilities. Second, and similarly, since future flight decks may not be fully augmented with the latest automation, and some ground elements (i.e., AOCs) may naturally possess more advanced automation there will be situations in which people on the ground may have more or different information and automated capabilities, than the flight deck. Access to additional information and automation might be useful, for example, in weather re-routing, where even today AOCs are given significant input into routing decisions. As noted above, re-routing is likely to become more complicated under NextGen TBO concepts and it seems only natural that the AOC or some other ground based system absorb that extra workload. Third, a ground-based team member may be better suited to evaluation of pilot incapacitation. While it may be possible to design reliable automation that will detect a number of physiological indicants of degraded capability or physical distress, people are certainly more sensitive than any present or envisioned automation to the behavioral subtleties that may signal a cognitive degradation (e.g., confusion, agitation, or emotional distress). Fourth, a ground-based team member would provide a partner that could hopefully mitigate issues of boredom through periodic interactions, and also provide any missing social pressure needed to support the diligent performance of duties.

However, along with the benefits of this approach, there are unique challenges. First, the issue of proper allocation of functions to the remotely located human was raised on numerous occasions. Since the particular tasks assigned to the ground-based team member will probably determine whether or not this arrangement is effective, the task choices are of utmost importance. For example, some information is probably best received and/or utilized when onboard the aircraft (e.g., turbulence). Second, in order for SPO to yield cost savings, this configuration may not be plausible unless the remote pilot can serve to assist multiple single pilots. Thus whether a team member on the ground can support multiple flights, and how high workload situations will be handled, must be addressed. Third, support for crew resource management (CRM) across distributed team members was also identified as a critical issue that must be examined. The efficacy of CRM in

making flight safer was highlighted at the TIM, and the criticality of developing air-ground teaming that retains this was emphasized. Finally, this configuration warrants asking whether the loss of the immediate interpersonal information and feedback between co-located pilots (e.g., body language, facial expressions, pointing/nodding at displays, etc) may be significantly detrimental to team performance, and how to compensate for it if it is. The TIM participants found this to be one of the critical issues to be addressed if a ground-based team member was going to function as described above. This last issue will be addressed in upcoming research.

#### **PLANNED RESEARCH BASED ON FINDINGS FROM THE SPO TIM**

A series of studies is being mapped out in which the goal is to assess the effectiveness of a distributed approach to SPO. The objective of the initial study is to explore the degree to which the location of pilots (proximate or remote) has an impact on their ability to work as a two-person crew. In this study, pairs of pilots will be asked to complete simulated flights in each of three conditions: co-located, remote and alone.

In the co-located condition, pilots will work together in a two person flight simulator that corresponds to current-day conditions. The remote condition will be almost identical to the co-located condition except that the right and left seats of the cockpit will be placed in different rooms. They will be allowed to communicate as freely as they would like, however they will not have the ability to see each other, observe each others body language or be able to point to information like weather cells on the navigation display. The inclusion of this condition allows the authors to assess if location (proximate or remote) results in performance differences. Finally, in the alone condition, one pilot will be asked to perform these tasks. This condition allows the researchers to determine if the scenarios used truly require the work of two people or if inclusion of a second person does, in fact, help some. In short, this phase serves as a baseline condition.

The pilots will be purposely presented with a critical situation that requires problem solving. The situation will be one in which the two-person crew encounters weather during their flight, and the weather is such that it creates the need to divert to an alternate airport. Scenarios will vary on a number of factors that add complexity to the diversion task, such as the amount of fuel onboard to support planned or unplanned diversions and system failures such as antiskid that require the crew to recalculate landing weights and distances.

In future experiments, we intend to create first generation ground dispatch station that fully support flight deck, AOC, and air traffic control collaboration in a NextGen TBO environment. This workstation may better represent what might ultimately be used on the ground by a remotely based second pilot to support all aspects of current and future flight operations. The station will allow the flight deck to

share all task, roles and responsibilities in a similar fashion is done in today's two-person flight deck. After developing such a station, a series of studies similar to the first will be conducted to assess the viability of the distributed concept.

#### **ACKNOWLEDGMENTS**

This research is part of a joint effort between ARC and LaRC into reduced crew operations that was initiated in April 2012 with a NASA-conducted TIM to explore the challenges of SPO. This effort is co-led by Walter Johnson (ARC) and Paul Schutte (LaRC). ARC is exploring a distributed, ground-based solution, while LaRC is exploring an airborne solution. We fully expect that the best solution will be a hybrid approach of the two.

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