The FAA Transport Airplane Directorate perspective on single pilot transports

Safety and Certification

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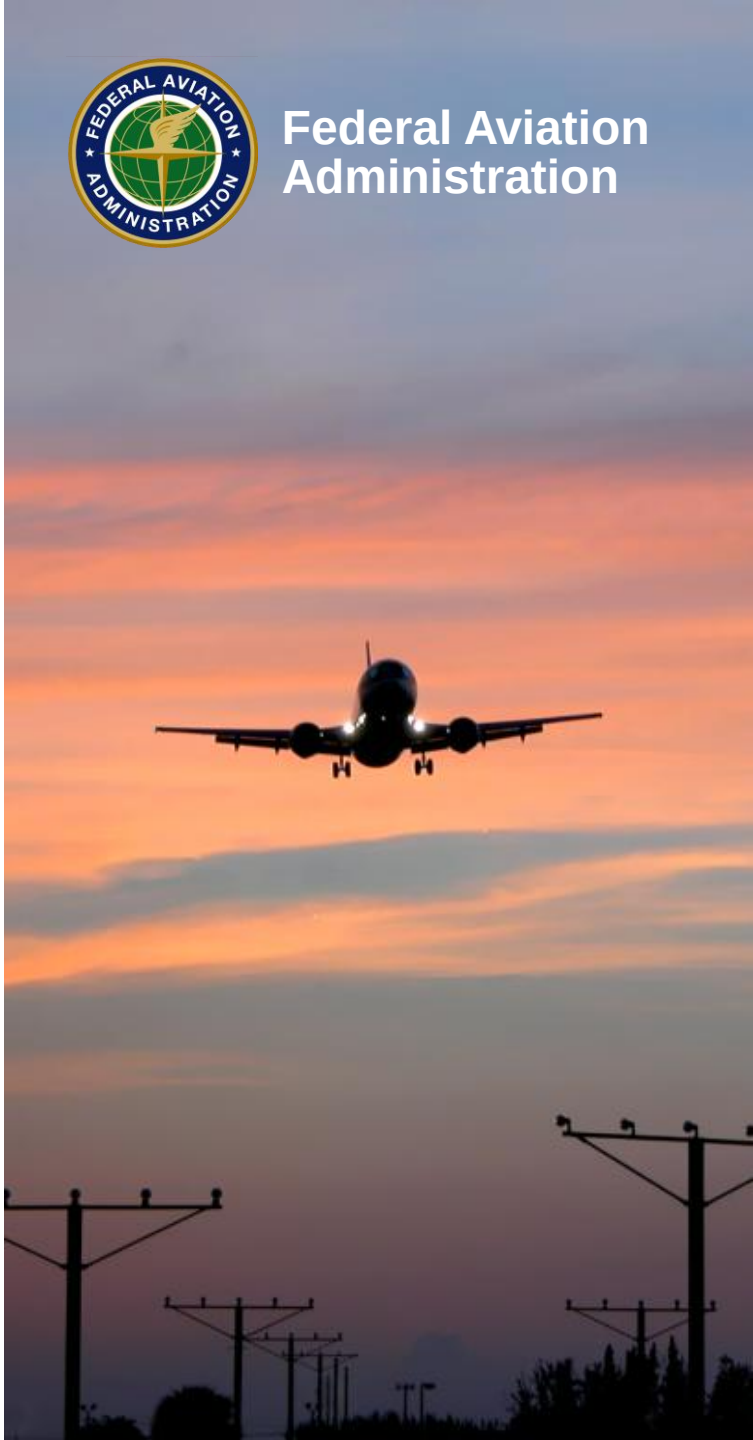

History of Minimum flight crew

- **In the late 60's, systems on smaller transports (e.g. 737/DC-9) were simplified/automated so that a flight engineer was unnecessary**
  - This was largely a flight crew workload issue.
  - Approach used by Boeing: Show that the pilot workload for a 737 (two-crew) was lower than pilot workload in a 727 (three-crew)
- **Wide bodies were soon introduced (747, DC-10. L-1011)**
  - For these larger transports, a flight engineer was still considered "required."

History (cont.)

- **Early 80's: Boeing simultaneously developed the 757 and 767**
  - By the existing policy, the 757 could be two-crew, but the 767 would have to be three.
  - Boeing was designing for a common type rating – minimal difference in pilot tasks and workload.
  - Boeing argued that there was no technical or safety reason for requiring the 767 to have a flight engineer.
- **This issue was highly politicized and visible at the Congressional level**
  - Boeing built a small number of "three-crew" 767s
  - Near the end of the program, it was finally agreed that a wide-body could be two-crew, and the issue was settled.

Civil Aviation Regulations (CAR 4b)

§ 4b.720 *Minimum flight crew.* The minimum flight crew shall be established by the Administrator as that number of persons which he finds necessary for safety in the operations authorized under § 4b.721. This finding shall be based upon the work load imposed upon individual crew members with due consideration given to the accessibility and the ease of operation of all necessary controls by the appropriate crew members.

This is a performance-based rule

Part 25 Regulatory requirements

Sec. 25.1523 Minimum flight crew.

The minimum flight crew must be established so that it is sufficient for safe operation, considering—

(a) The workload on individual crewmembers;

(b) The accessibility and ease of operation of necessary controls by the appropriate crewmember; and

(c) The kind of operation authorized under Sec. 25.1525.

[The criteria used in making the determinations required by this section are set forth in Appendix D.]

Appendix D was the major changes from CAR 4b

Regulatory requirements (cont.)

- **Appendix D (issued in 1965) provides the Criteria for determining minimum flight crew.**

a. *Basic workload functions.* The following basic workload functions are considered:
(1) Flight path control.
(2) Collision avoidance.
(3) Navigation.
(4) Communications.
(5) Operation and monitoring of aircraft engines and systems.
(6) Command decisions.

Workload factors (Appendix D)

b. *Workload factors.* The following workload factors are considered significant when analyzing and demonstrating workload for minimum flight crew determination:

(1) The accessibility, ease, and simplicity of operation of all necessary flight, power, and equipment controls.

(2) The accessibility and conspicuity of all necessary instruments and failure warning devices. The extent to which such instruments or devices direct the proper corrective action is also considered.

(3) The number, urgency, and complexity of operating procedures.

(4) The degree and duration of concentrated mental and physical effort involved in normal operation and in diagnosing and coping with malfunctions and emergencies.

Workload factors (Appendix D) cont.

(5) The extent of required monitoring of systems.

(6) The actions requiring a crewmember to be unavailable at his assigned duty station.

(7) The degree of automation provided in the aircraft systems to afford (after failures or malfunctions) automatic crossover or isolation of difficulties to minimize the need for flight crew action.

(8) The communications and navigation workload.

(9) The possibility of increased workload associated with any emergency that may lead to other emergencies.

(10) Incapacitation of a flight crewmember whenever the applicable operating rule requires a minimum flight crew of at least two pilots.

First, normal operations…

- **It's likely that additional automation could be introduced that would mitigate workload for a single pilot.**
- **NextGen will provide some verbal comm and nav relief, but will also shift some ATO controller monitoring tasks to pilots.**
- **More complex and heavily "populated" airspace will add cognitive and task load**

However, normal operations are not the critical issue!

System safety

25.1309…

(b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that—

(1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and

(2) The occurrence of any other failure condition which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable.

(c) Warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards.

Guidance on system safety

(1) Minor: Failure conditions which would not significantly reduce airplane safety, and which involve crew actions that are well within their capabilities. Minor failure conditions may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload…

(2) Major: Failure conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions the extent that there would be, for example, --

(i) A significant reduction in safety margins or functional capabilities, a significant increase in crew workload or in conditions impairing crew efficiency…; or

(ii) In more severe cases, a large reduction in safety margins or functional capabilities, higher workload or physical distress such that the crew could not be relied on to perform its tasks accurately or completely…

More on the guidance…

- **For catastrophic conditions, the failures must be extremely improbable**
  - Not expected to happen in the life of the fleet
  - Typically once per billion flight hours (1E-09)
- **For severe major (i.e. hazardous) conditions**
  - Typically once per 10 million FH (1E-07)
- **For major conditions**
  - Typically once per 100K FH (1E-05)

Note: these standards are for hardware failures only, not those that are caused by software design errors.

System failures

- **System safety assessments attempt to predict failure conditions and their consequences (hazard categories)**
- **System reliability/integrity are then matched to the hazard level**
- **Changing to single pilot will likely elevate the hazard category for many failure conditions, requiring much more robust designs.**
- **Single pilot designs may actually increase the number of significant failures**

However, our ability to anticipate failure conditions is far from perfect.

Qantas A380 uncontained engine failure

Qantas A380 uncontained engine failure

- ***In the cockpit, pilots faced a "cascading series of critical system failures", the Associated Press reports, and were confronted with 54 flight system error messages to work through, a task that took 50 minutes to accomplish.***
- ***A weight imbalance caused as fuel leaked from the tank complicated matters further, the agency reports.***
- ***Wiring damage prevented the pilots from being able to pump fuel between tanks, and the plane became increasingly tail heavy, raising the risk of a stall.***
- ***"I don't think any crew in the world would have been trained to deal with the amount of different issues this crew faced," Richard Woodward, a vice-president of the Australian and International Pilots Association, is reported as saying.***
- ***"The amount of failures is unprecedented," he said. "There is probably a one in 100 million chance to have all that go wrong."***

Complex systems and software

- **Modern large transports can have**
  - Highly complex and integrated systems
  - 10's of millions of lines of code
- **Our ability to…**
  - analyze systems,
  - predict failure modes,
  - prevent/predict software design errors,
  - Develop/validate/verify requirements, and
  - generally assure ourselves that the systems are safe

  … can be outstripped by the pace of new designs and new design methods
- **Example: Model based development and automatic code generation**
- **The level of automation, complexity, and integration needed for a single pilot transport will exacerbate this problem.**

Flight crew errors

- **Mitigating flight crew errors**
  - While we often hear about flight crews making errors, but we don't often talk about the safety that flight crew members add.
  - Many errors by one pilot are identified and addressed by the other pilot.
  - CRM is specifically intended to maximize this benefit.
  - A single pilot will not have another pilot helping to manage errors.
  - The proposed new flight crew error rule (25.1302) has a requirement for design features that support error management.

Pilot “failure”

- **Appendix D requires that the design account for an incapacitated pilot.**
- **Pilot incapacitation is not frequent, but it does occur with some regularity.**
  - Unconsciousness or death
  - Severe acute illness
- **A single pilot transport with an incapacitated pilot is an *ad hoc* UAS with hundreds of passengers on board!**
- **However, as recent events have shown, a simple inability to fly the airplane is NOT the worst case scenario of pilot incapacitation**

3/27/12: Jet Blue pilot “meltdown”

- During the flight, the First Officer (FO) became concerned about Capt’s bizarre behavior. As the A320 departed Kennedy Int’l, the Capt reportedly told the FO to take the controls and work the radio. He then began ranting incoherently about religion, saying "things just don't matter," and he eventually yelled over the radio at air traffic controllers.
- Concerned, the FO suggested that an off-duty captain join them in the cockpit, and Capt "abruptly left the cockpit to go to the forward lavatory"
- While he was gone, the FO ushered the off-duty captain into the cockpit, locked the door and when the Capt returned, pounding on the door to be admitted, the FO used the public address system to ask passengers to restrain the erratic pilot and they obliged.

How would this pilot incapacitation event have played out if the Capt were the only pilot in the flight deck?

Dealing with a mentally incapacitated pilot

- **In case of psychological breakdown, one pilot may need to wrest control of the airplane from the other.**
- **In a single pilot transport, would the systems be expected to do that?**
- **Current design practices are based on a premise that the pilot can take control from a malfunctioning (not just failed) system. The system safety assessments often depend on that mitigation.**
- **Reversing that premise would…**
  - Require a total rethink of how airplane systems are designed
  - Would introduce new potentially catastrophic system failures that would also prevent the pilot from intervening

Our top priorities and my thoughts…

- **Safety –**
  - So far, there is no apparent safety benefit to be gained from single pilot designs, and it is likely to be very difficult to even approach a safety-neutral design.
  - Compliance with current regulatory requirements may not be feasible.
  - The FAA's stated goal is to continually increase the level of safety.
- **National Airspace System (NAS) capacity –**
  - It seems highly unlikely that going to a single pilot design would increase our ability to push more airplanes through the system, and…
  - Given the change in air traffic management strategy embodied in NextGen (more aircraft-centric), single pilot ops may actually compromise that goal.

As you go forward with this discussion…

- **The starting premise of a single pilot transport research effort should be (to borrow from Hippocrates): "First, do no harm."**
- **The initial questions to be answered: What benefit is being sought? Why?**
- **The next question: "Is a single pilot transport design the best, most effective, or even a plausible approach for achieving that goal, given the need to increase aviation safety and NAS capacity?**
- **Then ask: Is a single pilot design likely to solve more problems than it creates? Will we be better or worse off?**