Technically Advanced Aircraft
Safety and Training

Appendix B

Selected articles from *AOPA Pilot*

Landmark Accidents: High-Terrain Tangle, The Lessons from Cali

By Bruce Landsberg
(From AOPA Pilot, *April 2001.)*

When American Airlines Flight 965 crashed into the mountains near Cali, Colombia, on December 20, 1995, it was an unusual accident for a U.S. carrier. Controlled flight into terrain, or CFIT, is more common in some developing countries where airlines fly older aircraft with less sophisticated crew training. It is a leading cause of fatal air carrier accidents worldwide. But Flight 965 did not fit that profile.

The Boeing 757 was equipped with a state-of-the-art flight management system (FMS), moving-map display, and a superbly trained crew that was familiar with the route.

General aviation accidents follow a similar pattern when a perfectly functioning aircraft is flown into the ground. While CFIT does happen with light single-engine airplanes, it seems to be more prevalent in high-performance singles and twins that are more likely to be out in the weather and flying at night. Ironically, the aircraft involved in CFIT accidents also tend to be better equipped.

This accident should serve as a warning to GA pilots. The IFR GPS receivers that are rapidly being installed in many of our cockpits are based on FMS technology and similar protocols. In most cases they will improve the pilot's situational awareness, but in a few they could degrade it catastrophically. The old problem of communication also played a part in the catastrophe at Cali. The information that follows was edited from the official accident report by Aeronautica Civil, Republica de Colombia (the Colombian equivalent of the FAA/NTSB).

Flight history

American Airlines 965 (AA965) departed Miami at 6:35 p.m. Eastern time, nearly two hours late for the three-hour, 12-minute flight to Cali. The route of flight from Miami went over Cuba, Jamaica, and then into Colombian airspace. Bogota Center cleared the flight direct from BUTAL intersection to the Tulua VOR (ULQ). At 9:10 p.m. the pilots communicated with AA's dispatch via datalink, asking for Cali weather. Cali reported clear, visibility greater than 10 kilometers, and scattered clouds.

At 9:26 the pilots requested descent clearance. The flight was initially cleared to Flight Level 240 and then to FL200. At 9:34 the flight was instructed to contact Cali Approach Control, a nonradar facility. AA965 contacted Approach at 9:34 and reported out of FL230. The controller asked, "DME distance from Cali?" The captain, who was not flying the aircraft, replied, "The DME is six-three." The controller replied, "Roger, [AA965] is cleared to Cali VOR, uh, descend and maintain one-five thousand feet. Altimeter three-zero-zero-two...no delay expected for approach. Report, uh, Tulua VOR." The captain confirmed the call and at 9:35 informed the first officer (FO) that he had "put direct Cali for you in there." This referred to programming the FMS.

The crew was prepared to land on Runway 1 at Cali, but the approach controller offered a straight-in approach to Runway 19. This shortened up the approach considerably and put the aircraft high relative to the north arrival fix, which was Tulua. To the runway change the FO responded, "Yeah, we'll have to scramble to get down. We can do it." The crew apparently felt some pressure to expedite the arrival following the long delay in Miami. Now things began to unravel.

The captain responded to Approach, "Uh yes, sir, we'll need a lower altitude right away, though." The controller then stated, "Roger. American 965 is cleared to VOR DME approach Runway One-Niner. Rozo Number One arrival. Report Tulua VOR." The captain replied, "Cleared the VOR DME to one-nine, Rozo One arrival. Will report the VOR. Thank you, sir." The controller stated, "Report, uh, Tulua VOR." The captain replied, "Report Tulua."

At 9:37:29 the pilots asked Approach, "Can American Airlines, uh, 965 go direct to Rozo and then do the Rozo arrival, sir?" The controller replied, "Affirmative. Take the Rozo One and Runway One-Niner, the wind is calm." The captain responded, "All right, Rozo, the Rozo One to one-nine, thank you, American 965." The controller: "Report Tulua and twenty-one miles, ah, five thousand feet." The captain responded, "OK, report Tulua twenty-one miles and five thousand feet, American 965."

At 9:37, after passing Tulua VOR during the descent, the airplane turned to the left of the cleared course and flew on an easterly heading for approximately one minute. The Boeing then turned right, while still descending. At 9:38:49 the first officer asked, "Uh, where are we?" and again, nine seconds later, asked, "Where we headed?" The captain responded, "I don't know...what happened here?" At 9:39:29 Morse code similar to the letters ULQ — Tulua VOR's identifier — was recorded.

At 9:40:01, the captain asked Approach, "And American, uh, thirty-eight miles north of Cali, and you want us to go Tulua and then do the Rozo, uh, to, uh, the runway, right to Runway One-Nine?" The controller answered, "You can [unintelligible word] landed, Runway One-Niner, you can use Runway One-Niner. What is altitude and DME from Cali?" The flight responded, "OK, we're thirty-seven DME at ten thousand feet." The controller stated at 9:40:25, "Roger. Report five thousand and, uh, final to one, one, Runway One-Niner."

The CVR recorded the crew's difficulties in programming the FMS. At 9:40:40 the captain stated, "It's that [expletive] Tulua I'm not getting for some reason. See, I can't get. OK now, no. Tulua's [expletive] up." At 9:40:49 the captain said, "But I can put it in the box if you want it." The FO replied, "I don't want Tulua. Let's just go to the extended centerline of, uh...." The captain stated, "Which is Rozo." At 9:40:56 the captain stated, "Why don't you just go direct to Rozo then, all right?" The FO replied, "OK, let's...." The captain said, "I'm goin' to put that over to you." The first officer replied, "Get some altimeters. We're out of, uh, ten now."

At 9:41:02 Cali Approach requested the flight's altitude. The flight replied, "965, nine thousand feet." The controller then asked at 9:41:10, "Roger, distance now?" There was no response. At 9:41:15, the ground proximity warning system (GPWS) sounded, "Terrain, terrain, whoop, whoop." The captain stated, "Oh [expletive]," and a sound similar to the autopilot disconnect warning began. The captain said, "Pull up, baby." The GPWS continued, "Pull up, whoop, whoop, pull up." The crew added full power and raised the nose until the stick shaker stall warning. The nose was lowered slightly, the stick shaker stopped, nose-up attitude then increased, and the stick shaker reengaged. The speed brakes that were extended during descent were not retracted.

At 9:42 p.m. AA965 crashed into a mountain in visual meteorological conditions near the town of Buga, 33 miles northeast of the Cali VOR (CLO) and 28 miles north of the approach end of Runway 19. The airplane struck El Deluvio Mountain at about 8,900 feet above mean sea level (msl), near the 9,000-foot summit. Of the 155 passengers, two flight crewmembers, and six cabin crewmembers on board, four passengers survived the accident.

Crew information

The 57-year-old captain and 39-year-old FO had more than 13,000 and 5,800 flight hours, respectively. Both had more than 2,200 hours in the Boeing 757. Including flights into Cali on December 9 and December 14, 1995, the captain had flown into Cali 13 times before the accident flight. The captain completed annual line checks on November 9, 1995 (domestic), and on December 9, 1995 (international). He had been employed by American since 1969 and was described by colleagues as respected for his professional skills, including his skill in communicating with crewmembers and passengers. The internationally qualified FO had never been to Cali but had flown to other destinations in South America.

Airplane information

The Boeing 757-223 was operated by AA since it was new on August 27, 1991. The aircraft was equipped with an FMS that included a worldwide navigation database that contained radio frequencies, with latitude and longitude coordinates of relevant navigation aids and airports appropriate for Boeing 757 operations. The database also included 757 performance data that governed autothrottle and autopilot functions. The FMS monitored the system and engine status and displayed the information, as well as airplane attitude, flight path, navigation, and other information, through cathode ray tube (CRT) displays.

The 757 was equipped with speed brakes, or overwing control surfaces, operated by a control lever located in the center control console. Speed-brake operation during flight is not automatic. Because of the limited airframe feedback from the speed brakes, the crew could be unaware that the brakes were extended.

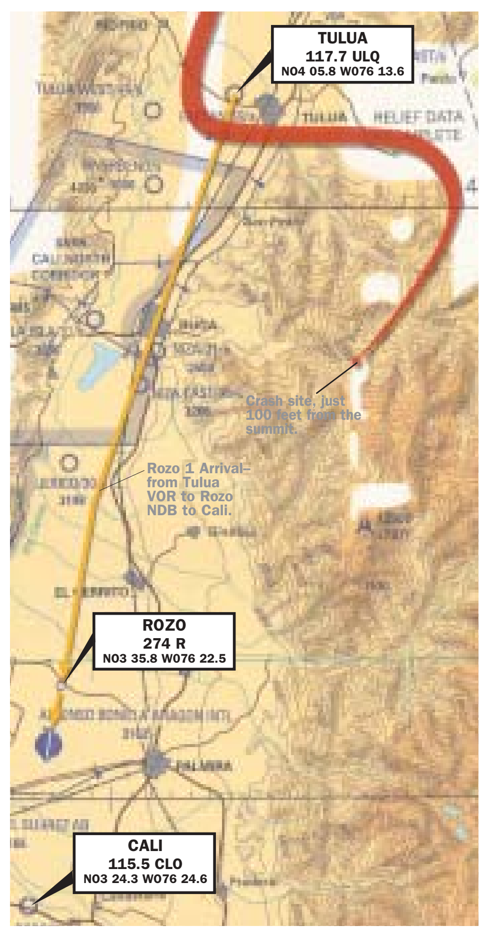
The GPWS escape maneuver in the flight operations manual directed that the aircraft be configured to attain maximum climb performance to avoid obstacles ahead. Pilot actions included the disengagement of autopilot and autothrottle systems as well as selecting maximum power and attaining best angle of climb.

American Airlines training

A two-day ground school for new pilots flying international routes and annual training are required and provided by American. A special ground school with emphasis on crew resource management was given to all crewmembers qualifying for operations into Latin America. This went beyond the FAR Part 121 requirement.

All pilots were given a reference guide devoted exclusively to the hazards and demands of flying into Latin America. Some of the topics should resonate with GA pilots: "Warning! Arrivals May Be Hazardous"; "They'll [ATC] Forget About You"; "When Knowing Where You Are is Critical"; and "How to Determine Terrain Altitude." The introduction to the reference guide is profound: "Flights

Confusion over the Rozo 1 Arrival and a second NDB in Colombia with the identifier of R apparently caused the crew to misprogram the flight management system. As a result of the error, the airplane turned toward the east—toward Romeo NDB, also identified as R. In attempting to turn back toward the proper course, the airliner struck a 9,000-foot-tall mountain. As a result of the accident, the identifier for Rozo has been changed.



into Latin America can be more challenging and far more dangerous than domestic flying or the highly structured North Atlantic/European operation. Some Latin American destinations have multiple hazards to air operations, and ATC facilities may provide little assistance in avoiding them. En route and terminal radar coverage may be limited or nonexistent. Mountains, larger and more extensive than anything you've probably ever seen, will loom up around you during descent and approach, and during departure. Communications, navigation, weather problems, and an air traffic control philosophy peculiar to Latin America may conspire with disastrous consequences. There are many hazards in this environment, but the greatest danger is pilot complacency. From 1979 through 1989, 44 major accidents involving large commercial aircraft occurred in South America. Of these 44 accidents, 34 were attributable to pilot error, or were pilot-preventable with proper situational awareness."

Analysis

There was no evidence of malfunction in the airplane, its components, or its systems. Weather was not a factor, both crewmembers were properly qualified, and all navigation aids were functioning properly. After contacting Cali Approach, the crew accepted the controller's offer to land on Runway 19 at Cali, rather than Runway 1 that was flight planned into the FMS. After receiving clearance to descend to 5,000 feet msl, the crew made no attempt to terminate the descent, despite deviation from the published approach course, which is in a valley between two mountain ridges. Less than one minute prior to impact, after the crew recognized that the airplane had deviated from the prescribed inbound course, they attempted to turn back to the "extended centerline" of the runway, which as the captain stated, "is Rozo." The accident occurred following the turn back to the right from a track to the east of the prescribed course and an attempt to fly in a southwesterly heading to directly intercept the extended runway centerline.

Why did such an experienced crew become confused? There was clearly a misunderstanding with the controller, whose native language was Spanish, but who was speaking English. The CVR transcript when written is much less ambiguous than listening to poor-quality radio transmissions in the cockpit.

Experts now believe that the Rozo 1 Arrival was improperly named because Rozo was the end point of the arrival procedure. In the United States and Europe, arrival routes are named after their entry fixes. Applying that convention, this arrival should have been called the Tulua 1 arrival. When the captain stated, "Can American Airlines 965 go direct to Rozo and then do the Rozo arrival, sir?" it made no sense that the flight

Back to Cali

In late January of 2001, I retraced from a Boeing 757 jump sea, the ill-fated flight from Miami to Cali. The crew and I reviewed the accident, and they explained the technical and procedural changes that had taken place. Amazingly, even today, in this world of database-driven systems, there are still dozens of navaids that are identified by a single letter. Requesting R from the FMS brought up two pages, and the only way to tell them apart was by latitude and longitude. When pressed to make a quick choice, this could be confusing. It seems like ICAO, the international governing body for aviation, and the various member countries could address this. Worldwide databases have been in widespread use for at least a decade and are here to stay.

My crew performed a thorough brief before leaving cruise altitude for the approach and discussed how contingencies, including an engine-out, were to be handled. One very noticeable difference between then and now is that one crewmember stays on "raw data," or ground-based navaids, while the other uses the "magic," as the automation is referred to. This is an excellent cross-check and clearly would have prevented the accident. There is wisdom here for GA pilots. If ground-based navaids are available, use them to back up the magic boxes. It may be old-fashioned, but it just might keep you out of the rough.

Flying into a South American valley at night is a no-jive situation. The minimum off-route altitude in all quadrants around Cali is 23,000 feet. The valley into Cali is deceptively wide (about 10 miles), and we could see the city lights from 30 miles out. At a speed of 250 knots, though, it would literally take only a minute to be at the high peaks to the east. We proceeded directly to Tulua VOR and flew the arrival. The winds on this clear evening indicated a landing to the north. We would overfly the airport, make a course reversal south of the airport, intercept the ILS, and land. I asked the captain about a visual approach since the weather was so good, but he stated that even with perfect conditions, they don't do visuals at night. Good procedure.

Former President Ronald Reagan said to "trust but verify," which is great advice to all pilots all the time, but doubly critical south of the border. Although the controller gave us the altimeter setting, the captain double-checked it with datalink hard copy from AA dispatch just to be sure. As noted in the analysis, one must listen very carefully to understand the controllers. Some of the backstops that we take for granted in the United States do not exist elsewhere. There is radar at Cali now, but if the pilot asks for an altitude below the minimum safe altiwould go to the final approach fix (Rozo) to fly outbound back to Tulua, which was the entry point for the arrival. The controller compounded the error by stating, “Affirmative, direct Rozo One and then runway one niner, the winds calm.” The captain replied, “All right, Rozo, the Rozo One to one-nine, thank you, American 965.” The controller stated, “Affirmative, report Tulua and twenty-one miles, 5,000 feet.” The captain acknowledged, “OK report Tulua, twenty-one miles at 5,000 feet, American 965.” Both parties acknowledged these transmissions but neither understood. English is the language of aviation, but it is practiced with varying degrees of proficiency. Another layer in the safety net was missing when the controller was unable to distinguish an inappropriate readback.

The crew likely had trouble entering the Rozo arrival because of a confusing situation that existed in the FMS database. They selected a direct course to the identifier R, in the mistaken belief that R was Rozo, as it was identified on the approach chart. Instead, they had selected the Romeo NDB, located near Bogota, some 132 miles east-northeast of Cali. Both Rozo and Romeo had the same radio frequency, 274 kHz, and the same identifier R provided in Morse code on that frequency. Not only was the identifier identical, but also there was a methodology in the database that might confuse more than a few pilots. When requesting navaid information from the database, the navaid identifier is used — but not always. The letter R was the default value for the Romeo NDB. Since Bogota city and airport are larger than Cali, the larger airports are entered sequentially at the beginning of the database to satisfy the most users. To retrieve the Rozo NDB, the letters R-O-Z-O would need to be entered into the FMS since that was the FMS identifier for Rozo. The R is shown as the identifier for Rozo on the 1995 approach chart. The name of the NDB and its identifier were changed after the accident.

The crew was never able to resolve the ambiguity, and neither pilot concluded that continued descent was becoming lethal. Today, the Boeing 757 FMSs are less likely to leave pilots completely stranded and can retain some intermediate fixes. In the accident FMS, once direct Romeo was entered, all other fixes disappeared from the moving map.

Overreliance on the FMS and electronic map displays left the crew with a low level of situational awareness. The electronic maps failed to show critical aspects of the approach, and the crew had not briefed using the paper charts. Pilots of glass-cockpit aircraft can select an instrument approach procedure stored in the FMS. They can then direct the FMS to fly the approach, manually fly it with FMS guidance, or fly by reference to ground-based navaids and not use the FMS at all. Retrieving the available approaches and selecting a procedure requires multiple keystrokes.

tude or en route altitude, frequently ATC will grant it, assuming that the pilot knows where he is and will maintain terrain clearance. Y'all be careful down there.

Some of the hardware on the 757 has changed from five years ago. Enhanced ground proximity warning systems (EGPWS) now look forward rather than straight down and, depending on the circumstances, will provide 20 to 40 seconds' warning rather than the nine seconds that the crew of AA965 had. One thing that has not changed is that there is still no speed brake annunciation unless the flaps are extended. The new procedure is to keep a hand on the lever while the speed brakes are in use. The multifunction displays (MFDs) now have a graphical depiction of the terrain around the airport, similar to what is now available on MFDs in GA. Off to the east we could clearly see the red shading that showed high mountains.

In addition to electronic terrain depiction, Jeppesen now graphically portrays the high ground around airports on paper approach charts. That might have alerted the crew that there was no future in flying to the east.

Perhaps the most important change that professional crews have made is to recognize that the magic can increase the workload significantly in some circumstances. American now teaches the pilots "to go down in levels of automation" as flight conditions change from the original plan. If the FMS is flying the aircraft and everything is programmed appropriately, life is good. Leave it alone but verify. As soon as ATC changes something that requires reprogramming, it's time to assess whether it's worth trying to salvage the automation. Frequently, it's not. Ditch the magic and fly the airplane — that's what pilots are supposed to do. It has been my experience with GA FMSs — and was confirmed in observation of the professional crews — that frequently the magic does something that the pilot doesn't expect. It usually isn't a big deal, but it confirms that these units are complex. They will nibble and occasionally bite, even when you think you've mastered the box.

There's a message for the avionics designers in both GA and heavy iron. They need to spend more time understanding how their equipment is used in the real world of turbulence, distractions from ATC, last-minute route changes, weather, pilot fatigue, and big mountains at night. Just because a microprocessor is capable of doing something doesn't mean that another layer of complexity should be added to satisfy the gadget freaks among us or someone's "great" marketing idea to make the unit more "capable."

Simpler is safer, and if a massive amount of training and button pushing is required to operate the magic, then maybe we need a smarter magician. The lessons of Cali for pilots, avionics designers, ATC, and regulators alike are written in blood. *— BL*

According to the accident report, "Human factors researchers have written extensively on the potential risks that have been introduced by the automation capabilities of glass-cockpit aircraft. Among those identified are: overreliance on automation; shifting workload by increasing it during periods of already high workload and decreasing it during periods of already low workload; being 'clumsy' or difficult to use; being opaque or difficult to understand, and requiring excessive experience to gain proficiency in its use. One researcher has observed pilots on numerous occasions, even ones experienced in the systems, asking, 'What's it doing now?' in reference to an action of the FMS that they could neither explain nor understand."

Had the crew retracted the speed brakes as soon as the GPWS sounded, the Boeing might have cleared the ridge, but that is speculative and the results of simulator tests after the accident were inconclusive. Most jet aircraft at the time did not have automatic speed brake retraction upon application of power. Boeing's flight manual recommended that the captain's hand remain on the speed-brake lever while deployed in flight, as a reminder. AA's procedure did not contain that caution. Boeing stated that retracting speed brakes during a full-power go-around at low altitude could result in an unwanted pitch up, which was a primary reason it elected not to use automatic retraction.

Changing the arrival when there is little time to change will lead to difficulty in any aircraft. The faster and more complex the machine, the more quickly things can go awry. The crew fell behind the airplane simply because there was too much to do in the time available. According to the accident report the crew needed to:

- Find the approach chart for Runway 19 and review the relevant information such as radio frequencies, headings, altitudes, distances, and missed approach procedures.
- Program the flight management system for the new approach and compare information on the VOR DME Runway 19 approach chart with approach information displayed in the FMS.
- Recalculate airspeeds, altitudes, configurations, and other airplane control factors for selected points on the approach.
- Increase the descent rate and monitor the aircraft, while coordinating with ATC.

Complacency is the greatest danger to experienced pilots. This was a routine operation in good weather to an airport where the captain had been many times before. The FO never challenged the decision to continue even after the aircraft turned off course. Cali was not on American's "hit list" of hazardous airports because it is not especially high (3,162 feet msl) and the valley is relatively wide. Human nature is such that once a decision is made, it is much harder to change direction even when there is conflicting information. It appears that the captain never reconsidered his course even though it was obvious that he was lost.

Probable cause

Aeronautica Civil determined that the probable causes of this accident were:

- The crew's failure to adequately plan and execute the approach to Runway 19 at Cali and its inadequate use of automation.
- Failure of the crew to discontinue the approach into Cali, despite numerous cues alerting them of the inadvisability of continuing the approach.
- The lack of situational awareness of the crew regarding vertical navigation, proximity to terrain, and the relative location of critical radio aids.
- Failure of the crew to revert to basic radio navigation at the time when the FMS-assisted navigation became confusing and demanded an excessive workload in a critical phase of the flight.

Contributing factors

Contributing to the accident were:

- The crew's ongoing efforts to expedite the approach and landing in order to avoid potential delays.
- The crew's execution of the GPWS escape maneuver while the speed brakes remained deployed.
- FMS logic that dropped all intermediate fixes from the display(s) in the event of execution of a direct routing.
- FMS-generated navigational information that used a different naming convention from that published in navigational charts.

Three more contributing factors might be added for your consideration:

- The controller's failure to catch an improper readback.
- The database naming convention that allowed duplications.
- Complex FMS programming.

How do pilots get into such situations? Ego and successful past experience condition us to perform at or perhaps beyond our capabilities to expedite a departure or arrival. It's worked every time before, so why not now? Pilots are confident, take-charge individuals, and we seldom pass up a chance to perform. How many times have you been in a hurry-up situation and managed to pull it out? We've all been there. The challenge is knowing when to say when.

Future Flight
Beaming Up the Weather
Today's services portend tomorrow's resources

By Thomas A. Horne
(From AOPA Pilot*, March 2000.)*

Of all the future technologies that await general aviation, the uplinking of textual and graphical weather could provide the greatest safety benefits. Think of it: Near-real-time Doppler radar imagery, contouring in six intensity levels, free of the attenuation effects that dangerously distort airborne weather radar returns. The projected locations of any storm cells for the next hour. Fast plotting of lightning-strike locations from the nation's ground-based lightning-detection network without the misleading, radial-spread signatures that characterize today's on-board lightning-detection instruments. The latest METARs and TAFs, called up on your display screen anytime you desire. Weather depiction charts. Satellite views. Graphically depicted airmets and sigmets, popping up on your navigation display as they are posted. Same thing with areas of forecast or reported icing and turbulence. Other late-breaking news from flight service stations and air traffic control, such as restricted areas that just went hot, can also be uplinked and plotted on your display. And more—such as e-mail and telephone service.

To make all of these cockpit wonders a reality, three elements must be in place: weather information providers, methods for uplinking data, and certified cockpit displays. Some of these elements are already up and running.

Weather service providers

Weather providers, for example, have been in business for years. The big players in this field include firms such as DTN/Kavouras, Litton/WSI, Universal Weather, Harris Corporation, Unisys, and, of course, the National Weather Service's aviation weather products, gathered and produced by the NWS's Aviation Weather Center. The text and graphics products put out by these outfits are accessible through the Internet and provide a wide array of products—for a fee. Except for the government's DUATs and NWS-generated weather products, that is. To get an idea of what the latest government products look like, check out the Aviation Digital Data Service (ADDS) Web site (http://adds.awckc.noaa.gov/projects/adds/index.html).

The number and quality of the weather products are changing at a very rapid pace. One recently introduced product shows the areas and vertical extents of any areas of suspected icing conditions, and identifies whether or not the icing ought to be of the very hazardous, large-droplet type.

Different suppliers have come to take on various personality types. DTN/Kavouras seems to be perceived as the megasource of the electronically represented weather world. Litton/WSI's aura is interpreted by some as most heavily influenced by meteorologists. Universal is known as having a big-iron, kerosene-burning personality. The NWS/ADDS's products, being free, are undoubtedly the best value for the money.

Regardless of these current products and perceptions, it's a safe bet that all will undergo significant change as the various companies and

Arnav's multifunction display, like so many others, can show radar returns and airspace boundaries relevant to ground track (left), METARs (top right), and weather depiction charts (lower right).

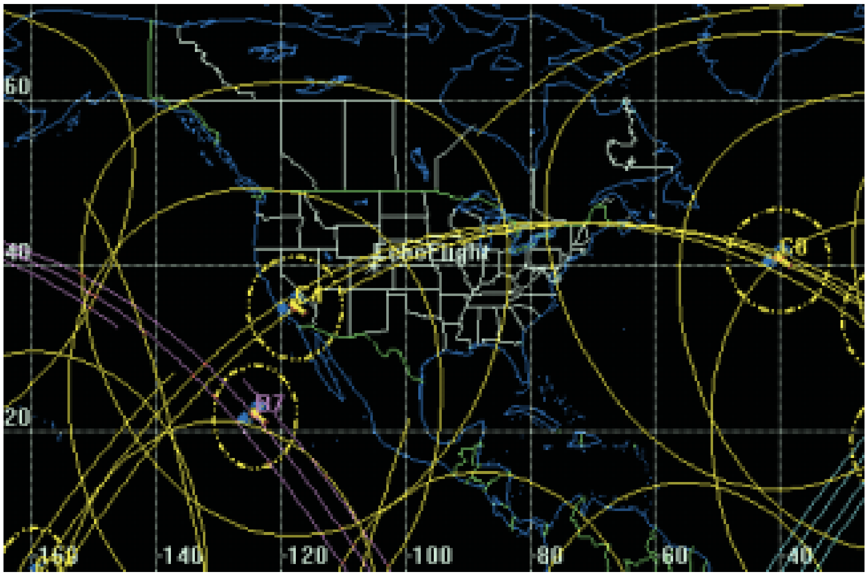
organizations respond to pilot feedback and market pressures. Expect more and better features in the future, though the ones that are available now are sufficiently impressive.

Datalink issues

As good as the weather graphics might be, they're of no use unless the signals carrying them can make the trip to the cockpit. This is where data linking enters the picture.

We have discussed data linking primarily in terms of the up linking and down linking of air traffic information (see "Future Flight: Links to Tomorrow," February 2001 *Pilot*). Some of the same issues confront the weather delivery systems of the future. In particular, the problems of bandwidth and coverage are major factors—and hurdles to overcome—in the leap to future in-cockpit weather technology. That's because weather graphics make for huge file sizes, and strategies for getting them to the cockpit are still evolving.

The bandwidth of a given frequency can be conceptualized using a conduit or water-pipe analogy. The bigger the diameter of the pipe (bandwidth), the more water (weather and other



EchoFlight's Orbcomm satellite coverage (above) is huge. Ground-based antennas have altitude limitations, but networks like Arnav's (below) are covering more and more airspace.

data, such as traffic information) you can move. Narrow the pipe, and the flow of water is restricted. Similarly, if you try to force too much data over too narrow a bandwidth, some of the transmitted information won't make it to or from the cockpit. Instead, pilots might receive incomplete information, or no datasets at all. In the case of traffic information, some critical targets may not show up on cockpit displays. In the case of weather graphics—which can take up a lot of bits and bytes—a file simply may not be able to squeeze through a too-narrow pipe…er, bandwidth.

Bandwidth is sometimes expressed as a function of how fast data transmissions take place—sort of the way we speak of modem speeds. Today, the available datalink bandwidths range from 2,400 baud per second (bps) to 31.5 kbps.

Generally speaking, the lower the frequency the less data you can move; the advantages, however, include longer-range transmissions. The higher the frequency, the more data you can transmit, but range is somewhat less—and the power required to make those transmissions goes up. Of course, it all depends on what you define as "data." Text messages, such as METARs or TAFs, take up little bandwidth and move easily. But a Nexrad image of the Northwest United States? That's another matter.

Airplanes also have to be in a position to receive uplinked weather, too. They have to be in the line of sight of ground-based antennas and within the coverage areas of any satellites being used for weather—or any other—uplinks.

Satellite or terrestrially based?

When it comes to coverage, satellites win big over ground antennas. From their perches in orbit, satellite signals can cover entire continents and reach airplanes at any altitude—even on the ground, and even though they may use higher-frequency transmissions. Ground antennas operate on a line-of-sight basis, so their signals radiate upward in a cone-shaped pattern. The problem here is that airplanes at too low an altitude, or flying around high terrain, may not be able to receive signals from a ground antenna, in much the same fashion as they might not receive a VOR signal.

To correct that problem, service providers using ground antennas have to install plenty of them in order for coverage levels to be acceptable. And indeed, all of these providers are now in the process of building up their antenna networks and expanding their coverage areas.

Today's delivery systems

Currently, there are several datalink providers who provide weather information uplinks. Some operate on a broadcast basis, meaning that information is broadcast on a certain schedule, and pilots simply receive information—based on their position. Request/reply service is self explanatory: You ask for certain information, and the system sends it back to your cockpit display. In the future, various levels of service may be offered: a free, text-based service from the FAA as a basic service; and increasingly diverse sets of information offered with higher, fee-bearing tiers of service. Think of it as cable TV today—you have a basic service level, and then you have the extra service packages that charge you for one or more premium channels such as HBO or Showtime.

EchoFlight uses the Orbcomm network of Orbital Sciences satellites to send weather, provide position reports, and send and receive e-mail. There is worldwide coverage—except for the polar areas—at all altitudes. Bandwidth is 4,800 bps, and transmissions are made using bursts of compressed data. This is a request/reply service that lets you ask for weather images anywhere in the United States. EchoFlight currently uses its StratoCheetah system as a display, which is essentially a laptop computer or other portable display that you plug into the cockpit. However, a recent agreement with Garmin will let users put EchoFlight's imagery on a Garmin 430 or 530 panel-mounted color display. The service costs $25 per month, and each image can cost you between 50 cents and $1 per view. Call 888/948-9657 for further information, or see the Web sites (www.echoflight.com and www.orbcomm.com).

Arnav currently uses a ground-based VHF broadcast system for its WxLink services. It won a five-year FAA contract to provide flight information service (FIS) to pilots. Under this scheme, basic text information is free. Extra services such as weather graphics are provided for a fee. Coverage in the United States is growing rapidly, and national coverage above 10,000 feet should be available by the end of 2000. Bandwidth is 2,400 or 9,600 bps, and unlimited service costs $595 per year. For the latest information, call 253/848-6060 or check out www.arnav.com.

NavRadio is another ground-based VHF broadcast system. It now has regional coverage but plans to offer national coverage above 5,000 feet by 2002. Bandwidth is 31.5 kbps, and a subscription costs $400 per year. Honeywell recently purchased NavRadio, so click on www.navradio.com for the latest information on prices and services.

ARINC, a well-established company with strong airline ties, is another ground-based VHF provider. Worldwide coverage above 10,000 feet is available today. Bandwidth is 2,400 bps, but an upgrade to 31.5 kbps is planned for 2002. This is a request/reply service that costs $100 per month. Call 410/266-4000 for more information, or check out www.arinc.com.

AirCell, the provider of airborne telephone services, provides both voice and data services. Now, coverages are regional in scope, but the company says that national coverage above 5,000 feet will be available by mid-2000. This is a request/reply service that now operates at 9,600 bps and costs $25 per month and $1.75 per minute of access. Call 303/379-0200, or click on www.aircell.com for more information.

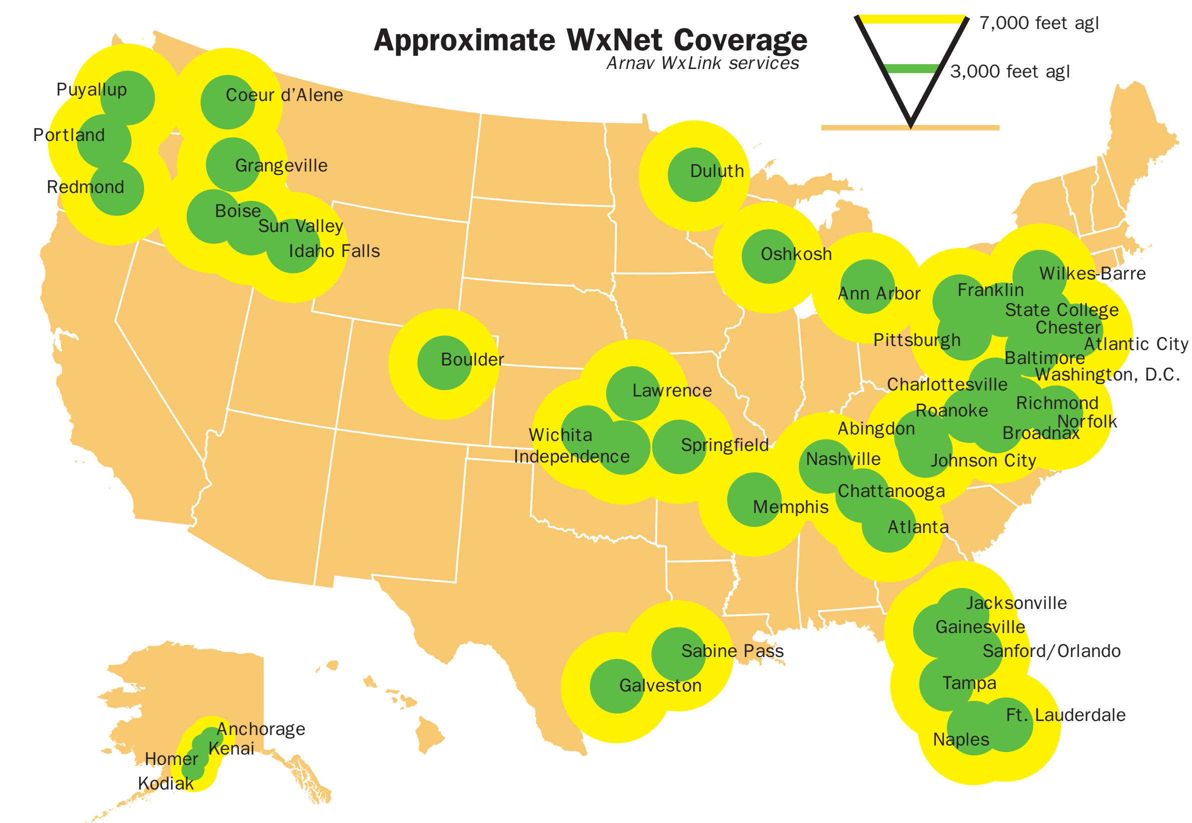
Iridium, like EchoFlight, uses low-earth-orbit satellites to provide phone and data service—both for aviation and the nonflying public. Coverage is worldwide, service is request/reply, and bandwidth is 2,400 bps. Service now costs $50 per month and $1.75 per minute. Iridium's recent financial difficulties may have upset its plans for the future, but call 888/474-3486, or click on www.iridium.com for the latest.

Displays

The number, size, quality, and features of the displays offered today are bound to go up—and fast. Call them flight situation displays, multifunction displays, or control display units, but the current crop gives a tantalizing look at what's to come, and in vivid color. Most can combine navigation (such as moving maps, including VFR and IFR charting), traffic, and terrain display information—not just weather. Many will be able to accept either satellite- or terrestrially based datalinks. Here are today's players in the large-display game. The prices mentioned are subject to change, and may not include the cost of antennas, installation fees, and certainly do not include the costs levied by the service providers.

Approximate WxNet Coverage

Arnav WxLink services



The UPS Aviation Technologies Apollo MX20 is a $5,995 unit that is currently available and has already been used in ADS-B trials depicting uplinked traffic information.

The Archangel CDS is a $9,995 display that, like the rest listed here, can show lightning-detection returns, IFR en route charts, and TCAD information.

The Arnav MFD 5200 ($7,995) and ICDS 2000 ($12,995—the ICDS stands for integrated cockpit display system) have top-of-the-line features like terrain warnings, IFR approach displays, BFGoodrich Skywatch, TCAD, and TCAS. All this, and uplinked weather, too. The 5200 is certified and now offered in the Cirrus SR20.

The $9,995 Avidyne FSD FlightMax 440 is another full-featured, certified situational display that can even make your existing monochrome radar yield color imagery. A growth version, the FlightMax 740, should even be able to show engine information and provide engine-trend monitoring.

The Honeywell Bendix/King KMD 150, 550, and 850 ($3,995, $4,795, and $6,250, respectively) also offer a full set of display features. The 150's price reflects its lack of an integral GPS receiver—but you probably already have one of those.

Changes and improvements to weather products and datalink technology seem to take place at breakneck speed. It's a safe bet that in a matter of weeks more services, different fees—and even new providers—may pop up on the scene. Soon, for example, you might be able to enter a flight plan and request weather products for your route of flight on your home computer over the Internet, then have it uplinked to your airplane's large-screen multifunction display, where it waits to appear after you turn on your master switch.

Future Flight
Links to tomorrow
Swapping data promises a simpler future

By Thomas A. Horne
(From AOPA Pilot, *February 2000.)*

Pilots of the future can look forward to more and better on-board safety equipment, thanks in large part to new services that are just now in the first stages of evaluation. In just a few years, it's very likely that the multiple navigation, weather detection, and traffic avoidance boxes common in many modern airplanes will be replaced by single units capable of combining and displaying all those functions on one screen—and boosting pilot situational awareness by orders of magnitude.

What will enable these information systems of the future? In a word, datalink. What's datalink technology? Simply put, it's a method of digital communication involving ground stations, satellites and aircraft—and between aircraft and other aircraft—using special transceivers. These transceivers are analogous to the modems we use to send and receive data through land lines.

With datalinks, aircraft can 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 uplinked 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, as evidenced by Echo Flight Inc.'s StratoCheetah. Its current satellite up- and downlinking services offer two-way messaging and ground-based weather radar imagery.

The goal: ADS-B

ADS-B stands for *Automatic Dependent Surveillance-Broadcast*. Under this scheme, aircraft with GPS receivers (although RNAV equipment will work, too) and special two-way digital datalink equipment (the system is "dependent" on GPS position information) automatically (that's the "automatic" part) transmit (that's the "broadcast" part) their positions, altitudes, groundspeeds, tracks, and other information (such as aircraft type and/or N-number) to other aircraft equipped with datalink equipment—and to ground-based antennas connected to ATC.

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 so as to avoid the chance of midair collisions. For more immediate traffic threats in heavily traveled airspace, ADS-B can work equally well, although ATC could issue traffic advisories, or TCAS-equipped airplanes could follow any traffic or resolution advisories issued by their own on-board equipment. For that matter, ADS-B could also be configured to give the same traffic and resolution advisories that TCAS II currently does.

The whole idea behind ADS-B is to expand system capacity and enable the Free Flight concept. 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 work load, 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. ADS-B has particular relevance to transoceanic traffic, where escalating numbers of airliners are held to 60-nm in-trail separation. With ADS-B, that distance could be narrowed, allowing more flights per route.

With the high closing speeds experienced by jets and other fast-moving, conflicting traffic, ADS-B's ability to see at long ranges should, in theory, mean much more advance warning of a potential midair collision.

ADS-B relies on data-sharing by everybody in the airspace system—even airport ground vehicles. GPS satellites are the crux of the system, because they provide position data. Traffic advisories can be uplinked from ground stations to cockpit displays.

Cockpit display of traffic information (CDTI) shows uplinked targets from ATC radar (above).
Blue symbols indicate conflicting traffic location, relative altitude, and flight paths. UPSAT's MX20 used in the Capstone project has a terrain and navaid database to boost situational awareness (right).

First things first

All this warm and fuzzy talk of an interlinked, omniscient traffic-avoidance and information system is nice, but first something very important has to be hashed out—what system and frequency will the datalinks use?

Some advocate using 1090 MHz, the same frequency used by Mode S transponders. The airlines are especially enamored of Mode S, because their fleets already have it as part of their TCAS systems. To be players in a Mode S world, general aviation aircraft would have to be upgraded with datalink-capable Mode S transponders (there's only one out there now—the $3,500 Honeywell/Bendix-King KT-73) and the necessary displays and controls, which could bump the ultimate cost to approximately $6,000 or more.

On the downside, Mode S wasn't really designed to pass huge amounts of data. Update rates of changing traffic situations may drop to critically slow speeds in areas of dense traffic. Also, Mode S doesn't have a sufficiently wide bandwidth to permit the exchange of weather graphics, text data (e.g. clearances, weather reports) and display traffic. Mode S, you see, already operates on a very crowded frequency—the one that supports TCAS and ground-based surveillance radars. With all those radar sweeps and TCAS interrogations and replies, it could be difficult to use the frequency to display all traffic.

Other frequency options are in the DME spectrum, and the equipment to use these frequencies is called the Universal Access Transceiver (UAT). UAT, developed by the Mitre Corporation's Center for Advanced Aviation System Development (CAASD), runs in the 966- to 981-MHz frequency range, and can exchange lots of data at a faster clip than Mode S. Experts guess that a UAT transceiver might cost around $2,000 (excluding display), so its lower cost and higher capacity make UAT the current favorite choice of most general aviation advocates.

The other ADS-B frequency option is in a very narrow (0.25 MHz) VHF bandwidth. It's called VDL-4, the "VDL" standing for VHF Data Link. Its strength is its ability to see far (about 300 nm), but it needs multiple frequencies and multiple receivers to display enough traffic to be optimally useful. In testimony to its ability to carry a big dataload, UAT has been able to display 700 targets at a time—as demonstrated in a test conducted in the Los Angeles area. With VDL, only 200 or so can be shown simultaneously. After that, targets may drop off the screen. If those targets pose an immediate threat, this bandwidth limitation could obviously have serious safety implications.

VDL research began some 10 years ago in Sweden, and it remains the ADS-B vehicle of choice among the European nations.

Traffic Information Services-Broadcast (TIS-B, for short) is another method of providing traffic—and weather—information. TIS-B can operate in a wide range of frequencies, making it compatible with both UAT and VHF equipment. With TIS-B, pilots would see the same traffic information that controllers do. That's good, because there's the promise of better coordination of traffic information between pilot and controller. The drawback? Detection ranges are limited to the radius of the ground-based surveillance radars being used. Also, the system will work only where ground-based radars exist, making it comparatively useless on transoceanic routes.

Unfortunately, the choice of equipment, systems, and frequencies is a political as well as technological issue. Obviously, all aircraft must use the same datalink equipment if the system is to work worldwide. For that to happen, there must be an intellectual as well as a political reckoning. Right now, that consensus seems a long way off. Mode S, UAT, and VDL advocates don't seem to be conceding much at this time.

Testing, testing

Under the FAA's Safe Flight 21 program, ADS-B and its candidate systems and frequencies have been undergoing a series of operational tests. These tests include the uplinking not just of traffic information, but also of ground-based Doppler and other weather radar imagery, and text messaging. At the same time, terrain databases resident in on board GPSs portray the nearby geography.

The first test was conducted with the help of the Cargo Airline Association (CAA), and took place in the Ohio River Valley region. There, four airplanes operated by Airborne Express, FedEx, and UPS successfully used all three frequencies—but the apparent favorite was UAT.

Recently, Safe Flight 21 embarked on the Capstone initiative, a three-year-long program to test ADS-B using TIS-B (with a terrain database) in the Yukon-Kuskokwim Delta region of Alaska. This region was chosen because of its paucity of ATC radars, its hostile terrain, its famously rotten weather, and its communities' dependence on regional commuter and Part 135 flights.

Under Capstone, ground-based traffic and weather radar imagery is beamed up to 132 aircraft fitted out with UPS Aviation Technologies (UPSAT, formerly known as II Morrow) avionics suites. These include UPSAT's Apollo MX-20 display screen, plus a GPS/com, a nav/com radio, and a Mode C transponder.

Under this setup, the MX-20 receives—via TIS-B uplink—the same traffic information seen on ATC radars (be they Mode C, Mode A, or Mode S targets), plus any participating ADS-B targets via a UAT radio. There's an uplink of precipitation echoes, and pilots can watch their progress on a moving map that shows both terrain and navaids.

Capstone's nine big goals foreshadow a rosy future wherein pilots will avoid midair collisions, controlled flight into terrain, and weather-related accidents by observing all these threats on one large screen, such as the MX-20.

There's another big goal, remind AOPA and other general aviation advocates. That's to make sure that the chosen system provides—free of charge—enough basic services so that general aviation owners and pilots will voluntarily equip their aircraft with the new technology. Private vendors would then, as always, be able to provide more enhanced, tailor-made services for those who want to pay for them.

Ground-based weather radar will soon be available on many general aviation cockpit display systems—not just the higher-end FMSs such as this Honeywell GNS-XIs.

State of the art

Thanks to a new generation of avionics from the private sector, some of those threats can be managed today. The former Bendix/King's (now Honeywell's, after those two companies merged) Integrated Hazard Avoidance System models IHAS 8000 and 5000 use the KMD 550 and 850 large multifunction displays, show terrain derived from GPS databases, and are already capable of uplinking Mode S-datalinked traffic information, lightning detection information, and text messages.

The Apollo MX-20 and other moving-map avionics come with terrain databases, so you don't have to be a Capstone participant to have a moving map with terrain highlights.

As for uplinking of weather radar, weather graphics, and textual weather such as METARs, Arnav already licenses weather data and imagery to manufacturers such as Archangel, Eventide, Garmin, Honeywell, and, soon, Avidyne—all for display on those companies' large, easy-to-read display screens. Weather data will be fed to Honeywell's IHAS units via a network of VDL stations that came with the company's purchase of NavRadio last summer.

Echo Flight's StratoCheetah can bring Nexrad radar imagery to the general aviation cockpit via satellite. And let's not forget the scads of lightning-detection units and airborne weather radars that have been available to general aviation for decades.

As for traffic avoidance, Ryan's TCAD, BFGoodrich's Skywatch and TCAS I, and TCAS IIs built by all the major avionics manufacturers also have given good service and had enhanced features added over the past few years.

Ground Proximity Warning Systems (GPWSs) are also becoming more popular. Honeywell's Mark VI EGPWS—the E is for "enhanced"—includes voice commands such as "pull up, pull up" when an aircraft flies too low to the ground. Less expensive (about $15,000) GPWS units paint approaching terrain in pixellated, symbolic shades: red for dangerously close terrain, and yellow and green for less threatening elevations.

Parallel worlds?

Given these capabilities that already exist, how will ADS-B make the pilot's job any different or safer? First, there will be more traffic information in the cockpit—although pilots will still be able to "declutter" distant targets to concentrate on closer-in threats. Because GPS information from other targets will contain flight path, altitude, rate of ascent or descent, and next waypoint—even N-number or type of aircraft—it will be easier for pilots of aircraft on conflicting tracks to share evasive maneuvering responsibilities with ATC. Second, the cockpit equipment will be able to cover longer ranges. Third, all information—traffic, weather, terrain—will appear via a single box. So once ADS-B is standardized, pilots will find it easier to go from aircraft to aircraft and from jurisdiction to jurisdiction without having to endure a potentially dangerous learning curve.

Some are more pessimistic about ADS-B, and say that it will be a decade or more, if ever, before the system becomes operational. In the meantime, pilots may wonder what will happen to the weather radar, TCAS, and other collision-avoidance equipment they've just purchased. Will ADS-B make them obsolete overnight? Air traffic controllers fear that the shared separation burden envisioned under the ADS-B scheme will erode their job security and make things more, not less, dangerous.

What's most likely is that ADS-B and traditional cockpit equipment will coexist through a lengthy transition period, and that controllers will still be vital to safety. Those with TCAS, TCAD, and weather radar will still be able to use it in an ADS-B world. In fact, for close-in work, where avoidance distances can be on the order of a mile or less, TCAS, TCAD, and airborne radar can continue to serve as necessary augmentations to ADS-B traffic and weather information services. Controllers? You bet we'll need them. When a dozen flights make a direct GPS "Free Flight" beeline for the same outer marker, we'll need some world-class people to make sure everyone doesn't arrive at the same time, and plays by the rules.

DA40-180
The Gee Meter
Garmin G1000 stars in Diamond DA40-180

By Thomas B. Haines
(From AOPA Pilot, *January 2004)*

A theory: The reason the new all-glass integrated flight deck in the DA40-180 Diamond Star is called the Garmin G1000 is because the average general aviation pilot will say, "Gee!" a thousand times during the demo flight.

Postulation perhaps, but given that many GA pilots have never flown behind even a horizontal situation indicator (HSI), the idea of an affordable all-electronic cockpit in a light airplane is revolutionary.

Actually, Garmin prefers to think of it as evolutionary, given that company founders Gary Burrell and Min Kao (the *Gar* and *Min* in Garmin) have envisioned the G1000 since before they produced their first product in 1989. From the beginning, Garmin planned that components of the GNS 430 and 530 first developed in the mid-1990s would grow into an integrated cockpit system. Now, with thousands of units delivered and many thousands of hours of flight time, these components bring a level of maturity to the new G1000 flight deck.

Diamond Aircraft, as innovative in its own right as Garmin, jumped at the chance to be the first to offer this new technology. The G1000, with its two 10.4-inch high-resolution displays, further expands the model offerings from Diamond. The airframer builds multiple versions of its two-place aircraft, from motorglider to military trainer. The four-place DA40-180 comes with conventional instruments and either Honeywell Bendix/King or Garmin avionics. Or you can upgrade to the Avidyne glass cockpit with Garmin avionics. Or finally, there's the latest variant with the G1000 integrated cockpit.

You want to go simple? Diamond recently introduced a lower-cost variant that replaces the 180-horsepower fuel-injected Lycoming IO-360 with a carbureted O-360 and swaps the constant-speed propeller for a fixed-pitch prop. The $10,000 price reduction makes the DA40-180FP a more affordable acquisition for flight schools and lowers ongoing maintenance costs. It also simplifies things for primary flight students.

Base price for DA40-180FP is estimated to be under $175,000. Final pricing will be set before the first one ships this summer. The DA40-180 with conventional instruments and Bendix/King avionics starts at $186,900; a Garmin panel adds $2,000. The G1000-equipped DA40-180 comes in at $224,900. A DA40 with a pair of Avidyne displays and a stack of Garmin avionics costs $228,800. First deliveries of the G1000 models are scheduled for this quarter.

Not much 100LL in your neighborhood? Diamond has delivered more than 30 Stars powered by the Thielert Centurion 1.7 turbocharged engine developing 135 hp. At this point, the diesel version is available only in Europe; Diamond isn't saying whether it will develop a North American version.

Innovation extraordinaire

The latest variant of the DA40-180 is no diamond in the rough. With customer feedback from more than 200 DA40s already delivered, Diamond implemented a number of enhancements to the latest models. Among the improvements is a speed kit that incorporates redesigned main landing gear struts with low-profile tires, fully enclosed main wheel fairings, a new nose landing gear strut fairing, and a low-drag nose wheel fairing. According to John Gauch, Diamond's vice president of sales and marketing, the change adds 2 to 3 knots, giving the Diamond Star a cruise of about 145 knots while burning just nine gallons of 100LL per hour.

The Garmin G1000 PFD (top left) includes the ability to show thumbnails of the moving map and flight-plan route. The MFD stacks engine instruments down the left side. The MFD can be configured to show terrain and terrain warnings (top right). The airport info page (bottom left) includes approach overviews. The MFD shows both traffic and conventional moving-map information (bottom right).

Inside, a new premium interior, an extra $4,900, incorporates more than a dozen upgrades, from concealed rudder cables along the sidewalls to leather seats and side panels, padded glareshield, and additional cup holders and storage compartments throughout. The changes move the DA40's comfortably sized interior from utilitarian to luxurious.

The most significant interior change is in the back. The open ski tube has been replaced by an aft storage area with a hinged door. With the door folded down flat, the compartment can hold two sets of golf bags plus baggage. Fold one or both of the rear seat backs forward, and the compartment can take longer items, such as skis or snowboards. Finally lift up the floor of the main compartment to find storage for the tow-bar and other flat items, such as computer cases or a few quarts of oil.

The air vents in the aft section accommodate the fans cooling the G1000 line-replaceable units (LRUs)—the black boxes—stowed underneath the compartment (more about LRUs in a minute).

With its long fiberglass and carbon fiber wing, unusual forward-opening canopy, and upward-swinging aft door, the DA40 probably looks nothing like most airplanes you've flown. Many say it looks small and kitelike. It isn't. Sit inside and fly it, and any pretense of this being a "toy" airplane is quickly banished. The stick makes it a joy to fly. The controls are well balanced and harmonized, with all flight controls except the rudder actuated by pushrods; the rudder is cable-powered. The seats do not adjust, but the rudder pedals do, giving most pilots both adequate headroom and a comfortable sitting position. The panel is tall. Those of us who are rather height-challenged will do well to use a cushion or at least to climb at something less than the VY of 73 knots indicated airspeed.

The airplane climbs well, given 180 hp and a large cabin—650 to 800 fpm depending on load and conditions. In level flight, it quickly speeds up to a comfortable speed of between 140 and 145 knots, again, depending upon power setting and conditions.

Land it like a Mooney and you'll get pleasing arrivals every time. How's that? Nail the approach speed and don't flare until the airplane is just inches above the surface. Arrive too fast or flare too high and that long wing will float you right down the runway.

Look outside!

Now here's the hard part: Take your eyes off that sexy Garmin display and enjoy Mother Nature's WYSIWYG moving map through the expanse of wraparound plexiglass. Up, down, and all around, visibility out of the Diamond Star is Imax-theater-like. But come an instrument day, you'll appreciate those big Garmin displays with long horizon lines. The extra-long horizon line on the primary flight display (PFD) allows you to catch the slightest straying from straight and level, even out of the corner of your eye.

Garmin built the G1000 to be flexible enough for installation in everything from light singles all the way up to jets. In fact, the Cessna Mustang jet will come with a three-tube G1000 set up: two 10.4-inch PFDs and a 15-inch multifunction display (MFD) in the middle. Diamond chose two 10.4-inch displays—a PFD and an MFD—for the DA40.

Details on how the displays work in a minute, but first it's important to understand that the G1000 is much more than just a couple of big, colorful screens. The G1000 is a system in the true sense of the word. Its many components in the panel and elsewhere in the airplane work together to help the pilot manage loads of information. In addition to the displays, the system consists of an audio panel (or two)—intended to be mounted vertically between the displays, but it can be mounted horizontally. The panel does all of the things you expect an audio panel to do, except in this case all of the sound is digital. A voice synthesizer alerts the pilot to system anomalies and, depending on the setup, can warn of traffic alerts and minimum altitudes, and provide other messages.

Another component may be an alphanumeric keyboard for entering data. The Mustang may get the keyboard; the Diamond does not.

That's it for the pilot interface. Elsewhere in the airplane is a rack of LRUs. The rack can be mounted anywhere. The displays are shallow enough that the rack can be mounted forward of the displays if desired—in the space normally occupied by panel-mount radios. Diamond elected to put the rack under the aft baggage compartment because it needed to move some weight back there for balance purposes. Each of the LRUs is a self-contained component—a nav radio, a com radio, a GPS sensor, a transponder, or an engine control unit. If any component fails, it's a simple matter to pull out the LRU and stick in another one (line-replaceable unit literally means it can be replaced while the airplane is still on the line—without taking it out of service). Every component in the system shares information with every other component through an Ethernet network. Ethernet is a high-speed data bus that basically allows one wire or one bundle of wires to connect all of the devices. It's digital so information can flow in both directions. Chances are your office computer network or that high-speed connection you get at your hotel is Ethernet. It's an industry standard in the computer world.

As a result, there's no need for panel-mount radios or transponders. Because the system is all digital, the remotely mounted radios can be controlled from anywhere.

In fact (here's the cool part), it doesn't even matter what model of airplane you put a display or LRU in. In the future, if you're flying a DA40 and a display goes out, you can land at an avionics shop and technicians there can grab a display off the shelf and stick it in your Diamond. A config.sys file in the airplane tells the display that it's in a Diamond and voilá it's ready to go. Meanwhile, your old display can be repaired, and if a Mustang rolls in with a bad display, your repaired one can go in the jet. Remarkably, even the engine data units (EDUs) are completely interchangeable—turbine or piston. The EDU is what gathers all of the engine data and displays it for the pilot on the MFD. The EDU on your jet goes bad? Borrow one from your Diamond. The G1000 doesn't care.

Fault monitoring in the G1000 tracks any problems and alerts maintenance crews. In flight, the system uses master warning and caution lights to tip off the crew to problems.

The heart of the G1000 is its attitude and heading reference system (AHRS). An AHRS is basically a solid-state gyro system. Conventional spinning gyros have a life of about 500 to 1,000 hours, depending upon whom you ask. Mean

The latest DA40s have an improved baggage compartment. Backseats fold flat, and flat items can be stowed beneath the floor (left). The door in the extreme aft opens to more storage. Control sticks (below) highlight the DA40's cockpit.

time between failures for a solid-state AHRS—about 10,000 hours.

Recognizing that it would take four to five years to develop its own AHRS, Garmin went shopping for technology and found Sequoia Instruments in November 2001. Sequoia had already developed much of the technology for an AHRS. Unlike expensive ring laser gyros costing more than $100,000 in business jets, Sequoia uses three-dimensional GPS, 3-D magnetometry (measurement of changes in the Earth's magnetic field), and 3-D air data information to compute the aircraft's attitude. All three components are combined to compute the attitude, but only two are necessary for determining attitude. If one input fails, the system soldiers on. As a result of the way it computes attitude information, the Garmin AHRS does not need to remain stationary for three minutes during start-up to configure itself. Other systems showing up in light airplanes require you to sit still for three minutes. The Garmin system can figure out where it is and what attitude it is in under about any circumstances. According to Bill Stone, Garmin's avionics product manager, it can be shut down while in flight even during a sustained bank. Turn it on and within 45 seconds it will tell you which way is up. Not even the systems on airliners or business jets can do that, Stone says. Of course, if you're in the clouds at night when that happens, those could be 45 long seconds.

Dual AHRS, which the Mustang is expected to have, could eliminate the need for any conventional instruments. However, to save cost, Diamond elected to use a single AHRS. Its backup is a conventional attitude indicator at top center of the panel, along with a conventional airspeed indicator and altimeter. The AI with its mechanical gyros has a backup battery pack of 28 AA batteries located behind the panel. The batteries will power the AI for 40 minutes after the alternator and ship's battery die. In the event of a display failure, the system automatically reverts to the other display, providing the pilot with everything needed to continue flying safely.

A new speed kit includes smaller tires (right), more tightly enclosed wheels, and streamlined struts.

Show time

The G1000 displays utilize the latest active-matrix (or thin film transistor—TFT) liquid-crystal display technology to bring 16 million colors and extremely wide viewing angles to the cockpit. If you're an IT person, you'll be interested to know that each XGA-quality 1,024-by-768-pixel display is powered by an X-scale microprocessor and features a high-performance graphics accelerator for superior 3-D rendering. Stone said that. Here's what I said when I first saw them: "Gee!"

According to Stone, the displays are purchased from the commercial market, but carry a great deal of customization by Garmin, including Garmin backlighting. They are only 2 inches deep and weigh about 6.5 pounds each.

Think of the PFD as replacing the conventional six-pack of instruments and more. Besides showing attitude and either an HSI or arc navigation display, the screen also depicts airspeed in a tape format with trend lines showing where you will be in a few seconds. Similarly, altitude and vertical speed are shown via tapes down the right side of the screen, also with trend lines.

The pilot can choose to show a thumbnail-size moving map elsewhere on the screen and/or a window showing flight-plan waypoints.

Across the extreme top are a number of pilot-configurable windows that depict typical GPS information, such as next waypoint, time, distance, and desired track. Upper left are the VHF navigation frequencies, controlled by a knob on that side. Below that knob is a control for the heading bug; a push syncs the bug to the current heading. Lower left is the altitude knob for setting altitude bugs. Upper right are the communications frequencies and their control knobs. Much of the communication and navigation frequency knob interface and the flight-planning interface will be familiar to anyone who has used a GNS 430 or 530. Below the com control knob is the control for setting barometric pressure and the course indicator. Next is the joystick for moving the cursor around the moving map. Below that is a series of buttons familiar to 430/530 users for setting up flight plans, instrument approaches, and other day-to-day navigation chores. An FMS knob works in tandem with the nav buttons. Soft keys across the bottom do a variety of things, from bringing up the transponder functions to clearing cautions and warnings, to configuring the display. They are called soft keys not because they feel soft, but because their functions are not hard-wired. In other words, the keys perform different functions depending on what you are attempting to do. Small menu choices appear or change above the buttons depending on the choices available in that setting. Conveniently, a Back button is usually available to back out of the menus.

The MFD will look surprisingly familiar because it is exactly the same display—same buttons, same labels. In fact, you can even use knobs on the MFD to perform functions on the PFD and vice versa. A change to a com frequency on one display, for example, is repeated on the other display—again, thanks to the Ethernet bus that allows every component to talk to every other component.

The MFD is where you can get creative with the setup. You can set the moving map any way you want—terrain off or on, obstruction and terrain warnings off or on, airspace, airports, navaids—you decide what you want.

In the Diamond, the engine instrument depictions occupy a strip down the left side of the MFD. Among the presentations are: manifold pressure; rpm; cylinder head temperature; fuel flow and quantity; oil temp and pressure; amps; and voltage. The individual displays provide

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Diamond DA40-180
Base price: $186,900
Price as tested with Garmin G1000: $258,763

Specifications

Powerplant	180-hp Lycoming IO-360 M1-A
Recommended TBO	2,200 hr
Propeller	2-blade Hartzell, 74 in dia
(Optional)	3-blade MT Propeller, 71 in dia
Length	26 ft 3 in
Height	6 ft 6 in
Wingspan	39 ft 2 in
Wing area	145.7 sq ft
Wing loading	17.4 lb/sq ft
Power loading	14.1 lb/hp
Seats	4
Cabin length	8 ft 6 in
Cabin width	3 ft 9 in
Cabin height	3 ft 8 in
Standard empty weight	1,620 lb
Empty weight, as tested	1,711 lb
Max gross weight	2,535 lb
Max useful load	915 lb
Max useful load, as tested	824 lb
Max payload w/full fuel	660 lb
Max payload w/full fuel, as tested	584 lb
Max takeoff weight	2,535 lb
Fuel capacity, std	41 gal (40 gal usable) 246 lb (240 lb usable)
Baggage capacity	100 lb, 24.7 cu ft

Performance

Takeoff distance, ground roll	800 ft
Takeoff distance over 50-ft obstacle	1,150 ft
Max demonstrated crosswind component	20 kt
Rate of climb, sea level	1,070 fpm
Cruise speed/endurance w/45-min rsv, std fuel (fuel consumption) @ 75% power, best economy, 4,000 ft	145 kt/3.1 hr (63 pph/10.5 gph)
@ 50% power, best economy (fuel consumption), 10,000 ft	120 kt/5.4 hr (40.2 pph/6.7 gph)
Service ceiling	14,000 ft
Landing distance over 50-ft obstacle	2,093 ft
Landing distance, ground roll	1,155 ft

Limiting and Recommended Airspeeds

V_R (rotation)	59 KIAS
V_X (best angle of climb)	66 KIAS
V_Y (best rate of climb)	73 KIAS
V_A (design maneuvering)	108 KIAS
V_{NO} (max structural cruising)	129 KIAS
V_{NE} (never exceed)	178 KIAS
V_{FE} (max flap extended)	91 KIAS
V_{S1} (stall, clean)	52 KIAS
V_{SO} (stall, in landing configuration)	49 KIAS

For more information, contact Diamond Aircraft, 1560 Crumlin Sideroad, London, Ontario, Canada N5V 1S2; telephone 888/359-3220 or 519/457-4000; fax 519/457-4021; or visit the Web site (www.diamondair.com). All specifications are based on manufacturer's calculations. All performance figures are based on standard day, standard atmosphere, sea level, gross weight conditions unless otherwise noted.

cryptic information, but certainly all that you need for most flying. If any item exceeds established parameters, the G1000 alerts the pilot. A touch of the Engine soft key brings up a larger display that shows cylinder head and exhaust gas temperatures for each cylinder and allows for managing fuel inputs. There's also a system to assist in leaning. The manifold pressure and rpm displays show both an arc with a pointer and an exact digital reading, but do not show any numerics along the arc. I found myself wanting to know where on the arc I could find, say, 24 inches of manifold pressure. Garmin representatives said they felt the extra digits would clutter the display. I had only a short flight in the DA40. I'm sure with a little practice it's easy enough to quickly nail a power setting.

Diamond is equipping the DA40 with the G1000 Mode S transponder and traffic information service (TIS) to depict traffic in terminal areas. Buyers can opt to install a terrain warning system and a weather datalink. The G1000 uses an XM Satellite Radio-delivered datalink that includes a host of weather products in the cockpit and 101 channels of entertainment.

Garmin is also developing a flight control system that will be integrated into the G1000. Since that component won't be available until later this year, Diamond has installed the Bendix/King KAP 140 two-axis autopilot.

Like the rest of the G1000 components, the flight control system will be fully integrated. There will be no main autopilot computer. Instead, each servo will be its own computer, feeding information back to the AHRS and other components for processing and use. Garmin is also developing an airborne weather radar system, positioning itself to sell the G1000 to aircraft even larger and higher flying than the Mustang.

The G1000 is already set to debut on the Diamond D-Jet. With Diamond's ability to turn out new models faster than just about any GA manufacturer and Garmin's avionics innovation, we undoubtedly haven't heard the last "Gee!" from this pair.

Alan and Dale's Excellent Idea

If you build it, they will buy one

By Steven W. Ells
(*From* AOPA Pilot, *February 2004)*

You can hear it when you talk to a Cirrus employee. It's evident in the professional salespeople who have jumped aboard the Cirrus bandwagon, and it's prompted a number of industry experts to pick up their families and move to Duluth, Minnesota. Cirrus is on a roll.

The Cirrus SR22

The FAA presented Cirrus Design with the type certificate for the SR22 in November 2000. Since then sales of the 200-horsepower SR20 and the 310-hp SR22 have been accelerating. In June 2003 the 1,000th Cirrus was presented to its new owner. From August through September 2003, Cirrus set a new company record by selling 223 airplanes.

On July 27, 2003, Alan Klapmeier announced that Cirrus was offering a Centennial edition of the SR22 to commemorate the first 100 years of powered flight. Each airplane had special touches such as an embroidered Centennial logo on the pilot and copilot seats and a chrome detail package (which trashed the 1950s hot-rodder's motto of "If it don't go, chrome it") to go along with a Centennial decal on the tail. But the real story is that the 100-airplane run of fully loaded—Avidyne FlightMax Entegra flight deck, Garmin avionics suite including dual GPS navigation and mapping systems, S-Tec Fifty Five X fully coupled autopilot with altitude preselect, TKS Ice Protection package, and L3 Stormscope WX-500 and SkyWatch traffic avoidance systems—Centennial SR22s sold out in 93 days.

Why has this airplane caught on with the airplane-buying public? Three reasons: value, the public's perception that the Cirrus airplanes are safe, and the company's efforts to promote Cirrus airplanes beyond the normal light-airplane marketplace.

For the money, a Cirrus buyer gets an airplane that's fast, carries a good load, is economical to operate, is fully certified to FAR Part 23 regulations, and has the latest in avionics and information technology.

The SR22 is powered by a 310-horsepower, six-cylinder, fuel-injected Teledyne Continental IO-550N engine with a 2,000-hour TBO. This engine has advanced features such as cross-flow heads for improved breathing, and a 9.5-1 compression ratio for better thermodynamic efficiency. The exhaust system is tuned to increase exhaust airflow and aid efficiency.

The SR22 has a maximum gross weight of 3,400 pounds, and a fuel capacity of 84 gallons. The base price is $313,900 for a well-equipped IFR airplane. Options include upgrades to the S-Tec autopilot, a Garmin GNS 430 in place of the standard GNS 420, the addition of L3 Stormscope and SkyWatch systems, the addition of an Avidyne EMax engine and fuel monitoring system, and the TKS Ice Protection system. An additional year of warranty can also be purchased.

The Cirrus line

Cirrus also sells two other models. The SR20 is a four-place airplane with a fuel-injected, six-cylinder, 200-hp Continental IO-360-ES engine, a 2,900-pound maximum gross weight, a fuel capacity of 56 gallons, and a 950-pound useful load. Cirrus advertises the cruise speed of the SR20 as 160 knots, although owners report that 150 knots is a more realistic number. The base price of an SR20 is $229,700.

The newest addition to the Cirrus fleet is the SRV. The SRV is an SR20 with VFR equipment and, while the panel has both an Avidyne primary flight display and multifunction display, the SRV is neither certified nor equipped for IFR flight. The base price for an SRV is $189,900.

The location of the sidestick makes it easy to see and reach the soft-key-selected menus on the two 10.4-inch LCD screens of the Avidyne Entegra flight deck. Markings on the sidestick control tube let you check takeoff elevator and aileron settings. Circuit breakers, TKS Ice Protection system controls, fuel boost switch, fuel tank selector, and the engine controls are on the lower console.

All models of Cirrus airplanes are offered with extensive options that permit the buyer to outfit the airplane to fit his or her needs. Yet, according to Heike Berthold, the regional director of the Southern California sales staff and my shepherd during a cross-country flight from California to Duluth, Minnesota, “Everyone wants the TKS, and almost every SR22 I’ve sold has been fully equipped.”

The big XC

I talked Kate Andrews, the media guru at Cirrus, into letting me fly a long cross-country in an SR22. Berthold was dispatched to keep an eye on me (and the company’s airplane). We launched from Paso Robles, California, at 6:39 a.m. on July 25, 2003, and landed at Duluth International Airport after a total flight time of eight hours and 19 minutes. One landing was made at Rock Springs, Wyoming, for fuel, a weather check, and snacks. Our vending-machine lunch reinforces a proverbial aviation truth—it doesn’t matter whether you fly an airplane worth $383K or one worth $15K, the airport snack machine is the great equalizer.

The fully loaded demo airplane we flew weighed 2,347 pounds, or 97 pounds more than the standard advertised empty weight. We topped off the two fuel tanks with 84 gallons (81 usable) of 100LL, and added baggage and golf clubs totaling 113 pounds into the baggage compartment. Another 35 pounds for flight gear, charts, survival gear, and other assorted items such as CDs, a CD player, sunglasses, snacks, and bottled water were added for crew comfort and safety. As we taxied out, the airplane was 70 pounds below maximum gross weight.

We cruise climbed upward at 880 feet a minute to 11,500 feet to get to a suitable crossing altitude for California’s Sierra Nevada. Four hours and one minute later we landed into a cold, blustery wind at Rock Springs. We had used 54.6 gallons of gas for an average fuel consumption of 13.64 gallons per hour. Our routing covered 680 nm. Our average groundspeed worked out to be 170 knots. True air speeds worked out to be 173 to 175 knots—slightly slower than advertised. Part of this can be explained by our decision to use lean-of-peak mixture settings in cruise—as recommended in the SR22 pilot’s operating handbook (POH)—resulting in less power at the prop.

During the second leg, from Rock Springs to Duluth, we flew into a band of lumpy air, experiencing light to occasional moderate turbulence from Rock Springs to the RULER Intersection abeam Mount Rushmore in South Dakota. We climbed to 13,500 feet msl to get out of the bad air, but it didn’t help. The relatively high wing loading (23.5 lb/sq ft) made the 240 nm of turbulent air more tolerable. East of the turbulence we descended over the plains of the Midwest. We landed in a rain shower four hours and 18 minutes after takeoff from Rock Springs.

The SR22’s 49-inch-wide cabin, good visibility, plentiful ventilation, and supportive and comfortable seats had provided us with an enjoyable and memorable cruise across the western half of our great country. The twin 10.4-inch-diagonal bright and colorful liquid-crystal display of the Avidyne FlightMax Entegra gave us instantaneous access to wind speed and direction, Jeppesen VFR and IFR charts, terrain, traffic, and lightning strike information. They also permitted us to monitor engine temperatures and power settings, and allowed us to modify or update our flight plan throughout the trip. Instead of the usual elbow-poking in the cockpit as we folded and unfolded cabin-filling charts and the riffling through 200 pages of paper POHs to determine engine power settings and fuel flows, we simply leaned forward, pushed the appropriate menu button on the PFD or MFD, and changed a setting or opened up a storehouse of flight data or other information that we desired.

The side-stick control, although new and different, was no problem. It was comfortable to use and provided unlimited visibility of the instrument displays.

Things were missing—there was no propeller rpm control nor was there a manual trim control. The prop governor linkage is connected to the throttle through a cam-type gizmo located in the center console. Push the power lever (throttle) full forward and the propeller rpm is advanced to 2,700, pull back a little and the rpm is reduced to the standard cruise setting of 2,500. The propeller rpm control cam maintains this rpm during cruise at various manifold pressures. As power is pulled back further, the power lever contacts the end of the prop cam control and rpm is reduced with power.

Electrically actuated pitch-and-roll trim is standard (rudder trim is an option) and is controlled by a button on top of the side-stick grip.

Ron Stein, who bought an SR22 to replace his Cessna 210 that was totaled, says, "There's no workload in this airplane. I don't have to work the landing gear or cowl flaps or prop control." Reducing pilot workload is just one piece of the Cirrus approach to flying and airplane safety.

Cirrus Design founders the Klapmeier brothers (Dale is the quiet one; Alan likes to speak out) felt that there was a need to widen the market for personal aviation airplanes—this term is one of many ideas Alan actively promotes—and they had a hunch that safety would draw new people into the small-airplane world.

Safety sells

The Cirrus Airframe Parachute System, or CAPS, is an important part of selling Cirrus airplanes. "We have people asking for demo rides who tell us that the parachute is the reason they're looking at a Cirrus," says Berthold.

Lessing Stern took a Cirrus demo ride while he was in the process of selling his Beechcraft King Air. He bought a Centennial SR22 and couldn't be happier. The CAPS and the other safety features caused him to evaluate and change one of his long-held personal rules.

"Before I bought my SR22, I had established a rule of never flying a single-engine airplane at night. I've amended that rule because of the safety features of my Cirrus," says Stern.

In addition to the CAPS, every Cirrus airplane is equipped with seats capable of absorbing 26 Gs of force, the occupants are surrounded by a tough carbon-fiber reinforced shell, and the wing incorporates spin-resistant features that comply with the most modern Part 23 mandates.

SR22 buyers do have to learn new systems. The latest SR22s have dual alternators (the second alternator is an option on the SRV and SR20) and no vacuum pump. There's a battery for each alternator. The electrical distribution system is sophisticated. Features such as a primary bus, an essential bus, a nonessential bus, dual batteries, and diode-isolated bus interconnects make the airplane's electrical system look more like something out of a turboprop twin than a typical single-engine airplane. When either alternator fails, the system automatically continues to supply power to essential communication and navigation radios and instrument lights.

There have been some teething problems with the SR22. Early airplanes were hard to start, some SR22 owners have reported nose-gear shimmy problems that have caused cracked and broken nose-gear wheelpants, and cracks have been found in the single-pipe exhaust system.

Performance made simple

Cirrus Design founder Alan Klapmeier says he can't remember a time when he didn't pay attention to airplanes. "The family story is that mom used to take me and my brother Dale to the airport to watch airplanes take off and land when we were little so we would give her some quiet time and she could read a book for a few minutes."

By the time he was 3 years old, Alan Klapmeier knew he wanted to fly. By the time he was in high school, he had earned his private pilot certificate and was talking about a career in aviation. By the time he was a senior in college, he and Dale had quietly begun working on their first airplane design.

That same year the brothers announced their plans to start an aircraft company. Their parents were supportive but skeptical. "I remember them teasing us that it was better to go broke when you're young," Klapmeier says.

And at times it looked like they might do just that. "I often tell people that what it takes to do a project like this is to be dumb enough to start and smart enough to finish," Klapmeier says. "You have to be willing to dive in and learn as you go because if you knew how hard it would be you just wouldn't try, and because of how hard it is, it's no wonder that so many people don't make it."

And while Cirrus aircraft are, in many ways, marvels of modern technology from their composite airframes to their big-screen avionics, Klapmeier has never thought of technology as an end in itself. "Technology is very much a series of forks in the road," he says. "Either it simplifies the process and adds value or it makes the process more complex. It may add more performance but the tradeoff is less value because of greater complexity." And finding that perfect balance between performance and simplicity is Klapmeier's personal and professional quest.

—Elizabeth A. Tennyson

SPECSHEET

Cirrus SR22
Base price: $313,900
Price as tested: $383,000

Specifications

Powerplant	310-hp Teledyne Continental Platinum IO-550N
Recommended TBO	2,000 hr
Propeller	Hartzell PHC-J3YF-1RF 3-blade, 78-in dia
Length	26 ft
Height	8 ft 9 in
Wingspan	38 ft 4 in
Wing area	144.9 sq ft
Wing loading	23.5 lb/sq ft
Power loading	11 lb/hp
Seats	4
Cabin length	10 ft 2 in
Cabin width	4 ft 1 in
Cabin height	4 ft 1 in
Cabin volume	137 cu ft
Empty weight	2,250 lb
Empty weight, as tested	2,347 lb
Max gross weight	3,400 lb
Useful load	1,150 lb
Useful load, as tested	1,053 lb
Payload w/full fuel	646 lb
Payload w/full fuel, as tested	549 lb
Fuel capacity, std	84 gal (81 gal usable) 504 lb (486 lb usable)
Oil capacity	8 qt
Baggage capacity	130 lb, 32 cu ft

Performance

Takeoff distance, ground roll	1,020 ft
Takeoff distance over 50-ft obstacle	1,575 ft
Max demonstrated crosswind component	20 kt
Rate of climb, sea level	1,398 fpm
Cruise speed/endurance w/45-min rsv, std fuel (fuel consumption)	
@ 75% power, best power, 8,000 ft	180 KTAS/3.8 hr (106.8 pph/17.8 gph)
@ 65% power, best power, 10,000 ft	174 KTAS/4.4hr (92.4 pph/15.4 gph)
@ 55% power, best economy, 10,000 ft	166 KTAS/5.9 hr (67.8 pph/11.3 gph)
Max operating altitude	17,000 ft
Landing distance over 50-ft obstacle	2,325 ft
Landing distance, ground roll	1,140 ft

Limiting and Recommended Airspeeds

V_R (rotation)	70 KIAS
V_X (best angle of climb)	78 KIAS
V_Y (best rate of climb)	101 KIAS
V_A (design maneuvering)	133 KIAS
V_{FE} (max flap extended)	119 KIAS
V_{NO} (max structural cruising)	178 KIAS
V_{NE} (never exceed)	201 KIAS
V_{S1} (stall, clean)	70 KIAS
V_{SO} (stall, in landing configuration)	61 KIAS
V_{PD} (parachute deployment)	133 KIAS

For more information, contact Cirrus Design, 4515 Taylor Circle, Duluth, Minnesota 55811; telephone 218/727-2737; fax 218/727-2148; or visit the Web site (www.cirrusdesign.com).

All specifications are based on manufacturer's calculations. All performance figures are based on standard day, standard atmosphere, sea level, gross weight conditions unless otherwise noted.

Maintenance procedures, service information, and parts changes and upgrades have been developed to address these problems, although some owners have expressed surprise when they learned that the full cost of a number of these fixes isn't covered under the two-year airplane warranty.

Selling the package

In August 2001 the Klapmeier brothers turned to outside investors to take Cirrus Design into the future. The resulting infusion of capital has been used to upgrade the production process and to hire the people to move the Cirrus Design dream into the twenty-first century.

The economic doldrums that swept the country in 2001 prompted Cirrus to trim excess fat off its existing production procedures. Just-in-time (JIT) and point-of-use (POU) parts and component delivery systems have reduced the need for warehousing. Eighty percent of company personnel are involved in production, and the company tries to put employees in their "best fit" positions. A production-tooling expert has created design fixtures that have resulted in the ability to fabricate and assemble parts to tolerances as tight as 0.005 inch. These changes have cut the number of parts and equipment vendors per airplane in half (to 140) and cut the total production hours per aircraft from 3,793 to 1,878.

Customer service has committed to making the buying experience easy and dignified. To this end, Cirrus has teamed with a financier to offer buyers a financing plan to fit their needs.

Just after the completion of a new delivery center in November 2002, Cirrus cranked up its reach-out program by adding more than 20 members to a national sales staff and setting up a program to make sure that every flight instructor in the country gets at least one introductory ride in a Cirrus. Any flight instructor who hasn't had a ride can contact the factory online (www.cirrusdesign.com).

From April 2001 through early 2003 there were six fatal crashes in Cirrus airplanes. Accident investigation teams cleared the airplane of any inherent fault, but the accidents raised some insurance underwriters' eyebrows. Cirrus put forth a dedicated effort to explore the cause of the accidents, and then prompted individual underwriters to visit the factory to learn about the safety features of Cirrus airplanes. As a result, the number of underwriters willing to write competitive policies for Cirrus buyers has grown, and one company has started writing commercial insurance for Cirrus airplanes.

Partly prompted by the crashes, Cirrus and other government-industry team members upgraded and modernized flight-training standards to incorporate technically advanced airplanes (TAAs) such as the Cirrus airplanes into the training fleet.

As a result, each buyer trains for two days with a Cirrus-endorsed instructor from the University of North Dakota Aerospace program. This training is included as part of the purchase. Eighty percent of buyers spend at least one additional day at the delivery center for extra training.

The rest of the story

The real story here is that Alan and Dale Klapmeier started with a dream and, within a remarkably short time, they not only designed and certified two state-of-the-art airplanes, but they also had the business acumen to attract some of the industry's best and brightest professionals to bring twenty-first-century manufacturing techniques to their company. The result is safe, fast, and reliable airplanes, backed by an organization that is succeeding in its goal of showing a new generation of airplane owners the value of single-engine airplanes for personal aviation travel.

Setting the Standard

A whole new panel for the Cessna 182

By Julie K. Boatman
(*From* AOPA Pilot, *March 2004)*

A new Cessna 182B graces the March 1958 cover of *AOPA Pilot*. When this magazine launched, the Skylane—born in 1956 as an upgrade of the 182—was flying out of Wichita's Cessna Aircraft Company Field at the rate of more than three a day.

While current production of the 182 is lower than during those heady days, the name Skylane still signals to pilots a reliable, capable ride, straightforward enough for most of us to fly with ease. When we looked at the first new Skylanes in 15 years (see "The New 182: A Sturdy Bird Flies Again," July 1997 *Pilot*), we were happy overall with the company's update of its proven design. And the minor misses we found are, by and large, addressed with the model's latest incarnation, the 182T.

But the question of the moment is about the avionics, not the airframe. That question—what's in the panel?—was answered last fall when Cessna announced that it would bring the Garmin G1000 integrated flight deck to one of the most popular general aviation airplanes of all time.

There is no doubt that glass cockpits have taken GA by storm, sweeping into the latest airframes—airplanes made of "glass" of a far stronger kind. But when Cessna, the old guard, the airplane manufacturer with indubitable staying power, slots the Garmin G1000 into the panel of its steady player, you know that glass is here to stay. That it adds this Garmin glass almost concurrently with Diamond Aircraft's similar upgrade to its fleet (see "Diamond DA40-180: The Gee Meter," January 2004 *Pilot*) means that the words old guard really don't apply anymore.

Going glass

We flew the newly equipped Skylane—the G1000 is officially part of the Nav III avionics package for the airplane—from AOPA Expo in Philadelphia to our home base in Frederick, Maryland, last fall.

Turning on the master switch launches the primary flight display (PFD) in a prestart mode, allowing you to view fuel, electrical system, and engine gauges during preflight and while starting the airplane. This was perhaps the biggest mental shift I made, as years of conditioning on how to preflight and start a single-engine Cessna flew out the window. I had landed on the moon and was searching for the familiar in a strange new world. How ingrained in a pilot is it to open the door, take the control lock out of the yoke, look at the ignition switch, flip on the master, and watch for the fuel gauge needles to rise? Where were they?! Oh—there!

The moment passed

When it came time to hop in and start up, I again had to refer to the map—in my case, asking Kirby Ortega, Cessna's flight training supervisor, for a hand with the checklist—and substitute the electronically rendered displays now in front of me for the analog gauges I remembered.

Again, the moment passed.

One nice change that takes all 182Ts—regardless of avionics package—into the "pro plane" category is the presence of a split electrical bus selectable on the avionics master, plus an additional essential bus with a standby battery and battery controller. The two sides of the bus power different avionics, allowing you to instantly shed load in case of an electrical system emergency or malfunction while preserving com and nav capability. (For those aircraft with the Nav I and II packages, Bus 1 drives the Honeywell Bendix/King KLN 94 on those aircraft so equipped, and the number-one nav/com. Bus 2 powers the Bendix/King KMD 550 multifunction display [MFD], if installed the number-two nav/com, and the transponder.)

The overall health of the stand-by battery is tested during normal start-up procedures by way of a switch, with a green light indicating that the battery has the juice to power the PFD, primary flight sensors for the air data computer (including outside air temperature, airspeed, pressure altitude, and vertical speed), engine monitoring

The panel offers a lot of real estate for the pilot to customize—although the latest avionics package doesn't leave much out.

sensors, and a single nav/com/GPS for at least 30 minutes. Nonelectric backup instruments—an airspeed indicator, vacuum-driven directional gyro, altimeter, and compass—complete the panel. Ortega pointed out that with the replacement of the traditional instruments with the G1000 may come a substantial weight decrease: The engineering airplane lost about 7 pounds when Cessna took out the old hardware and wires and replaced them with the new.

The primary flight display came online within a few seconds of start-up, and I soon found everything I needed. We departed Philadelphia International Airport on Runway 35, on an IFR flight plan, into 3 miles visibility in a high-pressure haze. I was glad I'd had my fill of Philly's sights during our stay, as the view inside the cockpit was far more compelling than the murky landscape outside.

The engine instrument displays on the G1000 in the 182 use green arcs to assist in setting typical percent power for normal cruise. I found this the path of least resistance, though finding a specific setting was a little more challenging. But for those who like keeping engine management simple, the green arcs make it so, as does a "lean find" feature, accessed by pressing the Engine soft key from the main G1000 MFD page.

I'd had a few hours working with the Garmin GNS 530 on a recent business trip, so the navigation and communication inputs for the G1000 came fairly easily as much of the logic is similar between the two units. In fact, as we headed southwest, the airplane and I soon settled into a quiet, relaxed partnership. Though I had far more layers of capability to explore within the G1000, the basics of flight management were just that, basic—and all this in an airplane that has been a friend for many years.

Good questions

One of the challenges confronting Cessna and other aircraft companies is how to incorporate new airplanes with advanced avionics smoothly into the training environment.

"How do you test partial panel during a checkride?" Ortega asked me during a subsequent flight. He has a point. Whereas previous integrated flight deck systems (such as Avidyne's FlightMax Entegra, as installed in the Cirrus SR20 and SR22 and Diamond aircraft) have relied upon a separate GPS navigator for course input, the G1000 is an all-in-one deal. If you turn off the PFD to simulate the "black screen of death," you lose course information, too. While at the outset this seems a frightening proposition as well as a training conundrum, realize that the chances of truly losing both displays are extremely slim.

A flight test is meant to test realistic failures, not once-in-a-lifetime events, according to Bruce Landsberg, executive director of the AOPA Air Safety Foundation: "The big question is the single-point failure." When the vacuum system was the main thing, the FAA tested on its loss because, as we well know, loss of the vacuum system or a single gyro-driven instrument was likely to happen in a given 1,000-flight-hour period. Mean time between failures for the AHRS (attitude heading and reference system) is 10,000 hours—a tenfold margin of safety. And if one screen toasts, the other screen automatically or manually reverts to a primary flight display function, and any required information for safe flight is displayable on that screen. In the event of total electrical failure, there's the standby battery, practically dedicated to the G1000, in addition to the ship's battery. In a nutshell, the chance of both screens failing, the AHRS failing, or the electrical system and batteries failing is roughly the same as my chance of winning an Olympic luge event.

"There is no single-point, or common mode, failure which would take a pilot down to standby instruments only," says Tom Carr, chief test pilot for Garmin. "In the event of a PFD failure, the pilot would activate the display backup switch, and the MFD would revert to a composite display [showing smaller chunks of the EFIS and HSI information as well as a moving map and engine information]," says Carr. "The same option is available for composite on the PFD, which allows monitoring of engine parameters. In the event of an AHRS failure, there is a backup attitude indicator—everything else on the PFD works correctly." If the air data computer fails, you can use the standby airspeed indicator and altimeter. If one of the integrated avionics units fail, you have another one, and therefore at least one nav/com. If the engine and airframe sensors fail, you lose engine data. And the backup plan for that loss? Use your ears—and probably land at the nearest suitable airport, as with any critical system failure.

During a subsequent flight, Ortega turned off the avionics master and main master switches to simulate a massive electrical failure and induce an in-flight restart of the G1000's PFD. We were in about a 20-degree-bank turn at the time, and maintained the turn for the duration of the reboot. The PFD came back on line within the time it took us to turn from downwind to base—about 15 seconds.

Skin deep

The turquoise, black, and white Skylane of the late 1950s is immediately distinguished from those 182s produced after 1997, when Cessna restarted its Skylane production. The newer models came from the factory painted white with two trim options, classic deep red and silver, or blue and gray. Instead of painted trim on the 182S and 182T introduced in 2001, Cessna went with a decal application that, while it saved time and looked sharp at first, fell prey to what might be called VDR, or critical decal-in-rain speed. Seems that a few ragged edges have appeared on these model 182s. For a number of reasons, Cessna has returned to painting exterior trim with the 2003 model year.

The 182T now features the same interior color choices as the T182T (the turbo'ed version). Leather or fabric seats—it's up to the owner as both are available with no price difference. A more neutral color on the side panels weighs in as a minor change but one to please aesthetes. And—certain happiness to those of us with sweaty palms in the hot months—the 182T has leather-wrapped control yokes. Keeping that powerful nose up during the landing roundout won't be such a challenge (sweaty hands tend to slip on plastic yokes). LED glareshield lighting similar to that on the T182T adds pop to the panel. A polished spinner completes the upscale look.

The T182T won a speed advantage (besides its turbo'ed engine) with several aerodynamic refinements. Similar changes slim the 182T's drag profile over its 182S predecessor. The airplane picked up a total of four knots through the following mods: a sleeker step for cockpit entry, reclocked fairings on gear legs and teardrop main wheel fairings, refined wing tips, and an improved cowling. The same 230-horsepower Lycoming IO-540, derated to 2,400 rpm, and three-blade McCauley prop that powered the S model now power the T. The match of engine to airframe is a good one. To the great relief of 182-model owners everywhere, the less-stressed version of the IO-540 on the 182S and T was not affected by 2002's snowstorm of emergency crankshaft airworthiness directives (ADs) aimed at those -540s producing 300 hp or more (see "Waypoints: Crank Calls From Lycoming," January 2003 *Pilot*). A lone AD calls for the replacement of a crankshaft gear retaining bolt on certain 182S and T engines prior to 2002.

However, the 182S took its share of other AD hits early on. A bum oil pressure switch that threatened to fail and send oil through the vent hole was found in some 182S serial numbers through 660. An angle stiffener on the wing was left out on other serial numbers through the 1997 model year, requiring installation of a reinforcement strip. And a weak exhaust muffler end plate—which could crack during backfires on engine start and vent fumes to the cabin—needed replacement in some 1997 models. A loose fastener in the autopilot servo actuator on the Bendix/King KAP 140 was possible as well through the 1999 model year. The good news is that none of the ADs are associated with any accident reports.

That's probably because the folks at Cessna watch these birds closely. What rolls off the line

SPECSHEET

2004 Cessna 182T Skylane
Base price: $250,000
Price as tested: $297,500

Specifications

Powerplant	Lycoming IO-540-AB1A5, 230 hp @ 2,400 rpm
Recommended TBO	2,000 hr
Propeller	McCauley 3-blade, constant speed, 79-in dia
Length	29 ft
Height	9 ft 4 in
Wingspan	36 ft
Wing area	174 sq ft
Wing loading	17.8 lb/sq ft
Power loading	13.5 lb/hp
Seats	4
Standard empty weight	1,897 lb
Max ramp weight	3,110 lb
Max takeoff weight	3,100 lb
Max landing weight	2,950 lb
Max useful load	1,213 lb
Payload w/full fuel	661 lb
Fuel capacity, std	92 gal (88 gal usable) 552 lb (528 lb usable)
Baggage capacity	200 lb

Performance

Takeoff distance, ground roll	795 ft
Takeoff distance over 50-ft obstacle	1,514 ft
Max demonstrated crosswind component	15 kt
Rate of climb, sea level	924 fpm
Cruise speed/range w/45-min rsv (fuel consumption), 6,000 ft @ 75% power, best-power mixture	140 kt/845 nm (16.5 gph)
@ 55% power, best-economy mixture, 10,000 ft	120 kt/968 nm (9.6 gph)
Service ceiling	18,100 ft
Landing distance over 50-ft obstacle	1,350 ft
Landing distance, ground roll	590 ft

Limiting and Recommended Airspeeds

V_R (rotation)	55 KIAS
V_X (best angle of climb)	63 KIAS
V_Y (best rate of climb)	80 KIAS
V_A (design maneuvering)	110 KIAS
V_{NO} (max structural cruising)	140 KIAS
V_{NE} (never exceed)	175 KIAS
V_{FE} (max flap extended, full flaps)	100 KIAS
V_{S1} (stall, clean)	54 KIAS
V_{SO} (stall, in landing configuration)	49 KIAS

For more information, contact Cessna Aircraft Company, One Cessna Boulevard, Wichita, Kansas 67215; telephone 800/423-7762 or 316/517-6056; or visit the Web site (www.cessna.com).

All specifications are based on manufacturer's calculations. All performance figures are based on standard day, standard atmosphere, sea level, gross weight conditions unless otherwise noted.

in Independence, Kansas, is Cessna-dependable, and the 182T is no exception. The controls still fall to hand, with the comforting feel of a flap indicator showing that you indeed have the flaps in your hand, and the elevator and rudder trim manipulated in the directions you'd expect. In fact, Cessna can credit a large part of its success over the years to adhering to a strategy of similarity. If ever you could compare a GA airplane to a rental car—you get into a new one in a distant city and you're ready to navigate unfamiliar territory after a cursory checkout—Cessna airplanes evoke that kind of "yeah, I've been here before" feeling. The airplane excels because it does what you expect it to do, and all the important things are where you'd expect to find them.

But, depending on the equipment installed, the 2004 182T includes a few things you might not expect, even if you don't opt for the big-screen Garmins.

Other avionics packages range from the standard Honeywell Bendix/King IFR package, which offers a single KX 155A nav/com with a matching indicator and KAP 140 two-axis autopilot, to the next package up, Nav I, which adds a KLN 94 GPS and KMD 550 multifunction display. Another upgrade, to the Nav II package, takes you into a KCS 55A HSI (horizontal situation indicator) system, including an analog KI 525 HSI replacing the VOR/LOC/GS display, and a KX 165A nav/com. The KMD 550 with Bendix/King's IHAS (integrated hazard avoidance system) is an option for $34,800, along with the KDR 510 datalink ($6,400), which delivers Nexrad radar, graphical METAR, and textual weather information from Bendix/King's network of ground stations (see "Weather to Go," previous page). The 850 also displays EGPWS (enhanced ground proximity warning system) information from an internal KGP 560 processor and traffic information from the internal KTA 870 traffic advisory system. At any level, you can put in an L3 Stormscope WX-500 processor for lightning detection. And an ADF is an option for $5,800, though at this stage in the nav game, not many opt.

For redundancy's sake, the modern line of 182s has instrument power neatly divided between the electrical and vacuum systems. The HSI or directional gyro runs off the electrical system, while the attitude indicator is vacuum driven. Dual vacuum pumps provide the backup in Nav I and II-equipped 182s, now thought of as necessary for most new aircraft, and both pumps run all the time—if one fails, the other automatically picks up the slack, with no action required by the pilot. A single vacuum pump drives the standard attitude indicator in Nav III airplanes.

Addressing one minor but sometimes frustrating gotcha in the 182S is the addition of a 12-volt power outlet in the T. Nope, no cigarette lighter on this airplane, but you can run a personal digital assistant or other gear in the cockpit with a 12-volt adapter. The 182 has a 24-volt electrical system.

Base price on the 2004 182T is $250,000, for a Nav I-equipped 182, and a Nav II-equipped model retails for $260,000. The Nav III package, including the G1000, goes for the same price as a 2003 182T equipped with the Nav II package: $297,500. The price point was announced at AOPA Expo 2003, to the delight of potential owners, and the possible groans of 2003-model buyers. Air conditioning can be had for an additional $23,500. The 1997 182S, with its much less sophisticated avionics, was originally offered at $190,600 and is currently holding steady at $169,000 resale, so even in a soft market these trusty companions hold their value reasonably well, at least better than your average luxury car—and you still can't fly a Lexus. While you pay a little more compared to similar aircraft on the market, you get the reputation of the Cessna name and service network, and a rock-solid safety record.

Ah, the benefits of flying with the old guard—ahem, with a proven performer.

Technically Advanced Aircraft
Safety and Training

Appendix C

Selected ASRS reports from pilots distracted by GPS or TAA-related avionics

There are literally hundreds of reports by pilots coping unsuccessfully with technology. In some cases it is simply that they should have been more familiar with their avionics unit. In others, perhaps the units are asking more from pilots than they can reasonably spare at that moment. Sometimes a change in procedure would have been all that was needed to prevent an accident. The message is that if the technology resides in the cockpit, you have to deal with it.

Table of Contents

I. Pilots distracted by GPS

1. A runway incursion close call as one pilot is unaware that his aircraft is moving as he plays with his GPS on the taxiway.
2. Altitude deviation occurs as a distracted pilot aides his copilot in programming the GPS.
3. An aircraft proceeds without clearance—working with GPS is noted as a distraction.
4. Pilot turns final onto the wrong runway—new GPS equipment is cited as a distraction.
5. Pilot deviates from ATC clearance because of his confusion with GPS unit.
6. GPS programming adds frustration to a dangerous situation.
7. Pilot's confusion from loss of nav equipment leads to an unauthorized encroachment of Class Bravo airspace.

II. Lack of situational awareness (total reliance on GPS)

1. Altitude deviation occurs because pilot relied on his GPS readings, which were off by 300 feet.
2. Loss of GPS navigation sends an aircraft 700 miles off course and is lost over the Pacific Ocean
3. Breaches restricted airspace following loss of GPS.
4. Map shift causes an aircraft to fly approaches off course.

I. Pilots distracted by GPS

1. Near miss

Aircraft 1: Cessna 206
Aircraft 2: Beechcraft A36 Bonanza
Nearest airport: 5T6

Problem area: Flight crew (human performance)

"I was landing on Runway 16 with three CAP cadets on board. I had touched down, after making three calls on approach, only to have the Bonanza A36 almost taxi on to the active runway while back taxiing for takeoff. He stopped with his propeller approximately three feet from the runway west edge. I had moved to east side of runway, prepared to take the grass. He indicated he was 'messing with his GPS' and not watching."

2. Altitude excursion

Aircraft 1: Learjet 35
Nearest airport: None

Problem area: Flight crew (human performance)

"During climb while on a vector, approach cleared us to the LEV VOR. Copilot was having trouble programming GPS. I looked down to help remedy his problem, which distracted me from flying the aircraft. Altitude alerter went off as we passed 300 feet off our altitude. As I corrected for the deviation, the altitude went to 15,500 feet. ATC informed us of the deviation as the alerter went off. We promptly corrected the deviation. There was no request to call ATC."

3. Deviation from approach procedure

Aircraft: Beechcraft A36 Bonanza
Nearest airport: SSI

Problem area 1: ATC (human performance)
Problem area 2: Flight crew (human performance)
Problem area 3: Weather

"ASOS at SSI reported weather as ceiling 1,200 feet overcast, visibility 9 miles, basically marginal VFR. I was about 50 nm away when I copied the ASOS and requested from Jacksonville Center the GPS approach to Runway 4 at SSI. I was instructed to 'proceed to the IAF' for the GPS. I was fascinated with my new IFR GPS, and was trying to ensure that I operated it correctly. I then realized I'd heard nothing from Center since I was inside the IAF. Center then said I was cleared for the GPS 4 approach. Working with the new GPS was a distraction on my end."

4. Lined up for wrong runway

Aircraft: Cessna 210
Nearest airport: APF

Problem area 1: Aircraft
Problem area 2: Flight crew (human performance)

"While lining up for Runway 5, we were distracted by the new GPS while attempting to follow elaborate noise-abatement procedures with the aid of the GPS. We misinterpreted the GPS data and began to turn final for the wrong runway. The confusion created while approaching APF was in part because of the unfamiliarity with the new equipment and perhaps an over reliance on the GPS equipment over conventional techniques."

5. Altitude excursion

Aircraft 1: Medium transport, two turbojet engines
Nearest airport: GJT

Problem area 1: Aircraft
Problem area 2: Flight crew (human performance)
Problem Area 3: Weather

"Unable to contact departure control on climbout from GJT; was attempting to enter my new destination in the Garmin GNS 430, but each time characters disappeared. I later discovered that the Garmin GNS 430 system uses the D> key to initiate the 'direct to' function, while other systems use the same key to terminate that sequence! Poor and inconsistent automation design can result in cockpit pandemonium."

6. Engine failure

Aircraft 1: Cessna Cardinal 177RG
Nearest airport: DLH

Problem area 1: Aircraft
Problem area 2: Flight crew (human performance)
Problem area 3: Weather

"Another pilot and I had an emergency in a Cessna 177RG. We lost all oil pressure as we were starting to return from DLH after realizing that we would not be able to get in (weather was 100 and 1/4). We were able to get it into Superior, Wisconsin, on the GPS approach. Lesson: fly the airplane. We had enough trouble with two instrument-rated pilots on board. I was concerned with best glide and flying the airplane, while the other pilot handled setting up the GPS. I now understand how easy it is to be overly distracted in this situation."

7. Class B incursion

Aircraft 1: Mitubishi MU2
Nearest airport: IXD

Problem area 1: Aircraft
Problem area 2: Airspace structure
Problem area 3: ATC
(human performance)

"While on climbout from IXD, we lost both VOR and GPS due to an electrical power interruption. ATC advised us to avoid MKC Class B airspace, but due to confusion with navigation instruments, we may have touched the Class B boundary."

II. Lack of situational awareness

1. Altitude excursion

Aircraft 1: Cessna 182
Nearest airport: GBR

Problem area 1: Aircraft
Problem area 2: Flight crew
(human performance)

"My GPS-indicated altitude was 5,700 feet msl, while my altimeter indicated 6,000 feet msl. The GPS altitude function is in for repair."

2. Lost

Aircraft 1: Gulfstream II
Nearest airport: None

Problem area 1: Aircraft
Problem area 2: Environmental factors
Problem area 3: Weather

"Both FMS units went into dead-reckoning mode, and the INS failed while indicating a position more than 300 miles away from our last known position. We believe we flew into an electromagnetic field, probably coming from the high-powered defense radars at Kwajalein, disabling all our long-range nav equipment."

3. Loss of positional awareness

Aircraft 1: King Air 100
Nearest Airport: HDH

Problem area 1: Aircraft
Problem area 2: Flight crew
(human performance)

"To help remain clear of the restricted area while lifting jumpers, we use a handheld GPS with an antenna that's attached to the window. Unbeknown to me, the antenna fell off the window, causing the GPS to become inaccurate and allowing me to drift into the restricted area. I was in the restricted area for about 3 minutes."

4. Off course

Aircraft 1: B767
Nearest airport: SCEL

Problem area 1: Aircraft
Problem area 2: Airport
Problem area 3: Chart or publication
Problem area 4: Company
Problem area 5: Flight crew
(human performance)
Problem area 6: Navigational facility

"FMS map on Boeing 767 shows map shift while on Andes 4 arrival to SCEL. Additional reports to ASRS confirm map shift in other 767 equipment."

Appendix D

Suppliers of Uplink Services

Suppliers of Uplink Services

This information changes constantly; it was current at date of publication. This is not intended as a complete listing or buyers guide but rather to give pilots and buyers a better understanding of the nature of TAA avionics.

Current suppliers of uplink hardware and services that would typically be used by a light general aviation TAA pilot include:

AirCell Guardian 1000/FlightGuardian

Provider: AirCell, 888/328-0200; www.aircell.com.
Price: Guardian 1000 telephone, $3,495; FlightGuardian software, $95; telephone charges, minimum of $50 a month, which includes 20 minutes of service.

The panel-mount Guardian 1000 is an AirCell inflight telephone system that can also receive data, such as uplinked weather Nexrad images. AirCell claims coverage above 5,000 feet msl over most of the country although AOPA test pilots found holes in its coverage, even when as high as 9,000 feet over parts of the Great Lakes states. It's also difficult to get a signal over the metropolitan areas from Philadelphia through Boston; coverage in other parts of the country varies.

Uplinked weather images are available with software from either ControlVision or AirCell's FlightGuardian, giving users a choice of Nexrad images, surface charts, or 12- or 24-hour prog charts. Data can be downloaded for the entire

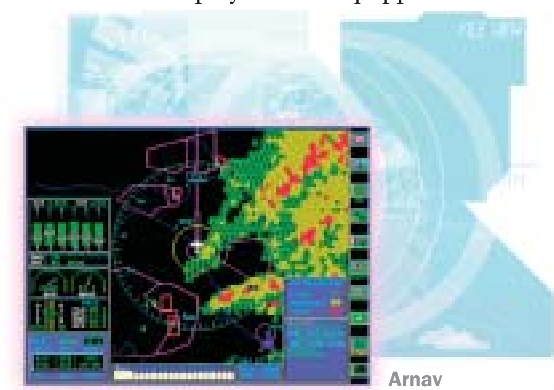
Guardian 1000

country or specifically for the regions of interest by touching areas on a map. Once the desired data has been selected, the AirCell phone automatically dials DTC DUAT and brings back the images. The maps are not presented relative to your route, so you have to know about where you are in the region in order to orient the information to your position. At least for those flying at lower altitudes, coverage isn't as robust as some of the satellite datalinks, but AirCell provides a weather datalink solution to those who find the phone itself useful.

Arnav WeatherView

Provider: Arnav Systems, Puyallup, Washington; 253/848-6060; www.arnav.com.
Price: RCOM-100 satellite transceiver, $6,995; service plans from $39.99 per month plus $2 per weather request and 99 cents per Globalstar satellite telephone connection

Arnav Systems now makes WeatherLink inflight weather available to Cirrus SR20 and SR22 owners whose aircraft use the Arnav ICDS2000 multifunction display and are equipped with



Arnav

RCOM-100 satellite datalink hardware. Weather products retrieved from the Arnav Network Operation Center include Nexrad radar, METAR graphics and text, graphical icing, freezing levels, turbulence, and convective information. The improved weather data is supplied by Meteorlogix, which also supplies Nexrad, text weather, satellite photos, and proprietary graphics to Echo Flight, Control Vision, and ARINC, as well as AOPA Online.

Avidyne FlightMax EX500

Provider: Avidyne, 800/284-3963; www.avidyne.com.
Price: The datalink receiver is standard in the $8,995 price for the EX500 MFD; datalink service costs $99 for registration, then 9 cents per message. The DC50 datalink receiver is available for $495 when purchased with the EX500.

Avidyne's datalinked weather is available in the FlightMax EX500 multifunction display or in the FlightMax Entegra integrated flight deck (currently in Lancair and Diamond aircraft Entegra installations). Rather than delivering weather for user-requested airports or regions, or based on the aircraft's current position, Avidyne's "narrowcasting" satellite receiver requests information from a radius (50 to 400 nm) along the current route, at a time interval set by the pilot (every 6 to 60 minutes). The result is a swath of data up to 800 nm around and along the route. A Datalink Setup page on the EX500 determines the range


Avidyne

and frequency of the data pull. Nexrad images are overlaid on the multifunction display's primary map page along with graphical TFRs (temporary flight restrictions), airmets, and sigmets. Textual weather information, such as METARs, is listed with each reporting airport on the Trip page.

The system uses Orbcomm's satellite network, and Avidyne utilizes its own Network Operations Center to distill and send the data. An antenna coupler, the DC50, allows the EX500 to access the network through a multi-mode antenna (coupling the datalink with either a com or GPS/com antenna), saving on installation costs and trimming the hardware farm on the airplane's fuselage.

Control Vision AnywhereWx

Provider: Control Vision, 620/231-6647; www.anywheremap.com.
Price: $2,145 includes Compaq iPaq 5550, AnywhereWx software, GlobalStar tri-mode satellite phone, Garmin GPS 35 GPS and antenna, yoke mount, and bag; datalink service through GlobalStar begins at $25 monthly plus $1.29 a minute; AnywhereWx service is $72 annually. The Tracker Blue GPS retails for $399.

An alternative for pilots who like their personal digital assistants (PDA) is Control Vision's AnywhereWx, an option for its AnywhereMap moving-map software for PDAs. AnywhereWx uses either an AirCell in-flight telephone or a satellite telephone linking it to the GlobalStar satellite network. The system delivers METARs, Nexrad images, and cloud-cover imagery from the National Oceanic and Atmospheric Administration's (NOAA's) GOES-8 satellite from Meteorlogix. These graphics are displayed on the primary map page, overlaid on the base map showing the aircraft's current position and route.

Data delivery is obtained through request/reply, and typical downloads take a minute or less to complete. Pilots can request data from any location, whether it's a current position, destination, or diversion airport. A recent update to the Control Vision product allows the AnywhereMap moving-map GPS program to utilize Control Vision's Tracker Blue GPS, a wireless GPS device that eliminates part of the wire mess that can accompany temporary cockpit PDA installations.

Echo Flight

Provider: Echo Flight, 888/948-9657; www.echoflight.com.
Price: Several plans are available starting at $9.95 per month plus $1 for each message, with unlimited service for $55 a month; FL 250 hardware/software package is $5,295, with the FL 270 for $5,695.

Echo Flight delivers Nexrad graphics, and graphical and textual METARs via Orbcomm's satellite network, downloaded to its proprietary portable hardware, called Flight Cheetah. The Flight Cheetah hardware has evolved from a tablet-size screen and separate keyboard to a portable unit that can be installed on a panel or yoke mount. Available in several versions, the latest is the FL 250, which features a bright 5.7-inch-diagonal display, WAAS-enabled GPS, datalink receiver, and portable hard drive. The FL 270 offers the same features with a 6.4-inch screen.

Traditionally, Echo Flight subscribers downloaded weather information on a request/reply basis, but in Spring 2003 Echo Flight announced automatic weather delivery, which downloads


AnywhereWx


Echo Flight

data in a constant stream, eliminating the need to make a call to the provider every time the pilot wants a weather update. The company recently added LandSat imagery to its database, enabling pilots in IFR or night conditions to view terrain and surface detail to a 15-meter resolution. Echo Flight offers in-flight e-mail and position reporting service in addition to weather. Echo Flight is also the weather provider to Garmin's GDL 49 STC'ed datalink hardware.

Garmin GDL 49

Provider: Garmin, 913/397-8200; www.garmin.com; www.wsi.com
Price: $3,495 for GDL 49.

The Garmin GDL 49 satellite datalink transceiver receives Echo Flight's weather service and displays it on Garmin's 400- and 500-series panel-mount moving-map GPS/nav/com radios. A subscription to the weather service is purchased separately from Echo Flight. In addition, Garmin AT offers WSI weather on its MX20 display.

Honeywell Bendix/King's Wingman Service

Provider: Honeywell Bendix/King, 877/712-2386 or 913/712-2613; www.bendixking.com
Price: KDR 510 datalink receiver, $5,730 ($3,690 when paired with the KMD 250); first three months of datalink weather are free under the "Wingman" roster of services, after that $49.90 per month for graphical weather products; textual weather products remain free; KT 73 Mode-S transponder, $5,220.

Honeywell Bendix/King has been selling its very popular IHAS (integrated hazard avoidance system) hardware and software for more than three years, and some 5,000 of these units are now in service. The idea behind the IHAS concept is to merge navigation, weather, terrain, and traffic information in a single display unit. The company offers three such units: a VFR-only box called the KMD 250, an IFR-certified unit called the KMD 550, and a high-end IFR unit with an interface for airborne weather radar called the KMD 850. The datalink component of the IHAS serves the weather and traffic-alert features. With the addition of Bendix/King's KDR 510 datalink receiver, aircraft can display textual weather products such as METARs, TAFs, pireps, sigmets, and airmets. As for weather graphics, Nexrad ground-based weather radar imagery with 4-km resolution is available, as are animated Nexrad imagery and graphically depicted METARs, sigmets, and airmets. Soon to come is Nexrad imagery with precipitation cell echo-top information. All of this information comes via a joint FAA-industry program called flight information services-broadcast (FIS-B). Other avionics manufacturers also make use of FIS-B, and it's one of the major recent advances in in-flight weather awareness.

The main drawback of the Bendix/King terrestrially based broadcast system has to do with line-of-sight limitations. For good, uninterrupted signal reception you may have to climb to altitude. For example, around some sites in the northeastern United States, reliable signals can't be received until you reach 4,000 to 5,000 feet. In some mountainous areas of the western United States, terrain-blocked signals mean that much higher altitudes are required for good reception. Bendix/King has been doing a good job plugging the holes in its coverage by adding more ground stations. Today, the coverage is much, much more extensive than just a year ago.

Digital datalink signals also provide traffic information to IHAS displays, using the traffic information system (TIS) established under another FAA-industry agreement used by several avionics manufacturers. Bendix/King's setup uses its KT 73 Mode S transponder. The KT 73 picks up ATC radar signals and sends them to the cockpit, where pilots can see the same targets as controllers. The good news: Better traffic awareness. The bad news: Only certain approach-control radar facilities provide these broadcasts. In the en route phase of flight, TIS often isn't available.

Bendix/King

More sophisticated products — such as onboard active air traffic surveillance, and enhanced ground proximity warning system (EGPWS) capabilities — also can be added to an IHAS installation. But in many respects it's the datalink services that provide the most bang for the buck.

TIS (Traffic Information Service)

Provider: Garmin and Bendix/King, www.garmin.com; www.bendixking.com.
Price: Garmin GTX 330, $4,995; Garmin GTX 330D, $9,995; Bendix/King KT 73 $5,220.

The FAA broadcasts the equivalent of ground-based radar displays to aircraft flying within 55 nm of more than 110 radar installations under its traffic information service (TIS). The information is the same as that included in VFR traffic advisories normally given by voice. All you need to receive it is a Mode S-capable transponder, and at the moment there are only three of those available to light general aviation aircraft: the Garmin GTX 330 and GTX 330D, and the Bendix/King KT 73. Oh, yes. To view the information you also need a display, like the Garmin AT MX20, the Garmin GNS 500- and 400-series GPS/nav/com units, the Avidyne FlightMax EX5000 and EX500 multifunction displays, or the Bendix/King KMD 250, 550, or 850 displays. The Bendix/King TIS data must be displayed on the Bendix/King displays, which only show Bendix/King TIS data — they will not display Garmin TIS data.

Garmin TIS

WSI InFlight

Provider: WSI, 978/983-6300; www.wsi.com
Price: InFlight pricing reflects a range of service packages. Hardware for the AV200 unit—which is for panel-mount displays—runs $4,995. Portable displays use WSI's AV100 $3,495 system package. These prices include datalink receivers, software, and antennas. Service packages run from $999 per year for the top-of-the-line "corporate" service to $199.99 per year and $19.95 per day for the "Pay 2 Fly" service aimed at occasional VFR-only pilots. All services include the Nexrad radar imagery. TFR and Canadian data are available as add-ons for all service packages save the corporate at $100 and $200 per year, respectively.

WSI uses satellite-broadcast technology to deliver the basic aviation weather products, plus some impressive radar imagery. WSI's newest service—called WSI InFlight—is compatible with a variety of panel-mount and portable display units.

Garmin AT's MX20 multifunction display (MFD) is one such panel-mount unit, and so are L-3 Avionics' iLinc, Chelton's FlightLogic EFIS (electronic flight information system), and Universal Avionics' UCD MFD. Portable displays compatible with WSI InFlight include Advanced Data Research's FG-3600 electronic flight bag (EFB); CMC Electronics' CT-1000 EFB; Fujitsu tablet computers and PC laptops; and virtually every handheld pocket PC and PDA capable of running Windows 98 and its successor versions. InFlight provides graphical and textual METARs, TAFs, sigmets, and airmets, and in this regard its services are very much like those offered by competing in-flight digital-datalink weather sources. Some new enhancements, such as pireps and winds aloft, will soon be available to owners of MX20 MFDs; they're already provided as part of the EFB service packages.

WSI's strong suit is its Nexrad radar graphics. The imagery comes in 2-km re-solution, which makes for superior radar signature interpretation, and the imagery is rebroadcast at 5-minute intervals. Animated radar imagery is also available, and so is a view that portrays precipitation cell echo tops and movement — a really invaluable resource in the thunderstorm season. WSI's goal in providing these levels of service is to equal what would be portrayed on a high-quality on-board weather radar. In truth, InFlight goes any on-board radar one better: There are up to five levels of precipitation shading; purple signatures for mixed precipitation and blue signatures for snow and ice; and none of the radar attenuation effects that plague airborne weather radar. Attenuation is a blocking of radar energy caused by heavy precipitation. This blocking can hide dangerous cells from an airborne weather radar's view. Datalinked radar imagery comes from a mosaic of ground-based Doppler weather radars, and because of its signal strength and narrow beam is free of attenuation effects.

WSI InFlight

WxWorx

Provider: WxWorx, 321/751-9202; www.wxworx.com
Price: WxWorx pricing is $659 for the Basic package and $860 for Premium with topography and GPS connectivity; XM Radio weather subscription, $49 per month plus one-time $75 activation fee; Heads Up Technologies receiver, $3,975. Cessna and Diamond will include display and receiver equipment costs in the price of their aircraft.

An increasing number of large GA manufacturing companies have turned to WxWorx in Huntsville, Alabama, for in-flight aviation weather that is broadcast over a channel of XM Satellite Radio. You can have it in certified and uncertified iterations.

WxWorx now offers an uncertified portable package starting at $659. The weather subscription is purchased directly from XM Satellite Radio. There is also a certified receiver built by Heads Up Technologies and offered through your local avionics dealer. Use it by plugging your computer into a panel receptacle.

The software is loaded on a laptop, which displays the downloaded weather. Destination Direct moving-map and flight-planning software will offer WxWorx designed to run with its products in 2004.

WxWorx is also available on these electronic flight bags (EFBs): Paperless Cockpit, 901/751-2687; AirGator's NavAirWx which makes WxWorx available on both a PDA and an EFB, 914/666-5656; Flight Deck Resources, 949/679-9900; and Approach View, 877/678-1602 or 713/552-1602. Soon it will be available on the TeleType GPS PDA unit and the Palm OS-based display from Hangar B-17.

WxWorx

Rockwell Collins will offer WxWorx on new and retrofit installations of its Pro Line 21 avionics: The Cessna CJ3 will be the launch aircraft for the new service. Garmin plans to include WxWorx on the G1000 integrated avionics display planned for several new Diamond and Cessna aircraft and is building its own receivers—the GDL 69 that will receive WxWorx and the GDL 69A that will receive WxWorx and XM's digital radio.

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Appendix E

A synopis of some of the avionics available in TAA.

This information changes constantly—it was current at date of publication.

This is not intended as a complete listing or buyers guide but rather to give pilots and buyers an better understanding of the nature to TAA avionics. These multifunction displays are grouped by manufacturers; suggested retail prices are included to provide some reference for level of sophistication for expected TAA applications.

Multifunction Displays

A multifunction display is just what the name says it is: a small TV screen (actually, an LCD panel) on which can be displayed virtually any information, from weather displays to navigation information to engine or instrument monitors to spheric detector information, possibly even your child's latest video game.

Several information-stream providers for TAA have made good use of the versatility of MFDs, allowing a recently unthinkable variety of services enhancing the usefulness of TAA. There are seven manufacturers who currently produce MFDs, offering them at prices ranging from a low of $6,995 to a high of $54,000.

L-3 Systems I-linc MFD, $8,850.

Formerly made by Goodrich Avionics Systems, this MFD is certificated for FAR Part 23 aircraft, but not FAR Part 25. A radar-compatible version costs $15,422.

Avidyne FlightMax EX500, $11,995.

The price for the EX500 includes an integrated data link transceiver. The unit is FAA-certificated for Part 23 aircraft. Pilots on a budget could opt for the non-radar version of this MFD for $9,995.

Avidyne FlightMax EX5000, $16,195.

The more expensive FlightMax EX5000 includes an integrated data link. A non-datalink version can be ordered for $12,995. The FlightMax EX5000 is certificated for FAR Part 23 aircraft. FlightMax is the only series allowing utilization of both of Avidyne's Narrowcast and XM's Broadcast weather services, either individually or together as complementary systems.

Chelton FlightLogic Synthetic Vision EFIS, $54,000.

Chelton manufacturers the world's only synthetic single-vision Electronic Flight Instrument System (EFIS). This unit, at the high end of what would normally be expected in a GA TAA, includes forward-looking real-time 3-D terrain modeling with worldwide coverage, HUD symbology, moving map, highway-in-the-sky navigation, conformal traffic display, weather interface, integrated voice warning master caution, GPS WAAS receiver, TAWS (Terrain Awareness and Warning System), solid-state gyroscopics, air data computer, digital flight recorder, on-screen flight management functions, and autopilot control.

Honeywell MFRD/80-5204, $42,500.

This unit combines weather, traffic, terrain, GPS navigation maps and other data in a single display unit. It is certificated on both FAR Part 23 and Part 25 aircraft. It does not offer TAWS capability, either TAWS-A or TAWS-B.

Rockwell Collins FDS2000, $43,000.

The Collins FDS-2000 includes the TAWS-B terrain avoidance warning system. This unit is particularly attractive to the retrofit market because the AFD-2000 Adaptive Flight Displays are functional replacements of conventional flight director indicators, such as Collins FD-108/FD-109 Flight Director indicators.

Sandel ST3400 TAWS, $20,950.

The Sandel ST3400 can meet either the TAWS-A or TAWS-B specifications, and has an optional traffic interface. (Price quoted is for the TAWS-B option.) This unit is attractive because it replaces an existing RMI, for a claimed 50% - 70% cost savings on the installation. and less downtime for the aircraft. The TAWS-A certificated unit costs $34,500.

Garmin International MX20 Series, $6,995 to $14,995.

Certificated in both FAR 23 and 25 aircraft, this popular MFD allows display of all the usual data inputs, plus allows a side-by-side display of any two MX20 charting functions. A vertical profile view of terrain peaks and obstructions relative to the current flight level can be displayed across the lower portion of the screen.

Universal Avionics MFD 640, $40,000.

This unit, which is available for both OEM and retrofit includes the capability of displaying Terrain Awareness and Warning Systems in map, profile and 3-D views. Like other units, it will display weather radar and uplinked weather graphics; information from the Flight Management System, including the flight plan, surrounding navaids, airports and more; monitor VOR bearing and DME.