Avionics Looking Forward… Far, Far Forward

BY GARY PICOU

In this 50th year of the Aircraft Electronics Association, it's natural to pause and look back to see where we came from. It's also fun to look forward — trying to imagine what the next 25 years might bring.

In this article, we let imagination take flight as we piece together the past progress, current research and future possibilities. The great thing about this techno-fiction fantasy is no one can argue right or wrong; only time will sort out the real story.

NAVIGATION

Since aviators first took off from here and went to there, navigation was the most important aspect of flight (other than basic aerodynamics). From signal bonfires guiding the airmail to space-based transmitters putting you over the numbers with 99.999 percent accuracy, we have come a long way.

This progress was realized because of ever-evolving electronics propelled by military applications. Yes, there has been some civilian advancement, including the general aviation area navigation (RNAV), pioneered by Narco in the early 1970s with the course-line computer (CLC60).

With GPS and fully automated flight management systems (FMS) getting you from takeoff to touchdown, including top of climb and start of descent in V-nav, have we reached the limit? Almost. Near-term navigation solutions will take you to and from the terminal and gate, and add a palpable level of safety to prevent inadvertent runway incursions and taxi collisions.

How can air navigation be improved further in the future? How about navigation by collaboration?

Imagine two-dozen aircraft headed between the Midwest and the West Coast. They are assigned a variety of routes and flight levels, and each has, moment-to-moment, a very precise, if local, picture of the airspace. Each aircraft's pilot knows the winds (air data and FMS), the turbulence, and the precipitation around and ahead (windshear radar, lightning detection). What if the future navigation system modeled all of these inputs in real-time and created the most efficient and smooth path in three dimensions from here to destination?

Today, we have, "Denver Center, Falcon 711 X-ray at four one, we have some moderate chop; is there a better ride at thirty-seven?" In the future, integrated and networked flight management systems would be able to look for smooth air, favorable winds and the best path through the weather to choreograph all flights in the most effective means.

Is this farfetched? Today, the military is working with swarms of unmanned aerial vehicles and ground sensors to coordinate surveillance and attacks. It's a small leap to apply this to a fleet of civilian aircraft.

The mid-21st century may have another dimension to navigate: extra-atmospheric flight. How does pilotage work at the edge of the atmosphere, close to escape velocity? "Gee, I think that looks like Cincinnati down there."

Future navigation systems will have to be more accurate and work faster to accommodate the 17,500 mph escape velocity, as a routine matter.

Future navigation systems also will be so accurate and reliable, with simple displays, that pilots will spend far less time interpreting the basic function, "How do I get to there from here?" This will allow pilots to concentrate on flying safely and with greater fuel efficiency.

Still, there is a weak link. Any system depending on GPS can be struck down in moments by a solar flare. The future navigation systems, tempered with the lessons of the solar max cycle of 2010, will have redundant interoperable sensors resistant to electromagnetic disruption in the H- and E-field.

Networking the aircraft will make it possible to detect anomalies in the navigation signals, or even detect anomalies in individual aircraft on "the net."

Consider a scenario in which a Piper Shoshone (a future model) begins to deviate from the logical path expected by the rest of the networked aircraft and ATC computers. The deviant aircraft can be contacted and the error corrected much faster than if a human controller was watching it, and the cause of the error could be diagnosed by comparing the onboard navigation to everyone else.

Similar to the way a cross-side nav comparator works on one cockpit, this one could compare dozens.

INSTRUMENTS

After the bonfires got rained out, but the mail still had to fly, it became apparent pilots had to fly without reference to the outside world. Lawrence Sperry and Jimmy Doolittle developed a system of aircraft instrumentation that let pilots fly in the clouds more than 75 years ago.

Advancement in instrumentation has been slow because the systems worked, were sort of reliable (at least the failure modes were well understood), and the sciences were materials and physics, not electronics. It is easier to control electronics with physics than the other way around.

The basic "T" instrument group, spiffed up and added to glass panels, is designed to help the pilot keep the machine upright and going straight when he can't see outside. One of the problems is, the human inner ear was not designed to work without reference to the visual world and is confused by six-degrees-of-freedom motion when there is no visual reference. It leads to vertigo and spatial disorientation, and kills just as surely as flying into a mountain.

Let's take another leap in technology. What if science could find a way to provide synthetic balance, such as it has with synthetic vision?

Here's the theory: Electrical stimulus to the vestibular area of the ear, generated by the aircraft instruments, overrides the "natural" feelings that cause disorientation and allows the pilot to feel the actual aircraft attitude. If the ears and eyes work together, spatial disorientation won't occur and pilots won't have to "ignore their ears and trust their eyes."

Research in this area is being done at Harvard (C. Wall et al/Vestibular prostheses: "The Engineering and Biological Issues," Journal of Vestibular Research, December 2003), but the focus is not aviation, rather it is correcting vestibular disorders that cause normal people to have vertigo. These devices will start in health care and be applied to aviation, resulting in a win-win for everyone.

Perhaps, the headset of 2032 will be equipped with transducers to correct the pilot's balance, as well as protecting hearing and helping the pilot hear the radios. In addition to reducing noise, it could correct the pilot's attitude perception and prevent the fatal balance misinterpretation that kills pilots of all experience levels.

COMMUNICATIONS

When a few hearty souls flew the mail, there was little need to talk to anyone. Today, air traffic control is all about voice communication. This will have to change, and it will change for the better.

Radio frequencies are crowded and, as technology has advanced, the airways have been sliced in smaller and smaller pieces. The aviation band used to have 90 communications channels, then 360, then 720 and, after some more radio spectrum, 760 channels. Quite recently, we have sliced it again, into more than 2,000 frequencies with the 8.33 kHz channel spacing.

But the problem is, even with tight channels, there are many airplanes on the same frequency. Most of the radio traffic on the frequency, no matter how thinly sliced, is not relevant to any specific airplane. This causes information overload, inattention and potential disaster.

The next phase of controller-to-pilot communication will look more like teenagers in the mall than the crowded radio channels for Atlanta arrivals, as the routine instructions are text-messaged to specific aircraft to be displayed to the crew. It's called controller-pilot data-link communications (CPDLC), and it was a $12 billion program pushed aside in the wake of the Sept. 11 terrorist attacks. But it is still the next generation of com radios.

So, in keeping with the distant future, what's next? Since mental telepathy has not been proven practical, let's take CPDLC just one more logical step. Instead of text messages, the data will be converted back to voice and presented to the pilot audibly. The pilot's eyes need to be outside, or on the gages, not reading some text on a screen. There is too much chance to misread

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something.

The answer is simple: Go back to using ears. Today, any computer with Windows XP can translate text into speech, so why not have the avionics translate the text data addressed to the aircraft into synthetic speech? “What are you doing, Dave? I don’t think that is a good idea, Dave.”

Generation-after-next communications can use voice, but it can be only the necessary, directed communications. We will lose the ability to overhear other conversations, to find acquaintances on the frequency, and a certain amount of on-air community that comes with listening into other’s conversations. But also gone are distractions caused by all of the former.

SURVEILLANCE

Surveillance, otherwise known as “radar contact,” has been a fact of life since airplanes started bumping into each other with disastrous consequences. Someone who has “the big picture” needs to know where every airplane is all the time.

Technology has improved, but even today, large gaps remain over unpopulated areas. These are the same areas, such as Alaska, that depend on aviation the most.

Are we about out of improvements? Mode S with data link provides almost all the information needed to know where an airplane is and what it’s doing. Automatic dependent surveillance-broadcast (ADS-B) allows all other equipped aircraft to have the same information as air traffic control, and it gives full situational awareness for position, altitude and speed.

In addition to security, what will the next generation of surveillance bring? How about efficiency and reliability? What if, along with position, altitude and speed, every aircraft was downloading the minutiae of engine and airframe performance?

Imagine a world in which real-time performance and efficiency data was collected for engines in service, and the lower performing ones could be flagged for improvement. By tweaking 5 percent more out of the engine, the improvements in reliability and efficiency alone could pay for the infrastructure, and reduced pollution would be an added bonus.

Far fetched? This was the original intent of AirCell more than a decade ago. Real-time engine performance data transferred from the aircraft to the central data-logging location, so any preventative or proactive maintenance could be planned while the aircraft was en route.

WEATHER

In the avionics world of the future, we should see several advancements in technology to improve safety. Imagine if all the aircraft networked together were providing real-time air-mass data to a central weather system. The modeling would improve weather prediction, which is important in the uncertain climate in years ahead.

The other aspect would be the combination of the weather radar, including advanced turbulence detection and Doppler systems, to paint a detailed picture of all the weather, not just what is ahead and 30 degrees to either side of a particular radar antenna. Networked airborne weather radar would paint precipitation from many angles, altitudes and distances for a composite 3-D picture of the systems.

TRAFFIC

What sort of collision avoidance improvements can we expect in the next quarter century? With ADS-B coming on, mid-air collisions ought to be a thing of the past. Will the collision avoidance systems of the future have full flight control authority to prevent a crash?

In the next 25 years, expect to see an array of autonomous unmanned aerial vehicles, performing tasks such as telecommunications relays to police patrol surveillance. These machines, and ours with breathing souls aboard, must be capable of instantaneous collision avoidance at a reflexive level.

Mid-air collisions occur because pilots aren’t where they thought they were, or where they expected other airplanes to be. So, yes, the error-prone human probably will have to be cancelled out of the equation for safety purposes.

CONTROLLED FLIGHT INTO TERRAIN

The same probably will apply for controlled flight into terrain (CFIT) in generation-after-next avionics. The airplanes will know where they are. They will know where the bumpy bits of cloud are and how to stay clear of them.

The electronics simply won’t allow the carbon-based equipment at the controls to override the silicon-based machine and drive into the side of a mountain.

Inadvertent flight into anything will be ancient history, as active warning and avoidance systems will save lives and hulls from the frail human senses and reasoning process. Will the pilot population like it? Resistance will be futile as insurance companies and common sense demand the machines are given more control.

FLIGHT CONTROLS

Laws of physics can't be broken, but there are different ways to manipulate them to our aerodynamic will. Autopilots will become more autonomous, smarter, more accurate and safer. That's a given. But what may be different?

Let's do away with servos, capstans, pulleys and bell cranks. Instead, nanotechnology and "smart materials" may reshape the airfoil to change the attitude of the aircraft and achieve the desired effect. Essentially, smart material would have the aircraft skin contain the sensors and actuators necessary for flight controls.

The Wright Brothers used a wing-warp method to control their machines, and in the future, we may return to that technique in a far advanced state called "wing morphing." A little push here, a tuck there, and the aerodynamics of the wings change the way an aileron does, but with less energy, less drag and more precision.

Nano sensors on the airfoil will act the same way basic instruments and feedback loops do today, but more precisely and faster.

Today, NASA's Morpheous Laboratory in Langley Va., and Europe's CERN are looking at this technology for micro-air vehicles. All it takes is a reinterpretation of the scale, and the aileron goes the way of the buggy whip.

ENGINE DESIGN

With each passing year and innovation, the line between electronics technicians and engine mechanics has gotten fainter. In the future, expect the line to be eliminated all together as the technology is integrated right into the moving parts.

Reliability is arguably the most important aspect of engine design, since airplanes started depending on motors to stay aloft. Looking at a current engine, however, with lots of opportunities to leak, break and come apart, one wonders why the designs haven't improved. Maybe it is, "the devil we know" and fear of unknowns.

Still, times are changing with a demand for reliability and economy, plus an absolute necessity to change fuels away from the leaded stuff.

The next generation of piston power will be diesel, and the generation after that may well not have pistons at all. The rotary engine is reportedly poised for a comeback, offering a smooth and reliable powerplant.

Advances in materials will make engines lighter, and nanotechnology will mean unparalleled efficiency and reliability. Health and usage systems will detect and diagnose problems well before they would be indicated on current instruments.

IN-FLIGHT ENTERTAINMENT

What will the future of in-flight entertainment (IFE) hold? The IFE industry is driven by consumer trends. Whatever the latest in consumer electronics offers, the aircraft owners will want it, if only to keep passengers happy. (Remember when just looking out the window was an exhilarating experience?)

Our crystal ball sees a satellite TV streaming video downloads and high-capacity storage. Why both? Because we want our movies stored, but we want sports in real-time.

SUMMARY

Everything you have just read is possible, practical and not far down the road. The limitations are not technological — much of this is in the pipeline already. Industry focus and public demand will determine how soon they become reality.

Advancements in technology can be derailed, however, by regulation or a decline in the industry for any number of reasons. Aviation is a tiny industry and the investment costs for technology is high.

Many projects have started and fizzled out. TCAS III, microwave landing, GLS LAAS, and even Loran-C have failed to bring the full range of benefits — not because the technology concept was flawed but because either they were lagging technology or could not get adequate user and regulatory backing.

So, we will wait and see — watching as the Flintstones transform into the Jetsons. Whatever happens, it's going to be an interesting ride. ■