



Technically Advanced Aircraft Safety and Training

An AOPA Air Safety Foundation Special Report



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Technically Advanced Aircraft
Safety and Training

Technically Advanced Aircraft (TAA) are entering the general aviation (GA) fleet in large numbers. The categories are newly designed aircraft, newly manufactured classic design aircraft equipped with new avionics, and retrofitted existing aircraft of varying ages.

Early reviews of accidents show nothing unique to TAA relative to other categories of aircraft.

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

Deliveries of new equipment have overtaken the training infrastructure in some cases. CFIs and pilots are adapting with the manufacturers and training organizations, ramping up in experience and in capability. More and better simulation will ease the transition. Training nontraditional avionics in the traditional inflight way is not optimal. Use of CD/DVD and online simulation is a big step forward, as is the development of relatively inexpensive simulators for new TAA.



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This report contains a preliminary review of Technically Advanced Aircraft (TAA) accidents. Since TAA are just starting to enter the marketplace in significant numbers, there have been relatively few accidents involving them, making any comparison of accidents rates between TAA and conventional aircraft statistically suspect. Therefore, any conclusions in this report regarding relative safety must be considered as preliminary. The AOPA Air Safety Foundation (ASF) will continue to monitor the TAA safety record and report as new findings come to light.

Questions this report will answer
This AOPA ASF Special Review of TAA will answer three questions:

- 1. What is a TAA?
- 2. What adaptations will be required for the general aviation (GA) training structure as TAA enter the fleet in significant numbers?
- 3. Do the earliest returns on GA accidents involving TAA show any trend that can be used to direct strategies for reducing GA accident rates in the future?

Technically Advanced Aircraft (TAA) defined *Technically advanced* aircraft are equipped with new-generation avionics that take full advantage of computing power and modern navigational aids to improve pilot positional awareness, system redundancy, and depending upon equipment, improve in-cockpit information about traf-

fic, weather, and terrain. By FAA pronouncement, a TAA is equipped with at least:
a) a moving-map display
b) an IFR-approved GPS navigator
c) an autopilot.

Many new aircraft go far beyond the basic definition, sporting enough electronic displays to qualify as having a “glass cockpit.” Exactly how much glass is needed to deserve that label is still being debated, but 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, weather, traffic, on-board weather radar, engine instrumentation, checklists, and more. (See Section V, page 28.)

In terms of new U.S. production, TAA have clearly arrived. In 2004, 1,758 light GA piston aircraft rolled off the assembly lines of General Aviation Manufacturers Association (GAMA) member companies, a 10.6 percent increase over 2003. Ninety-two percent were either true TAA or sporting TAA-like equipment. The remaining 8 percent were generally tailwheel aircraft, and field reports indicate that even those buyers are often opting to include elements of TAA as the avionics evolution moves forward. There is no current reliable estimate on how many existing aircraft have been retrofitted to become TAA, but it will be in the thousands.

Fleet sales to active flight schools and university flight departments in the last two years have generally been TAA, even for basic trainers. Several aviation universities have adopted TAA to prepare pilots for the next generation of flight, be it GA, corporate, or air carrier.



Fig. 1: Primary Flight Display (PFD).



New TAA
Adam Aircraft
A-500.

New, classic, and retro

Some TAA are completely new designs such as the Lancair, Cirrus, Diamond, or Adam 500, while others are updated versions of newly produced classic machines such as the Cessna 182, 206, Piper Saratoga, Beechcraft Bonanza, and Mooney. Retrofitted—or Retro—aircraft are older aircraft with reworked instrument panels.

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 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.

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.



Classic TAA
Instrument panel in
a Mooney Ovation 2GX.



New TAA
Instrument panel in
a Diamond DA-40.



Retro TAA
Instrument panel in
a Piper Twin Comanche.

New bizjet glass cockpits in a Citation (right) and Beechjet (far right).



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, and Lockheed aircraft.

Initial versions of computerized cockpits, in the 1980s and early 1990s, 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.

The new systems 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. 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.

Today, although the bulk of the existing 180,000-plus light GA airplanes still use steam gauges, virtually every newly designed transportation airplane is a TAA, including Lancair, Cirrus, Diamond, and the Adam 500. And very few buyers of new production classic machines such as the Cessna 182, 206, Piper PA-28/32 series, Bonanza, and Mooney even consider steam gauges, but go directly for glass. Many owners are retrofitting their classic aircraft to TAA with IFR-certified GPS navigators and multifunction displays.

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



Traditional "steam gauges" or "six-pack" on an instrument panel (below).





Full-glass cockpit (left).

What's next?

Moving into the twenty-first century, airliners and business jets are on the brink of even more sophisticated cockpit technologies, and GA aircraft are likely not far behind. The new Boeing 787, Airbus A380, and the Dassault Falcon 7X 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 will likely migrate to keyboards with hard and soft key functions in the next few years, replacing multifunction controls that must first be configured before data can be entered. Keyboard and trackball data entry, not currently available on new light GA TAA, is due largely to the space and cost constraints of smaller aircraft.

In the last decade, IFR-approved GPS navigators have been added to panels already crowded with conventional avionics even for newly built aircraft. 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, two companies currently survive but others are rumored to be readying new designs. The surviving companies that are committed to the development of TAA equipment are generally well capitalized, which will allow more investment in the human factor interface.



On new/classic TAA there is plenty of space for new pilot interfaces (left).

TAA are creating both a new world of opportunity and challenge 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.

The good news

Moving maps with pinpoint GPS navigational accuracy provide pilots with significantly increased positional awareness. Overlays that can include data-linked weather information, terrain databases and traffic avoidance equipment 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 that 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 benefits will depend on training and ultimately, on a continuing evolution in equipment design. Having watched GPS navigators evolve over the last 15 years, the present generation is far superior to early models and we have every reason to believe that it is only going to get better.

The challenge

The AOPA Air Safety Foundation identified two areas of TAA that are likely to have the most impact on the GA safety record. The first is the different

A multifunction display showing two of many available functions—terrain/routing (top) and traffic (bottom).



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.

Increased speed and unique handling characteristics of some TAA are likely, without proper training, to lead 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 a tail strike, a nose wheel landing or an inadvertent stall. (See illustration at right.)

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 TAA 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 on landing.

One current difficulty is finding instructors who are knowledgeable and experienced on the new aircraft, but that will improve as more TAA enter the fleet. 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, pun intended, 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 farther 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 additional learning curve of new avionics adds to the initial workload.

The advantages of TAA are many, but realizing those benefits will require pilots to shift from a typical GA piloting approach. 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 possibly some unsafe situations.

The physical airplane

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.

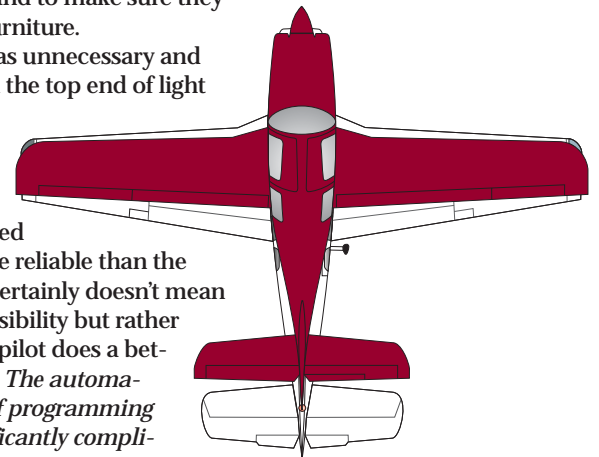
- Maintaining V_Y precisely during a climb.
- Holding altitude within 50 feet.

- Tracking a VOR needle within one dot on either side.
- Landing in a full stall, with 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, which 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 and watch and to make sure they didn't get their feet on 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 largely changed 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 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.



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

The mental airplane

The early corporate and airline operators who installed the new equipment 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 glass cockpit 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

The more things change...

Conventional wisdom still applies: Extensive cross-country flying on a schedule really should be done by instrument-rated pilots or by those who have plenty of time to wait on the vagaries of weather. The idea that the new technology is so simple and will protect the uninformed or overbold is oversimplifying the current realities of cross-country flight. It may become easier in the future but the AOPA Air Safety Foundation will take the conservative view until hard statistics show otherwise.

See and avoid: TAA equipment increases pilot performance
 In a September 2004 paper presented to the Human Factors and Ergonomics Society annual meeting, “The Effect of an Advanced Navigation Display with Traffic Information on Single-Pilot Visual Flight Operations,” by Kevin W. Williams of the FAA, the FAA found pilots could spot traffic faster with traffic displays. Sixteen pilots were tested in a flight simulator under VFR conditions. Results were mixed, but generally showed that even though pilots looked outside less when using traffic displays, they were more successful at locating traffic but with some cautions. Some GA traffic will not be transponder-equipped for detection by TAA anti-collision equipment so pilots must maintain an outside scan, particularly in high density traffic.

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 Collision Avoidance Systems [TCAS], and spending much of the flight in positive control airspace (Class A). Most operators have an inside/outside policy where one pilot is clearing visually while the other deals with the internal systems. For the single pilot, the attention must be appropriately split.

There have been numerous Aviation Safety Reporting System (ASRS) reports on crew confusion stemming from use of TAA or equipment that is typically installed in TAA. (See appendix C.) Reports included missing assigned routes, mis-programming approaches, mode confusion, 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 the case of corporate and airline operations, the landmark TAA-related accident that graphically defined the potential dangers occurred in Cali, Columbia, in 1995 when an American Airlines Boeing 757 collided with 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 for GA pilots to write a safer history for TAA. (See “High Terrain Tangle” and “Back to Cali,” Appendix B.)

The GA Future
 The corporate and airline experience with TAA-induced confusion and workload issues is present in GA TAA also, but the degree to which those issues are or will be a factor is not yet clear. Don Taylor, vice president of training and safety for Eclipse Aviation, manufactur-

Trust, but verify
 Understandably, the American system of free enterprise does nothing to discourage perceptions of equipment as able replacements for pilot experience or diligence. ASF found one such example by pairing a product review for a GPS unit with an ASRS report that belies the boosterism:

From *Flight Training* magazine, July 1995: “The presentation of special-use airspace boundaries is one of the unit’s handiest features. The depicted boundaries are quite accurate, and just as long as the map’s airplane symbol doesn’t touch a boundary line, you should be safely outside the depicted airspace.”

An ASRS report filed by a Mooney pilot facing legal action as a result of entering restricted airspace over Virginia in February 2002: “At no time did my GPS indicate I was inside restricted airspace (but later was) contacted by FAA and informed of a potential violation of restricted airspace.”

er of the new Eclipse 500, cautions, “It is too early to say that glass cockpits increase workload for the single pilot by an inordinate amount.” Eclipse officials believe that extensive use of integration simplifies the operation of the aircraft’s systems and reduces the chance of overload and error. Taylor concedes, however, that pilots must be well trained to use technically advanced aircraft. That comment, however, applies to any high performance aircraft flown in the IFR system. The Eclipse VLJ purports to have an even higher level of automation than most TAA today. This may simplify the pilot’s task.

There are not enough ASRS reports from GA pilots to validate a statistical link between the airline and corporate experience and that of GA TAA aircraft. ASF’s analysis of GA TAA accidents reported by the NTSB to date also showed no statistically valid link between distractions blamed on TAA and other distraction-caused accidents in the non-TAA fleet.

Beyond workload: over-reliance

A related safety issue, identified by the FAA as part of its recent hearings and reports on the FAA-Industry Training Standards (FITS), concerns pilots who apparently develop an unwarranted over-reliance in 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 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 enroute. Some pilots did not understand that FL250, the Malibu’s highest operational altitude, was arguably 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.

Related to the over-reliance 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 FAA TAA Safety Study found that poor decision-making seems to afflict new TAA pilots at a rate higher than that of GA as a whole.

The review of TAA accidents cited in this study shows that the majority are not caused by something directly related to the aircraft but by the pilot’s lack of experience and a chain of poor decisions. The fact that the aircraft involved was a TAA appears to be coincidental. One consistent theme in many of the fatal accidents is continued VFR flight into Instrument Meteorological Conditions (IMC).

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 less than 12,500 pounds), accounting for more than 42,000 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 accidents investigators note the on-board avionics in accident aircraft. This will allow a more precise determination of which aircraft are involved in what type of accidents.

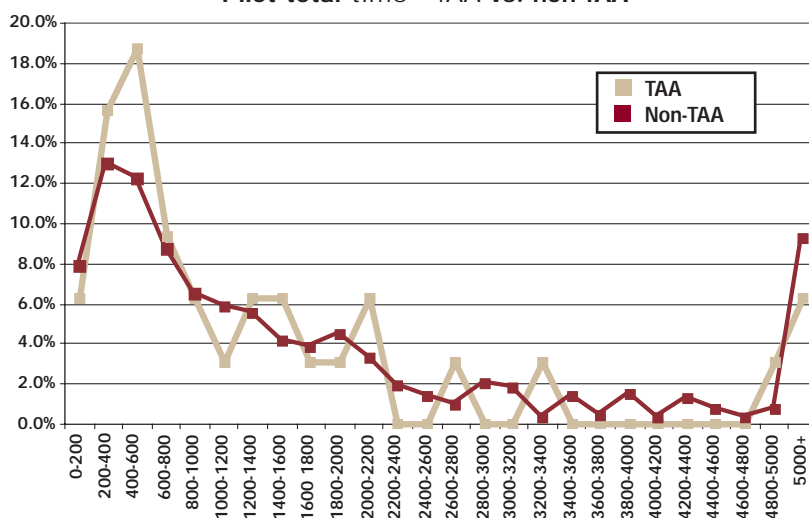


Comparing TAA accident pilots to non-TAA accident pilots

A comparison of the experience of 41 TAA accident pilots vs. accident pilots in comparable non-TAA aircraft (Bonanza, Mooney, Cessna 210, Cessna 182) revealed some interesting information. Although TAA accident pilots had a higher average total time—2,413 hours vs. 2,030 hours—they had a much lower average time in type—305 hours vs. 451. This amounts to about 30 percent less time in type at the time of the accident. The distribution of total time shows that a higher percentage of low time pilots are having accidents in TAA.

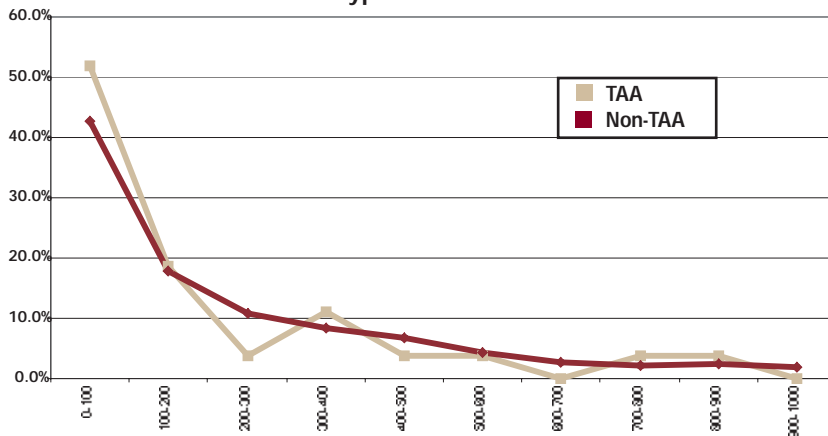
	TAA	Comparable Non-TAA
Total Time	2,413	2,030
Time in Type	305	451

Pilot total time—TAA vs. non-TAA



(Non-TAA pilots—Cessna 210 and Mooney aircraft)

Pilot time in type—TAA vs. non-TAA



Non-TAA pilots—
Cessna 210, Cessna
182, Mooney, and
Bonanza aircraft.

The TAA population is still very small, compared to classic aircraft. Two of the TAA accident pilots included in the above averages had more than 20,000 hours of total time. This somewhat skewed the TAA average total flight time to the higher end.

New TAA vs. classic TAA accident summary

Twelve Cirrus SR 20 and SR 22 accidents studied:

- Three appeared to be caused by pilot decisions to continue VFR flight into instrument meteorological conditions.
- Two indicated the pilot was performing maneuvers that exceeded design limits of the aircraft.
- One resulted from inadequate preflight planning, when the aircraft was unable to out climb terrain in a takeoff accident during conditions of high density altitude.
- One occurred when the aircraft hit trees or terrain on an IFR approach.
- One suffered interference between an electrical switch and flaps, for which an AD was subsequently issued.
- Two appear to be pilot spatial disorientation.
- One appears to be a stall/spin on initial climb.
- One appears to be flight into icing conditions.

Nine Cessna 182 model accidents studied:

- Two stalled during an attempted go-around (one is preliminary).
- Two suffered pilot loss-of-control after entering instrument meteorological conditions during VFR flight.
- Two were classified as pilot spatial disorientation.
- One hit terrain while operating VFR in mountainous terrain.
- Two hit trees or terrain while executing an IFR instrument approach.

There are two hypotheses as to why TAA accident pilots have lower time in type as compared to the comparable non-TAA pilots. It may be actual differences in pilots because of training, technique, or inadequate risk assessment, or merely the fact that TAA are new to the fleet. If so, the average accident pilot time in type may increase somewhat over time.

Comparing new TAA to classic TAA accidents

To conduct at least a preliminary comparison, ASF focused on two aircraft models that could reliably compare the accident rate of new classic TAA to newly designed TAA: the Cirrus SR20 and SR22, versus newly-built Cessna 182 models 182S, 182T and T182T (turbocharged) built from 1999 to 2003. All or almost all

of these aircraft could be considered TAA because they have IFR GPS navigators with moving maps and autopilots. Why select only new aircraft? Because there is some evidence that new aircraft are purchased by a different economic cohort of pilots who use them differently than third or fourth generation buyers. ASF's experience in conducting more than a dozen safety reviews has consistently showed a much higher accident correlation to how an aircraft is used than to a particular make and model.

At the time of the study, each manufacturer had produced a similar number of aircraft: 1,680 for Cirrus and 1,567 for Cessna. After discarding one Cirrus accident that occurred during a manufacturer's test flight during the period studied and was not considered indicative of normal flight operations, there were a total of 21 fatal accidents in TAA, 12 for Cirrus and nine for Cessna. This results in a fatal accident rate per 1,000 aircraft produced of 7.1 and 5.7 respectively.

Of more interest were the reasons these accidents occurred. All the accidents closely resembled typical non-TAA accidents with a few possible exceptions: One Cirrus accident with very sketchy information, from which no reasonable guess could be made of causal factors, and a Cessna T210 which was not included in the statistical comparison but has all the earmarks of a pilot losing situational awareness despite having one of the newest GPS navigators. At the time of this report there were two fatal Cirrus accidents in preliminary status involving a possible loss of flight instruments and another with icing in a TKS equipped, but non-icing approved SR22.

Both the Cessna and Cirrus models can generally be considered "traveling" airplanes, likely to be used much more extensively in cross-country operations than, say, Piper Warriors or Cessna Skyhawks, which are often used as trainers. As a natural consequence, cross-country accidents such as weather involvement, are more likely.

To expand the comparable aircraft study slightly, ASF also searched accident records for Beechcraft A36 Bonanzas, which have long been prototypical "traveling" airplanes for GA pilots. As expected, the long-term accident record for these aircraft includes a relatively high percentage of weather-related accidents, typically pilots with no instrument rating or not on an IFR flight plan, penetrating weather. Interestingly enough, of the approximately 247 new Beechcraft Bonanza A36 aircraft delivered since January of 2000, predominantly with Garmin 430/530 GPS navigator units, ASF found only two accidents, neither of which could be even remotely considered to be TAA-involved. One was attributed to a loss of control during a go-around, and the other resulted from fuel mismanagement.

Accident summaries and commentaries

Of the Cessna 182 and Cirrus accidents included here, a few were selected for their instructional value as part of this report. A brief summary of the accident is presented first, followed by ASF comments. More detailed NTSB accident reports are included in Appendix A. ASF comments are offered for educational purposes only. In some cases an accident is in preliminary status so the analysis must be considered as preliminary also. Please note that instrument approach procedure charts, provided to help readers better understand the flight environment, are current at the time of publishing and may not exactly reflect the procedure as it was at the time of the accident.

Accident 1

January 2003, about 4 p.m.; Cirrus SR20; San Jose, California. Likely cause: Lack of situational awareness.

HISTORY OF FLIGHT

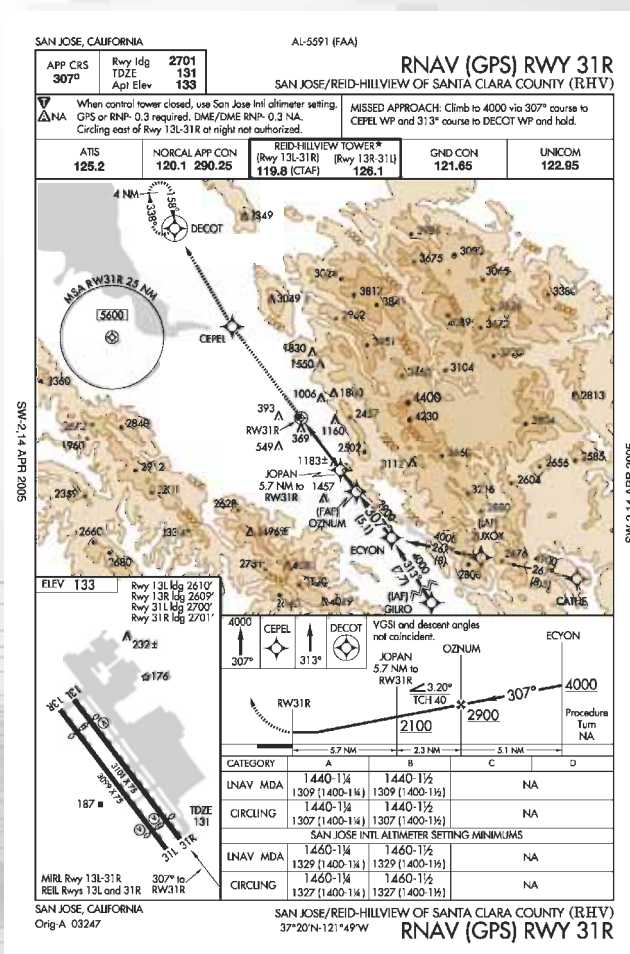
This crash took place near the end of a trip from Napa County Airport (APC) to Reid Hillview Airport (RHV), both in California. The weather along the route varied from marginal VFR to light IFR, and the pilot was operating on an IFR flight plan. Along the way, ATC had provided numerous traffic avoidance vectors.

At 1627, when the airplane was approximately abeam Oakland International Airport, the controller instructed the pilot to proceed to a fix near Palo Alto Airport (PAO), believing it was the pilot's destination. The pilot questioned the clearance, confirming that he was actually enroute to Reid-Hillview. The controller then cleared the pilot to an initial approach fix for RHV, but observed the aircraft heading toward the erroneously issued Palo Alto fix. After a correction and a reissuance of the Reid-Hillview fix clearance, the aircraft tracked more or less southbound for 3 miles before turning toward the correct fix.

ATC again provided the wrong tower frequency as the aircraft started flying the approach. The pilot finally got to the right tower frequency, correctly reported his position and then for reasons unknown, made a 90-degree right turn. The radar track was lost in a mountainous area with high-tension power lines. The Mode-C-reported altitude was 1,700 feet.

ASF comments

This appears to be a loss of situational awareness leading to the impact with power lines and a mountain.



However, there are some clues that the pilot was having trouble with the technology. The first indication comes from radar data reported in the full NTSB report, “The controller issued a clearance direct to OZNUM. After this exchange, radar indicated the airplane turned almost 90 degrees to the right, and tracked on a course consistent with proceeding direct to PAO.” The pilot could have programmed PAO into the GPS before the clearance changed to OZNUM, and with the autopilot coupled, the aircraft would have turned toward PAO.

The second clue occurred during the last moments of the flight. “As the airplane passed just northwest of OZNUM, the controller instructed the pilot to contact the tower on frequency “118.6.” This is the PAO tower frequency, not RHV. The pilot queried the controller but the controller insisted, “Yes sir, it is.” The pilot complied and contacted PAO tower. The pilot and the PAO controller discussed that he was on the wrong frequency and the pilot said he would switch to the RHV frequency of 119.8. During this conversation, radar indicated the airplane began

a turn to the right, with the target visibly displaced from the final approach course at 1652:33, approximately over JOPAN waypoint.

The Cirrus' control stick is located on the left side of the pilot, while the GPS on the lower right of the pilot. NTSB noted that the pilot was likely hand-flying the aircraft, while possibly programming the GPS on his right, he could have inadvertently started a right turn by "leaning" to the right and moving the control stick to the right. This is, again, speculative and the exact cause of the right hand turn into the power lines will never be known.

Accident 2

May, 2002; Cessna 182S, in Sheboygan, Wisconsin. Likely cause: Failure to maintain control of the aircraft during a go-around.

HISTORY OF FLIGHT

A Cessna 182S crashed in VFR conditions while executing a go-around from Runway 21 at Sheboygan County Memorial Airport, Wisconsin. Witnesses stated the aircraft began to drift to the right during landing before the attempted go-around. Local winds were reported from 150 at 9 knots. Witnesses reported the aircraft banked to the right entered a right downwind to Runway 21, then impacted the ground. Several pilots stated the engine sounded as though it was running smoothly at the time of the accident. The aircraft was observed in banks of approximately 40 to 60 degrees and as far as 90 degrees prior to impact. The aircraft was reportedly very close to the ground (approximately 10 to 20 feet agl) when making its first turn, and approximately 200 feet agl when banking sharply to the right to enter a downwind leg for Runway 21 prior to impact.

ASF comments:

The presence of TAA equipment on this aircraft appears to have no bearing on this accident, which from all indications, was caused by a simple lack of pilot proficiency and the inability to fly a normal pattern.

Accident 3

October 2002; Cessna 182S; Accident, Maryland. Likely cause: Continued VFR flight into IMC.

HISTORY OF FLIGHT:

While en route, the noninstrument-rated private pilot contacted air traffic control for flight following advisories and information about the cloud conditions ahead of him. The pilot also contacted

a flight service station (FSS), for further weather advisories. Upon contact with FSS, the pilot stated that he was in level flight at 3,300 feet, flying in and out of the clouds, and encountering light icing conditions. The FSS specialist advised the pilot of instrument meteorological conditions along the route of flight, mountain obscuration, and icing conditions. The FSS specialist also recommended that the pilot climb to 6,000 feet, where he could expect VFR conditions. The pilot responded that his flight conditions were "not that bad," and he would remain at 3,300 feet.

The pilot recontacted the air traffic controller, requesting a climb because he was accumulating rime ice. The controller replied that an airplane had reported ice at 7,000 feet, and another had reported cloud tops at 7,400 feet. The pilot then stated that he could not maintain VFR, and had "been in it" for 10-15 minutes. He further stated that ice was building up, but he was "OK" with it. The target disappeared from the radar screen.

ASF comments:

It is possible that this pilot succumbed to the belief that the advanced avionics on board his aircraft would compensate for the lack of qualification to fly in instrument weather conditions, and thus he entered deeper into IMC before calling for help. Or perhaps not, since a significant number of such VFR-into-IMC accidents occur each year in non-TAA. In any event, this pilot was not responding appropriately to the obvious weather warning signals.

Accident 4

September 2003; Cessna 182T; Concord, Massachusetts. Likely cause: Spatial disorientation.

HISTORY OF FLIGHT

The pilot received vectors for a daytime ILS approach for Runway 11 at Bedford, Massachusetts, in IMC. The airplane crossed the outer marker approximately 500 feet high, and then descended 1,300 feet in 40 seconds. It then started a climbing, left turn. When questioned by the controller, the pilot reported headings that were consistent with his radar track. The pilot's answers to questions from the controller were sometimes delayed and/or incomplete, and when instructed to execute a missed approach, the pilot did not know what heading to fly. The airplane turned more than 360 degrees before descending into the trees in a steep left wing down bank.

ASF comments:

Although this instrument-rated private pilot was estimated to have flown 60 total hours in the last six months, there was no record of the amount of instrument time. It appears that the pilot was not instrument proficient. Attempting to verify controller instructions may have caused him to use rapid head movements to reference instrument charts. Witnesses also reported hearing a large increase in power, which may have also contributed to kinesthetic illusions.

Basic lack of proficiency in attitude instrument flying, exacerbated by spatial disorientation, was the apparent cause of this accident. The use of autopilot could have helped. There is no indication that the TAA equipment on board was any factor.

Accident 5

October 2004; Cessna 182S; Santa Rosa, California. Likely cause: Spatial disorientation.

HISTORY OF FLIGHT

The instrument-rated pilot took off from an airport with a 600-foot ceiling. During his climb in instrument meteorological conditions, the pilot failed to maintain directional control and altitude, and subsequently entered a right descending spiral until impacting terrain 2 miles west of the airport. According to the aircraft operator, the pilot rented the 182S because the Cessna 206 he normally flew was down for maintenance. According to the operator, there was no record of the pilot ever being checked out in the 182S. The pilot's logbook was not located, and the pilot's recent instrument experience was not determined.

ASF comments:

It's likely that this pilot became spatially disoriented when trying to use avionics that he was unfamiliar with. Flying single pilot in actual IFR conditions is not the time to learn how to program the GPS. The use of autopilot could have helped.

Accident 6

November 2003; Cirrus SR 20; Las Vegas, New Mexico. Likely cause: Spatial disorientation.

HISTORY OF FLIGHT

During a cross-country flight, the non-instrument rated private pilot encountered heavy fog and poor visibility, and the airplane was destroyed after impacting the terrain in a wildlife refuge. An airmet, issued and valid for the area, reported the following, "Occasional ceiling below

1,000 feet, visibility below 3 miles in mist, fog...mountains occasionally obscured clouds, mist, fog..." On the day of the accident, the pilot did not file an IFR flight plan or receive a formal weather briefing from an FAA Flight Service Station.

ASF comments:

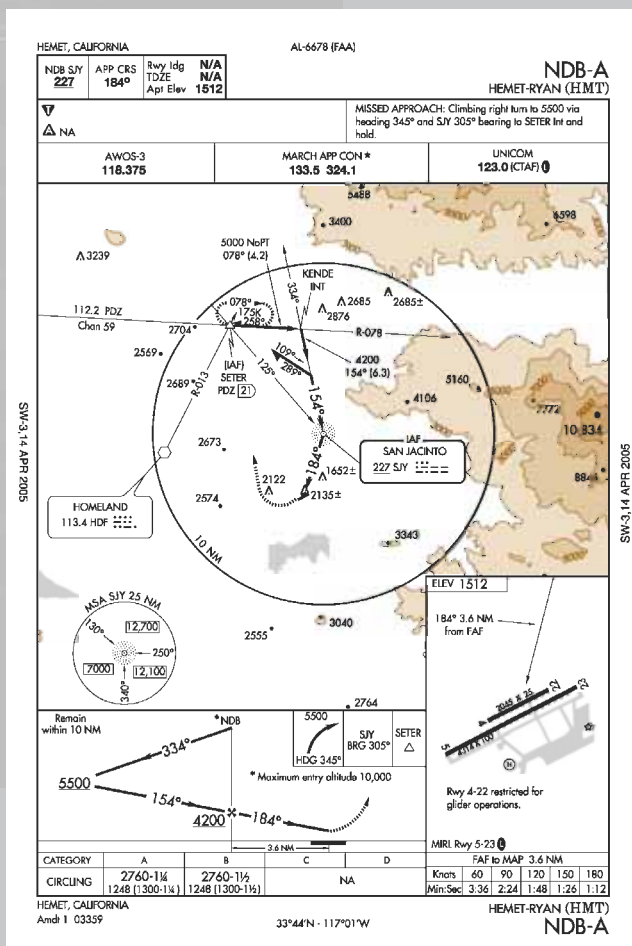
The noninstrument-rated pilot in this accident may or may not have been tempted to continue his flight when encountering IMC conditions because he had TAA equipment on board. ASF files bulge with similar accidents involving non-TAA, going back to 1983.

Accident 7

December 2001; Cessna 210TC; San Jacinto, California. Likely cause: Loss of positional awareness.

HISTORY OF FLIGHT

During a GPS approach in IMC, the pilot did not turn onto the prescribed course toward the final approach fix. The pilot initially navigated along the prescribed instrument approach course, but failed to make a critical 75-degree course change



toward the final approach fix. Instead of maintaining the 4,100-foot msl minimum altitude until passing the final approach fix, the pilot descended to 3,550 feet msl. The airplane was equipped with a late-model GPS receiver with a moving map. The airplane crashed 5.9 nm east of the prescribed course and 550 feet below the authorized altitude. The reason for the pilot's loss of situational awareness and his track divergence is unknown.

ASF comments:

Although the NTSB does not speculate on the reason for the pilot's loss of situational awareness, it's possible that he was either distracted or confused while dealing with the details of the GPS approach on the moving map display in his T210. In the full NTSB report (contained in Appendix A), the flight instructor who conducted this pilot's last Instrument Proficiency Check did not report any GPS approaches performed during the check. The availability of high-tech equipment does not alter the pilot's responsibility to know where the aircraft is relative to high terrain but it should help him to locate it.

TAA and the parachute

Some TAA 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 is designed to be deployed when the pilot believes there is grave danger.



Information from the Cirrus Design Web site "Ace in the Hole" regarding the Cirrus Airframe Parachute System (CAPS) says, "This safety system will lower the entire aircraft to the ground in extreme emergencies and when all alternatives to land have been exhausted. With the pull of a handle, a solid-fuel rocket blows out the top hatch, deploying the parachute, and buried harness straps unzip from both sides of the airframe. Within seconds, the canopy will position itself over the aircraft and allow it to descend gradually. The final impact, roughly equivalent to falling 10-12 feet, is absorbed by the specialized landing gear."

The parachute raises questions that will almost certainly affect other areas of TAA training, including:

- Will the presence of such a potentially life-saving tool encourage pilots to intentionally fly into situations they would not normally attempt in more conventionally equipped aircraft?
- What detailed guidance (if any) should be conveyed to pilots of chute-equipped TAA to determine when to "pull the chute?"

At publication time, there had been four reported accidents involving use or possible attempted use of the CAPS system. They are summarized here. The NTSB accident reports are included in Appendix A.

Accident 8

March 16, 2002; Cirrus SR20; Lexington, Kentucky. Likely cause: Pilot failure to maintain control of aircraft after apparent malfunction of turn coordinator in IMC. Additional information: Pilot attempted to deploy the Cirrus Airplane Parachute System (CAPS) parachute, but was unsuccessful. Parachute apparently deployed after ground impact.

HISTORY OF FLIGHT

The instrument-rated pilot and a passenger departed into instrument meteorological conditions (IMC), intending to practice some instrument approaches. Shortly after takeoff, the pilot reported a turn coordinator failure. The turn coordinator indicated a left bank regardless of control inputs, disorienting the pilot. The pilot stated he pulled the CAPS activation handle repeatedly, however, the cable did not extend and "nothing seemed to happen." The airplane broke out of the cloud layer, and the pilot performed an emergency landing to a field. Witnesses near the accident site reported that the CAPS parachute deployed after ground contact. Post-accident testing of the wreckage did not reveal any pre-impact instrumentation, or autopilot failures. The CAPS system also functioned normally, how-

ever, it was noted that the pull forces to activate the CAPS parachute varied significantly.

ASF comments

Pilot decision-making in a potentially deadly situation appeared to be proper, given that the pilot apparently believed that a crash would ensue without deployment of the parachute.

There was extensive post-crash investigation by the NTSB and Cirrus Design regarding pull force required to activate the CAPS system. As a result of this accident, and the subsequent testing, Cirrus Design issued Service Bulletin 20-95-03, which required replacement of the CAPS handle access cover. The new cover incorporated an expanded description for the CAPS activation handle use. Additionally, on July 10, 2002, SB20-95-05, was issued and required the replacement of the CAPS activation cable to further reduce the pull forces required to deploy CAPS. Cirrus Design issued similar service bulletins for the SR22 series airplanes, which were also equipped with CAPS.

Pilot decision-making appeared sound given the situation, ASF reviewers questioned why loss of the turn coordinator only (as reported) should cause an instrument pilot to lose control of an aircraft in otherwise-benign IMC, but when faced with what is a perceived life threatening situation—pull the chute!

Accident 9

April 24, 2002; Cirrus SR22; Parish, New York. Likely cause: The pilot's failure to maintain air-speed, which resulted in an inadvertent stall/spin. The continued spin to the ground was a result of the pilot's failure to deploy the onboard parachute recovery system.

HISTORY OF FLIGHT

The airplane was maneuvering about 5,000 feet above the ground, where witnesses noted that it seemed to be repeatedly practicing stalls, when it entered a right, flat spin. It continued the spin to the ground, without deployment of the onboard parachute recovery system. Examination of the wreckage, and a subsequent examination of the engine revealed no mechanical anomalies. The two accident pilots purchased the airplane 6 days before the accident and had separately received airplane-specific training. The accident flight was their first flight together. The pilot in command, and the pilot at the controls leading up to and during the accident sequence could not be determined. The pilot's operating handbook states that the only approved and demonstrated method for spin recovery is the deployment of the parachute recovery system.

ASF comments

Whether the pilots believed that chute deployment was not needed, were unable to pull the chute for some reason, or simply forgot under the stress of the moment is not clear. If pilot decision-making (or non-decision-making, as the case may be) was a factor here, it argues for emphasis on scenario/case study type of instruction during transition training.

ASF reviewers also questioned why a spin was allowed to develop, considering that spins are clearly not approved in Cirrus aircraft. Was the presence of the CAPS a factor in encouraging the pilots to presumably take the aircraft beyond its flight limits, creating a false sense of safety?

Accident 10

September 19, 2004; Cirrus SR22; Peters, California. Likely cause: The pilot's loss of control after a possible weather encounter resulted in what the pilot deemed to be a spin. Additional information: The pilot activated the CAPS parachute, preventing almost certain loss of life.

HISTORY OF FLIGHT

On September 19, 2004, at 1550 Pacific Daylight Time, a Cirrus SR22 landed in a walnut orchard during an emergency descent. While flying in an area covered by a convective sigmet and where radar data showed the aircraft having considerable altitude deviations, the pilot deployed the CAPS about 16,000 feet msl, and the airplane made a parachute landing into the walnut orchard. The instrument-rated commercial pilot and single passenger were not injured, but the airplane was substantially damaged. Instrument meteorological conditions prevailed, and an instrument flight plan had been filed but not activated. The flight originated at Redding, California, at 1500.

The pilot reported to the NTSB that he was passing through 14,000 feet msl with the autopilot set at 100 feet per minute (fpm) rate of climb. He and his passenger were using supplemental oxygen. There was a broken cloud layer 1,500 feet below the airplane and he was in visual meteorological conditions steering east to avoid some weather. He said he heard a "whirring" sound in his headset and the nose pitched up. He disconnected the autopilot, the left wing dropped and the airplane appeared to enter a spin. The pilot determined that the airplane would be in the overcast cloud layer before he could recover and decided to activate the CAPS. The CAPS deployment was successful; the airplane broke out of the clouds about 2,500 feet above ground level (agl), and landed in the walnut grove.

There was a convective sigmet active in the vicinity where the airplane landed, warning of a line of severe thunderstorms 30 nm wide moving from 300 degrees magnetic at 15 knots with cloud tops to 27,000 feet; hail up to 1 inch in diameter; with wind gusts up to 50 knots possible. Weather radar showed Level 5 and Level 6 (extreme) thunderstorms predicted in the vicinity of the accident.

ASF comments

This is one of several accidents that shows successful deployment of the CAPS system in an actual emergency, likely saving lives. Given that the pilot believed the aircraft had entered a spin, the decision to activate the parachute appears to be correct decision making, and the end result (no fatalities) bears this out.

A fair question is whether the availability of CAPS was a factor in the decision-making that led this pilot into an area of Level 5 (severe) and Level 6 (extreme) thunderstorms in the first place. Had CAPS not been available as a last resort, would the pilot have ventured into such inhospitable weather? Is it possible that the autopilot played a part in the loss of control by attempting to climb or hold the aircraft in turbulence? None of this can be answered with certainty at this point, but training and attitude are as important to TAA as they have been in the past with classic aircraft.

Accident 11

October 3, 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, shutdown 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.

Accident 12

April 2004 over mountainous terrain in Canada. Cirrus SR20. Likely cause: Undetermined at this time.

HISTORY OF FLIGHT

The aircraft was flying at night over rugged mountains in Southern British Columbia. Mountain peaks in the area rise to more than 9,000 feet. A Canada’s Transportation Safety Board spokesperson noted “We have radar data showing the aircraft in a spiral before it goes off radar.” There were reports of significant turbulence in the area. What caused the aircraft to depart controlled flight remains the subject of investigation. The aircraft descended under the parachute, alighting on a steep rocky slope where the four occupants stepped out uninjured.

ASF comments

While one certainly cannot debate the outcome, many experienced mountain pilots would question the wisdom of flying a light single-engine aircraft fully loaded at night over high terrain in windy conditions. Almost any one of these circumstances would be cause for concern. Collectively they point to a pilot who was likely depending upon the aircraft’s “last resort” technology where the risk/reward equation was not properly balanced, in our opinion.

Conclusion

As noted earlier, there aren’t enough accidents yet involving TAA to draw statistically valid conclusions on the role (if any) that TAA might play in GA safety. It is encouraging, however, to see that there are no strong negative indicators for TAA effect in the accident rate based on the very limited data.

Training providers are jumping on the TAA bandwagon. As mentioned earlier, FBOs and aviation colleges are all rapidly adding TAA to their fleets. Various commercial providers and equipment manufacturers are rushing to take advantage of the need for specific training on TAA avionics. A CD-ROM based interactive instructional system from Electronic Flight Solutions was introduced this year, bringing to five, the number of instructional volumes in its *Complete Learning*TM library. Many of those volumes are directed at operation of specific TAA-related avionics.

On the local level, more than 150 avionics shops that are members of the Aircraft Electronics Association have adopted CD-ROM-based training for TAA-type avionics.

Other commercial users of the software include Professional Instrument Courses and OurPlane, a fractional ownership company for general aviation pilots.

The U.S. government has adopted TAA training programs on CD-ROM, with the U.S. Navy committing to such education for its fleet of Garmin 530 units installed in Grumman E-2s.

Manufacturers of full-motion 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, promises full-motion visual simulators at locations near Atlanta, Georgia, and on both the East and West coasts in Cirrus Training Centers.

The units simulate either Avidyne Entegra PFD or standard instrument displays, and include a parachute activation scenario for the Cirrus Airframe Parachute systems to emphasize the decision-making process leading to CAPs deployment.



Vflite's interactive CD for GPS is shown at left.

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





Simulators help effectively train pilots in the new environment.

A training sequence

In the AOPA Air Safety Foundation's opinion, the best way to train pilots, either from the beginning (ab initio) or for transition, 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 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, is appropriate. Much training can take place long before the pilot shows up at the training center or before starting with a CFI, especially as a transitioning pilot.
2. The next level would be a 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 units came with ground power supplies and simulation software so pilots could practice. With a full glass cockpit 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 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, sometime much less, 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

TAA simulation—a better training environment

The same technological advances that have allowed the development of TAA are also giving innovative opportunities for flight training providers, and may create significant momentum for an entirely new model of flight training in GA.

The first example of this is a remarkably realistic flight-training device for new TAA. Designed by Fidelity Flight Simulation, Inc., this device provides motion cueing, external visual displays, and realistic aerodynamic modeling for various aircraft models.

Motion is created with electric motors, rather than expensive traditional hydraulic actuators typically used in motion simulators for airline and corporate operators. Equipped

with a four-panel LCD, the cockpit can be configured for virtually any TAA. According to the manufacturer, these new units can help revolutionize flight training by providing superior procedures training at a lower cost than conventional in-aircraft training.

As part of the research for this study of general aviation TAA, ASF traveled to Fidelity headquarters in Pittsburgh to evaluate the Cirrus-style simulators. After a demonstration ride that included simulations of a downwind landing, a control system failure and a CAPS chute deployment, our opinion is that this generation of electronic simulators will be just the first stepping stone for revolutionizing the flight-training system.

The initial application of this technology for general aviation TAA is being pioneered by a start-up group called SimTrain, which has purchased three Fidelity Flight simulators and configured them as Cirrus SR22 TAA models. Plans are to place one of the simulators on the West Coast and one on the East Coast, most likely in the pilot-rich Boston-Washington corridor. One additional SR-series simulator is planned for the Atlanta area.

ASF has long advocated use of both partial-task and full-motion simulator training in Part 61 and Part 141 curriculums, both for instructional efficiency and for keeping the cost of flight training affordable. This approach holds great promise for doing exactly that.

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, and possible loss of control.

As soon as the pilot has mastered the most basic handling, 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.

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 5 days or longer and for very low time pilots, particularly those that are transitioning to faster TAA, a reasonable mentoring period is suggested. They should be gradually introduced to the broad range of conditions that the aircraft will ultimately encounter.

An experienced 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 or manufacturers.

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.

Training a new breed of pilots?

The FITS group 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



Cirrus full motion flight simulator by Fidelity Flight Simulation, Inc., (above).

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.

While these comments suggest that a fundamental shift is occurring with new pilots, this is largely anecdotal. 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.

We believe a split still exists, often dictated by personal economics. Those that have a need to travel and the financial wherewithal will buy a high performance aircraft. And those that previously followed a traditional approach to aircraft upgrading

may now become “fast burners” because of some TAA system simplicity (fixed gear, FADEC, etc.) and attractive pricing. It’s too early to determine if this is anything more than a slight upsurge or a fundamental shift in the pilot population.

There may also be a new group of pilots who enter the system through Sport Pilot. They will have learned basic flight skills, but there will be a significant transition into a full-fledged TAA.

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, they move 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 TAA are simpler and slower than the jets, the workload is nearly the same. Since pilots operating TAA 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. Departures, en route, arrivals, and approaches should be flown such that the pilot is comfortable and completely proficient. Some hand-flying skill is appropriate but in many cases it 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. The autopilot will methodically trim against the pilot and will either win the fight or

My Point—Evolving design and some thoughts for the future

By Bruce Landsberg, executive director of the AOPA Air Safety Foundation

Some pilots and pundits have expressed skepticism about TAA and their inherent systems. The most common statement in the advanced avionics cockpit, according to airline and corporate pilots is “What’s it doing now?” This refers to the avionics doing something that the crew didn’t expect.

Chip Rosenthal, CEO of Unicom Systems Development notes, “I’m not schooled in the science of human factors, but I suspect surprise is not an element of a robust user interface.”

Jeff Raskin, Apple Computer’s former manager of advanced systems, was more direct. “The multiple stupidities of even the latest designs...show either an unjustifiable ignorance of, or a near-criminal avoidance of what we do know [about existing engineering methods for designing human-computer interfaces].”

In designing aircraft and avionics, key interface considerations are simplicity and consistency. The pilot’s primary job is to know where the aircraft is

in four-dimensional space and where it needs to go next. Beyond that, we’re getting into niceties. Change in flight is constant and inevitable, so inputs must be made quickly and the system must be fault tolerant. The multifunction display and moving map are huge improvements to situational awareness, and we can’t say enough good about them. They provide the electronic “map in the head” that all instructors attempt to build into their students.

But it often takes too many button pushes and knob twists to get the hardware to display the promised high level of situational awareness in the time that the single pilot has available. Technology emerges as a double-edged sword, increasing pilot and aircraft capabilities but frequently at the price of increased workload and education.

Some designers do not yet fully understand their customers or the environment in which they operate. That is not unique to aircraft, of course, and can be seen daily in our technophile or techno-

phobe society—new home entertainment systems, wireless networks, computer software, PDAs, automotive sound systems—the list is endless.

The difference with complex avionics and aircraft design is that the penalty for slow learning, improper operation, or misunderstanding the equipment can be fatal. From an accident investigation perspective, the probable cause will likely be “the pilot failed to follow the instrument approach procedure” or “became disoriented for unknown reasons.” Tying the cause of an accident back to a complex user interface requires analysis that is probably beyond the current state of the art in accident reconstruction.

To be fair, marketers, engineers, and customers themselves are constantly balancing pricing, competitive features, and the technology as it evolves, to make the right decision. This is not easy to do or we wouldn’t have so many examples of technology that could be improved. The nature of invention is to build products

disconnect with the aircraft badly out of trim and very difficult to control. Some autopilots have a rate of climb (ROC) or descent select. In our opinion, this capability is a potential trap especially in piston aircraft. In a few documented cases, ROC mode was selected, for example, at 700 fpm and as the aircraft climbed, the engine power output declined with altitude. As the actual ROC declined, the autopilot attempted to maintain the selected rate and pulled the aircraft into a stall.

Malfunctions are rare, far less than with human pilots, and these must be handled appropriately. This is best done 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 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 or lower traffic density.

The FAA, in testing TAA pilots, should adapt to the reality of autopilots as well. That moves away



Chelton Flight System's autopilot (above)—the TAA pilot's friend.

from the traditional test methodology that requires pilots to hand fly complex departure and approach patterns. The use of autopilots in TAA and the FAA's approach to testing should be handled as they are in single-pilot jets.

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 George Orwell approach to safety, since it involves using

that invariably are improved. *It's much easier to criticize than to create.*

More features are not better, better functionality is better. (A limited ASF study supports this view; because of the small sample size we continue to gather data. Preliminary findings show that pilots, as a group, preferred simple design and fewer choices to highly capable, complex machines.) It takes a very good understanding of the **single-pilot** environment and a clear sense of direction to achieve this.

In the airline and corporate pilot environment where pilots are paid to think about their jobs constantly and must undergo extensive training on a regular basis, equipment design and training tasks are easier. The target population is more homogeneous and their motivation is clear. In light GA, the motives and the pilot population are completely different even though the penalties for failure are just as severe.

The occasional, or renter, pilot will have a steeper learning curve to enjoy many of the promised advantages of the current TAA, especially if he or she flies

several aircraft with different navigation systems. In the future, that barrier may go away as aircraft systems and avionics get smarter. At this writing, more systems commonality is gradually coming which eases the learning process, but there is still a way to go.

To achieve the goal of significantly safer flight for many more people, the interfaces and the skills required must become less demanding. Training and maintaining proficiency must take less time and be simpler. Extensive training to make up for complex design puts a tremendous burden on users. It's impossible to consistently replicate excellence in that wonderfully variable and unpredictable device—the human pilot. Far better results are achieved by designing the product so well that most pilot can consistently perform well.

Some might call it the “dumbing down” of aviation but the major advances in airline and GA safety have historically come from technology. For the airlines and corporate flight departments, jet engines, ground proximity warning devices, traffic collision avoid-

ance systems (TCAS) and advanced simulation for training had a huge impact on safety. In GA, the advent of nose-wheel aircraft sharply reduced landing accidents. We predict that terrain, weather, and traffic avoidance now coming into the new TAA will help—and all of those require little or no manipulation on the part of the pilot to provide life-saving functionality. They also the require pilots to recognize the equipment-pilot-aircraft limitations and not put themselves in a high risk situation based on the idea that the technology changes the fundamentals of aviation safety.

We are now on the cusp of a new era that includes better training simulation, new engines, and some of the high-end technologies that the jet world has enjoyed for decades. There will be growing pains however, as manufacturers and customers come to understand each other. The TAA and glass cockpits are a bold step in this direction. Evolution will precede revolution but the long-term result will be a much safer and an ever more useful light aircraft transport system than we have today.

Counterpoint—The future is now

There are clearly other points of view on the advanced technology. Without embarrassing or identifying anyone, here are some enthusiastic proponents of TAA including marketers, reviewers or users:

- “The big difference is that a gaggle of human factor experts have devised a way to present all the information in a small area, thus reducing the range of one’s scan. Moreover, through the use of tape-type indications and digital displays, the information is more intuitive and easier to process.”
- “The MFD can basically be thought of as a situational presentation. That is, it can electronically display on the LED screen just about anything the MFD vendors can dream up.”
- “You can go very fast in comfort and safety with terrific visibility flying behind a state-of-the-art panel that provides unprecedented situational awareness in all types of weather.”

- “Exceptional positioning information is the key to flight safety.”
- “Isn’t this GPS technology wonderful?”
- “Add to all that the fact that GPS is widely regarded as the single easiest way to navigate, and you’ve got plenty of reasons to go shopping for a unit of your own.”
- “On a basic level, GPS will provide reliable, accurate navigation to any point on Earth. Before *situational awareness* became an aviation buzzword, pilots flew safely by continually asking and answering three questions: Where was I? Where am I? Where am I going? With a GPS receiver’s moving map, those questions are answered with a momentary glance. There is no substitute for this tremendous advancement.”
- “This new all-glass cockpit is the greatest avionics system to come along in nearly three decades.”
- “For pilots, that means that the new GPS system could allow aircraft to land

in zero/zero conditions, and for the military, Navy pilots can put a fighter down on the deck of a pitching, heaving aircraft carrier—even when they can’t see it.”

- “In a sense, the...system may be almost too talented. The two screens integrate so much information so conveniently that you’re tempted to keep your eyes inside the airplane too much, obviously a major benefit in IFR conditions, not so practical in good VFR.”

It could also be said that the pilot is ultimately responsible for understanding how installed equipment works – every avionics manual has bold print warnings not to operate the aircraft until fully checked out. —***Caveat emptor!***

Copy of a warning from a GPS manual: “Caution: *Use the [GPS Unit] at your own risk. To reduce the risk of unsafe operation, carefully review and understand all aspects of this Owner’s Manual [in excess of 140 pages] and the Flight Manual Supplement and thoroughly practice basic operation prior to actual use....*”

monitoring devices permanently installed in the aircraft to record flight operations.

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.

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. TAA accidents examined for this report were largely indistinguishable from accidents with non-TAA equipment. 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 in the 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 lends itself to being recorded much more easily than in the past because the information is electronic. It does not require the retrofit of servos, transducers and additional computers, as would be the case with the large, existing fleet of light aircraft. This remains prohibitively expensive and difficult. Those concerned with privacy or “big brother” will rebel against this approach to safety, since it involves using monitoring

devices permanently installed in the aircraft to record flight operations. However, the only time the information should be used is when there has been an accident.

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 are use radar, laser and camera devices to monitor speed on the highways, drivers slow down. To see how FDRs might affect GA, it's predictive 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; seat-belt 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 defense of the company in a product liability lawsuit.

Some automakers are reluctant to use EDR 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.

- 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 TAA have installed small digital cameras and 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 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 emerge as a two-edged sword however, and in those cases where an aircraft or piece of equipment is shown to be defective, the manufacturer should settle the claim fairly and then quickly resolve the technical problem for the rest of the fleet. The advent of new production model TAA equipped aircraft with FDRs may improve safety where product liability and tort reform advocates have been unsuccessful.

Typical TAA displays

- *Weather* is usually a Nexrad or enhanced radar image.
- *Terrain* denotes the vertical extent of terrain shown by the moving-map display.
- *Traffic avoidance* is provided by either ATC radar or returns from ADS-B transponders in Capstone-equipped aircraft independent of ATC equipment.
- *Engine instrument displays* replaces conventional round dials or even more modern gas discharge displays.

The multifunction display (MFD) is the center for all these functions. MFDs come in a variety of forms, and accept input from several providers. A listing of MFD-equipment manufacturers and the providers of data streams are included in Appendix D.

Weather displays on TAA

Until very recently, anything approaching real-time display of convective weather in the cockpit was limited to aircraft with onboard radar. This equipment is the gold standard for

Datalinked weather is displayed on a Apollo (now Garmin) MX20 (below).



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 mosaic display that requires considerable interpretation.

In TAA, however, suppliers of datalinked weather images are making major inroads and such displays may greatly improve utility for light GA. Weather graphics datalink has the potential to greatly simplify inflight decision-making. Depending on aircraft and pilot capability, the decision can be made, based on the latest data, to divert, delay, continue, or land asap. Likewise, the availability of the latest TAFs and METARs for reporting airports allow both VFR and IFR pilots to monitor weather ahead and around them. There will be very few excuses for being surprised.

Terrain awareness

Integral to most new GPS navigator units these days is terrain awareness, usually displayed on an MFD in a format using different colors to indicate different elevations. 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.

TAWS is mandatory on March 29, 2005, for all turboprop or jet aircraft with six or more passenger seats, including those operated under FAR Part 91. As prices drop, pilots of smaller TAA may expect to see TAWS emerge in their cockpit.

TAWS (technically, TAWS-B, a variation on the TAWS-A equipment required on Part 121 aircraft as early as 1974) 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 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-B units (the version most commonly installed in 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 60-second and 30-second warnings.

60-second aural warning: “Caution, terrain; caution, terrain” (or “Terrain ahead; terrain ahead”) and “Caution, obstacle; caution, obstacle.”

30-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.



TAWS-B units are most commonly installed in general aviation aircraft.

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!”

- **Negative climb rate or altitude loss after take-off.** 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!”

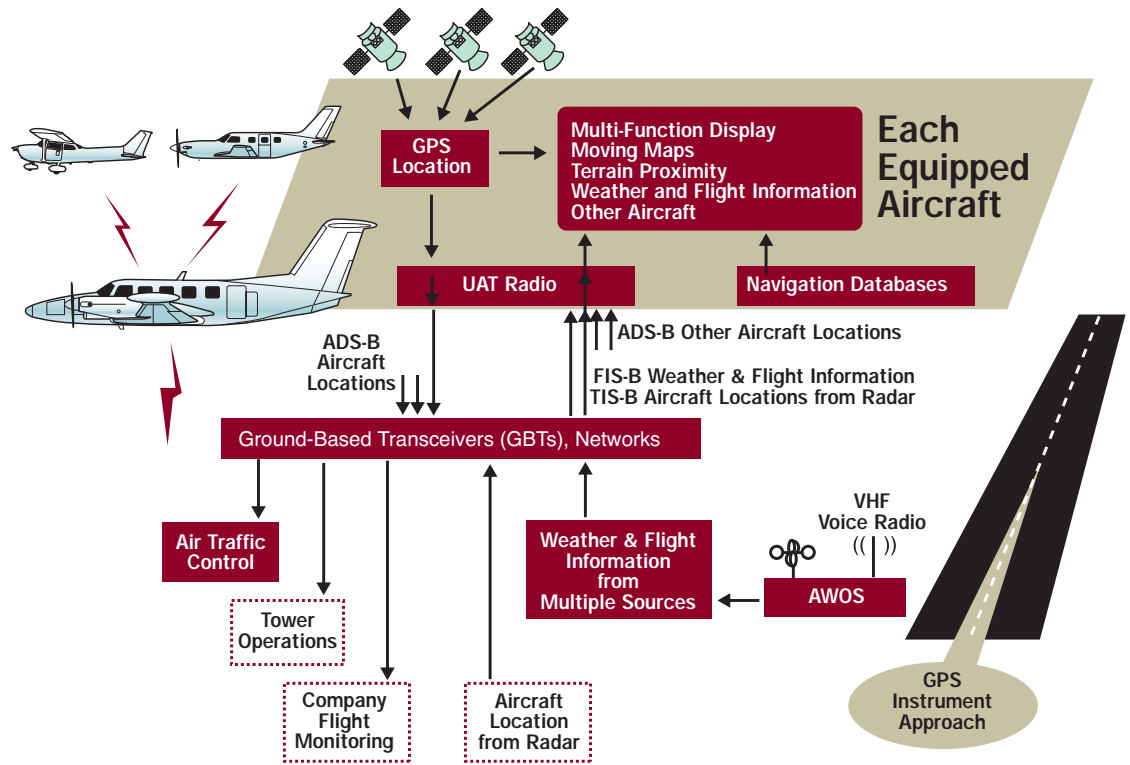
- **The 500-foot "wake-up call."** This occurs whenever terrain rises to within 500 feet of the aircraft, or when the aircraft descends within 500 feet of the nearest runway threshold elevation during an approach to landing. It's intended as an aid to situational awareness, and doesn't constitute a caution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

Call-out: “Five hundred.”

Traffic avoidance

AOPA has assisted the FAA test in a project in Alaska and in the Ohio Valley that promises not only weather datalinks but also collision avoidance, even in non-radar areas. Should this TAA-related technology prove itself, 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. The three-year program called *Capstone*, is designed to evaluate various avionics systems that could become an important part of air traffic control within the National Airspace System. Most of the

ADS-B Technology



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 selected 150 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. (This is the surveillance component of the acronym.) 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.

Traffic displayed on an Apollo MX20 (below).



The whole idea behind ADS-B is to expand system capacity and enable the Free Flight concept, a logical extension of the capabilities of TAA. 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 (Fully Automatic 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.

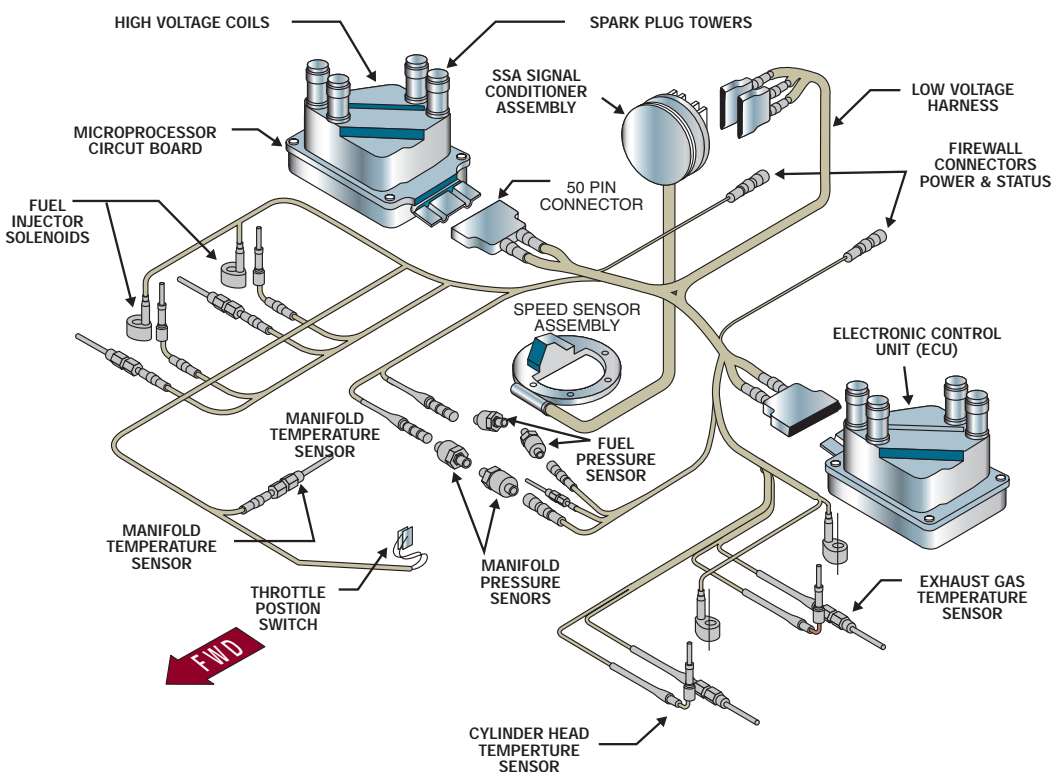
If a parameter moves into the “yellow” for whatever reason, unlike gauges of old where the pilot must constantly monitor a needle for a 1/8- inch movement, the MFD automatically advises the pilot that something is out of toler-



Chelton's Highway in the sky.

ance 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.



FADEC sensing system.

Engine monitoring is displayed on screens such as this one from Meggitt.



Technology abused?

All tools have the potential to be misused and new tools have the greatest risk because users have to learn the pitfalls. Much of the new technology aboard TAA falls into this category. A few, including some regulators, have suggested that because something can be misused, that it should not be developed or at least severely restricted. That logic would have forestalled the development of aviation itself.

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 is the case with an onboard radar. The time lag between capture of the radar image and the datalink display may be anywhere from 5 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.

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

Fabulous fuel solution

Other hardware-based display solutions have already proven successful, and some are being adapted from other modes of transportation. For instance, new GA aircraft annunciator technology has virtually eliminated fuel mismanagement in new-production Cessna piston aircraft. Low-fuel warning lights for each tank, prominently featured in the panel annunciator system and separate from occasionally inaccurate fuel gauges, have resulted in a major accident reduction in this common pilot misjudgment area. According to Cessna safety engineering personnel, there have been no recorded fuel-exhaustion accidents involving more than 5,000 Cessna singles built since 1995.

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. There was one accident in the Capstone project in Alaska where this happened. On balance, however, the value of knowing obstacles are ahead dramatically lowered the number of Alaska accidents.

Traffic avoidance—As mentioned earlier, pilots generally can acquire targets visually faster with on board 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 non-towered airports there will be more transponderless traffic so pilots will have to continue to scan outside.

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 few years off.

In the final analysis, the benefits offered by this equipment far outweigh the downsides.

“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

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.

Current accident figures are generally comparable to classic single-engine aircraft. Until more TAA are introduced to the fleet, it will be difficult to directly measure the safety benefit. In a few cases, parachute-equipped aircraft have certainly saved lives. 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 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 is 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. Poor judgment will always be poor judgment. Did the new TAA cause the ensuing accident? Certainly not! It may have enticed the pilot slightly, but that is not an inherent fault of the aircraft. As long as pilots are human they will continue to make mistakes.

The real comparison of glass, not just TAA, will occur as we acquire data on classic TAAs, the proven, old-line aircraft given a new panel. It’s premature to predict the outcome with certainty but you can place your bets!

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 tell the computer 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.



