Technologically Advanced Aircraft
Safety and Training

AOPA AIR SAFETY FOUNDATION

Executive summary

Technologically Advanced Aircraft (TAA) have been entering the general aviation (GA) fleet in large numbers since early in the decade. TAA are grouped into three categories: newly designed aircraft, newly manufactured classic design aircraft equipped with new avionics, and retrofitted existing aircraft of varying ages.

Our analysis, while preparing this report, shows TAA having proportionately fewer accidents compared to the overall GA fleet. TAA have experienced reductions in the percentage of takeoff/climb, fuel management, and maneuvering accidents, and increases in landing, go-around and weather crashes, as compared to the fleet.

Light GA pilots are now undergoing the transition that the airlines and corporate pilots underwent in prior decades. The use of autopilots as an integral part of single-pilot IFR TAA operations should be embraced. Training requirements center on differences in new-design TAA handling characteristics and the addition of capable but complex avionics packages.

Deliveries of new equipment have been accompanied by insurance coverage requiring factory-approved training. CFIs and pilots are adapting along with the manufacturers and training organizations, gaining in experience and capability. More and better simulation is gradually becoming available to TAA pilots and ASF considers this an essential part of learning to use the avionics.

Training to use nontraditional avionics using traditional methods is not optimal. Use of CD/DVD and online simulation is a step forward, as is the development of relatively inexpensive simulators for new TAA.

Table of Contents

Mooney Ovation 2 GX

Introduction and overview

The first edition of this report was published in 2004 as a preliminary review of Technologically Advanced Aircraft (TAA) accidents. Since then, TAA have entered the general aviation fleet in significant numbers, with more than 5,700 GA glass-cockpit aircraft having been delivered. This updated version of Technologically Advanced Aircraft: Safety and Training provides a statistical analysis of TAA accidents, comparing their safety with that of conventional aircraft. This analysis is based on accident data contained in the AOPA Air Safety Foundation (ASF) Accident Database.

Questions this report will answer

This AOPA Air Safety Foundation Special Review of TAA answers three questions:

1. What adaptations to the general aviation (GA) training structure have been made as TAA have entered the fleet in significant numbers?

2. What GA accident trends have emerged involving TAA?

3. What changes to TAA or training might be considered?

Legacy TAA Instrument panel in a Mooney Ovation 2GX.

New TAA instrument panel in a Diamond DA–40.

Technologically Advanced Aircraft (TAA) defined

Technologically advanced aircraft are equipped with new-generation avionics that take full advantage of computing power and modern navigational aids to improve pilot situational awareness, system redundancy and dependence on equipment, and to improve in-cockpit information about traffic, weather, airspace and terrain. By FAA pronouncement, a TAA is equipped with at least the following:

- a moving-map display
- an IFR-approved GPS navigator
- an autopilot

Nearly all new aircraft go far beyond the basic definition, sporting enough electronic displays to qualify as having a "glass cockpit." ASF's working definition of a "glass cockpit" includes a primary flight display (PFD) to replace the traditional "six-pack" or "steam gauges," as round-dial mechanical instruments are known, and a multifunction display (MFD). The MFD, as the name implies, can show myriad items including a moving map, terrain, airspace, weather, traffic, on-board weather radar, engine instrumentation, checklists, and more. As this went to press, more than 5,700 GA glass-cockpit aircraft had been delivered. According to a recent AOPA study more than 90 percent of new production aircraft are being delivered with glass, so it's a safe bet that sooner or later, most active pilots will be transitioning.

There is no current reliable estimate of how many existing aircraft have been retrofitted to become TAA, but it will be into the tens of thousands. New fleet sales to flight schools and university flight departments are almost universally glass cockpit—even for basic trainers. Most leading aviation universities have adopted TAA to prepare pilots for the next generation of flight, be it GA, corporate, or air carrier.

New and legacy glass cockpits

Some TAA are completely new designs such as the Cirrus, Columbia and Diamond, while others are updated versions of legacy machines such as the Cessna, Piper, Beechcraft, and Mooney product lines.

Retrofitted, or retro, TAA are previously delivered legacy aircraft with instrument panels reworked to add TAA equipment. *This report focuses on newly designed and updated legacy aircraft with factory-installed glass cockpits.*

More than hardware

Many observers believe that the deeper importance of the TAA takeover goes beyond just equipment. The larger definition includes a new mindset for pilots, encompassing a revised view of what constitutes GA flying, with airline-style procedures, regular use of autopilot, and greater dependence on avionics for multiple tasks beyond pure navigation.

Although pilots flying classic high-performance aircraft under IFR often use this approach, its application is essential in the successful operation of TAA. To process large amounts of information and not allow flight safety to suffer, pilots must add “systems manager” to basic stick and rudder skills. This mental shift has proven to be a challenge for some conventionally trained pilots. There is a belief by some pilots, abetted by sales literature and aircraft sales personnel, that TAA has altered the fundamentals of GA flying. *Despite some significant differences involving how the aircraft is operated, the core of pilot decision making and many of the risk factors remain exactly as they have been with non-TAA aircraft.*

History of TAA

From the beginning of powered flight, through the 1970s and 1980s, traditional instruments and displays dominated aviation. For much of that time, VOR, DME, and ADF were considered state of the art, but were not a major concern in the aviation training process. Once pilots mastered the principles of avionics systems management, transition to a new airplane required only cursory instruction on avionics because all equipment worked essentially the same way. The bulk of pilot checkouts were spent learning the handling of airplane characteristics and systems.

Then, in the late 1970s, the first GA area-navigation (RNAV) systems appeared. By the early 1980s, general aviation began to embrace the technological revolution as computers worked side by side with humans in the cockpit. The transition was visible first in military aircraft a decade or so before, but it wasn’t long before “glass” started invading the cockpits of business jets and large Airbus, Boeing, McDonnell Douglas and Lockheed aircraft.

Columbia 400

Left to right: Eclipse keyboard, Garmin data entry pad in Columbia, and Dassault Falcon EASy™ Flight Deck with cursor control devices (trackball mouse)

COURTESY OF ECLIPSE AVIATION

In the 1980s and early 1990s, the initial versions of computerized cockpits were relatively simple by today's standards: small glass TV screens (cathode ray tubes, or CRTs) capable of displaying graphics of traditional aircraft flight instruments. These electronic flight instrument systems (EFIS) came to be known as "glass" and aircraft sporting them as glass-cockpit aircraft. CRT displays were superseded in the mid-1990s by liquid crystal displays (LCDs) that delivered much larger pictures at a considerable savings in weight and energy consumption.

Even the early CRTs, however, could graphically represent multiple items of flight information in the same location on the screen, forever changing the basic six-instrument scan three generations of pilots had come to know so well. For many pilots, the change to glass PFDs was straight-forward. The attitude indicators and flight directors looked pretty much the way they always had and they were always in the center of the display.

Today, although the bulk of the existing 180,000-plus light GA airplanes still use steam gauges, virtually all new GA aircraft are delivered with glass cockpits. While some manufacturers still offer the traditional six-pack instruments, few aircraft are delivered with this option, except those intended for pure recreation.

Many aircraft owners are retrofitting their classic aircraft to convert them to TAA with IFR-certified GPS navigators, multifunction displays and upgraded autopilots.

What's next?

As technology continues to evolve, airliners and business jets are sometimes on the leading edge of even more sophisticated cockpit technologies, though GA aircraft are likely not far behind. The new Boeing 787, Airbus A380, and several business jets will work with Microsoft Windows-like displays and trackballs to simplify data input. Knobs, in fact, will serve only a backup function as equipment tunes everything automatically.

The trickle-down of flight management systems (FMS) for light aircraft is already providing keyboards and other user interface enhancements, replacing multi-function controls that must first be configured before data can be entered. Keyboard and trackball data entry can benefit the pilots of space- and cost-constrained smaller aircraft.

Cockpit space constraints were at least part of the rationale behind limited control interfaces, which experience shows to be one of the more challenging aspects for pilots transitioning to TAA. In the early 1990s there were at least five manufacturers building IFR GPS navigators and all had different operating logic and displays. This contributed significantly to the training challenge for pilots who flew multiple aircraft equipped with different units. At this writing, that number has dwindled to two or three.

Further down the road is the possible introduction of head up displays (HUD) and enhanced vision systems (EVS) in general aviation cockpits, although for the near term these devices will likely go to high-end aircraft. Such systems allow an easier transition from flying instruments to visual references during instrument approaches.

Light GA is leading the way over its larger and more expensive cousins with datalink and WAAS installations. In some cases these are on portable devices that are not officially approved for IFR flight, but pilots use them for supplemental guidance, thus gaining valuable experience that can be applied if they upgrade to an approved installation.

Safety Implications

As TAA were being introduced, both regulators and industry recognized that they were creating a new world of opportunity and challenges for general aviation pilots. In 2003, ASF participated with the FAA, academia, and other industry members to help write *General Aviation Technically Advanced Aircraft—FAA/Industry Safety Study.*

The team findings were:

1. "The safety problems found in the accidents studied by the team are typical of problems that occurred after previous introductions of new aircraft technology and all also reflect typical GA pilot judgment errors found in analysis of non-TAA accidents."

2. "Previous safety problems similar to those identified in this study have been remedied through a combination of improved training and, in the case of new aircraft capabilities, pilot screening (i.e., additional insurance company requirements of pilot experience)."

3. "The predominant TAA-system-specific finding is that the steps required to call up information and program an approach in IFR-certified GPS navigators are numerous, and during high workload situations they can distract from the primary pilot duty of flying the aircraft. MFDs in the accident aircraft did not appear to present a complexity problem. The team also believes that PFDs, while not installed in any of the accident aircraft and just now becoming available in TAAs, similarly are not likely to present a complexity problem."

4. "TAAs provide increased 'available safety,' i.e., a potential for increased safety. However, to actually obtain this available safety, pilots must receive additional training in the specific TAA systems in their aircraft that will enable them to exploit the opportunities and operate within the limitations inherent in their TAA systems."

5. "The template for securing this increased safety exists from the experiences with previous new technology introductions—the current aircraft model-specific training and insurance requirements applicable to high-performance single- and multiengine small airplanes. However, the existing training infrastructure currently is not able to provide the needed training in TAAs."

6. "Effective and feasible interventions have been identified, mostly recommending improvements in training, and effective implementation mechanisms for the recommended interventions exist. Therefore, TAA safety problems can be addressed, and the additional available safety of TAAs to address traditional causes of GA accidents can be realized as well."

We'll explore these findings in greater detail while commenting on the aircraft themselves.

A new Cessna 182 equipped with a Garmin G-1000.

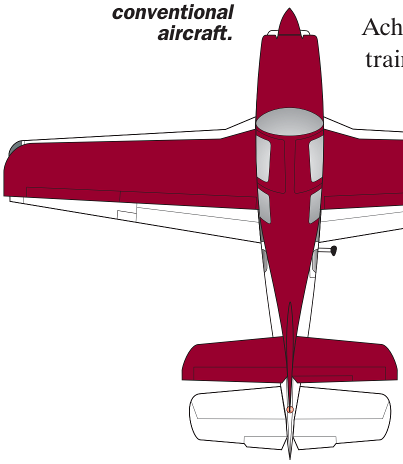
The good news

The MFD provides an unprecedented view of the environment in which the TAA pilot operates. Moving maps provide pilots with significantly increased positional awareness with pinpoint GPS navigational accuracy. Map overlays include data-linked weather information, terrain databases, obstructions, airspace, and traffic locations. Additional information includes communications and navigation frequencies, airport data, and engine and systems status. Some systems even provide depictions of the wind-corrected range based on the remaining fuel. Such tools have tremendous potential to increase GA safety.

Some newly designed TAA themselves, with higher wing loading and sleek aerodynamics, are faster than traditional light GA aircraft with similar power. Better systems redundancy reduces the probability of single-point failure.

The new look has an undeniable appeal for the light GA industry, which has seen lackluster sales for more than 20 years. With progress invariably comes responsibility on the part of designers, regulators, CFIs, and, most importantly, pilots to make sure that all the features, performance, and extra information available with TAA actually translate into safer flight.

Achieving the potential benefits will depend on training, and, ultimately, on a continuing evolution in equipment design. GPS navigators have evolved for nearly two decades, and the present generation is far superior to early models. We have every reason to believe that it is only going to get better.



The wing, fuselage, and empennage area of a Columbia 350 is superimposed on a Beechcraft Bonanza A36. Proper training is necessary to overcome different handling characteristics between some TAA and conventional aircraft.

The challenge

The AOPA Air Safety Foundation has identified three characteristics of TAA that are likely to have the most impact on the GA safety record.

The first is the different physical handling characteristics of some new design TAA. This is obvious, straightforward, and will be relatively easy to manage.

The second is the widespread adoption of new piloting techniques—different from the traditional role of the GA pilot. This may prove a bit more difficult.

The third challenge is finding instructors and flight schools that are knowledgeable and experienced on the new aircraft, although this will improve as more TAAs enter the fleet and more flight schools become equipped with appropriate simulation devices to assist in avionics training. Again, we emphasize the importance of an appropriate level of simulation early in the training process. Several manufacturers have embarked on ambitious programs to educate CFIs, and they are commended for their efforts. A related training issue is to bring the "planning ahead" skills of lower-time pilots up to speed as they transition from slower training aircraft to faster, sleeker designs.

Any experienced CFI is well aware of the extra instruction required for pilots to think further ahead in a faster airplane. If the aircraft is descending at 180 knots into the terminal area, the pilot had better be thinking at 220 knots. With TAA, the CFI must guide the pilot along the additional learning curve of new avionics and development of the skills to manage their workload.

The advantages of TAA are many, but realizing their benefits will require pilots to shift from a typical GA piloting approach.

The physical airplane

Increased speed and unique handling characteristics of newly designed TAA have, without proper training, led less experienced pilots into difficulty in takeoffs and landings and in managing arrivals into the terminal area. Some of these aircraft handle differently than conventional aircraft, with different "sight pictures" in the takeoff and landing phases of flight. Using the "old" techniques with a new design may lead to pilot-induced oscillations, loss of directional control, or an inadvertent stall.

When the Boeing 727 was introduced to the airline community in the early 1960s, there were a number of accidents until pilots and instructors figured out the quirks of the new design. Different does not mean bad, but the training challenges for some new TAAs exceed those for pilots moving between many other classic aircraft. High-wing loadings on some of the new aircraft produce blazing speeds and give a smoother ride in turbulence, but they also develop a higher sink rate without power during approach and landing. They typically increase the required landing distance as well, so short field airports that may have been safe for legacy aircraft should be carefully evaluated for newly designed aircraft suitability.

New aircraft designs are also prone to “teething problems” in the first few years after joining the fleet. Examples of this include problems with both Diamond and Cirrus aircraft with doors opening or separating in flight. The Cirrus has also experienced several brake fires because of improper taxi techniques, and in-flight instrument malfunctions because of water in the pitot-static system. As these new designs mature, such problems are eliminated through changes to production aircraft and retrofits to the existing fleet.

The advanced avionics are also prone to growing pains. Reliable datalink connections, hardware reliability, and user interface issues have all been encountered in the first few years of TAA service. One item of concern has been the ability of the Garmin G1000 aural warnings to override ATC communications. This can be tricky if the pilot needs to coordinate with ATC to deal with the source of the warning tones coming through the headset.

Since Wilbur and Orville, pilots have defined “good piloting” primarily as a set of eye-hand or stick and rudder skills that result in predictable outcomes:

- Maintaining V_Y precisely during a climb.
- Maintaining altitude within 50 feet.
- Tracking a VOR/GPS course within one dot of the centerline.
- Landing with the desired speed and attitude, and the rate of descent perfectly arrested at the exact instant the tires brush the concrete.

As part of this mindset, alertness to the physical environment is valued (“keep your eyes outside the window for traffic”), as is an almost Zen-like unity with the airplane (“can’t you feel that little buffeting? It’s telling you it’s ready to stall.”).

“Physical airplane” pilots, which is to say most GA pilots who trained before 1980, often carry a do-it-yourself attitude that regards assistance as an affront. Popular writings by author Ernest K. Gann capture this way of thinking, telling of early airline co-pilots who were often told by their captains to shut up, watch, and keep their feet off the furniture. Autopilots were scorned as unnecessary and were often only available on the top end of light aircraft so it was largely a moot point.

This view of the pilot has changed completely in airline and corporate cockpits. The pros have recognized that the hardware is far more reliable than the humans overriding it. This certainly doesn’t mean an abdication of pilot-in-command (PIC) responsibility but rather an acceptance that the autopilot does a better job of mechanical flying.

The automation, however, is incapable of programming itself and at times will significantly complicate a basic flying task. GA pilots are just beginning to face this transition.

Cirrus SR22 GTS

The mental airplane

In TAA, piloting moves from the “physical airplane”—the stick and rudder skills—to a more mental approach. Pilots who successfully adapt will enjoy these aircraft while gaining situational awareness, and those who don’t will find challenge, complexity, and probably some unsafe situations when they are distracted from the primary task.

The early corporate and airline operators who installed advanced avionics employed primarily “physical airplane” pilots, and the transition to glass cost considerably more time and money than expected. While most pilots were eventually successful in the move to the glass cockpits of Boeing 757/767 and Airbus equipment, some were not and retired. Some senior pilots admitted they remained anxious about the complexities of glass right up to their last day.

The transition to the “mental airplane” means coping with distractions from the additional information and learning unfamiliar displays. This is the root cause of the additional transition time.

Among the casualties: a good see-and-avoid lookout for other aircraft. In airline and corporate cockpits, much of this is negated by having two professional pilots, having traffic alert and collision avoidance systems (TCAS), and spending much of the flight in positive controlled airspace (Class A). Most operators have an inside/outside policy where one pilot is clearing visually while the other deals with the internal systems. That they operate in largely “sanitized” airspace of Class A, B, and C also contributes to a different approach to collision avoidance. It’s worth noting that with the advent of TCAS there has not been a single GA vs. airliner or airliner vs. airliner collision in U.S. airspace. Traffic awareness systems found on many TAA provide some of this protection. But for the single pilot, the attention must be appropriately split. There have been numerous Aviation Safety Reporting System (ASRS) reports on crew confusion or distraction stemming from the use of TAA or equipment that is typically installed in TAA. Reports included missing assigned routes, mis-programming approaches, mode confusion, and altitude busts because of distraction with the equipment. It should be pointed out that pilots have always been susceptible to distraction, and many of these same problems are manifested in classic aircraft. Identical ASRS reports continue today, and for the same reasons.

In spite of manufacturer claims, the avionics in TAA only provide the POTENTIAL for better situational awareness. The tremendous flexibility and amount of data made available to the pilot of modern aircraft has equal ability to inform or distract. *Which result takes place is largely dependent on how the pilot flies the mental airplane and manages his use of that information.*

In the case of corporate and airline operations, the landmark TAA-related accident that graphically defined the potential dangers of automation and FMS occurred in Cali, Colombia, in 1995, when an American Airlines Boeing 757 struck terrain at night after the crew misprogrammed its FMS. After that tragedy, the airlines changed their procedures in how crews interacted with cockpit automation. There are lessons to be learned from Cali for GA pilots to write a safer history for TAA.

Beyond workload: over-reliance

A related safety issue concerns pilots who apparently develop an unwarranted over–reliance on their avionics and the aircraft, believing that the equipment will compensate fully for pilot shortcomings. This is perhaps more related to human nature than to TAA itself and was raised more than a decade ago after several accidents that occurred shortly after the Piper Malibu was introduced. At that time, FAA instituted a Special Certification Review that ultimately exonerated the aircraft, finding that the Malibu problems were largely self-inflicted by pilots unfamiliar with operations in high altitude environments. Many of the fatal accidents occurred after encounters with convective weather while en route.

Some pilots did not understand that FL250, the Malibu’s highest operational altitude, was one of the worst levels to penetrate a thunderstorm. Clearly, these pilots believed that the aircraft, a fine piece of engineering, was capable of more than reality allowed. The early marketing materials did nothing to dispel that belief by touting that when flying a Malibu one could fly above the weather. To Piper’s credit, that approach was changed.

Related to the over-reliance on hardware is the role of aeronautical decision making, which is probably the most significant factor in the GA accident record of high performance aircraft used for cross-country flight. The fact that the aircraft involved was a TAA appears to be coincidental.

TAA accident history

ASF's GA Accident Database contains NTSB data on virtually every accident involving GA aircraft in the United States from 1983 to the present (fixed-wing, weighing 12,500 pounds or less), accounting for more than 50,000 records. Unfortunately, government information-gathering on those accidents generally contains no clear markers that define TAA from non-TAA. For the future, ASF has requested that accident investigators note the on-board avionics in accident aircraft. This will allow a more precise determination of what avionics are involved in what type of accidents.

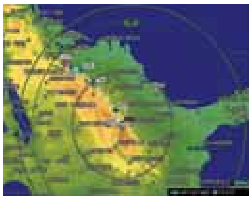
It is possible, however, to identify those aircraft that were delivered by the factory with glass cockpits. Using aircraft serial numbers and delivery dates from NTSB and manufacturer data, ASF has analyzed accidents involving glass-cockpit GA aircraft from 2003 to 2006 and compared them to the overall GA accident record. This analysis uses similar methodology to that in ASF's annual *Joseph T. Nall Report*.

Comparing glass-cockpit TAA to all GA accidents

Between 2003 and 2006, glass-cockpit TAA accounted for 57 of the 3,783 total GA accidents. Eighteen of the 792 total fatal accidents were in such aircraft. It is encouraging to note that while 2.8 percent of the GA fleet were TAA, the advanced aircraft were involved in only 1.5 percent of the accidents.

The distribution of these accidents also provides several interesting comparisons (Figures 1 and 2). For both total and fatal accidents, *TAA have had fewer than half as many takeoff/climb accidents as the overall GA fleet.* One contributing factor for this improvement may be the ability to display critical V-speeds directly on the airspeed indicator. This gives the pilot an instant picture of the current airspeed relative to that desired.

Glass-cockpit TAA have had NO fatal accidents related to fuel management. This is an important victory over a long-time cause of GA aircraft accidents. Many TAA MFDs include a "range ring" that superimposes the aircraft's range with available fuel over the map display or a digital readout of fuel remaining and range, which is calculated based on current fuel flow and groundspeed.



Pilot-Related Accident Categories, TAA vs. Fleet—Total

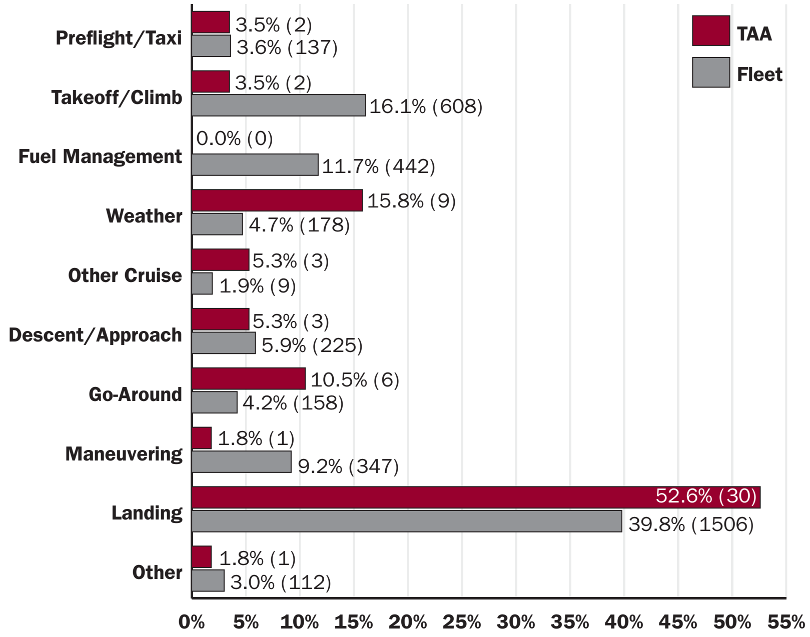


Fig. 1

Pilot-Related Accident Categories, TAA vs. Fleet—Fatal

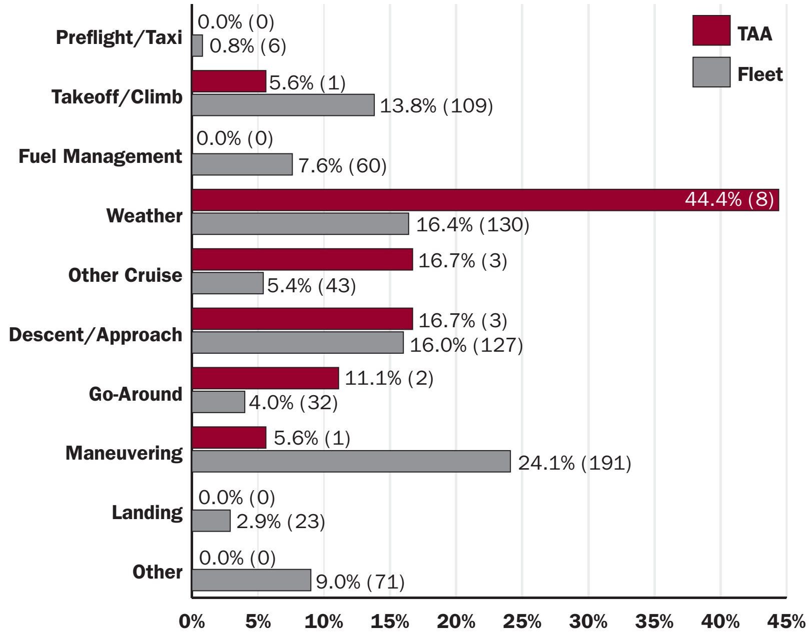


Fig. 2

Maneuvering accidents, a leading cause of fatalities in GA overall, have also been greatly reduced in TAA. During the period studied, 9.2 percent of all GA accidents, and a troubling 24.1 percent of GA fatal accidents, occurred during maneuvering flight. This compares with 1.8 and 5.6 percent respectively for TAA. While the data do not clearly point to the reason for this improvement, it is speculated that higher levels of transportation use of these aircraft could be a factor—i.e., pilots are flying to some place rather than spending so much time in the practice/local area or traffic pattern where maneuvering accidents are prone to occur.

Accident 1 [ATL05FA034]

December 9, 2004; Diamond DA40; Pelzer, South Carolina; Likely cause: Diverted attention to program new instrument approach.

History of Flight

Near the end of an IFR flight from Jacksonville, Florida, to Greenville, South Carolina, the CFI-rated pilot was advised by ATC that the weather was below approach minimums and was asked if he wanted to divert to his alternate airport. The pilot told the tower controller that he did not have an alternate filed. The tower controller advised the pilot that Donaldson Center Airport was nearby and asked the pilot if he would like to divert there. The pilot elected to divert to Donaldson and was given radar vectors for the final approach course for Runway 5. As the pilot maneuvered for the approach, the airplane descended below the minimum safe altitude (MSA) of 2,500 feet, at which time the tower controller issued a low altitude warning with no response from the pilot. Attempts to re-establish communication with the pilot were unsuccessful.

Examination of the crash site revealed a damaged power line about 75 feet above the ground and that the tops of four trees were also damaged. Airplane debris was scattered in an area 100 feet wide by 450 feet long. No mechanical problems were reported by the pilot prior to the accident, and post-accident examination of the wreckage failed to disclose a mechanical problem or component failure. Radar data showed the airplane losing 600 feet of altitude in a period of 14 seconds before the airplane was lost on radar.

ASF Comments

This accident appears to be a loss of altitude awareness leading to descent and striking of power lines and trees. TAA displays provide excellent depictions of the flight path, desired course, and other data on a map display. They are less helpful in providing a clear picture of aircraft altitude compared to that desired. Altimeter "bugs" allow the pilot to set target altitudes, but not all pilots use them effectively. In this particular case, the pilot may have been reprogramming the navigation system for the newly assigned approach. Such a distraction could result in loss of altitude awareness. Appropriate use of the autopilot is essential in these situations.

Despite the promising record for takeoff/climb, the accidents studied showed TAA have a *higher percent of landing (52.6 percent vs. 39.8 percent) and go-around (10.5 percent vs. 4.2 percent) accidents than the overall GA fleet.* None of the glass cockpit landing accidents was fatal, however. With slick composite fuselages and wings, some new design TAAs can be difficult to slow down to the desired approach speed, leading to porpoising during the flare or long landings. While trying to correct the situation, or when initiating a go around, torque from the high-powered engine can lead to directional control problems and this has led to fatal accidents.

The area where TAA fared the worst was in weather related accidents. These accounted for nearly half (44.4 percent) of glass-cockpit fatal accidents compared to 16.4 percent for the GA fleet. There is still no way to determine how many of these pilots had datalink weather available to them. The news on weather accidents isn't all bad, however. Continued VFR flight into instrument meteorological conditions, while accounting for two-thirds (67.7 percent) of fatal GA fleet weather accidents, only account for a little over one-third (37.5 percent) of the fatal TAA weather crashes.

While the analysis of the NTSB accident reports does not provide clear insights, there are several factors that could contribute to the high number of TAA weather crashes:

- As discussed above, TAAs are believed to have a higher percentage of use in a transportation role, increasing their exposure to adverse weather compared to those whose primary use is for training.

- Unlike NEXRAD weather radar displays, METAR surface weather reports and most forecasts provided by datalink are typically presented on the MFD in text format. Lack of an easy-to-interpret graphic presentation of nonradar weather data may negatively impact the pilot's ability to get a clear mental picture of overall weather conditions, and relate it to the route being flown.

- Like traditional weather information sources, the pilot must enable datalink weather displays. If they don't "ask" for the weather, they don't get it. Once a weather product is available in the cockpit, it is the pilot's responsibility to know how to interpret the information and integrate it with other weather information.

- A number of TAA accident pilots may have believed that access to near real-time weather improved their chances of dealing with adverse weather. ASF's observation is that reliance on the hardware, as previously mentioned, must be accompanied by a much stronger decision making regimen. When the decision is made to go, that's only the beginning of the ADM process and puts a significantly greater burden on the pilot to make the tough call to bail out or divert when the weather dictates.

There is one aspect that is impossible to measure that may mitigate this somewhat gloomy assessment. There is no way to know how many trips are successfully completed in either TAA or classic aircraft. It is entirely possible that the trip completion ratio is higher with TAA than with classic aircraft but at this point that is speculative. We hope that a method will be devised to measure this aspect of TAA to determine a better denominator for measuring the actual weather accident rate.

Cirrus accidents

Cirrus Design is the most successful manufacturer of new design TAA, as measured by delivered aircraft. They began deliveries of the SR20 in 1999 and now have several models, including a turbo-normalized version of the SR22. Through the end of 2006 they had delivered more than 3,000 of the total 5,700 TAA. To better understand TAA safety as it relates to the current market leader, ASF analyzed glass-cockpit Cirrus accidents during the period from 2003 through 2006.

The Cirrus record shows improved safety versus the GA fleet for takeoff/climb, maneuvering, descent/approach, and fuel management. Like other TAA, fuel management accidents were entirely eliminated in glass-cockpit Cirrus during the period studied. Fatal accidents followed trends similar to overall accidents (Figures 3 and 4).

Weather showed the largest negative difference when comparing Cirrus accidents to the overall GA fleet, with nearly one-third (31 percent) of all Cirrus accidents involving weather, compared to 4.7 percent for GA overall. Weather proved to be uncommonly deadly in the

Pilot-Related Accident Categories, Cirrus vs. Fleet—Total

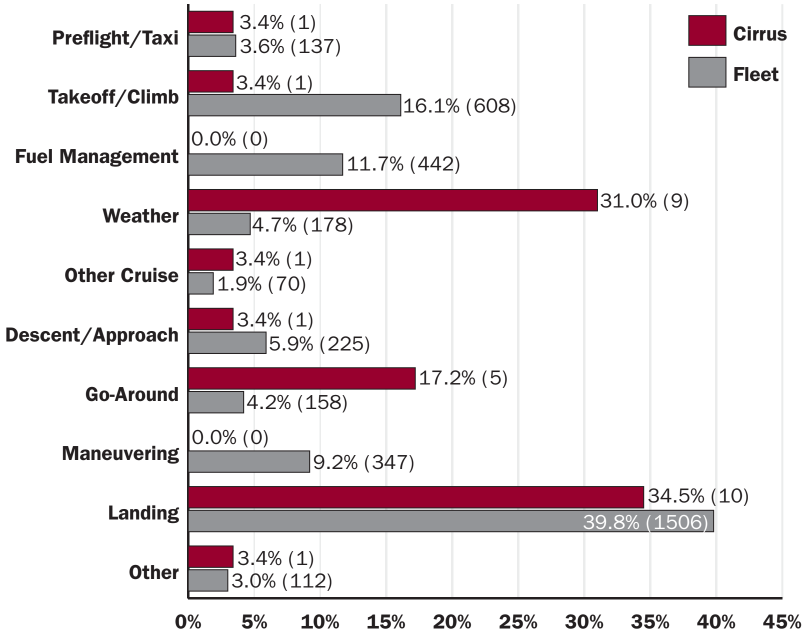


Fig. 3

Pilot-Related Accident Categories, Cirrus vs. Fleet—Fatal

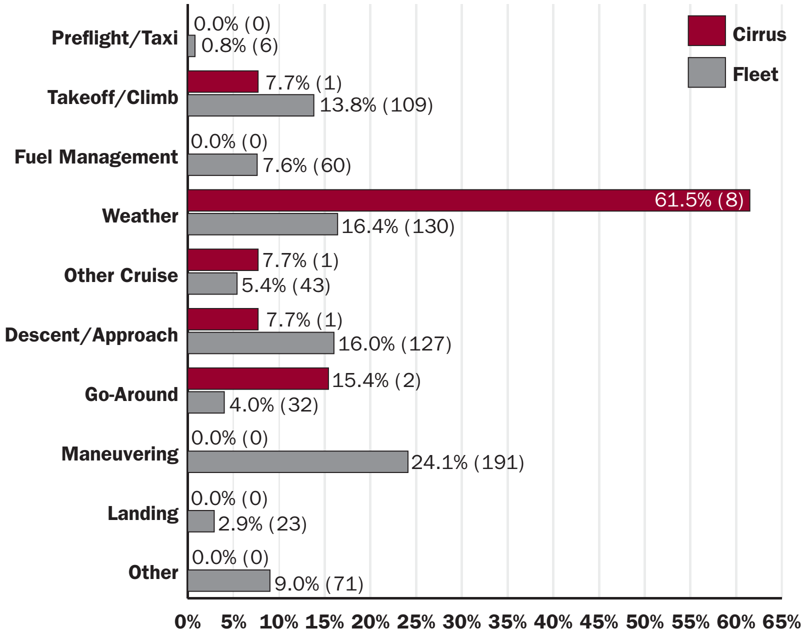
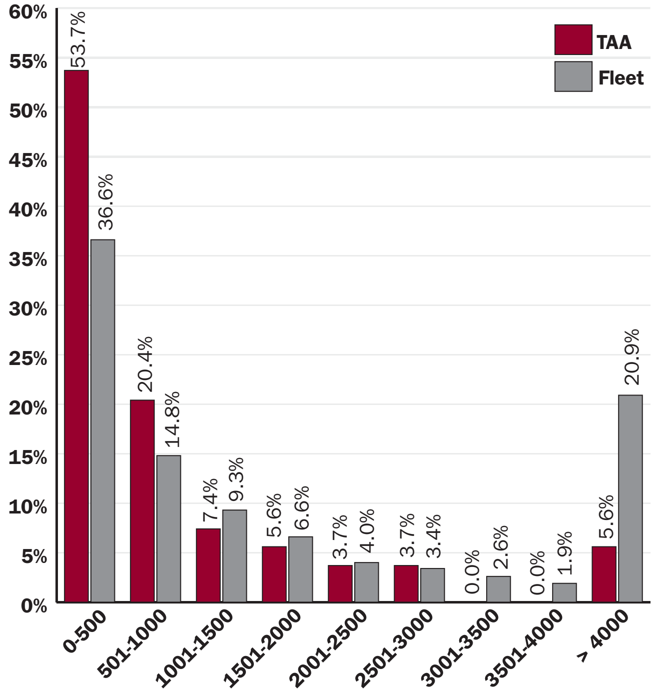
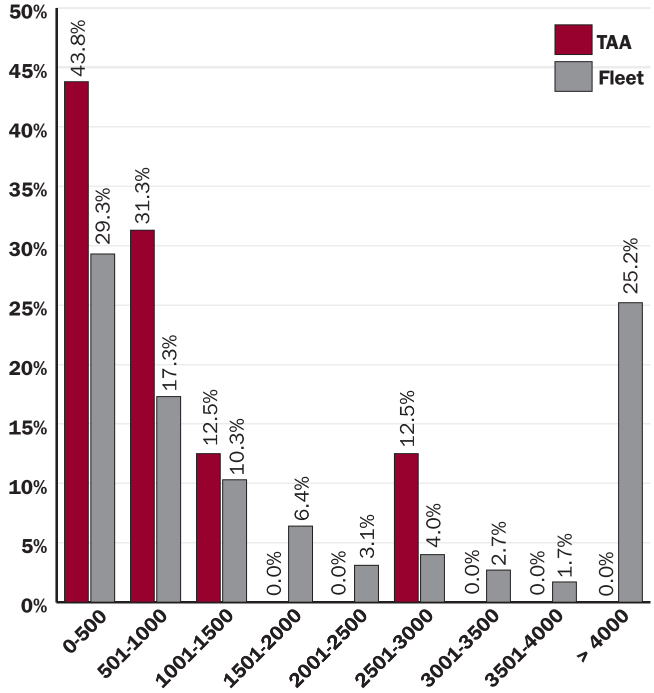


Fig. 4



Accident Rates by Hours of Experience, TAA vs. Fleet—Total

Fig. 5



Accident Rates by Hours of Experience, TAA vs. Fleet—Fatal

Fig. 6

Cirrus, accounting for nearly two-thirds (61.5 percent) of fatal accidents. In the overall GA fleet, weather was identified as the cause in 16.4 percent of fatal accidents.

Go-arounds also proved troublesome in the Cirrus, accounting for 17.2 percent of all accidents and 15.4 percent of fatals. This compares to 4.2 and 4.0 percent respectively for the overall GA fleet. This problem may be a result of higher wing loading combined with higher horsepower engines.

Type of operation

The purpose of accident flights was also studied with some interesting differences between GA and glass cockpit accidents (Figure 7). While there were fewer (59.7 vs. 67.5 percent) accidents when glass-cockpit aircraft were flown for personal reasons, that difference was almost perfectly accounted for by the increase (13.4 vs. 3.5 percent) in business mishaps. Instructional flights also proved troublesome, accounting for 23.9 percent of the glass cockpit total, compared to only 15.1 percent of the overall GA accidents. ASF's experience in analyzing the safety record of over a dozen different makes of aircraft is that *the record largely reflects how the aircraft is used rather than a fundamental flaw that was missed in the certification process.* In the case of Cirrus, this translates to relatively few takeoff accidents compared to the rest of the fleet and more cross-country accidents, often related to weather or terrain encounters. This is because the aircraft are used predominantly in transportation roles and not in primary training where many takeoffs and landings are practiced. It is too soon to tell if Cirrus takeoff and landing accidents will increase on a percentage basis as they find their way into more primary training roles.

Type of Operation

Type of Operation	% of Flying (2005)	% of TAA Accidents	% of Fleet Accidents
Personal	49.4	59.7	67.5
Instructional	18.4	23.9	15.1
Aerial Application	5.1	0.0	5.5
Business	15.1	13.4	3.5
Executive/Corporate	4.3	1.5	0.4
Positioning	*	0.0	1.9
Ferry	*	0.0	0.5
Other Work Use	0.5	0.0	1.3
Aerial Observation	3.5	0.0	0.6
Other/Unknown	3.7	1.5	3.7

* Included in Other/Unknown

Fig. 7

Comparing TAA accident pilots to non-TAA accident pilots

Pilot experience is another area of interest when examining TAA safety (Figures 5 and 6, p. 12). When looking at total time in all aircraft, pilots with 1,000 hours or fewer are more likely to experience a mishap in a glass cockpit aircraft than in a traditional GA aircraft. Fatal accidents in TAA were more common for even more experienced pilots, with those logging 1,500 or fewer hours having over 85 percent of fatal TAA accidents, compared to 57 percent for the fleet.

Time in type was also problematic for the TAA pilot, with 300 hours in type or less accounting for more accidents in TAA than GA in general (Figures 9 and 10). This was even more exaggerated in fatal accidents where the TAA risk factor went up to 500 hours in type.

The proportion of accident pilots holding instrument ratings (Figure 8) was similar in overall TAA and GA accidents, while a higher number of TAA fatal accidents (70.6 vs. 61.5 percent) involved instrument-rated pilots. This suggests that the transportation role of many TAAs motivates a higher percentage of pilots to obtain an instrument rating. It may also be related to the lower number of VFR into IMC accidents discussed above.

% of Pilots with an Instrument Rating

Aircraft	% of Total With	% of Total Without	% of Fatal With	% of Fatal Without
TAA	55.3	44.7	70.6	29.4
Fleet	52.3	47.7	61.5	38.5

Fig. 8

TAA and the parachute

Some TAAs have added new features that did not exist just a few years ago. One such change is Cirrus Design's complete aircraft parachute. The chute should be deployed when the pilot believes there is grave danger.

According to the Cirrus SR22 Pilot Operating Handbook, "The Cirrus Airframe Parachute System (CAPS) is designed to lower the aircraft and its passengers to the ground in the event of a life threatening emergency. However, because CAPS deployment is expected to result in damage to the airframe and, depending upon adverse external factors such as high deployment speed, low altitude, rough terrain or high wind conditions, may result in severe injury or death to the aircraft occupants, its use should not be taken lightly. Instead, possible

Accident Rates by Time in Type TAA vs. Fleet—Total

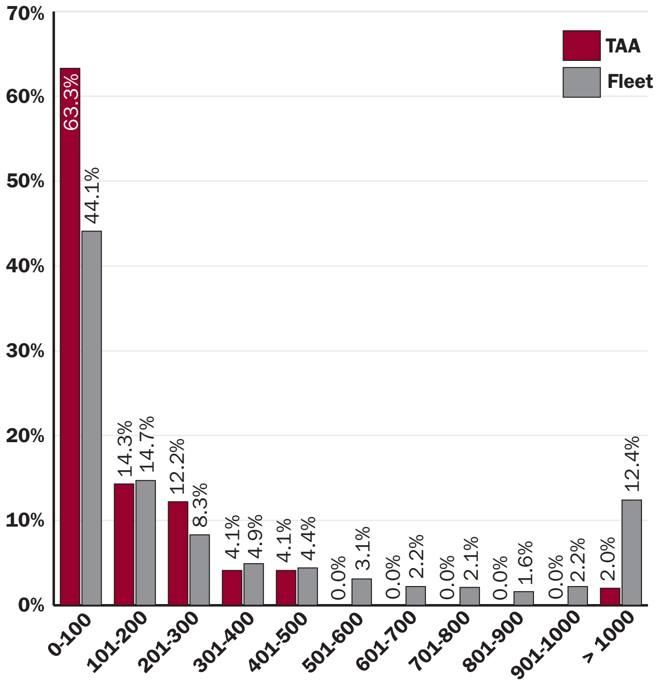


Fig. 9

Accident Rates by Time in Type, TAA vs. Fleet—Fatal

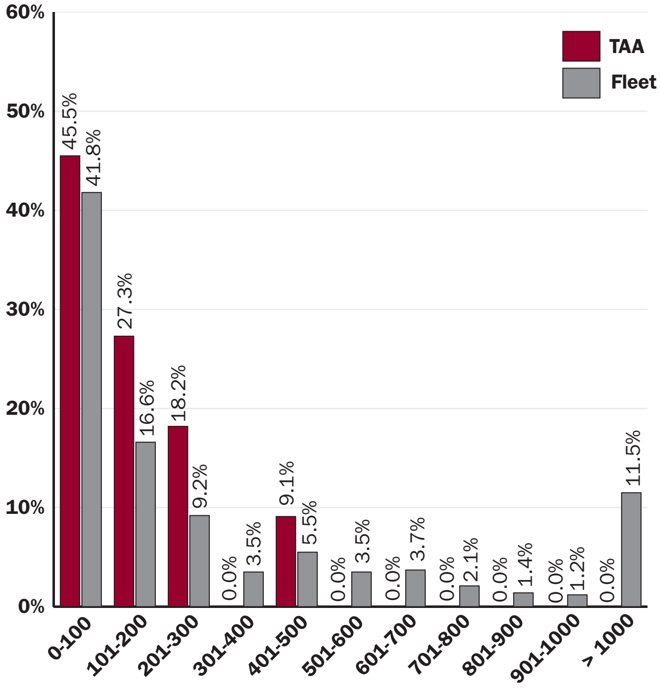


Fig. 10

CAPS activation scenarios should be well thought out and mentally practiced by every SR22 pilot."

The POH goes on to describe the types of situations in which CAPS use would be appropriate. These include:

- Mid-air collision
- Structural failure
- Loss of control
- Landing in inhospitable terrain
- Pilot incapacitation

The parachute has stimulated strong debate within GA about whether the presence of such a potentially life-saving tool encourages pilots to intentionally fly into situations they would not normally attempt in more conventionally equipped aircraft. Whole-airframe parachutes will likely be offered on other manufacturers' products in the future. They are already available as retrofits on Cessna products and a wide variety of ultralight aircraft. Perhaps the parachute's effect on pilot decision making is as irrelevant as equipping an aircraft with shoulder harnesses. One never intends to use them but they are there in the event of need, regardless of whether the pilot created the problem or was a victim of circumstance.

To date, there have been more than 10 reported instances of use or attempted use of the CAPS system in Cirrus aircraft. Some resulted in situations in which the pilot's decision making placed the flight in jeopardy, but use of CAPS likely prevented a disastrous outcome. Other CAPS deployments resulted from mechanical or other nonpilot factors. In at least one case, use of CAPS was attempted in a high-speed dive after a severe icing encounter but the chute separated from the aircraft due to the high deployment loads well in excess of the maximum designed deployment speed. Following are summaries of several CAPS-related accidents:

CAPS Deployment 1 [FTW03LA005]

October 03, 2002; Cirrus SR22; Lewisville, Texas; Likely Cause: The improper reinstallation of the left aileron by maintenance personnel.

History of Flight

During cruise flight the left aileron separated from an attach point, and the pilot executed a forced landing to a field. Prior to the accident flight, the airplane underwent maintenance for two outstanding service bulletins. During compliance with one of the service bulletins, the left aileron was removed and reinstalled. The pilot confirmed with the service center personnel that the maintenance on the airplane was completed. After departure the airplane was level at 2,000 feet msl for approximately one minute, the pilot noticed that the airplane began "pulling" to the left, and the left aileron was separated at one hinge attach point. The pilot then flew toward an unpopulated area, shut down the engine, and deployed the aircraft's parachute system. Subsequently, the airplane descended to the ground with the aid of the parachute canopy and came to rest upright in a field of mesquite trees.

Examination of the left aileron and the airframe aileron hinges revealed that the outboard aileron hinge bolt was missing, with no evidence of safety wire noted. According to maintenance manual procedures, the bolt and washer hardware were to be safety wired.

ASF Comments

Here is an excellent example of the safety factor intended by Cirrus Design through use of CAPS. The aircraft was being operated properly, and the pilot made an excellent choice to deploy the parachute when a flight control malfunctioned after routine maintenance.

CAPS Deployment 2 [NYC05LA110]

June 30, 2005; Cirrus SR22; Haverstraw, New York; Likely cause: Pilot incapacitation.

History of Flight

According to the pilot, the airplane was in cruise flight at 3,000 feet, when the pilot suffered a seizure and lost consciousness. When the pilot awakened, the airplane was in a high-speed descent. In addition, he felt disoriented and felt numbness in his right leg. The pilot recovered from the descent at an altitude of about 1,700 feet and elected to deploy the CAPS parachute system. The airplane descended under the parachute and impacted in a river. The airplane sustained substantial damage to the underside of the composite fuselage. The pilot sustained a fractured vertebra and was able to exit the airplane before it sank. Subsequent medical examinations on the pilot revealed the presence of a brain tumor.

ASF Comments

This is another example of the parachute saving a pilot who likely would not have been able to get back on the ground safely. Each year there are a few accidents attributed to pilot incapacitation. To date, there have been two cases where CAPS has been used to change the outcome of an incapacitation accident. Ironically, both cases involved a water landing under the chute. While the water landing poses challenges of its own, the parachute at least gives the occupants the opportunity to increase their odds of survival.

CAPS Deployment 3 [ATL06LA035]

January 13, 2006; Cirrus SR22; Childersburg, Alabama; Likely cause: Loss of control due to airframe icing.

History of Flight

The experienced CFI departed Birmingham, Alabama, bound for Orlando, Florida. The airplane was equipped with datalink weather. The airplane was identified by radar and cleared to climb to 7,000 feet. It entered the clouds at 5,000 feet on autopilot and climbing at 120 knots. Upon reaching 7,000 feet the airplane encountered icing conditions. The pilot informed the controller that he would like to climb to 9,000 feet, which was approved. As the airplane reached the cloud tops in visual flight conditions at 8,000 feet the airplane began to buffet. The pilot looked at his airspeed indicator and it indicated 80 knots. The airplane stalled and entered a spin back into instrument flight conditions. The pilot deployed the ballistic parachute system and informed the air traffic controller of his actions. The airplane descended under the parachute canopy into an area of trees.

The NTSB determined that the probable cause of this accident was the pilot's inadequate preflight planning, failure to obtain a current weather briefing, and his decision to operate the airplane into a known area of icing.

Accident 2 [DEN06FA131]

September 15, 2006; Cirrus SR20; Maybell, Colorado; Likely cause: Inadequate preflight planning.

History of Flight

The private/instrument pilot and one passenger were enroute from Tooele, Utah, to Lincoln, Nebraska. The pilot contacted air traffic control and stated he needed a lower altitude, as he was encountering icing conditions. Several altitude changes were assigned. Ultimately the pilot was assigned a block altitude from 12,000 feet to 13,000 feet. The pilot reported serious icing conditions and the controller cleared the pilot to an altitude of 11,000 feet. Shortly thereafter, voice and radar communications with the airplane were lost.

The wreckage was located scattered over a 1.5 mile area between Colorado and Wyoming. Evidence was consistent with a ground impact deployment of the Cirrus's parachute recovery system, resulting in the airplane being dragged by high winds. Examination of the airplane's systems revealed no anomalies. Thunderstorm activity existed along the route of flight along with severe icing and turbulence. The pilot had not obtained a full weather briefing prior to the flight.

ASF Comments

Inadequate flight planning has long been a contributing factor in weather-related accidents. It is possible that this pilot believed he could rely on the onboard datalink capabilities of his advanced glass cockpit to provide the weather information needed to safely complete the flight. MFDs have the ability to display a variety of weather products. Since icing is one of the most difficult hazardous conditions to report and forecast, this pilot may not have recognized that he was entering an area with conditions favorable to the formation of airframe icing until it was too late. Once the pilot lost control of the iced-up plane, the whole airplane parachute system could have been used to make a safe descent. It was not. The chute deployed due to impact forces, and high surface winds dragged the aircraft on the ground for more than 1.5 miles.

ASF Comments

While the first two CAPS examples saved the day in a case where the pilot was not at fault, this one is a different matter. Here the pilot clearly entered dangerous flight conditions because of his own errors and oversight. The parachute was used to save the lives of those on board, and without the chute this would likely have been fatal. This was an expensive lesson but not a fatal one.

Accident 3 [LAX05FA032]

November 10, 2004; Piper PA-32R; Santa Barbara, California; Likely cause: Controlled flight into terrain.

History of Flight

This VFR flight ended when it struck rising terrain during level controlled cruise flight on a night cross-country from Bakersfield, California, to Santa Barbara. After departure the pilot climbed from 4,900 to 5,200 feet and requested information from ATC about the elevation of the clouds. He admitted that he “seems to be in a little bit of clouds...sort of in and out.” The pilot continued climbing into clearer conditions. The flight continued and the airplane tracked near the centerline of Victor Airway 183. The pilot was familiar with the round-trip route between his Santa Barbara home-base airport and Bakersfield, and he had previously flown over the route. During the last few minutes of the radar-recorded flight, the pilot was cruising at about 6,500 feet, as indicated by the mode C altitude reporting transponder. The pilot was receiving radar flight following service from a controller at the Los Angeles Air Route Traffic Control Center. The controller observed the airplane and was aware that the minimum en route altitude (MEA) for airplanes on instrument clearances along the airway was 9,000 feet. The controller and the pilot had sectional aeronautical charts available for use that depicted a 6,840-foot msl mountain peak along the flight route. The pilot’s course did not vary as he approached and impacted the mountain during the dark nighttime flight. The controller did not issue a terrain-related safety alert, as required by FAA procedures.

ASF Comments

The pilot may have been lulled into a state of complacency. Flying a very well equipped airplane in smooth weather over a familiar route could have led him to omit important planning and en route monitoring that would have avoided this accident. The encounter with clouds during climb out by the VFR-only pilot suggests that preflight planning may have been inadequate. Striking terrain in level flight is indicative of a serious loss of situational awareness. This accident is also a reminder that even when a pilot is in contact with ATC, full responsibility for safety of the flight remains with the pilot.

CAPS Deployment 4 [LAX05FA088]

February 06, 2005; Cirrus SR22; Norden, California; Likely cause: Attempted deployment with excessive airspeed.

History of Flight

The private pilot was enroute from Lake Tahoe, Nevada, to Oakland, California, on an IFR flight plan. The pilot received a preflight weather briefing, which advised that there were no pilot weather reports (pirep) for the intended route of flight, and that the freezing level in the Reno area was 6,000 feet with no precipitation. There were no valid SIGMETs or AIRMETs for icing conditions along the pilot’s route. The pilot filed his IFR flight plan for 12,000 feet, but indicated he might request 14,000 feet once airborne. After takeoff, the pilot contacted Oakland Center and requested to climb to 16,000 feet to try to get above the clouds. Upon reaching 16,000, the pilot reported that he was still in the clouds and asked about going lower. Soon after, the pilot advised ARTCC that if he could go up another 200 to 300 feet, he could get above the clouds. ARTCC requested clarification if the pilot wanted to go up or down. The pilot responded that he would like to go up first to build up some airspeed. The pilot was cleared for a block altitude between 16,000 to 17,000 feet. About two minutes later, the pilot transmitted that he was “coming down” and that he was “icing up.” He departed from controlled flight, entered an uncontrolled descent, and hit the ground.

Following the examination of the parachute system, investigators determined the system was deployed outside of the operating envelope of the system, which is 133 knots indicated airspeed maximum. The airplane was also equipped with an Ice Protection System that, when activated, supplied deicing fluid to the wings, tail, and propeller. The aircraft was not certified for flight into known icing and the Pilot Operating Handbook reads that, “Flight into known icing conditions is prohibited.”

ASF Comments

This is a case where the parachute could have made a difference if it had been used in time. Unofficial reports indicated the parachute was deployed at an airspeed well in excess of the airplane’s red line speed. The loads on the chute caused it to fail without any appreciable effect on the airplane’s descent. Pilots of parachute-equipped aircraft must have a clear understanding of when they should elect to descend under the canopy. This is a decision that can be practiced effectively during training.

Training for the glass age

Both aircraft manufacturers and traditional training providers have jumped on the TAA training bandwagon. As mentioned earlier, FBOs and aviation colleges are all rapidly adding TAAs to their fleets. Various commercial providers and equipment manufacturers provide products and services to meet the need for specific training on TAA avionics.

A wide variety of seminars, online training programs, videos, and computer-based simulators are now available for all popular avionics systems used in TAA. Manufacturers of full motion flight simulators, formerly reserved for airline and high-end corporate flight departments, are introducing models specifically for the Cirrus SR20 and SR22 aircraft.

SimTrain, the first such company, provides full motion visual simulators at locations near Atlanta, Georgia, and on both the east and west coasts in Cirrus Training Centers. The training programs include a parachute activation scenario for the Cirrus Airframe Parachute System to emphasize the decision-making process leading to CAPs deployment.

Training requirements and sources

With the introduction of new design TAA, there was concern about pilots' ability to handle aircraft that have both state-of-the-art aerodynamics and avionics. The manufacturers of glass-cockpit TAA responded to these concerns by offering factory-approved training for both pilots and instructors. This solution to the pilot qualification problem has been expensive because of the limited number of CFIs who have acquired or maintained the rigorous qualifications required by some manufacturers' programs. The lack of affordable, widely available part task trainers for avionics is also problematic.

Early in the life of the glass-cockpit TAA, insurance companies expressed the unknown level of risk in the form of higher premiums and additional training and flight experience requirements. As loss experience with these aircraft increases, coverage rates are beginning to decrease and permitted sources of training are becoming more numerous. This results in a reduction in the cost of owning or operating a TAA.

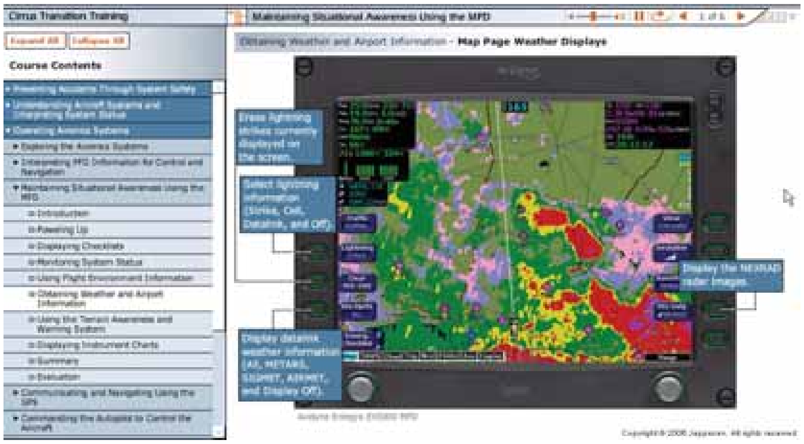
Instrument training in a Cirrus (note the back-up instruments in front of the pilot, under the PFD).

A training sequence

In ASF's opinion, the best way to train pilots, either from the beginning (ab initio) or for transition to TAA, is to start learning the aircraft on the ground. That's nothing new.

1. System training and basic avionics should be done with CD/DVD, part-task trainer, or online. According to our surveys, most pilots do not find print media particularly helpful for advanced avionics systems. Too much interactivity is required to learn effectively by just passively reading. Quick-tip cards with shortcuts, after the pilot has a basic grasp, are appropriate. Much training can and should take place long before the pilot shows up at the training center or before starting with a CFI, especially as a transitioning pilot. Jeppesen has teamed with Diamond and Cirrus to provide an online learning program. Pilots can use the program either prior to flight training or afterwards to reinforce the concepts.

Screen shot of Cirrus Transition Training lesson (bottom). Cirrus full motion flight simulator by Fidelity Flight Simulation, Inc. (far bottom).



Erase lightning strikes currently displayed on the screen.

Select lightning information (Strike, Cell, Datalink, and Off).

Display the NEXRAD radar images.

Display datalink weather information (All, METARS, SIGMET, AIRMET, and Display Off).

Avidyne Entegra EX5000 MFD

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2. The next level might be a part-task trainer that simulates the GPS navigator or PFD/MFD cockpit. Having the actual knob/switch configuration of the most complex part of the instrumentation and proper reaction to all pilot inputs will go a long way to preparing the pilot for flight. Here is an area where both avionics manufacturers and training providers have typically fallen short in offering an inexpensive way to actually practice with the equipment outside of an aircraft. This is gradually changing, as training providers understand what is needed to effectively train pilots in the new environment. Some of the older GPS units came with ground power supplies and simulation software so pilots could practice by actually removing the unit from the aircraft and setting up at home or at the school. With glass cockpits and large moving map displays this is clearly not feasible. Short of having a dedicated ground trainer, the next best alternative is to plug the aircraft into a ground power unit. The disadvantage is that both the aircraft and power must be available.

3. Ideally, the next step is a cockpit simulator or flight-training device. This may or may not have a visual system or motion but it duplicates all other aspects of the aircraft. Simulation has been proven very effective in larger aircraft. With the advent of relatively low cost visual systems and computers, the new systems now typically cost less than half than the aircraft they replicate and can be so effective in preparing pilots that we wonder why anyone would train from the beginning in the aircraft itself. Professional pilots certainly don't.

4. Finally, it's time to go to the airplane. This doesn't preclude experiencing some basic physical airplane handling and local flights before sim training is complete, but the full-fledged cross country VFR and IFR departures and arrivals should wait until the pilot has a solid grasp of the glass or MFD/GPS equipment. *Too much training is currently done in the actual airplane, resulting in great inefficiencies and higher risk situations because of pilot and instructor distractions. These include midair collision risk, airspace blunders, blown ATC clearances, possible loss of control, and extended training time required in the aircraft.* It may be entertaining for the CFI but is far from optimal for the pilot who is attempting to grasp the basics of the avionics. As soon as the pilot has mastered the most basic handling and after having demonstrated proficiency with the avionics on the

ground, we recommend as much actual short, high workload cross-country experience as possible.

Droning around the pattern practicing touch and goes at slow speeds in aircraft with wide-ranging speed operating envelopes does not prepare pilots for the critical transition phases of flight. Few pilots have difficulty leveling off at pattern altitude, throttling back to pattern speed and performing the before-landing check while staying in the pattern. En route, at altitude, the workload and risk is also low. It is the airspeed/altitude transition that causes the problem. Unless the pilot is very light on cross-country experience and dealing with weather, the training time is better spent in the high-workload areas such as the departure/arrival phases where problems invariably arise with altitude, speed, and configuration changes. Heavy use of autopilot and appropriate division of attention is critical.

New pilots who have limited cross-country experience— and by this we'd arbitrarily say several hundred hours on cross-country trips of more than 200 miles—should fly with a mentor in actual weather. This seasoning process should not be rushed as the new pilot develops an appropriate level of respect and knowledge that cross-country flying requires, regardless of onboard hardware and software. It can take the form of the mentor not necessarily being on board, especially in the latter stages. The mentor is there to provide guidance in the planning and decision to go or not go, just prior to departure.

How long should all this take? As always, it will depend on the pilot's experience and the tools available. A new pilot could take five days or longer and for very low time pilots, particularly those who are transitioning to faster TAA, a reasonable mentoring period is suggested that might extend over several months. Pilots should be gradually introduced to the broad range of conditions that the aircraft will ultimately encounter.

An experienced and instrument-competent pilot with considerable high performance time—and a good grasp of the avionics—might transition successfully in two or three days. If they haven't mastered the GPS navigator, expect to easily double the time to IFR proficiency.

One size certainly does not fit all, as convenient as that may be for the training schools, CFIs, or manufacturers. Each pilot will bring different strengths and weaknesses that need to be addressed, and flight instructors should perform an assessment to specifically identify those weaknesses, and tailor the training accordingly. *After training it is essential for all pilots to get out and practice what they've learned. Wait longer than one week to get back into the aircraft or into a simulator and much of the retention is gone without additional instruction. Considerable practice is the only way that pilots will develop and retain a high skill level. This is more critical now than it has ever been with the new complexity and capabilities that these aircraft introduce. This can be done in conjunction with supervised operating experience (mentoring), to work on operational proficiency (for example, dense traffic areas).*

A final point—the traditional method of spending a few hours in ground school on aircraft systems and a cursory review of the avionics before hopping in the aircraft for a few hours of familiarization is now long outdated. Any training institution or CFI that attempts to do in-the-air training on advanced IFR GPS navigators, FMSs, or glass cockpit aircraft before having a thorough introduction

Training in a 182.

and practice on the ground via simulator, ground powered aircraft, or at the very least with computer based instruction, is just not performing in the best interests of the client.

Training a new breed of pilots?

Some market analysts have theorized that a new breed of pilots may be emerging, one that represents a significant change in the pilot population. Many are thought to be successful business people who want aircraft strictly for personal and business transportation and are not necessarily aviation enthusiasts. They view an airplane, like a car or a computer, as a business tool.

These people typically do not hang around airports for long periods to pick up an hour or two of flight time. They are busy professionals who will not be satisfied with a VFR private pilot certificate and want to be unrestricted by weather. Consequently, they need to earn a private pilot certificate with an instrument rating quickly and efficiently.

The traditional training approach needs modification for this customer. These people are focused on results, not the process to get there. This group may also place unwarranted trust in technology to compensate for developing skills and their inexperience. They may also be persistent and decisive in running a successful business. These are not traits that serve new pilots well.

There is little evidence to prove or disprove that new pilots are more focused on transportation flight as opposed to local recreation flight. It is logical, however, to think that pilots who buy aircraft capable of flight at more than 150 knots might be interested in going somewhere. There have always been the “fast burners” who learned to fly in basic aircraft and within a year or two upgraded to high-performance cross-country machines. The traditional sequence is still followed by many pilots: Start in a basic trainer, upgrade to a slightly larger four-place aircraft, and spend several years getting cross-country and instrument experience before making the jump to a high-performance aircraft. This allows seasoning and judgment to take place in addition to formal training, a factor that some think is lacking with the fast burners.

Chelton FlightSystem’s autopilot.

We believe a split still exists, often dictated by personal economics. Those who have a need to travel and the financial wherewithal will buy a high-performance aircraft. And those who previously followed a traditional approach to aircraft upgrading may now become fast burners because of some TAA system simplicity (fixed -gear, full authority digital engine controls, etc.) and attractive pricing.

There may also be a new group of pilots who enter the system through the sport pilot certificate. They will have learned basic flight skills, but there will be a significant transition into a full-fledged TAA and longer trips. Because the sport pilot certificate is so new, it is too soon to tell how this will play out: A pilot tries out flying and as he or she becomes financially able and desirous of more capable aircraft, moves from a very basic physical airplane into a mostly mental one—the TAA. This is a big step but not insurmountable with the right training approach and appropriate mentoring.

Autopilot essentials

For single-pilot IFR operations in TAA, we believe that autopilots are essential. All single-pilot jets require an autopilot and pilots are trained to rely on it right from the beginning.

While TAAs are simpler and slower than jets, the workload is nearly the same. Since pilots operating TAAs are required to function more as programmers and managers, it only makes sense to delegate much of the physical aircraft handling to a reliable piece of hardware. GA pilots need to view the autopilot as their second-in-command, and use it appropriately.

This is not how light-GA pilots have traditionally been trained. The autopilot was considered ancillary rather than essential. The airlines and corporate world left that concept behind decades ago, recognizing that a properly managed autopilot can reduce workload tremendously. First, the use of the autopilot must be considered as core to the operation of TAA and pilots should be trained in its routine usage. The FARs require single-pilot IFR flights under Part 135 to have a fully functional three-axis autopilot.

Departures, en route operations, arrivals, and approaches should be flown such that the pilot is comfortable and completely proficient. Some hand-flying training is necessary in the event of an autopilot failure, but in many cases hand flying is indicative of pilots who do not have the requisite autopilot skills to properly manage high workloads in single-pilot TAA.

Proper programming is critical. Mismanage the machine and the workload is increased well beyond normal. Pilots must learn all the modes and their limitations. Confirm that the aircraft is doing what they asked it to do—trust but verify—and how to react when the autopilot is, inevitably, misprogrammed. Learn from those mistakes to reduce their frequency in critical situations.

Some potential problem areas include fighting the autopilot by holding onto the control yoke or side stick. Runaway trim is one example. The autopilot will methodically trim against the pilot and will either win the fight or disconnect with the aircraft badly out of trim and very difficult to control. Pilots need to diagnose an autopilot problem quickly and know how to disable both electric trim and autopilot quickly.

Some autopilots have a vertical speed mode selection. In our opinion, this capability is a potential trap, especially in piston aircraft. In a few documented cases, vertical speed mode was selected—for example, at 700 fpm—and as the aircraft climbed, the engine performance declined with altitude. As the airspeed declined, the autopilot attempted to maintain the selected rate and caused the aircraft to stall. A better mode selection would be to use airspeed but that usually requires an air-data computer, which increases the cost and complexity of the system.

Malfunctions are rare, far less than with human pilots, and these must be handled appropriately. Malfunctions are best practiced in a simulator where pilots can actually experience the sensations and learn the proper responses. In actual IMC this will include advising ATC that the flight has an abnormal situation. The concept of an abnormal situation may be new to GA pilots, but simple to understand. It is in between normal operations and a full-blown emergency. The situation may not yet require drastic action, but if not handled properly, a real emergency could be imminent. When in an abnormal situation, ask for help. This might be nothing more than insisting upon radar vectors to the final approach course and no changes in routing. It may also be prudent to divert to an area of better weather, lower traffic density, or an easier instrument approach. It is not the time to show just how good you might be. Studies have shown that pilots persistently believe their skills to be higher than they actually are.

The FAA has recognized the realities of autopilot use in TAA and made appropriate modifications to the Instrument Practical Test Standards requiring demonstration of autopilot skills as part of the Instrument Airplane flight test.

Pilot performance and its effect on human factors

TAA accidents examined for this ASF report were largely indistinguishable from accidents with non-TAA equipment. Would a more direct approach to human factors in GA accidents make sense? Some will refer to this as the big brother approach to safety, since it involves using monitoring devices permanently installed in the aircraft to record flight operations.

Accident 4 [SEA06CA187]

September 22, 2006; Cessna 172; Naples, Florida; Likely cause: Student landing accident.

History of Flight

This student pilot, on his second solo flight at Naples, Florida, reported that he had completed a practice landing on Runway 14 and was applying power in preparation for another takeoff when the aircraft encountered a “wind gust” from the right. The pilot applied corrective rudder and aileron, but the airplane veered off the runway and struck a ditch. The weather observation at Naples indicated that the wind was from 140 degrees at eight knots.

ASF Comments

TAAs are entering the training fleet in increasing numbers, with the result that more new pilots are learning to fly using the latest technology. This is an example of an accident that would have occurred regardless of the type of avionics installed. An inexperienced pilot encountered a situation that he couldn’t handle and lost control of the airplane. The difference between aircraft used primarily for transportation and those used for training will have to be considered as TAA safety is analyzed in the future.

The airlines have employed this technology, called Flight Operations Quality Assurance (FOQA) for years. It allows airlines to periodically download data from the aircraft and to look for major anomalies from normal flight operations. This might include unstabilized approaches, improper use of flaps, poor speed and altitude control, etc.

British Airways has employed this approach for more than a decade and claims that it has allowed them to catch pilot performance problems and correct them before accidents or incidents occur. It is too early in the transition to see how this approach might be applied to Part 91 operations or if it is cost-effective.

Accident 5 [NYC06FA072]

February 22, 2006; Columbia 400; Stafford, Virginia; Cause: Descent below minimums during instrument approach.

History of Flight

The private pilot was conducting an IFR flight between Winston-Salem, North Carolina, and Fredericksburg, Virginia. The pilot attempted a night GPS instrument approach, but executed a missed approach. He subsequently requested and flew an ILS approach to the Stafford, Virginia, airport. Radar and transponder returns confirmed the airplane flew the localizer course down to about 200 feet above ground level (agl). Weather about the time of the accident included calm winds, 1.25 statute miles visibility, light drizzle, and an overcast ceiling of 500 feet. The airplane's wreckage was located in a wooded area, about 300 yards left of the runway and three quarters of the way down its 5,000-foot length. Tree cuts were consistent with the airplane having been in a 30-degree left turn. The missed approach procedure was to climb to 600 feet msl (400 feet agl), then make a climbing left turn to 2,000 feet, direct to a VORTAC, and hold. There was no evidence of mechanical malfunction.

ASF Comments

The evidence in this case is consistent with the pilot failing to establish a positive climb while following the missed approach procedure. The Columbia 400 is representative of the new generation of slick, high-powered TAAs. When executing a missed approach, the application of power and subsequent need to trim for a climb could lead the pilot into a difficult situation if priorities are not firmly set. The old maxim of "aviate, navigate, communicate" is as valid for the TAA as it is in traditional aircraft. Training to maintain proficiency in challenging maneuvers such as missed approaches in night instrument weather conditions is also important.

Tracking pilot performance and its effect on training

As we transition into the glass age, it's still essential to study accidents and mishaps to understand how they occurred and what can be done to prevent them. This has ramifications for aircraft design and, perhaps most importantly, for training. If we could reasonably and inexpensively capture what the aircraft and the pilot were doing just prior to impact it would help distinguish between aircraft malfunctions, pilot judgment, and skill issues. That would help to improve training curricula, identify where a piece of equipment did not perform properly, or where poor pilot judgment was the culprit.

Highly sophisticated flight data recorders (FDRs) have been used in large corporate aircraft and airliners for decades to track dozens of parameters regarding flight control input, switch positions, aircraft configuration, attitude, altitude, engine parameters, and speed. The FDR and companion cockpit voice recorders (CVR) have become essential in identifying the probable cause of heavy aircraft accidents. Their use in light aircraft has been impractical due to very high cost, complexity, and weight constraints.

However, the digital data used for PFDs, MFDs, and navigation in new and in newly-built classic TAA is stored and can be downloaded for analysis. In some cases, pilots can access such information to review their own performance and that of their aircraft. The NTSB occasionally uses such data during its accident investigations, although in many cases the equipment is destroyed due to fire, impact, or water intrusion.

Those concerned with privacy or "big brother" will object to this approach to safety, since it involves using monitoring devices permanently installed in the aircraft to record flight operations.

Microprocessors in new aircraft engines and in engine monitoring equipment have the ability to track how the engine is being flown. Engine monitoring has been successfully and inexpensively retrofitted to many airplanes after manufacture. It guides both pilots and manufacturers in running engines more efficiently, is used in troubleshooting, and is widely available for existing aircraft, although not without some expense. Engine management has been greatly simplified and improved with this equipment.

The automotive experience

There is no doubt that human behavior changes when participants know they are being watched and usually it improves. When police use radar, laser, and camera devices to monitor speed on the highways, drivers slow down. To see how FDRs might affect GA, it's instructive to look at how event data recorders (EDRs) have affected the automobile industry. Automotive fleet studies have shown that the installation of EDRs can reduce collisions by 20 to 30 percent. Since 1990, General Motors has equipped more than six million vehicles with the monitoring capability. Events commonly recorded by automotive black boxes include vehicle speed; brake and accelerator pedal application forces; position of the transmission selection lever; seatbelt usage; driver seat position; and airbag deployment data—very similar to FDRs. The data collected belongs to owners except when requested by police or court order. Auto manufacturers also will use it as a company defense in a product liability lawsuit.

Some automakers are reluctant to use EDRs for fear of how the information will be used in court. GM, however, believes that the potential for improvements in auto safety far outweigh any possible increase in litigation and in most cases, driver mishandling has caused the accident, not the vehicle—exactly the same circumstance as with aircraft. Here are some examples:

- Data from a black box caused jurors to question the prosecution's argument that the driver was speeding recklessly before a fatal head-on crash with another vehicle. The driver was found not guilty after his truck's black box showed 60 mph at impact—not above 90 mph, as a witness had claimed.
- A police officer won a major settlement for severe injuries he suffered when a hearse struck his squad car. The hearse driver claimed a medical condition caused him to black out before he hit the police car. But the hearse's black box showed the driver accelerated to 63 mph—about 20 miles more than the posted limit—seconds before he approached the intersection, then slammed his brakes one second before impact. The black-box information was an unbiased witness to the crash.
- After a high-profile crash that killed a former pro football player, the family filed a $30 million civil suit that claimed the vehicle's air bag deployed after the car hit a pothole and that caused him to hit a tree. Data from the black box showed the air bag deployed on impact as designed, and the survivors lost the case.

Training, liability, and flight data recorders

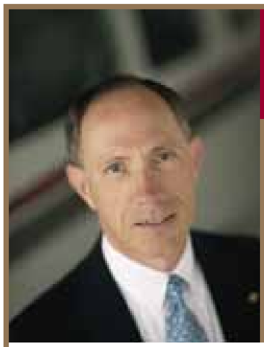
Some large U.S. flight training institutions using TAAs have installed small digital cameras and flight data recorders (FDRs) that allow fast, comprehensive reviews of training sessions on what actually occurred in the cockpit or simulator. The electronics revolution of the last decade—which itself has helped make TAA possible—offers small and relatively inexpensive digital devices ideally suited for this purpose. The fact that these are usually installed at the time of manufacture versus an expensive retrofit have made them an inexpensive benefit in training. There's nothing like seeing video or a flight path of a training scenario to guide instructors and students. Olympic athletes, skiers, golfers, and swimmers all use monitoring to improve performance.

One leading GA aircraft manufacturer has seen its airframe liability insurance premiums triple in the past few years because of consumer legal action claiming defective equipment. It is rumored to be considering some form of FDR in its new production models to reduce its liability from speculative lawsuits and to improve the aircraft. For the builders of very light jets, several companies have mentioned that FDRs and CVRs might be a part of the package.

After many accidents, when lawsuits against manufacturers ask for millions in compensation, it is to everyone's benefit to see that the facts are presented unemotionally and correctly. From the manufacturers' standpoint, claims for maintenance and warranty service can often be more fairly adjudicated with data from the devices. Historically, about 90 percent of the accidents investigated by the NTSB show no design or manufacturing defect.

FDRs can also support the legitimate claims of pilots, and in those cases where an aircraft or piece of equipment is shown to be defective or improperly maintained, the manufacturer or maintenance provider should settle the claim fairly, and then quickly resolve the technical or procedural problem for the rest of the fleet. The advent of new production model TAA equipped with FDRs may improve safety where product liability and tort reform advocates have been unsuccessful.

Appareo GAU 1000 flight recorder.



Safety Pilot

Autopilot supermen

By Bruce Landsberg

Reprinted from the October 2006 issue of AOPA Pilot.

As we move into increasingly sophisticated aircraft with more data, more glass, and more speed, what role should an autopilot (AP) play? You wouldn't think that a great laborsaving device like the autopilot could create such a diversity of opinions.

Autopilots have been around for nearly the entire history of powered flight, starting with a primitive model invented by Elmer Sperry just before World War I. Today, autopilots are essential on turbine aircraft, commonplace on GA cross-country aircraft, and even showing up on trainers. How should pilots use them and how much should we depend upon them?

There are those who live by AP: wheels up, AP on; wheels down, AP off, or, if the ceiling is low, the pilot-engagement point becomes "runway in sight." If the gear is fixed, 500 feet above ground substitutes as the on-off point. Those who routinely fly this way are abdicating their basic flying skills to the hardware.

The other extreme is the pilot who hand flies a four-hour trip even though automation is available. He or she may be highly proficient, but the wear and tear on the pilot is likely to be significant, depending on the physical condition, age, and experience of the marathoner. Such a pilot's flight path may be somewhat erratic, especially if the avionics require much attention, and flight management may occasionally become secondary to aircraft control.

When I started flying, back in the Pleistocene era, autopilots were a rarity in light aircraft. New instrument pilots had to keep all the balls in the air manually, and while it may not have always been graceful, it worked—mostly. We weren't trained in the use of automation and even when it was available, many of us considered it a crutch.

After checking out in bigger, faster aircraft with more sophisticated avionics, I learned that flight management was more than just a term; it was a useful concept for negotiating high-density airspace and dealing with inevitable changes, allowing the aircraft to perform the basic flight tasks, with supervision. The autopilot became an essential crewmember in the single-pilot cockpit.

As a new IFR pilot, I checked out in a Piper Arrow. The avionics packages in those days were mostly basic and standardized, and the instructor provided a cursory briefing on the autopilot. It was a single-axis device that held heading or track, but did not have an altitude-hold function.

On one of my first Arrow trips in the clouds, I was hand flying, minding my own business, and marveling at my ability to survive. New York Center decided that things were going entirely too smoothly, and gave me the obligatory reroute. I copied the clearance, which included intersection names known only to FAA planners, while attempting to hold straight and level, retune the VOR, reset the OBS, and fumble with the transponder. On most tests, getting four out of five elements isn't bad and 80 percent is considered a passing grade most everywhere. This overlooks my F grade for altitude control. At some point during the breakdance the controller politely reminded me to check the altimeter setting, probably knowing full well what was going on. The autopilot, even without altitude hold, would have been a fabulous asset if I had used it, and the whole deal would have been accomplished far more elegantly.

We are required on the instrument practical test to handle the aircraft, reroute, reprogram, and stay within checkride tolerances. In the real world, while dealing with turbulence, fatigue, passenger distractions, and myriad other items, the reality is that those tolerances are sometimes stretched into "pink-slip" territory. It shouldn't happen, but then IFR life isn't exactly as portrayed in training. Ask me sometime why that's nearly impossible to do effectively. Also understand that I'm not advocating loosening the standards.

When Cessna introduced the Citation line of jets, the autopilot was integral to the FAA's single-pilot approval. Pilots were taught that the autopilot flew the aircraft and it was to be used in all normal circumstances. If the autopilot broke before takeoff, the flight was canceled and if it failed en route that was an abnormal procedure. The pilot was expected to be able to handle the aircraft, but it was appropriate and expected to ask for ATC assistance, if needed, and divert to the nearest suitable airport. The extra time and mental processing power was used to manage the avionics and stay at least 10 miles ahead of the aircraft. Required autopilot use was a major attitude shift for the light-aircraft crowd, most of who used autopilots periodically and didn't really trust them. With the arrival of very light jets, you can be certain that the autopilot will be a required piece of equipment and that pilots will be expected to use it religiously.

Let me clarify something for the "what-if-it-fails" crowd. In searching the AOPA Air Safety Foundation's accident database back to 1983, we were unable to find a single accident where NTSB considered autopilot failure as the probable cause. That doesn't mean that it can't happen or that you should give up practicing hand-flying skills. But a shift in attitude is appropriate as we transition to complex avionics packages that deliver a far better flight-path product and situational awareness, but need much more programming and demand more attention than the old ones.

Today's autopilots are much more reliable than the humans programming them. I concede that a few units built on Friday afternoons before a holiday may be less trustworthy than a politician at a PAC reception. But as a group, humans are far more likely than our electromechanical helpers to deviate from a heading, miss an altitude, blow through a final approach course, or wobble down the localizer.

So how do you balance being a good enough hands-on pilot in command with intelligent use of the autopilot?

As the equipment has changed, so too should the testing and training for light aircraft, mirroring the single-pilot jet that our cockpits are now emulating. How about treating autopilot failure in actual instrument conditions in the same way as an engine malfunction on a multiengine aircraft? When an engine acts up or fails, the mode of operation changes. We set priorities very carefully, advise ATC that we have a problem that may develop into an emergency, or declare the emergency outright. A diversion should be made to the nearest suitable airport, not necessarily the nearest airport, which may have a complex and difficult approach. Vectors-to-final is a smart way to handle this.

I have played and inflicted "what-if" games on students, including scenarios when a controller's radar is down, or a position 300 miles from nowhere, and a bogeyman that jumps out if you don't keep it all going perfectly. The traditional approach to training for an autopilot failure is often to continue the trip as if nothing had happened. Just suck it up, son, and, by the way, I've got a reroute for you with a hold and a course reversal on a back-course approach with a dogleg at the final approach fix. It's a par four, and mind the sand trap. The proper answer in the real world is, "Unable—we've got an equipment failure and I'll need vectors to the ILS at downtown municipal." If you're sinking, ask ATC for the localizer frequency, inbound course, and altitudes in sequence so the workload remains manageable.

If you can reasonably handle a bit more, that's good, but in the real world, the idea is to manage risk and work load. In the minds of some instructors, pilots should just meekly accept all the stuff that is shoveled into the cockpit by the CFI or ATC, instead of acting as pilot in command. Here's what's bad about this 400-pound bench-press approach to training: In an actual situation, pilots tend to react as they have been trained. If the autopilot dies, they may revert to the Superman mode they learned in training, even though most of us aren't Superman or Wonder Woman six months after training. In really nasty weather after a series of long workdays and perhaps not flying quite as much as we would have liked, it's not going to be the same as the environment created by the tough-as-nails coach omnipotently sitting in the right seat. To continue the sports metaphor, this isn't the time for the Hail-Mary pass—just get first downs until you get to the runway. If you can only bench-press 100 pounds, train to where you might get to 120.

So how do you balance being a good enough hands-on pilot in command with intelligent use of an autopilot? I like to hand fly departures until about 5,000 feet, let the machinery do the mindless en route part, and, on at least every other trip, hand fly the approach. This keeps me conditioned, but I also go for weightlifting sessions and coaching every six months.

Some flight schools are now buying full-glass-cockpit aircraft without autopilots to save money and perhaps to train pseudo supermen and women. It's a false economy and premise. Either go with the full package and learn how to use automation intelligently or stick to steam gauges and basic avionics. Let's train for the real world!

TAA hardware and software

Modern integrated avionics systems use large liquid crystal display (LCD) screens to display data to the pilot. The primary flight display (PFD), as its name implies, provides the most important information the pilot needs to operate the aircraft. In streamlined format, the PFD shows:

- Attitude
- Airspeed
- Altitude
- Primary navigation data
- Supporting data

Multifunction displays (MFD) come in a variety of forms and accept input from aircraft and datalink sources. MFD data can include:

- Engine and systems status
- Moving maps with airports, navigation aids, and waypoints
- Approach, taxi, and navigations charts
- Terrain and obstructions
- Traffic avoidance
- Datalinked weather including NEXRAD precipitation, TAFs, and METARs
- Airspace

Integrated avionics

Avidyne, Garmin, and Chelton are currently the leading suppliers of GA integrated avionics systems. In some cases they provide equipment and components for retrofit into legacy aircraft. While each manufacturer takes its own approach, the pilot interface is similar.

Integration means that most information about the airplane and its environment can be controlled and displayed through a single system. The two main displays can be configured to meet the pilot's needs and preferences. Useful information is brought up as it is needed while less important material remains hidden—but available.

Datalinked weather is displayed on a Garmin GMX200.

Common hardware components in integrated systems allow the displays to be switched back and forth in the event of equipment failures. Such reversionary capabilities greatly reduce the risk resulting from critical instrument failures. It also puts an increased burden on the manufacturers to ensure that single point or cascading failures do not catastrophically degrade safety. Utility can be adversely impacted where a component in an integrated system results in a unable-to-fly condition whereas a noncritical instrument or system failure in a legacy aircraft is a minor inconvenience but not flight-canceling.

Primary flight display

In general, the PFD replaces all six of the traditional flight instruments, plus some. The "directional gyro" mimics the more sophisticated HSI (horizontal situation indicator) combined with a radio magnetic indicator (RMI). Recent advances also provide a capability rarely available to light GA pilots—the flight director. The flight director provides computed attitude commands that allow the pilot to hand fly the aircraft with the same precision as the autopilot, provided that the pilot reacts in a timely fashion to the flight director's directions.

Weather displays

Until TAA, anything approaching real-time display of convective weather in the cockpit was limited to aircraft with onboard radar. Radar is the gold standard for tactical avoidance of thunderstorms but is expensive, somewhat fragile, and heavy. Smaller GA aircraft usually made do with lightning detection devices such as a Stormscope or Strikefinder to mark the location of suspected turbulence, but they provided a display that required considerable interpretation. It should be noted that one doesn't need glass to get datalinked weather, as it is available through the use of some excellent portable devices than can be used aboard any aircraft.

In TAA, however, suppliers of datalinked weather are making major inroads and such displays may greatly improve utility for light GA. Weather graphics datalink can simplify in-flight decision making. Depending on aircraft and pilot capability, the decision can be made to divert, delay, continue, or land ASAP. Likewise, the availability of the latest TAFs, METARs, winds aloft, and other products allow both VFR and IFR pilots to monitor weather ahead and around them. There will be very few excuses for being surprised, however, pilots are still capable of getting themselves into trouble, either by failing to understand the limitations of the product, or not knowing how to correctly interpret the information provided.

Terrain awareness

Integral to most new GPS navigator units these days is terrain and obstruction awareness, usually displayed on an MFD in a format using different colors to indicate different elevations. Symbols show obstructions such as towers and buildings and their relative height. In some cases, the terrain shown near the aircraft will change color, based on the GPS-derived separation between the aircraft and the ground.

TAWS (terrain awareness warning system)

While GPS mapping modules with integrated vertical dimensions (elevation data) displayed via different colors are becoming an expected part of new TAA displays, an extra feature designed to prevent perfectly good airplanes from smacking the ground while under control is becoming popular. Terrain awareness warning system (TAWS) became mandatory on March 29, 2005, for all turboprop or jet aircraft with six or more passenger seats, including those operated under FAR Part 91. TAWS has emerged as a common component in the TAA cockpit as well.

TAWS evolved from radar altimeters, devices that emitted a warning when terrain directly below the aircraft became closer than a preset value. The original device, called a ground proximity warning system, or GPWS, used ground return radar to measure the altitude from the airplane to points directly below. The devices worked fairly well, and the rate of controlled flight into terrain (CFIT) accidents in the late 1960s and early 1970s was significantly reduced. But the radar altimeter GPWS units had a major shortcoming: altitude measurements and thus the warnings of potential CFIT were unable to prevent fast-moving aircraft from striking rapidly rising terrain if the aircraft had a high rate of descent. The integration of GPS navigation and terrain database technology allowed the design of equipment that computed aircraft position, groundspeed, altitude, and flight path to calculate a dangerous closure rate or collision threat with terrain or obstacles, and provided a predictive warning. This is the technology behind TAWS.

The five functions provided by TAWS units most commonly installed in high-end general aviation TAA includes the appropriate audio alert for:

- **Reduced required terrain clearance or imminent terrain impact.** This is the forward-looking terrain-alert function. This warning is generated when an aircraft is above the altitude of upcoming terrain along the projected flight path, but the projected terrain clearance is less than the required terrain clearance. The warnings depend on the phase of flight, and whether the aircraft is in level or descending flight. There are sixty-second and thirty-second warnings. Sixty-second aural warning: “Caution, terrain; caution, terrain” (or “Terrain ahead; terrain ahead”) and “Caution, obstacle; caution, obstacle.” Thirty-second aural warning: “Whoop, whoop. Terrain, terrain; pull up, pull up!” or “Whoop, whoop. Terrain ahead, pull up; terrain ahead, pull up.” The “whoop, whoop” sweep tones are optional.

- **Premature descent alert.** This alerts the pilot if there’s a descent well below the normal approach glidepath on the final approach segment of an instrument approach procedure. Aural warning: “Too low, terrain!”

- **Excessive descent rate.** This is a carryover from GPWS, and alerts you if the rate of descent is dangerously high compared to the aircraft’s height above terrain—and, for example, if flying level over rising terrain. Caution alert: “Sink rate!” Warning alert: “Whoop, whoop! Pull up!”

Terrain is displayed on a Garmin GMX200.

- **Negative climb rate or altitude loss after takeoff.** Another GPWS function, this is to assure a positive climb rate after takeoff or a missed approach. Caution alert: “Don’t sink!” or “Too low, terrain!”

- **The 500-foot “wake-up call.”** This occurs whenever terrain rises to within 500 feet of the aircraft, or when the aircraft descends within 500 feet of the nearest runway threshold elevation during an approach to landing. It’s intended as an aid to situational awareness, and doesn’t constitute a caution or warning. Call-out: “Five hundred.”

Airspace displays

Most current generation GPS navigators include airspace information in their databases. The pilot can superimpose graphic depictions of complex airspace such as Class B on the MFD maps and access relevant altitude and communications information. Using datalink sources, temporary flight restrictions (TFR) can also be displayed.

Traffic avoidance

Today, many TAAs have the ability to display symbols representing other transponder-equipped aircraft on their MFD. This information allows the pilot to have another set of eyes to spot and avoid traffic. While this system is useful, there are future developments that will enhance its function.

AOPA has assisted the FAA in the testing and selection of a system that promises not only weather datalink but also collision avoidance, even in nonradar areas. As it is implemented across the country in the coming years, it will represent a dramatic departure from the traditional full-time separation provided by ground-based air traffic controllers. It may also help push TAA more quickly into the realm of “free flight,” a new model for air traffic control now under FAA consideration as one possible answer to over-saturation in the existing radar-based ATC system.

Traffic is displayed on a Garmin GMX200.

A three-year program called Capstone was designed to evaluate various avionics systems that could become an important part of air traffic control within the National Airspace System. Most of the testing was conducted in a remote corner of Alaska, with GA aircraft serving as the test vehicles. Why test in a remote corner of Alaska, rather than a high-density area in the Lower 48? The answer is that when Free Flight is fully implemented all participating aircraft are expected to be fully equipped with appropriate avionics. Therefore, any evaluation of Free Flight concepts becomes more realistic as the percentage of equipped aircraft flying in the test airspace increases.

In Bethel, Alaska, the FAA was aiming for nearly 100 percent participation. Excluding the high-altitude airline traffic and a few daily commuter flights, it’s estimated that there are fewer than 200 aircraft operating within 100 miles of Bethel. Mainly, these are single-engine air-taxi “workhorses” such as Beavers, Caravans, and a host of smaller machines, down to Cessna 180s, plus a handful of helicopters. These were the Capstone participants. The FAA equipped 195 of these aircraft for the project, outfitting each with a GPS receiver, a color multifunction display, and an automatic dependent surveillance-broadcast (ADS-B) transmitter/receiver.

The ADS-B equipment allows aircraft to broadcast their positions to each other—and to air traffic controllers on the ground—via special transceivers and ground stations. By the same token, air traffic painted on ground radar can be datalinked to aircraft displays. So can Doppler and other weather radar imagery, as well as text messages such as ATC clearances and weather reports. Even e-mail messaging is possible.

In the ideal world of the future, pilots and controllers would see the same targets and the same information on a single display. Pilots could see potentially conflicting targets as far away as 100 nautical miles, and alter their courses and altitudes to avoid midair collisions. For more immediate traffic threats in heavily traveled airspace, ADS-B could work equally well, although ATC would issue traffic advisories, or TCAS-equipped airplanes could follow any traffic or resolution advisories issued by their own on-board equipment.

Under the Free Flight proposal, aircraft would be free to fly more direct routes using GPS; pilots could see virtually all of the traffic around them, and do more to safely separate themselves; and ATC could be freed of much of their en route controlling workload, letting controllers focus more on the efficient management of the entire airspace system, and to concentrate their energies on sequencing and separation in terminal areas.

Engine/systems monitoring

Another area where the MFD excels is in helping pilots to manage their engines. Some of the new installations have FADEC (full authority digital engine control), which allows the pilot to move only one power lever, much like a turbine. There is no need to adjust propeller or fuel mixture—it is all done automatically correcting for ambient temperature and altitude. Gone are the concerns of detonation, temperature control, and fuel flow.

If a parameter moves into the “yellow” for whatever reason, unlike gauges of old where the pilot must constantly monitor a needle for a 1/8-inch movement, the MFD automatically advises the pilot that something is out of tolerance before it becomes critical. The equipment also monitors the engine’s overall performance and is routinely downloaded during maintenance to allow technicians a quick look at the engine’s history. This holds great promise to increase reliability. Even routine engine parameters, such as cylinder head temperatures, EGTs, carburetor temperatures, and duty cycles are now monitored as an accepted part of TAA instrumentation. TAA instrumentation often provides more data than most pilots know what to do with so there is another need for training.

Technology abused?

All tools have the potential to be misused and new tools have the greatest risk because users have to learn the limitations of those tools and the pitfalls that can occur if those limitations are ignored. Much of the new technology aboard TAA falls into this category. A few, including some regulators, have suggested that because something can be misused, it should be severely restricted or not developed at all. That logic would have forestalled the development of aviation itself and the installation of airborne weather radar or deicing systems. Current statistics do not indicate any widespread systematic trends toward the misuse of the advances of TAA. There have been, and will always be, some individual failures.

Engine monitoring display on an Avidyne Entegra system.

Some concerns

- **Weather datalink—**There is some potential danger for TAA pilots who mistakenly believe their datalinked radar images constitute true real-time weather, such as the case with an onboard radar. The time lag between capture of the radar image and the datalink display may be anywhere from five minutes to 20 minutes. In a very active thunderstorm situation, a pilot attempting to navigate around cells using old data could be in serious jeopardy. This has already happened on several occasions. Similar dangers exist with radar-equipped aircraft when a pilot gets too close to a cell. This has happened infrequently in both airline and corporate flight. No one would suggest that on-board radar be removed because it is occasionally misused. Rather, we identify the incident or accident as an anomaly, publicize it for educational purposes, and move forward.

- **Terrain—**As with weather graphics, there is potential to misuse the terrain databases for scud running or an attempt to operate VFR in areas of IMC. A Cirrus POH Supplement warning states: “Do not use the Terrain Awareness Display for navigation of the aircraft. The TAWS is intended to serve as a situational awareness tool only and may not provide the accuracy fidelity on which to solely base terrain or obstacle avoidance maneuvering decisions.” There was one accident in the Capstone project in Alaska where this happened. On balance, however, the value of knowing that obstacles lie ahead dramatically lowered the number of Alaska accidents.

VFR into instrument conditions is a leading cause for weather accidents in all aircraft, TAA or legacy. A classic accident occurred in 2005 when a Cirrus SR22 piloted by a 1,100-hour flight instructor and the plane's owner struck a mountain while scud running up the Columbia River gorge at night. Friends noted that the pilot had done this sort of thing a number of times before in the Cirrus. Even with the latest avionics, including terrain awareness systems on a large MFD, this activity is as deadly as it has always been.

- **Traffic avoidance—**As mentioned earlier, pilots generally can acquire targets visually faster with onboard avoidance systems. Airline and corporate systems have worked very well to date. To be sure, there are two pilots and they tend to operate in highly controlled environments. In the more open areas and smaller nontowered airports there will be more transponder-less traffic so pilots will have to continue to scan outside.

As the Cirrus POH supplement points out, "SkyWatch can only detect aircraft that are equipped with operating transponders. Traffic information…is provided as an aid in visually acquiring traffic. Pilots must maneuver the aircraft based only upon ATC guidance or positive visual acquisition of conflicting traffic."

- **Engine/systems monitoring—**The only negative that we can see is if the system fails. Cessna's experience with fuel monitoring has been so positive that even an occasional malfunction will not override the benefits derived from spotting problems sooner.

- **Parachutes—**A minor downside to aircraft parachutes is that pilots may come to rely on them when better decision making would have prevented them from getting into a bad situation in the first place. Several fatal accidents have occurred when pilots may have rationalized that the chute would save them if problems got out of hand and then failed to deploy when needed with fatal results. The technical solution is to have an "auto-deploy" system when the aircraft senses itself in grave danger. That level of machine intelligence is probably still a number of years off.

Piper Saratoga II TC

There is another downside to use of the parachute. If deployed over an area with surface high winds, it is possible that the parachute can drag the aircraft along the ground after touchdown. This happened after a fatal accident near Maybell, Colorado, in 2006. Evidence at the scene suggested ground impact caused deployment of the parachute recovery system, resulting in fragmentation of the airplane over a 1.5-mile area as it was dragged by high surface winds.

In the final analysis, the benefits of whole airplane parachutes—as described earlier in this report—far outweigh the downsides.

- **Integrated Systems—**Modern integrated avionics systems offer a high level of flexibility and allow the pilot to set up preferences that suit personal operating style. In a rental environment, this could lead to pilots not knowing just what data is going to be displayed without a comprehensive inspection of the many setup pages on the MFD. Work by the avionics manufacturers to allow portable preferences or to allow EASY access to a default page to reset to a basic simple configuration would overcome this issue.

Avionics maintenance and ownership

The owners and operators of TAAs are finding that modern avionics change several maintenance aspects of these aircraft. First, not every avionics shop is trained or equipped to work on such systems, and even if they are they often troubleshoot down to the line replaceable unit (LRU) level only, exchanging the malfunctioning unit for a functioning one. LRUs often can only be opened and repaired by the manufacturer. It should be noted that FAR 91.187 requires the pilot on an IFR flight plan to report loss of any navigation, approach, or communication equipment as soon as practical to ATC. It's also a good idea to have the avionics technician fill out a Service Difficulty Report, or SDR, on any significant problem.

Software updates are another maintenance consideration. Pilot using GPS navigators are likely familiar with the need to update the navigation database on a regular basis. Like other computers, however, TAAs' sophisticated computers and software are updated regularly to add new features and correct errors. Occasionally, these updates also require hardware updates. Almost all new technology goes through growing pains and it is no different with TAA. Several MFDs have had multiple software updates and reconfigurations to address slow update rates, mislabeling, or outright failures. As with all computer equipment, upgrades and updates are prone to potential failures and it is critical for manufacturers to advise pilots of problems and address them immediately.

Accident 6 [IAD05FA032]

January 15, 2005; Cirrus SR22; Coconut Creek, FL; Likely cause: Loss of control because of avionics failure.

History of Flight

The commercial pilot departed from Fort Lauderdale, Florida, on a flight to Naples, Florida, to gain experience in IMC. Shortly thereafter, he misinterpreted a series of air traffic control instructions to be for his airplane when they were for another airplane. Callouts and responses by the pilot indicated confusion, to the point where he stated, "I gotta get my act together here." Less than one minute later, the pilot reported "avionics problems," and about 40 seconds after that, during his last transmission, he stated that he was "losin' it." The airplane subsequently descended nose-down, out of the clouds, and impacted a house and terrain. The airplane was equipped with a primary flight display (PFD), as well as separate backup instruments in case the display failed. The airplane had approximately 98 hours of operation since being manufactured, and had a history of reported PFD problems. The pilot had previously practiced partial panel (no PFD) flight. The airplane was also equipped with a parachute system, which was not deployed, nor was the autopilot engaged, despite over two minutes of significant altitude and heading deviations.

ASF Comments

This accident suggests that the pilot was struggling with a flight instrument problem and became increasingly disoriented and confused. Failure of a TAA glass cockpit display should not be a fatal problem. These aircraft are equipped with traditional round dial flight instruments that are available as backups. As has been the case for decades, there is an alternate static source that can be selected in the event of water or other obstructions in the system. As a last resort, the Cirrus offers the pilot the use of the CAPS parachute system in the event of pilot incapacitation or impending loss of control. Thorough initial and recurrent training programs address complex emergency situations. In particular, flight simulators tailored to TAA allow the pilot to practice dealing with such emergencies effectively.

Report conclusions

While TAA are moving GA forward, they still share many characteristics with older aircraft, at least at this point in the transition. The penalties for poor judgment, misinterpretation, misprogramming, or clumsy flight-control handling remain the same as they always have. Learning to fly TAA will change the flight-training world, and it should pay noticeable dividends to all segments of the industry.

While current accident figures are generally comparable to classic single-engine aircraft, there are some causal factors such as weather where TAA pilot decision making may create a higher risk factor than traditional aircraft. This is troubling in aircraft that provide unprecedented access to weather information in the cockpit. In multiple cases, parachute-equipped aircraft have certainly saved lives, but in other cases, although available, pilots did not use them at all, or in time. While the track record of that technology is still being written, there is evidence to show that even though a pilot may have made a bad in-flight decision, the negative outcome was measured in insurance dollars rather than lives.

In the end, these discussions are not so much about airplanes but about the people who operate them. Although the on-board technology and performance of TAA are rapidly evolving, and despite the fact that the pilot-training industry is making a strong attempt to better integrate pilots with their aircraft, pilots, for the most part, have not changed. A VFR-rated TAA pilot who departs into an area of deteriorating weather may well have attempted the same trip had he been flying a classic aircraft, or he may have been enticed by the machine's capabilities. Poor judgment will always be poor judgment. Did the new TAA cause the ensuing accident? Certainly not! As long as pilots are human they will continue to make mistakes.

It's also about the environment in which they operate. Automobiles are not affected much by low ceilings or visibilities, strong winds, or thunderstorms. They are largely weather-tolerant machines. Light aircraft are affected to a much greater degree by all of these phenomena and while changing the avionics may help somewhat by giving the pilot more information, it does not change the fundamental environment. A small TAA or a small legacy aircraft all share the same weaknesses. Until we address those shortcomings, the advances will be smaller than some marketers would have us believe.

New generations of autopilots might allow for full auto-land capabilities in small GA aircraft. This may allow a low-time IFR—or in an emergency, a VFR pilot—the opportunity to fly an approach to minimums. On-board systems may eventually function as the equivalent of a senior instructor, able to offer advice based upon the inputs of all aircraft system sensors combined with up-linked information from the ground to form a forward-looking picture of what the aircraft is about to encounter.

TAA offer increased safety with added situational awareness. But for pilots to avail themselves of these improvements, the key ingredient will remain a balance between training tied to experience and ever-improving, smarter technology and retention of basic piloting skills.

> *"Get rid at the outset of the idea that the airplane is only an air-going sort of automobile. It isn't. It may sound like one and smell like one and it may have been interior-decorated to look like one; but the difference is—it goes on wings."*
>
> —Wolfgang Langewiesche
> From *Stick and Rudder,* originally published in 1944

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