COCKPIT AVIONICS

Technology for the pilot's sake

What if technology could help pilots recover an airplane when it is clear (to the software) that the pilot's actions are trending toward an accident?

by Matt Thurber

Consider the Air France 447 and Colgan Air 3407 accidents. In the Air France accident, the Airbus A330 stalled into the ocean from cruise altitude, following icing of the pitot sensors. The consensus is that the pilots just needed to move the control stick forward to unload the wing and the Airbus would have resumed flying. In the Colgan accident, the pilots failed to add power after their Dash 8-400 slowed while leveling off during approach. The Dash 8 was on autopilot, and the autopilot kicked off when it reached a limit, handing the pilots an airplane that was about to go out of control. Investigators concluded that the captain reacted incorrectly, and the Dash 8 stalled and crashed.

In both cases, the pilots were not ready for what happened, and they did not figure out what was wrong in time to prevent an accident. Also, it is assumed that the airplane designers didn't anticipate those occurrences or the way the pilots reacted. No designer can anticipate every way that a system or a pilot can mess up. But what if technology could help the pilot rescue the situation when it is clear (to the software) that the pilot isn't about to resolve the problem? If this is even possible, does it make sense? And, what would something like this look like in practice?

To answer these questions, **AIN** *interviewed avionics manufacturers and asked how their products can help pilots and also what developments in their back-room laboratories are under way to address these problems.*

Simple Solutions?

Imagine, in the case of Air France 447, that the avionics were designed such that in a loss-of-control (LOC) situation, the pilots are presented with a simple graphic showing the exact attitude of the airplane. During the four or so minutes that Air France 447 was held in a stall until it hit the ocean, the pilots were faced with a vast array of information, both visual and aural, which may have added to the confusion.

In another example, the crew flying a Qantas A380 after an uncontained engine failure after takeoff from Singapore on Nov. 2, 2010, complained about the barrage of warnings and other information streaming at them. As captain Richard de Crespigny wrote in his book, *QF32*, "We had to deal with continual alarms sounding, a sea of red lights and seemingly never-ending ECAM checklists."

Instead of adding yet more alerts and more confusion to the cockpit, why not blank all the screens and present only information that will help the pilots? For Air France 447, could a simple exocentric (outside) view of the airplane and its attitude have helped the pilots realize that the airplane was in a stall?

This technology already exists, although it isn't employed for this particular use. Universal Avionics, which was an early adopter of synthetic vision technology on its EFI-890 display, offers pilots an exocentric view that is also an accurate representation of the aircraft's attitude. One possibility would be to add symbology that shows actual angle-of-attack (AOA) and color to indicate a stall AOA. Could an exocentric display have helped the Air France pilots? Setting up the sequence in a simulator and testing it on pilots could provide the answer.

For the Colgan accident, technology already exists and has bubbled up from the lighter end of the market, in autopilots from Avidyne and Garmin. Rockwell Collins is developing a loiter mode that could help. "Step one into the future," said Bob Ellis, Rockwell Collins director of flight information solutions marketing, "are developments occurring today in the area of flight control modes, particularly in single-pilot operations or [in the event of an] incapacitated crewmember." If the pilot loses spatial awareness, for example, pushing the loiter mode button automatically flies the airplane away from the navigation track and into a holding pattern. "It allows the crew to get ahead of the aircraft," he said. "We'll see this in airplanes in the near term."

Also promising are systems that can guide or fly an airplane from the point of total engine failure to the end of the nearest runway. "We're looking at an algorithm," said Matt Carrico, Rockwell Collins senior engineering manager of advanced concepts, "that, in the rare event of a dual engine failure, could give pilots as much guidance as possible. We can automatically compute the most efficient flight path and glidepath to the nearest runway and give flight-director cues to the pilots so they have mental time for other tasks."

Rockwell Collins has run the US Airways Hudson River ditching sequence using this algorithm and found that it would have been possible for the pilots to make it to a runway after losing both engines to bird strikes, had they known exactly where to turn and done so immediately.

Laminar Avionics's $99 Xavion app was released in November and works either with an external AHRS from Levil Technology ($795) and an external GPS or using the iPhone/iPad's internal gyros, accelerometers and GPS. The external AHRS works better, but even without the Levil unit, the iPhone/iPad's sensors can provide usable guidance, according to Laminar Avionics, as long as pitch and bank are kept within certain parameters and the airplane is flown steadily.

During flight, Xavion continuously calculates the airplane's gliding capability, and the display is color-coded to show not only the area within gliding range but also the airports that can be reached without power (green). Airports on the edge of gliding range are yellow, and red airports are beyond reach.

In case of an engine failure, pushing the red "Hoops" button shows a path defined by hoops (like highway-in-the-sky) that lead to the runway end. A bug on the speed indicator is set to what Laminar calls "nominal glide" speed, which is halfway between best glide and worst glide configurations. An energy meter shows whether the aircraft needs more or less energy to make the end of the runway safely.

The Xavion app is just the beginning of what Laminar plans for its artificial intelligence (AI) cockpit aid. Next up is conflict alerting using ADS-B IN sensors (weather and traffic) and Aspen's Connected Panel as a data source for engine problems. "All of these things and much, much more are in the works," according to Laminar, "with the underlying rule that all information is assessed by the AI and presented in the most user-friendly format, just as a good copilot would present that information to you."

Key Information

All the data already flowing through modern avionics systems is the key to enhancing safety, assuming this data can be captured and used, according to Dan Schwinn, president and CEO of Avidyne. An example is the Connected Panel system developed by Aspen Avionics, which allows avionics data to be delivered to external devices such as an iPad, which can then leverage that data for other uses. Avidyne is a Connected Panel partner and is working on new products that will apply avionics data to safety solutions.

MATT THURBER

Universal Avionics, which was an early adopter of synthetic vision technology on its EFI-890 display, offers pilots an exocentric view that is also an accurate representation of the aircraft's attitude. Could such a view help show that the aircraft is in a stall?

But Avidyne is also a hardware manufacturer and has worked on solving some of the difficult problems that result in accidents, especially LOC, currently at the top of the list of accident causes. A problem with most autopilot systems is that they slavishly follow pilots' commands. As Schwinn pointed out, in a typical general aviation airplane, if the pilot selects heading and altitude hold, then the power is cut, "it's going to trim full aft and stall the airplane. This is not a good thing to do." (Of course this can happen in larger airplanes, too.)

Avidyne's DFC90/100 autopilot includes envelope protection (EP) and envelope alerting (EA). The alerting feature works whether or not the autopilot is on, warning the pilot of excessive bank, overspeed or if the airplane is slowing below 1.2 Vso. With EP, the autopilot will keep the airplane within a safe flying envelope if those parameters are exceeded. In the case of leveling off without adding power, EP would simply allow the airplane's AOA to decrease to maintain 1.2 Vso and not let the airplane stall.

Avidyne's autopilots also offer an unusual attitude recovery button that levels the wings, zeroes out the pitch and maintains airspeed within a safe range. This button can even recover control of an airplane from an inverted attitude, according to Schwinn.

Garmin has developed the electronic stability and protection (ESP) system. ESP works with the autopilot on or off and helps the pilot maintain a safe pitch and roll attitude and airspeed, including low-speed protection. Some Garmin-equipped airplanes include a LVL button on the autopilot controller, which automatically rolls the airplane level and holds altitude, giving pilots time to recover after losing spatial orientation. ESP is available on Garmin-equipped Cirruses and King Airs with the G1000 upgrade and upcoming Garmin flight decks. "There's no additional hardware involved," said Bill Stone, Garmin avionics product manager. "It uses the data in autopilot servos. Part of our philosophy is how to create a safer, more efficient environment for the pilot to work in."

Another example of capitalizing on existing hardware is Garmin's emergency descent mode, which is a feature on the G1000-equipped Cessna Mustang and on the new Learjet 70/75. This capability is now common on larger business jets and automatically and swiftly takes the airplane down to a safe altitude in case of cabin decompression. "You hope you never need it," he said, "but knowing it's there is quite the peace of mind."

Simpler Interfaces

Garmin is moving swiftly into simplifying the way pilots interact with avionics, starting with touch control on its GTN-series navigators and G2000 through G5000 touchscreen-controlled flight decks. Voice control is also available now, via Garmin's Teligence system. Teligence currently allows pilots to control the GMA 350 audio panel and is finding a market in helicopters, where pilots generally need to keep both hands on the controls. "It allows the pilot to stay focused on flying the aircraft," said Jim Alpiser, director of aviation aftermarket sales, "and worry less about interacting with the avionics."

"We think there are tremendous opportunities to reduce pilot workload, increase situational awareness and go a long way to making [flying] safer," said Stone.

In a facility in Ottawa, Canada, a team of about 15 experts is thinking through all these issues to help Esterline CMC Electronics develop new products that meet the safety and usability needs of modern pilots.

Rockwell Collins is developing surface guidance cues that are integrated on the Head-up Guidance System for enhanced ground operations.

"There's a lot of potential to make big improvements," said Dave McKay, manager of advanced systems. But there is a caveat: so much information is available that designers need to be careful what they throw at pilots. "Look at all these technologies," he said. "What I as an interface designer want to do is not what is fairly easy, to overwhelm the pilot. Before pilots had access to all this data, how to train them was fairly straightforward. You can't put complex systems in front of them without making it abundantly apparent that they have to understand how it works. Otherwise it's just too overwhelming."

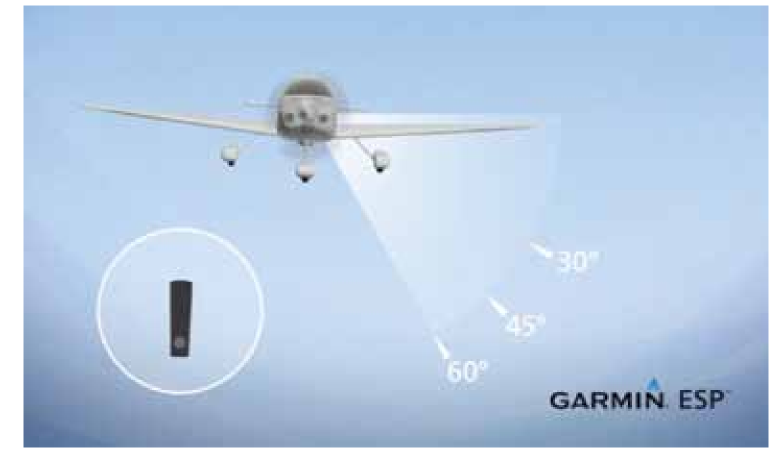
CMC is developing touchscreen and voice control features on its SmartDeck cockpit. "We feel they are going to be great enablers to prevent controlled flight into terrain," said Greg Plantz, SmartDeck director of marketing and sales. Pilots need more than just an audio alert, he said. "It's one thing to see the Taws display. But instead of saying 'terrain,' maybe 'pull up four degrees or turn left 20 degrees' would be better." Then the software would monitor the pilot's actions to make sure the potential danger has been averted.

"We're developing a way for pilots and cockpits to interact to prevent loss of control and loss of situational awareness," said Patrick Champagne, vice president of cockpits and systems integration at CMC. "The brain of the pilot has not grown, but the density and complexity of systems has. We need to make the right integration of information to point out to [the pilot] the relevant stuff." To that end, CMC has been working with the Canadian military to help pilots with safe cockpit automation procedures. "If this happened," he said, "this is how the automation reacts and this is what the pilot should be doing. Is there something that the cockpit could suggest to him to help him understand better? The availability of data is just one factor; knowing what to look for–a relation between variables–is important."

The ultimate goal is what CMC product director of advanced vision systems Marc Bouliane calls an enhanced situation display. This display, he said, "really talks to the pilot's being able to see at the right time what he needs to see. Whether it's 2-D nav, terrain charts with FMS, synthetic and enhanced vision, the whole package is how do we enhance the pilot's view? We're in the early days of taking those and starting to marry their output into an enhanced display."

Connecting the Data

Aspen Avionics is well aware that the glut of information available to pilots presents a problem. The company's Connected Panel system pulls data from installed avionics and also allows pilots to input flight-planning information and set radio frequencies using an iPad. "That's what Connected Panel is all about," said Brad Hayden, Aspen vice president of marketing. "It's the power of being able to bridge the uncertified and certified data. You start having the horsepower of being able to use this uncertified platform [the iPad] and data from behind the panel. We're providing the bridge: increased access to relevant information."



GARMIN

Garmin's ESP works with the autopilot on or off and assists the pilot in maintaining a safe pitch and roll attitude and airspeed, including low-speed protection.

But just throwing more data at pilots isn't conducive to safety, and Aspen and Connected Panel partners are working on delivering useful information. The idea is not just to create an app for pilots but also to allow pilots to customize the app to match their needs for each phase of flight.

Aspen isn't the only company connecting iPads to avionics data. DAC International's GDC64 offers four Arinc 429 ports delivering avionics data to portable devices. Guardian Avionics makes a device that wirelessly transmits GPS data from installed avionics to mobile devices. Avionics Systems & Integration Group and Shadin are collaborating on the fly-Tab avionics interface module, which sends Arinc 429 and Mil Std 1553 data to iPads. CMC PilotView electronic flight bags can capture avionics data via the company's Tandem software.

Making all this data available to mobile devices offers many new opportunities for unique products, especially because they can be delivered much faster because no certification is involved. Aspen's Hayden suggested a product that uses onboard data sent to an iPad to record flight parameters, a sort of inexpensive flight operational quality assurance (FOQA) system that would be ideal for flight schools and fleet operators that don't want to pay tens of thousands of dollars for traditional FOQA equipment and analysis. An iPad app called CloudAhoy offers a glimpse into this future, although it uses only GPS data to record flights for later analysis.

Human Factors Factor

One element remains critical in the future of avionics development, and that is human factors. Just because technology offers more capability doesn't mean that pilots can easily make use of that capability or know what to do when the technology fails.

Many of the shortcomings that have resulted in accidents are being addressed successfully,

Continues on next page ▶

© 2012 AIN Publications. All Rights Reserved. For Reprints go to www.ainonline.com.

COCKPIT AVIONICS

Technology for the pilot's sake

▶Continued from preceding page

according to Ratan Khatwa, Honeywell senior chief engineer, human factors, including controlled flight into terrain (EGPWS), turbulence detection (RDR 4000) and runway incursions and excursions (SmartRunway and Raas). The challenge now, he said, "is superior integration of information on the flight deck, and [providing] additional safety to the flight crew."

Don Bateman, who conceived the ground proximity warning system (GPWS), outlined some new-technology areas that Honeywell is exploring. These include more use of AOA information, such as a voice warning to the pilot before the stick shaker activates; wake turbulence indicators, now that more aircraft are squeezing into ever tighter blocks of airspace; and a takeoff acceleration monitor that measures real-time conditions in case dispatchers calculate weight-and-balance and performance incorrectly. Honeywell has also looked at an automatic pull-up system to recover control of an airplane in trouble, although "pilots don't like the airplane being taken from them," he noted.

Human factors, said Khatwa, "are a huge part of the challenge. Today we see a physical control panel. Now we've got touchscreens. How do you make sure that the equivalent set of controls [is available as] on a hard panel, and how do you make sure the interface isn't opaque? You don't want to bury [important information] three or four layers down in the menu. Anything critical has to be at the top level."

In addition to touchscreens, Khatwa sees voice control as a key interface. And, he added, "The provision of larger panoramic displays is going to play a bigger role in tomorrow's flight deck." But the principal question remains, he explained. "What do you automate, when and what level of automation do you use? That's the next level, how do you better share the task between man and machine?"

Workload Reduction

While Honeywell human-factors research is looking at the intelligent assistant concept, the key to making that work, said Khatwa, "is to reduce pilot workload when the crew is highly saturated." But the system needs to know when the pilot is saturated, so Honeywell has done research on evaluating flight-crew overload. "Cortical activity goes up as more cognitive effort is required to perform a particular task," he said. "We're able to measure it fairly accurately." While this is easy to do by placing a brain wave-measuring cap on a pilot's head, that's not likely to work in real life. Khatwa said that further testing has been done by measuring pupil diameter using eye trackers. "We're inferring cognitive state from non-invasive sensors. The challenge is to do that outside the confines of a pristine lab environment. We're talking way into the future."

"We have the ability to provide more data than a person can ideally work with," said Mike Glover, director of Innovative Solutions & Support's Atlanta region office. IS&S makes the avionics suite for the Eclipse 500/550 as well as retrofits for Boeing 757, 767 and 737 Classics and military programs. The IS&S approach is to add new safety features via built-in EFB software that displays on the flight deck's MFD instead of on a separate device. "There's no additional hardware incorporated; it's part of the design of the system," he said.

Because the Eclipse is usually flown by one pilot, IS&S designs for that case. "As more capability exists, especially in single-pilot aircraft, we're going to need more logic in the architecture to be able to assist pilots," Glover explained.

Accident Prevention

Rockwell Collins designers are looking at how avionics can help prevent accidents, either by showing some information to pilots or even controlling the aircraft if necessary. An example of where this might show up is in airport operations, which continue to present hazards. Using information derived from ADS-B OUT, synthetic and enhanced vision systems, avionics can easily show the location of other aircraft and ground vehicles, but do we really want pilots looking down at a display and not outside while taxiing? With its Head-up Guidance Systems head-up display (HUD) technology, Rockwell Collins can put such information on the HUD, in the pilot's view through the windshield. "That's an example of where onboard avionics can play a significant role in helping the pilot prevent and detect a blunder on the ground," said senior engineering manager Carrico.

Beyond that, he added, are explorations into the nature of how pilots and automated systems interact. "What are degraded modes of operation," he asked, "and how can automation be designed to degrade more gracefully so that we don't dump into the pilot's lap an airplane that is horribly mis-trimmed? We're looking at a more holistic view of automation, with better architecture and a better human-machine interface that will degrade and upgrade in a more predictable fashion."

Failure-free Flight Deck

"Designing the cockpit for its crew is a huge challenge now," said Denis Bonnet, vice president for technical development for Thales's avionics division. "We need to account for the fact that we have a human being in front of us, not only a machine."

Interfaces must focus on the tasks that a pilot needs to achieve, Bonnet explained, whether that's looking outside because the weather is good or managing a mission without having to know the underlying technology that makes that possible, while at the same time using familiar interfaces that don't change as the mission changes. "We also need to take into account training," he said. "We cannot design the system thinking that training will compensate for things that do not work so well."

Second, he added, is designing safety nets around the technology. The loiter mode developed by Rockwell Collins is one such example of "something that will, depending on the attitude of the aircraft, avoid crashing in controlled flight and bring it to a safe attitude."

Most important is designing the flight deck so that failures are avoided, and this is the focus on the Odicis effort under way by Thales and other partners. "In Odicis," Bonnet explained, "the technology allows the cockpit to be always available. There's no need to learn to fly with a standby instrument." In other words, the interface always remains the same, no matter how much the underlying technology fails or degrades. In the Odicis cockpit, there is no primary and no standby, just the same cockpit. Or as Bonnet put it, "Having a primary mode maintained as long as possible, and rich backups that bring in front of your eyes an image that looks exactly like the one you would have with nominal systems."

Thales and the Odicis team are working with regulators, who understand that human-factors issues need more attention, according to Bonnet. "Just saying [that] human errors are the problem is not enough. We need to find ways to reduce this human error, whether by training or better interfaces. And we have to face the nature of human beings. There is a common understanding and shared vision about this." ❑

The Rockwell Collins Fusion system is targeted at a wide sector of the market, from single-engine turboprops and light jets to Part 25 jets. Collins engineers are studying how avionics can prevent accidents by guiding the pilot or controlling the aircraft.

Innovative Solutions & Support supplies a retrofit avionics suite, below, for the Boeing 757/767/737 Classics and military programs as well as the cockpit avionics suite for the Eclipse 500/550. Further details of the IS&S displays are shown above.