Alone at 41,000 Feet

Single pilots of VLJs and other technically advanced aircraft need comprehensive training in resource management.

BY BARBARA K. BURIAN AND R. KEY DISMUKES

The cockpit could be a crowded place in the early days of commercial aviation. Pilots and copilots were accompanied by flight engineers, navigators and radio operators, and together they got the aircraft and its occupants from point A to point B. As aircraft systems became more reliable and technology advanced, the six crewmembers eventually became three and then two. Although large transport category aircraft are still piloted by two flight deck crewmembers, single-pilot commercial operations will expand greatly with the advent of very light jets (VLJs) and other technically advanced aircraft (TAA).[1]

The demand for pilots for fractional operations, air taxi services and corporate flying is expected to approach that for major airlines during the next 12 years. Single-pilot operations in TAA will help operators meet this demand. At the same time, some TAA will enable single pilots flying for personal reasons to extend into high-altitude, high-speed operations that have been the exclusive domain of commercial aviation.

There is a natural concern about how flight safety will be affected by single-pilot operations in TAA. Single-pilot flying is nothing new, being the predominant mode in tactical military operations and personal flying. However, military flying has far different requirements and risks than either commercial or personal flying, and personal flying by single pilots in TAA in the upper flight levels will bring with it demands that differ from the demands of personal flight in airplanes such

as Beech Bonanzas, Cirrus SR22s or Diamond Twin Stars.[2]

Manufacturers have been developing advanced technologies to reduce workload and enhance situational awareness for single-pilot operations in all types of aircraft. One manufacturer even describes its automation and avionics suite as a virtual copilot.[3] The technology systems currently or soon to be available can do much to support the single pilot, but advanced technology does not really replace the second pilot, at least not yet. Technology cannot perform some of the most critical functions of a second pilot, and in some instances in which advanced technology performs some of the second pilot's tasks, it does so differently, thereby creating new kinds of workload and cognitive demands for the single pilot.

Let us examine what is lost when the second pilot steps out of the cockpit and what is gained when advanced technology steps in. This examination can help developers optimize design of automation, training and procedures for single-pilot operations and will help pilots prepare to better meet the challenges of single-pilot operations in TAA and VLJs.

The Role of a Second Pilot

Obviously a second pilot takes on some of the workload and assists with tasks far beyond fetching coffee and conducting preflight inspections in the rain. While one pilot checks the weather and plans the route, the other pilot may supervise fueling, load luggage and brief passengers. The pilot who is not flying can program the flight management system (FMS) or global positioning system (GPS), perform checklists, handle air traffic control (ATC) communication, look up landing distances for a high-altitude wet runway and so on.

Beyond relieving the flying pilot of some cockpit tasks, a second pilot also provides a second set of informed eyes. The copilot can keep track of aircraft configuration, energy state and flight progress; monitor instruments, weather radar and the actions of the other pilot; look for airports and traffic; and read approach charts and minimum equipment list (MEL) procedures. In short, the copilot takes in information and processes it intelligently.

Most importantly, copilots act on that information. They tell the flying pilot that the fuel burn is greater than expected, they correct the incorrect numbers dialed into the altitude alerter, they recognize that an approach is unstable and advocate going around, they verify that the engine being shut down is the one that is malfunctioning, and they point out that a checklist has not yet been completed. Through hard experience, the airline industry has learned that monitoring, cross-checking and challenging are crucial roles for the pilot not flying — so much so that this pilot is now usually called the monitoring pilot.[4]

Equally important, if not more so, the second pilot plays a crucial role as a sounding board — someone to help think through decisions, to question a course of action, to help identify risks and to suggest alternatives. It is in this role that the second pilot makes some of his or her greatest contributions to the flight.

The Role of Advanced Technology

Advanced technology can greatly reduce workload in the cockpit. It can automatically check the status of systems on startup, manage cabin pressure, prompt troubleshooting steps when systems fail and simplify the tasks of navigation and conducting approaches. With technological assistance, flying a perfect holding pattern in strong winds aloft is a snap, identifying the location of a thunderstorm relative to the route of flight becomes easy, and the top of descent is calculated for the pilot and shown graphically in relation to the aircraft's current position.

Through sensors, data-link and on-board databases, advanced technology also takes in information and processes it for presentation to the pilot. For example, a moving map may be combined with weather, terrain and traffic information in a single display, and a ring surrounding the aircraft's position may show how far the aircraft can go with existing fuel and winds. Multi-function displays also can depict a vast amount of information, such as airport layouts, to support situational awareness during taxiing.

Many very light jets — including the Hondajet, scheduled to go into production in 2010 — are designed for either one pilot or two.

Although advanced technology and copilots both assist the flying pilot by providing crucial information, the way in which this information is provided differs substantially. Technology can only make the information available, preferably in an easy-to-interpret format. It is often up to the pilot to know that the information exists and how and where to locate it. In situations of high workload, the pilot may forget the information is available or may lack the time to access it. In contrast, a copilot can determine what information the pilot needs at a given moment, call attention to that information in a manner that minimally interferes with the ongoing task, and help the pilot think through the implications of the information. Additionally, technology can provide information crucial to decision making but cannot tell the pilot that a decision must be made. Technology will not question the pilot's behavior, identify risks or suggest alternate courses of action. Without the second pilot, the sounding board is gone.

Technology Brings Benefits, Problems

Advanced technology and cockpit automation also have introduced problems and hidden levels of complexity. Hart Langer, while vice president of operations at United Airlines, characterized the FMS as "a giant vacuum cleaner that sucks in eyeballs and fingertips." For example, when given last-minute runway changes during approaches to busy airports, flight crews have gotten into trouble by attempting to re-program the FMS — action that has diverted their attention from other flight tasks — instead of using a lower level of automation to control the flight path.

Airline pilots have been known to ask three questions about flight deck automation: What is it doing? Why is it doing it? What is it going to do next? In fact, several airline accidents have occurred because the pilots were confused about the mode in which the automation was operating. Although there are fewer automated flight modes in TAA compared with modern transport category aircraft, the potential remains for confusion and mistakes. For example, it is not uncommon for pilots to miss a GPS's failure to switch from terminal mode to approach mode 2 nm (4 km) from the final approach fix and to mistakenly continue to fly the approach. Several studies have found that training for automation and advanced technology too often focuses on which buttons to push and does not provide pilots with adequate mental models of how the advanced technology operates and why.

Displays and interfaces that use layered menus and "soft keys" — buttons that perform different functions, depending on previous button presses — greatly increase demands on pilot memory and attention. Working memory — what we can hold in mind at any one instant — and attention are cognitive resources of extremely limited capacity that are essential to managing concurrent tasks, maintaining situational awareness, evaluating risks and making decisions. Single-pilot operations require innovative approaches to the design of advanced technologies and displays to reduce cognitive demands substantially below the demands from technologies designed for two-pilot cockpits. In addition to design, training and procedures for managing advanced technologies must be tailored to single-pilot operations.[5,6,7]

CRM vs. SRM

Following a series of accidents involving perfectly functioning aircraft in the 1970s, the airline industry and the U.S. National Aeronautics and Space Administration (NASA) developed the concept of crew resource management (CRM), which has been credited with averting accidents and saving lives. Single-pilot resource management (SRM) is an analogue of CRM, but successful implementation of SRM requires close examination of how resource management in a single-pilot cockpit differs from that in a multi-crew cockpit.

U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 120-51E lists topics to be addressed in CRM training such as communications processes and decision behavior, including briefings, inquiry and advocacy, crew self-critique and conflict resolution.[8] Team building and maintenance of the team also are essential elements of CRM, including leadership and followership behaviors, interpersonal relationships, group climate, shared situational awareness, avoiding distractions and distribution of workload. Clearly, the emphasis is very much on the crew — how its members communicate, coordinate and work together as a team.

In SRM, the emphasis must shift. Workload management becomes central, because the single pilot lacks a crewmember who can share the skilled tasks of piloting. It is through proper workload management that the single pilot is able to maintain situational awareness, avoid distractions, retain enough mental capacity to make good decisions and utilize the advanced technology and resources to their greatest effect. An effective approach to workload management is particularly important when considering the speed with which events will transpire in VLJs, and thorough familiarity and currency with the advanced technology is essential.

© Adam Aircraft

How a single pilot approaches workload management must be very different than how a crew might manage it. Planning and preparation, always crucial in aviation, become even more so for single pilots. Planning should not just address expected conditions, routing, cruising altitudes, notices to airmen (NOTAMs), destination approaches, risk assessment and mitigation, passenger needs, and the like, but must also anticipate contingencies such as unforecast weather changes and equipment failures. As much work as possible should be accomplished before flight and during relatively low workload phases of flight. For example, complete flight plans should be entered into the avionics before taxi-out — climbout is not the time to be punching numbers into the box.

When workload becomes heavy during flight because of unanticipated events, such as complicated re-routings or equipment malfunctions, the single pilot must be proactive in off-loading as much work as possible. Strategic use of automation is crucial, but of course this requires a solid and accurate mental model of how the automation works and proficiency in setting it up. When getting overloaded, pilots can build in extra

Manufacturers of some very light jets, including Adam Aircraft's A700, have entered into partnerships with training providers to teach owner-operators about single pilot resource management.

time, for example, by negotiating with ATC to turn away from rising terrain or to enter holding to sort things out. Prioritization and the strategic shedding of tasks can also provide time and free up mental resources to perform the most crucial tasks. Strategic shedding is the thoughtful elimination or deferment of less essential tasks to allow the time and mental and physical resources necessary to devote to more essential tasks.

Managing workload effectively does require a strategic approach. Unfortunately, the Catch-22 of workload management is that strategic behavior requires mental resources. When pilots get overloaded, strategic management often falls away as pilots adopt the less demanding — and far less effective — tactic of just reacting to events as they occur.[9] Situational awareness, judgment and decision making are impaired when pilots are overloaded. Skill at strategic management of workload requires explicit training in specific techniques. Ideally, this training includes practice in simulators with realistic flight scenarios.

The challenge of cockpit task management is not limited to overload situations, though. The single pilot does not have the luxury of focusing on one task to completion before turning to other tasks; rather, he or she must "multi-task," switching attention among task demands, something like a circus juggler. Multi-tasking is far more vulnerable to error than most people realize, as evidenced by the large number of automobile accidents in which cell phone conversations were involved. When focusing on one task that demands mental resources, such as re-programming an FMS, we are all vulnerable to the "tunneling" of attention in which we lose track of the status of other tasks. Research is needed to identify specific techniques for effectively managing attention allocation during concurrent tasks in single-pilot operations.

Although SRM has been mentioned in pilot literature for some time, detailed and comprehensive SRM training programs, for the most part, have yet to be developed.

Challenges in Training

There are several ways to facilitate safe and efficient single-pilot operations in both commercial and personal flying. Manufacturers already are contributing by designing advanced technology to support the single pilot and to simplify cockpit tasks. This technology can be enhanced by careful analysis of both the benefits and the difficulties encountered with existing airline cockpit automation. Innovative ways to make automation displays and functions more transparent and to reduce cognitive demands would benefit not only single-pilot operations but also crew operations. Automation training that focuses on developing solid mental models rather than on "switchology" would reduce workload and errors.

SRM training could greatly help single pilots manage their tasks, but this training will be effective only if detailed curricula are developed that focus on the special character of single-pilot operations. For single pilots who do not fly frequently, maintaining currency in TAA is a crucial challenge.

VLJs and other TAA are the result of remarkable engineering innovations. Our challenge is to be equally innovative in developing technology functionality and interfaces, training and procedures to better support single-pilot operations. ●

Barbara K. Burian, Ph.D., studies aviation safety human factors in the Human Systems Integration Division at NASA Ames Research Center. R. Key Dismukes, Ph.D., is chief scientist for aerospace human factors in the Human Systems Integration Division at NASA Ames. Both are general aviation pilots.

Notes

1. "Technically advanced" typically refers to small aircraft with sophisticated avionics, engines — such as those with full authority digital engine control (FADEC) — and autoflight systems comparable to those of modern airliners. In this article, it refers to glass cockpit, high performance aircraft such as VLJs, though much of the discussion applies to single-pilot operations in other TAA, such as the Cirrus SR22.

2. National Business Aviation Association (NBAA). *Training Guidelines for Very Light Jets and Technically Advanced Aircraft.* <http://web.nbaa.org/public/ops/safety/vlj>.

3. Eclipse Aviation. *Flying the Eclipse 500.* <www.eclipseaviation.com/eclipse_500/avio_ng/flying_the_eclipse_500.html>.

4. Sumwalt, R.L. III; Thomas, R.J.; Dismukes, R.K. *Enhancing Flight-Crew Monitoring Skills Can Increase Flight Safety*. In *Keeping Safety a Worldwide Priority: Proceedings of the 55th annual International Air Safety Seminar*, Flight Safety Foundation. Alexandria, Virginia, U.S.: Flight Safety Foundation, 2002.

5. NBAA.

6. Burian, B.K.; Dismukes, R.K. (2007). *Training the VLJ Pilot*. <http://human-factors.arc.nasa.gov/eas>.

7. Burian, B.K. "Very Light Jets in the National Airspace System." In *Proceedings of the 14th International Symposium on Aviation Psychology*. Dayton, Ohio, U.S: Wright State University Press, 2007.

8. FAA. AC 120-51E, *Crew Resource Management Training*. Jan. 22, 2004. <http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/80038cf51aace53686256e24005cbb23/$FILE/AC120-51e.pdf>.

9. Dismukes, R.K.; Berman, B.A.; Loukopoulos, L.D. *The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents*. Aldershot, England: Ashgate, 2007.