The Brains Behind Glass Cockpit Beauty

What Makes Glass Cockpits So Smart?

BY GARY PICOU

Today's avionics are marvels of technology, integration, application and innovation. They bring safety and convenience to the pilot in new ways, while maintaining a consistent structure that is recognizable to any pilot with a few hours under his belt.

This entire slick human interface, which often looks like a Microsoft flight simulator, didn't just happen. All of this technology has taken years of work, study, research and development.

So, what happens behind the panel — from design to signals in space — that allows pilots to fly behind a glass panel?

What Is This Thing Called?

Let's define some terms to help us understand the avionics environment pilots find themselves moving toward.

• Glass Cockpit: This term conjures up an image of fragility, but it is really a throwback to the first generation of electronic flight displays, or EFIS (electronic flight instrumentation system). These were cathode ray tube (CRT) systems that started as a way to concentrate the vital data while mimicking the conventional instrumentation.

The first use of EFIS for civil aviation was in the Boeing 757 and 767 in 1978. Boeing began development of the 757 and certification of the electronic cockpit. In general aviation, the Beechcraft Starship was the early adopter for electronics instrumentation, with 27 CRT displays that mimicked the electromechanical instrumentation, which was introduced in 1988.

Today's "glass cockpits" are actually a collection of flat-panel, liquid crystal displays (LCD) with the latest in technology for rendering crisp pictures in a wide viewing angle, in bright sunlight or in the dark of night. Any glass is relegated to a non-glare cover on the front — the CRT has gone the way of the 8-track and betamax.

• Steam Gauges: This is a descriptive term for the electromechanical instrumentation. These are the mechanical instruments dating back to Elmer Sperry and Jimmy Doolittle that have been both the reliable standard and have caused disaster or heartache when they are misinterpreted or fail.

• EHSI: The most basic of glass cockpit instruments is the electronic horizontal situation indicator (EHSI). This takes a conventional HSI and replaces the wiggly needles with an electronic display that can portray navigation information in a variety of formats, from mimicking a compass card and course deviation indictor to a full moving map with weather and anything in between.

• MFD: The multi-function display (MFD) is the screen that gives the background and supporting information about a flight, an airplane and the surroundings. Here is where the maps are — the weather presentation, be it from the satellite datalink, radar or Stormscope.

• PFD: The primary flight display (PFD) is where all the critical, need-to-know-now information lives — such as attitude, heading, airspeed and altitude — that must be in front of the pilot at all times.

• IFD: The integrated flight display (IFD) has it all in a composite of all the flight information, navigational and situational information combined into a single display. This is where the industry is headed with "highway-in-the-sky" (HITS) displays.

What's Behind the Panel?

The picture you see is only the very surface of the system. It is the end result of all the development, engineering and certification efforts that take years and millions of dollars to complete. Today's glass panels are much more than a computer simulation of the instruments of yesterday. They leverage every advance in technology, from Apollo moon landings to the cell phone/HDTV of tomorrow.

The pretty picture you see is only as good as the information that feeds it, and this is where science and technology have had the greatest impact. These screens are populated with precision data from an array of sensors in, on and remote.

Gyros

Gyroscopic instruments represent the area in which today's glass cockpits have improved the most over steam gauges. The reliability of attitude and heading systems has improved 100-fold over vacuum instruments.

The reason for improvements in accuracy and reliability is today's micromachining electronics. Older instruments were only slightly better than Elmer Sperry's spinning iron gyros — bigger mass meant more stability, but was harder to keep spinning. Today's micromachines are smaller, have few moving parts, and are highly reliable under the most severe environmental conditions.

Glass cockpits typically use an attitude heading reference system (AHRS), which is a collection of accelerometers and micro-gyros that provide the same information as the artificial horizon, directional gyro and turn coordinator: "Which way is up, which way are we going?"

The new generation of attitude and heading sensors (calling them gyros is like saying a Cessna Mustang is a "flying machine") is a remarkable source of accurate data with high-speed digital outputs. These systems have more in common with the airbag sensor, which responds within microseconds, than the directional gyro of old, which had to be reset from time to time.

Air Data

The airspeed and altimeter steam gauge instruments that rely on pitot and static pressure have been replaced with an air data system that relies on the same pitot and static pressure. Physics is physics, after all.

However, improvements have been made with a shift away from a mechanical bellows type of pressure instrument to an electronic pressure sensor with more precision and reliability.

Computational power allows the components of the air mass, such as absolute pressure, pitot ram pressure and temperature, to be converted into useable information in real-time. The E6B will take its place next to the slide rule and sextant. (We will leave the debate about using machines to do important tasks without having a basic understanding of the fundamentals to the fourth-grade teachers who deal with long division versus calculators.)

Data Concentrators

In any given airplane, there are a slew of signals available, and these have to be input into the glass cockpit's "brain" and sorted out with regards to the nature of the information, the relative importance and the update rate.

For instance, the information from the attitude sensor is very important and dynamic, changing in a matter of fractions of a second, and therefore, has to be updated and presented to the pilot almost instantly. On the other hand, the weather, while important, doesn't have to be updated as often because it doesn't change as often and is not a part of the pilot's moment-to-moment scan.

Continued on following page...

GLASS COCKPIT

Continued from page 39

Elements like traffic and terrain are somewhere in between. These decisions are designed into the glass cockpit by the engineers and vetted by certification. But the data will vary depending on the type of information and the source.

If you have a clean sheet of paper and all of the systems come from a single source, you can have one data-transfer format. This sounds like a good idea, but in actuality the real work often makes a single format impractical.

In the free market, “Company A” may make up 90 percent of the cockpit, but “Company B” comes up with a better mousetrap — or lightning detector. The consumer demands the “Company B” system be integrated into “A’s” glass cockpit, but the data format is different. So, “Company A” will make accommodation in the glass cockpit suite.

That’s just one example. Imagine if there were four or five different formats required, which occurs frequently with retrofit avionics — such as if you want to update your airplane to add a moving map, but not the heading system, which is a 20-year-old HSI with analog outputs.

Data concentrators may not be a separate box and may just be some circuits of processors inside the main avionics suite, but they are still there and a valuable part of the glass-cockpit experience, acting like a bunch of UN translators to convert one format to another and feed it to the central processors.

GPS

That pretty map would not be useful without the addition of pan-accurate position indication. We’ve become so spoiled by the sub-meter accuracy of our ubiquitous GPS that we lose sight of the technological wizardry inside.

Consider the GPS. This unit, which is somewhere between a pack of cards and a credit card in size, will receive signals from nearly 11,000 miles away — signals so small they can’t be detected without the aid of sophisticated filters. These signals — from three, six or more individual satellites at any one time (two dozen in all) — must be heard and understood. Then, the precious timestamp is fed into more filtering, and microsecond delays teased out of the arithmetic.

Finally, the GPS will evaluate these time differences and compute a position relative to those satellites and convert that to a position relative to an arbitrary planet model, then it will calculate a latitude and longitude based on a look-up table — and do all this three times each second without error.

Terrain

The GPS is capable of determining an aircraft’s position to within a few feet. The database available to the GPS may contain the distance and heading for the airports, navaids or McDonald’s. But it also can contain a database of the surface features of the planet, including man-made protuberances that present a hazard to airplanes. Now, that’s smart.

When that information is made available in the MFD, or even overlaid on the PFD, it can be a lifesaver. Controlled flight into terrain (CFIT) is second only to flying into weather for airplane fatalities.

Mode S

Where does a transponder fit into a glass cockpit? Usually, the transponder only rides along for the benefit of ATC, and only helps the pilot by keeping him out of trouble with the FAA. But the Mode S transponder is different because it can contribute some important information to the pretty pictures on the display.

Today, traffic information service (TIS) is uploaded from the FAA stations to the aircraft, where it is presented on the display.

TIS

The traffic information system, or TIS, was designed as a low-cost alternative to the TCAS I and TCAS II collision avoidance systems. By using the information available on the ATC radar sites and up-linking it to the airplane over the Mode S data link, pilots can have a near real-time presentation of the traffic situation around them on their MFD.

The beauty of TIS is, all of the computational power resides with the FAA’s ground system — they ship you the picture, reducing the hardware cost for the consumer. The bad news is, the future of TIS is uncertain. Economics and politics may mean TIS service is not able to realize the capability TIS promises.

Automatic dependent surveillance–broadcast (ADS-B) is another traffic avoidance system that will provide a situational display of nearby threats and can be a replacement for the TIS.

ADS-B doesn’t need any ground system and works because each aircraft will broadcast its position in space. Every other ADS-B airplane within range of the transponder signal will "hear" the location and plot it on the MFD.

Weather

For all of the hazards lurking in the sky, nothing kills more aviators than weather. It could even be said that weather radar was the first "glass cockpit" when dim green spots were first shown to pilots as indications of deadly storms.

Today, airborne weather radar, more sophisticated and accurate, is but one way to paint precipitation and other hazards on a screen. Besides radar, which needs a complicated antenna and airframe room, there are systems like the Stormscope that detect lightning dangers and can paint the location of discharges on the screen.

In addition, there are several ways to upload weather depictions from service providers to present the same sort of an overall weather picture from ground-based radar, satellite images and METAR data. These can be combined as well, providing a comprehensive look at what is happening in the atmosphere around the airplane — and between you and your destination.

Radios

Nearly a half century ago, Narco Avionics introduced a general aviation radio that was mounted in the center of the instrument panel. Called the Mark II, it was 6.25 inches wide. Today's avionics by Narco, Garmin and Honeywell often are 6.25 inches wide, or "mark width." With a glass cockpit, there is no reason to have mark-width radios on the instrument panel.

In a glass-panel environment, the controls of the radios are presented in the order of importance and intelligently keep some traditional attributes, such as active and standby frequencies, and conventional names, like NAV 1. But the radios themselves are somewhere else, leaving the valuable real estate for information important to the pilot. That's smart.

Autopilot

The autopilot has two important inputs for the glass cockpit: mode indications and selector controls. Traditionally, in steam-gauge autopilots, the mode indication was close to the attitude indicator, square in the pilot's field of vision. It is important to know what the autopilot is up to, after all.

On the PFD, many glass-cockpit autopilots will have graphic pointers showing the selected modes, the selected altitude and/or vertical speed. On the MFD, there will be indications for the selected heading and course, course deviation trend indicators, and plotted course along the map.

Engine Gauges

A wise person once said the propeller's job was to keep pilots cool, because they really sweat when it stops. If the engine is working within nominal limits, we don't care what those numbers are; yet, it is critical the engine operating parameters are available to the pilot at all times and they are monitored in case they get out of kilter.

One of the more important aspects of the glass cockpit is the addition of sophisticated engine instrumentation. These electronic "brains" watch the engine sensors continually and with more accuracy than their human counterpart. However, they don't bother the flight crew unless something is going off kilter. When something drifts out of established limits, the glass cockpit will inform the pilot immediately, or at least in some timely manner relative to the severity of the condition.

Full authority digital engine controls (FADEC) represent a complete fusion of technology with the traditional aviation demand for simple, reliable engine operation, and will inevitably make flying safer and easier.

Pretty Colors

Those pretty colors showing up on the glass-cockpit displays are far more than an artistic interpretation — they are the smart result of years of research by government and industry into human factors. How a picture is presented is as important as what is shown — if a pilot doesn't understand it, it is useless or even hazardous or misleading, which can present a worse situation. The use of red, green, blue and brown may seem intuitive, but it needs to be applied with consistency.

To learn more about making a smart glass-cockpit display, or any aspect of a fully integrated cockpit, download GAMA Publication 12 from www.gama.aero. This free publication, "Recommended Practices and Guidelines for an Integrated Cockpit/Flightdeck in a 14 CFR Part 23 Certificated Airplane," has a wealth of interesting information valuable for homebuilders, avionics installers and aircraft owners who want to upgrade their panels. It takes the guesswork and subjectivity out of cockpit planning because it is based on extensive research and experience.

Shiny Buttons and Knobs

Intelligent design meets artistic interpretation in the careful place-

Continued on following page...

Continued from page 41

ment of the buttons, knobs and human-input devices the pilot uses to manipulate the glass cockpit. These controls — and there are many of them — need to make logical sense to a majority of pilots, which is no small feat.

Their arrangement is the subject of much research. Where we find differences is between manufacturers. Each manufacturer has a design philosophy they believe in and have been able to certify. This is also an area where human factors meet brand loyalty. Because you like "Company A's" human interface, you may want to stick with that company through upgrades even though your hangar-mate prefers "Company B."

Synthetic Vision

Beyond the glass panel is something called synthetic vision: "We won't need no stinking windows because the electronics will gather all of the information around the airplane, sense all of the threats and show us the way to fly to the destination on a display mounted in front of our eyes."

This is not some Buck Rogers fantasy — synthetic vision is real and in use today. It's a similar application as the first glass cockpits of 30 years ago, as commercial aircraft are perfecting the system for general aviation.

There are many technologically advanced integrated cockpits on the market, and more are on the way as new companies are springing up with innovations to keep the industry fresh and growing. ■