

Wearable Technologies as a Path to Single-Pilot Part 121 Operations

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ABSTRACT

Labor costs rank second only to fuel in expenses for commercial air transports. Labor issues are a growing concern in the airline industry, with an impending worldwide pilot shortage. One solution proposed and requested by some of the industry leaders is to allow a single flight crew member to operate the aircraft.

Safety concerns represent the dominant barrier to single-pilot Part 121 operations. The FAA and Congress consistently demonstrate a bias toward conservatism in their regulation of airlines and commercial aircraft. Bureaucrats and the general public fall prey to isolated news stories that highlight pilot error and anchor their viewpoint on further regulating a two-person crew. Yet, in an alarming spate of recent airline accidents, the presence of multiple crewmembers did nothing to prevent, and actually may have contributed to, the crash.

Technology is not the problem. The real challenge is to convince Federal regulators and the flying public that Part 121 operations can be performed as safely with a single pilot as with two. This will require a redesign of the flight deck for next generation aircraft, as well as inclusion of emerging, yet stable, technologies to allow a single pilot to manage workloads traditionally requiring two crewmembers. This paper outlines the framework for a single-pilot flight deck system for Part 121 cargo operations, complete with considerations for training and redundancy. This design is made feasible by the inclusion of wearable devices to assist the pilot with flight deck duties in place of a second pilot.

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I. INTRODUCTION

The aviation industry has pushed the envelope of innovation and advancement from the beginning. Its pioneers accomplished the impossible, and made profound impacts on the world. Today safety, passenger comfort, and fuel economy are at their all-time highs in aviation, thanks to the forward-thinking of many individuals and incremental technological advancement. Yet, experts are quick to discount the possibility of one or zero pilots occupying the flight deck of a modern airliner.

Lest we forget, from the 1910s until 1982, a third required crew member (serving the role of navigator or flight engineer) occupied the flight deck of commercial transports. In the late 1970s and early 1980s, manufacturers met great opposition by proposing a two-crew flight deck. However, technology proved to be a suitable replacement for an extra crewmember - the introduction of modern avionics and crew alerting on the 757/767 and beyond facilitated this reduction. Just as the 70-year tradition of a three-person crew came to an end, the two-pilot standard for large commercial transports will not remain forever.

There has been no better time to challenge the status quo of dual-pilot commercial operations. Passenger and cargo airlines have expressed demand and intent to reduce the minimum number of flight crew members. With labor costs around 20% of airlines' operating costs, and

flight crew costs constituting about 1/4 of overall labor costs, eliminating one flight crew member could reduce total operating costs by 2-3%.¹ With the industry historically operating at slim margins, this represents a substantial impact to an airline's bottom line. It's no wonder that major global players like Ryanair (Ireland), FedEx, and United Parcel Service (UPS) are at the forefront of the single-pilot revolution.

If operators like these could act freely, they would directly seek unmanned passenger flights. However, due to concern for public safety and strict regulatory structure, such a leap is unlikely. The path to unmanned large commercial transports first requires safe, reliable demonstration of single-pilot operations, which is now feasible due to the maturation of the required technologies.

II. SINGLE-PILOT OPERATIONS

A. History

In 1977, the United States Federal Aviation Administration (FAA) approved single-pilot jets up to 12,500 lb. gross weight to operate under 14 CFR Part 135 - Commuter and On-demand Operations for Compensation or Hire. These operations encompass small business jets for charter. The FAA has gone to great lengths to establish training programs, aircraft certification, and pilot certification for single-pilot operations within this domain. This begs the question,

why have single-pilot operations not been approved for Part 121 - Scheduled Air Carrier Operations? The answer is a combination of technical hurdles and human welfare concerns.

Whereas business jets were designed with the single pilot in mind, large commercial aircraft were designed with the assumption of having two crewmembers. Single-pilot workload in normal and non-normal (emergency) situations is manageable in certified business jets, while the same situations would jeopardize safe flight in current generation commercial aircraft. Therefore, a flight deck redesign would be required for single-pilot large commercial aircraft, to include a complete re-examination of crew procedures, human factors elements, and system and pilot redundancy. Since the costs of retrofit, certification, and training are immense, such a redesign would most certainly take place on a new aircraft, rather than as a modification to existing models.



Figure 1. Example of single-pilot approved business jet cockpit Credit: Cessna



Figure 2. Example of current-generation commercial aircraft flight deck Credit: Boeing

B. Current Research

Recent industry research supports the notion of future aircraft flight decks supporting a single pilot. Avionics and display company Thales introduced their concept for a future flight deck called Cockpit 3.0, compatible with a single flight crew member. The unique features of their proposal are the use of existing commercial off-the-shelf (COTS) tools, and an artificial intelligence-like system analysis and suggestion feature.² The U.S. National Aeronautics and Space Administration (NASA) recently approved funding for avionics manufacturer Rockwell Collins to pursue single-pilot flight deck design. The one-year contract tasks Rockwell with researching “crew capacity, ground and flight deck resource management, physiological monitoring technologies and automation needed to make [single-pilot ops] viable.”³ The European Union (EU) and European aircraft manufacturer Airbus have partnered on the Advanced Cockpit for Reduction Of Stress and Workload (ACROSS) program, focusing on primarily technological hurdles to allow for safe *unplanned* single-pilot commercial operations (e.g. incapacitation, restroom breaks).

They are currently in a technology development phase with validation trials scheduled for 2016.⁴ A 2005 NASA paper described the human factor elements of single-pilot commercial aircraft operations (hereinafter referred to as single-pilot ops). This paper reviewed NTSB reports and provided an outline and path forward for executing commercial procedures as a lone pilot safely.⁵ The FAA's long-term air traffic control plan, NextGen, has been provisioned with single-pilot ops in mind. Technologies such as data communication, Required Navigation Performance (RNP), and Automatic Dependent Surveillance-Broadcast (ADS-B) improve situational awareness and reduce pilot workload.

C. Safety

The single greatest barrier to single-pilot ops is public perception of its impact to aviation safety. Aviation legislation by the U.S. and EU tends to be overly conservative and restrictive out of concern for safety. Examples include regulation of minimum flying experience, crew duty times, and medical history. The proposed solution would need to be near perfect to garner buy-in from the public and government representatives.

The public and legislators hold a false assumption that a two-person crew is always safer than a single-pilot schema. Although many examples exist where effective crew resource management (CRM) among a two-person flight crew prevented an accident, recent fatal airline accidents show that sometimes having a multiple-person crew generates more confusion than cohesion. On Air France flight 447, following a system malfunction, a breakdown of CRM led to pilots giving opposing control inputs and ultimately loss of the airplane and all souls aboard. On Asiana flight 214, cultural forces among the pilots influenced them to not take action in a critical situation, leading to a crash in the terminal environment. In other accidents, the pilots monitoring repeated erroneous commands and callouts, failing to serve their purpose as a confirmation. In still other situations, unnecessary cross-talk or use of electronic devices distracted pilots from their flying duties, putting people's lives at risk. A single-pilot flight deck system can be as safe, if not safer, than the current dual-pilot standard. The redundancy required to maintain this safety will be discussed in [section V](#). Comprehensive System.

In order to ease public buy-in, we will propose introducing single-pilot ops in the cargo/freighter segment. Regulators are more likely to take a risk in this domain when packages and 2-3 souls are at risk, as opposed to an airliner full of passengers. Once proven on this platform, parlaying to passenger commercial operations could be pursued.

III. WEARABLE DEVICES AS THE CONDUIT

Aerospace companies and governments alike recognize the need for identifying the appropriate technology to facilitate single-pilot ops. A 2005 master's student thesis described the technological hurdles for eliminating a required crewmember. The primary concerns identified were managing workload, pilot monitoring, and system redundancy.⁶ What has not been proposed is adopting wearable devices such as head-mounted displays to address these concerns and make possible single-pilot ops.



Figure 3. Head-mounted displays under consideration: MetaPro, Epson Moverio, and Microsoft HoloLens



Figure 4. Checklist item executed

A. Features

A next-generation head-mounted display could serve as a replacement for a first officer, in addition to opening the door to new safety enhancements. What now exist as individual wearable devices will soon be integrated into a highly-capable vision and computing system. The following is a list of features that the proposed device could provide:

- Replacement for current-generation Head-up Display (HUD)
- Guide the execution of and compliance with checklists (e-checklist replacement)
 - Normal and non-normal
- Crew alerting (EICAS/ECAM) and time-critical warnings
- Point pilot to panel switches
 - Aid execution of checklists
 - Switch indications correlated to crew alerts
 - Audit - glance at panel to confirm compliance with phase of flight
- Out-the-window overlays (similar to efforts conducted by AeroGlass)
 - Route guidance
 - Traffic
 - Terrain
 - Airspace
- Airports/diversion
- Airways
- Waypoints
- Synthetic vision
- Pilot fatigue and incapacitation monitoring
- Display video feeds from aircraft cameras
 - Pilot moves head to pan
- Communications
 - Standard headset voice communications
 - Voice recognition to/from controller-pilot data link communications (CPDLC)
 - Real-time speech-to-speech translation (language independent communication)
- Improved training

B. Hardware and Proposed Imagery

Figure 3 shows three potential head-mounted displays that are being considered for this application. The team is currently testing Meta and Epson hardware and is awaiting developer release of the HoloLens.

Shown here are draft designs showing how the augmented reality glasses might assist the pilot with checklists and locating switches on various panels. Figure 4 shows a checklist item, computing the landing gear down. The checklist box resides in the upper corner of