

New technologies are setting stage for change, even automated aircraft

by Kerry Lynch

While industry leaders debate the possibilities for fully automated aircraft in the future, the most recent-generation business jets—and the next generation—are already introducing technologies that set the stage for that possibility.

The new aircraft are coming to market wholly integrated, with fly by wire, Fadec and more extensive electrification, said Greg Bowles, v-p of global innovation and policy for the General Aviation Manufacturers Association (GAMA). “All are necessary steps to put in the final piece, which is automation.” These changes are starting with the design and integration of systems, he said. “We are seeing aircraft that are designed so the entire layout is integrated in a way that is straightforward to operate, much simpler to follow and much, much more intuitive,” he said.

In the past systems were designed separately, and

the approach to certification would be separate. The avionics interface with the pilot, the engine controls and information displays and the hydraulics would all be separate, with various gauges and displays.

But glass cockpits, touchscreen controls and new approaches to design allow that information to be presented as a holistic picture of the aircraft and its operation. Airframers are “working with vendors to integrate the airplane. From the moment you sit down, it all flows,” Bowles said. The result is much more intuitive, he added, particularly for the next generation of pilots. In fact, when discussing how to attract the next generation of pilots, GAMA president and CEO Pete Bunce noted the aversion younger pilots might have to a cockpit full of round steam gauges. “But if it has a screen that looks like a computer, they



While not a fully automated cockpit, the Garmin G3000-based Perspective Touch flight deck in the new Cirrus Vision Jet offers advanced features such as touchscreen controllers, including one (leftmost) that doubles as a standby display, Electronic Stability and Protection flight envelope protection, autopilot level button and autopilot-coupled go-around.

get excited...even before it is turned on.”

The single-engine Cirrus Vision Jet is an example of this integration, Bowles said. The aircraft has integrated its pilot interface through the Garmin-powered Perspective Touch avionics suite, which provides touchscreen and split-screen capabilities and presents information in a clear and concise way. The approach is integrated into the checklist, where switches are placed in a sensible order.

Most of the manufacturers are adopting this strategy, Bowles noted. “It is straight up happening,” said Brad Thress, senior v-p of engineering for Textron Aviation, pointing to the design of the Garmin 5000 suite on the Citation Latitude and Longitude. “You don’t push buttons any more,” he said. “You use a Garmin touch controller and it is intuitive, just like your phone,” he said. Thress noted that he grew up with the “button pushing system” but finds that he was able to adapt easily to the new system. He agreed with Bunce that this is second nature for younger pilots. “That’s all they’ve ever known.”

He also noted that the split-screen formats provide much more information in a simple way, enabling one side to show attitude, heading and

altitude while the other side can present “all the information you would like”—Tcas, weather radar, synthetic vision—in the format of your choice.

The Gulfstream G500 and G600 take that further with the overhead touchscreens of the Symmetry flight deck. The suite is powered by Honeywell Primus Epic avionics and Esterline touchscreens. Gulfstream has taken a fresh approach to the G500/600 program, bringing in a full-motion simulator and using an iron bird much more extensively during the development of these aircraft than previous models. “We wanted to make sure we understood everything from the pilot’s perspective,” said Dan Nale, senior v-p of programs engineering and test.

ALWAYS-ON SAFETY SYSTEMS

With the new interfaces comes a spate of safety-enhancing technology that is automating aircraft. “We’re seeing updates to systems that keep them online even in emergencies,” Bowles said. “During emergencies in the past, we’ve taken away the automation and put that workload on the pilot. And that was based on what we knew then. Today we are starting to see systems stay online all the time.”

Phil Straub, v-p and managing director of aviation



Dassault’s new FalconEye combined vision system (CVS) blends synthetic vision, thermal (infrared) and low-light camera imagery into a single depiction of the outside world on the head-up display. Already certified on the Falcon 2000S and LXS, FalconEye was certified on the 8X last month, followed by a dual-HUD system next year.

for Garmin International, pointed to systems such as the Garmin Electronic Stability and Protection (ESP) system, which works in the background to monitor and correct pitch, roll or high-speed deviations on aircraft without fly-by-wire. Garmin also has developed technology to keep the autopilot coupled during a go-around, providing automation during one of the busiest phases of flying, he noted.

The safety equipment is providing far more advanced capabilities. Dassault Aviation recently certified the FalconEye combined vision system, a head-up display (HUD) that provides both synthetic, database-driven terrain mapping and enhanced vision. Initially certified for the Falcon 2000S and LXS, the equipment will be certified soon on the 8X.

EVS and HUD technologies have made their way onto numerous larger jets, from Bombardier's Globals to Gulfstream's large-cabin line.

LARGE-AIRCRAFT CAPABILITIES IN SMALL AIRCRAFT

Advances in technology are bringing that safety equipment—once limited to military or the most expensive jets—into smaller, lighter and less expensive aircraft, said Bowles.

Cessna is offering the combination of HUD

and enhanced vision on the super-midsize Longitude. Embraer broke new ground in the light and midsize segment by offering the Rockwell Collins HGS-3500 head-up guidance system and the multi-spectral EVS-3000 enhanced vision system on the Legacy 450 and 500. Recently certified on the models, the systems offer both synthetic and enhanced vision in a compact unit sized for smaller cockpits.

“Certification of the HGS and EVS on these aircraft is a big step toward the widespread use of head-up vision systems as a primary means of operation,” said Craig Olson, v-p and general manager of business and regional systems for Rockwell Collins, in announcing the approvals last fall.

This technology is capturing even greater attention in light of the FAA's recent rule that facilitates the use of enhanced vision while landing. Companies such as Rockwell Collins and Honeywell have long been researching further advancements of enhanced and synthetic vision with full overlay of both features.

The Legacy 450 and 500 also broke new ground in their cabin size with the incorporation of full fly-by-wire with sidestick controls. The technology began with military and commercial aircraft and first appeared in business aviation on the Dassault Falcon 7X and Gulfstream G650.



Gulfstream's new G500 and G600 step up the technology ante with not only electronically interconnected BAE active fly-by-wire sidesticks but also touchscreen displays affixed throughout the cockpit.

“Historically these designs were extremely expensive and could not get into an aircraft that cost less than \$50 million,” Bowles said. “Now everybody sees the path. With the evolution of technology, we have started to figure out how we can be smarter with integrated systems.”

In fact the technology, which replaces traditional hydraulic systems with electrical flight controls, has generated so much interest among manufacturers that the FAA recently hired a fly-by-wire specialist to look at “cracking the code” for use in smaller and smaller aircraft. “It is so important to the agency that the Small Aircraft Directorate has dedicated a resource just to that technology,” Bowles said.

“Fly-by-wire is going to migrate into lower-cost airplanes because it is a much more mature technology,” Textron Aviation’s Thress agreed, adding that it is providing a new level of safety. “You can tell the airplane to stall, but the control logic is structured such that it won’t let that happen.”

Cessna is incorporating fly-by-wire for the first time on the Hemisphere. Thress cited the safety and ease-of-flying benefits, but added that it also cuts weight and is more easily maintained. “It’s to the point now where the cost ratio makes sense to us and fly-by-wire earns its way onto the aircraft.” Bombardier is introducing fly-by-wire to business jets, drawing on the architecture of the system used on the CSeries airliners for the Global 7000.

For the G500 and G600, Nale said, Gulfstream is building on the G650 system by “simplifying” it in the way the components are installed and how the system is used. Gulfstream is incorporating new active sidestick controls, which enable feedback from the pilot to the copilot so “they are constantly communicating” and each is aware of what the other is doing, Nale said. Gulfstream has incorporated coordinated turning into the system, which he said provides for smoother turning and eases the pilot’s workload.

Fly-by-wire also provides for more electrification of the airplane, Bowles said. “There is a lot of research on how we can generate more electricity on board to power lighter-weight systems,”

Bunce agreed. Bowles cited the Boeing 787, which is largely an electric aircraft, and said the trend in design is to push many of those concepts into smaller aircraft. “When everything becomes electronic, it makes it easier to integrate the aircraft. Taking mechanical systems and making them flow beautifully with electric systems is tough. Sometimes it is not feasible,” he said, adding that this provides incentive to move farther away from mechanical systems.

On the G500/600, Gulfstream is incorporating a data concentration network (DCN), technology that is found on the 787. The DCN centralizes the onboard data system, reducing wire and cable runs, Nale said, which “saves weight and cuts power consumption and maintenance requirements.”

Integration and electrification are working their way onto aircraft in many ways. Textron Aviation has patented a hydraulic aux pump system that is combined with a power transfer unit. “It is a practical thing, but cool technology,” said Thress. Beyond the systems, Wi-Fi capabilities are producing advances in technologies and are now a must for new aircraft. “The joke is that the Internet is now the new go/no-go item, the grounding item,” observed Thress. Most new aircraft are either produced with the capabilities or designed to accommodate them. New Wi-Fi services, such as Inmarsat Ka-band, are smoothing out the kinks in global high-speed connectivity. Bombardier has certified the Wave system on Globals to accommodate Inmarsat Ka-band.

Access to Wi-Fi aboard business jets of all sizes is opening the door to new levels of support and diagnostics such as the Textron Aviation LinxUs system, which monitors the aircraft and reports faults to both the company and the operator. It also facilitates recording of aircraft performance data over time to view trends.

Bowles said all of these technologies prepare for the future of automation. GAMA members have become increasingly interested in automation technologies, Bunce said. “Automation really has taken on a life of its own,” he said, with members looking at what they can do across the board. □

Additive Manufacturing Poised To Become Wave of Future

Experts are predicting that additive manufacturing, also known as 3D printing, will sweep across the aerospace industry in a few years. The process has already begun to take root at many business aircraft, engine and component manufacturers. In fact GE Aviation, acknowledged by industry peers as a leader in the field, has invested \$1.5 billion in the technologies. The company declared last fall that "The Future is Now" as it prints Leap engine nozzle injectors that it says are 25 percent lighter and five times more durable than traditional injectors.

GE has big plans for additive manufacturing and expects to operate 50 printing machines in a factory in Auburn, Ala., and produce 100,000 nozzle injectors through the manufacturing technique by the end of the decade.

Further, GE is planning another center to produce components for the new Advanced Turboprop Engine (ATP), chosen by Cessna to power the Denali pressurized utility single, and estimates that as much as 35 percent of that engine will be produced by additive processes.

DRAMATIC PRODUCTION CHANGE

Greg Bowles, v-p of global innovation and policy for the General Aviation Manufacturers Association, conceded that while additive manufacturing might not sound exciting, "it's going to change the nature



GE is pushing the envelope with complex additive manufacturing.

of aircraft." The process typically takes a digital design from computer aided design (CAD) tools and produces a part by adding layer upon layer of material. The manufacturing approach holds the promise of vast savings for the manufacturers, more reliable parts and components, better maintainability, and lighter and more efficient aircraft, industry experts agree.

Additive manufacturing experts "are talking about taking components that were 300 to 400 pieces put together by soldering and riveting and making the entire thing as one manufactured part," Bowles said. "It will be more cost effective, and parts will conform better without the little variations. The life of the parts will improve and there is potential for maintenance to go way down."

The process is still in the early stages, and the extent of its use varies among manufacturers. Textron Aviation and Aurora Flight Sciences are using fiber placement, a similar

process that could be considered a form of additive manufacturing. At Textron Aviation, the process was used to produce the Hawker 4000 but is now used on the Scorpion light military aircraft. Textron Aviation uses 3D printing techniques for nonstructural components such as glareshields and other small parts, said Brad Thress, senior v-p of engineering.

Aurora uses it for the horizontal tail of the Gulfstream G500. "We have several things going on that are pretty exciting with additive manufacturing," said Dan Nale, senior v-p of engineering and test for Gulfstream. Some of the uses involve manufacturing tooling, interior parts, prototyping and prototyping of models for wind-tunnel testing.

Honeywell has certified a part for use on the HTF7000 turbofan, said Bill Traxler, director of marketing and product management for Honeywell Aerospace. "Instead of having a multi-piece assembly, it's a one-piece component that is a complex configuration," Traxler said, noting that the process saves weight and reduces the cycle time to get the parts.

Walter Di Bartolomeo, v-p of engineering for Pratt & Whitney Canada, further highlighted the role additive manufacturing is playing in development and testing. "In early prototype engine testing, it allows us to make parts quickly without developing final configurations and without tooling. So there is an expediency," Di Bartolomeo said. He emphasized that the process enables companies to design shapes or parts that would not otherwise be possible.

Manufacturers are considering new approaches to aircraft design in the long term, such as embedding wiring bundles into the structure, Bowles said. "Theoretically you would lay out wiring and sensors and start to build metal around those things. Everybody recognizes that you get a lot of benefit out of additive manufacturing from the production standpoint," Bowles said, noting that it eliminates the work and effort involved with assembling tiny pieces to make complex parts. "There's a huge incentive to do more with additive. As a result, companies are really pushing additive machine manufacturers to make bigger and bigger machines," he said. "There's discussion about trying to make an entire cross section."

A key to this evolution will be examining the "allowables"—essentially the strength and performance—of the materials produced by additive manufacturing and getting the regulators to sign off on the new materials, Bowles said. Textron Aviation is exploring the allowables of new materials that might one day make their way onto aircraft through additive manufacturing, Thress noted.

"There is no question that additive manufacturing is going to take on a bigger role when the process matures as the allowables are demonstrated," Gulfstream's Nale predicts. "At some point it will replace machining parts. The first company that can make a wing out of additive manufacturing will be a big deal."

"Will we ever see an entire aircraft printed?" Bowles pondered. "I don't suppose we will. But you never know." —K.L.



VTOL, electric motors and robotics shaping future of aircraft

When the people who shape traditional aviation look to the future, they see a conventional aircraft powered by petroleum-based fuel and operated by pilots sitting in the nose. But in their vision those aircraft are sharing the skies with unmanned and optionally piloted fixed- and rotary-wing, vertical takeoff and landing (VTOL), all-electric and hybrid aircraft, machines that have new shapes and aerodynamics that are unlike anything carrying people and cargo today.

Such a future is coming sooner than most expect, say many of those researchers.

“Every company in this industry is vulnerable to disruption. If you think you’re safe with your technology, you might want to rethink that,” warned John Langford, chairman and CEO of

Aurora Flight Sciences, which is researching several disruptive technologies. “We have technologies that go across the aviation spectrum and turn upside down what you think about airplanes and what you think about this industry.”

Langford cites the explosive growth of the unmanned market as a lesson for the industry. More than half a million people signed up with the FAA’s drone registry within the first eight months, and within its first decade Chinese drone maker DJI has reached a valuation of \$8 billion. “The sensors and computer software have made these things so easy to fly that literally anyone can do it. The technology has moved from the realm of enthusiasts into a world where people can use them for economic purposes. All of this is being

driven by technology that is so easy to use that it has masked the complexity. That is what is going to happen to the rest of aviation.”

Greg Bowles, vice president of global innovation and policy for the General Aviation Manufacturers Association, agreed: “Unmanned is really spurring on this industry. What is possible today is filtering down from drones.”

AUTOMATION TESTING UNDER WAY

Bowles believes that the auto industry will help bring a cultural change to aviation. In a few years, more people will be riding in self-driving cars, he said. “The first months will be a little weird. After that, you will never look back,” Bowles predicted, adding that the safety benefits will be clearly apparent. “We will have that kind of safety expectation for flying. I think pilots will fly aircraft for a long, long time. I think we will make aircraft that are really fun to fly. But we will be making systems that are

safer and will provide the option of not controlling the vehicle.”

He noted that this evolution is already under way with the use of more automated systems in today’s conventional business aircraft. Aurora and Sikorsky, for example, have successfully tested optionally piloted aircraft. Aurora has been testing two approaches to the concept, one involving the Centaur demonstrator, a specially equipped Diamond DA-42 that is optionally piloted, and the other involving a portable robot called Alias (Aircrew Labor In-cockpit Automation System) that could be trained to fly a variety of aircraft.

The Centaur can be piloted either remotely or on board. Since it is a modified manned aircraft, Langford said, the path to certification is much easier than for an aircraft developed exclusively for unmanned operations. The company recently partnered with the marine conservation organization Ocearch to use the Centaur to support shark tracking off the coast of Nantucket, Mass. Aurora notes the aircraft can operate in controlled



Aurora's XV-24A LightningStrike UAV distributes a hybrid electric power system throughout this unusual unmanned aircraft's wings. Plans call for first flight of the VTOL LightningStrike next year.

airspace or in conditions that might be too dangerous for traditional manned aircraft.

Alias builds on the optionally piloted concept. Tested under a Defense Advanced Research Projects Agency (Darpa) contract, Alias provides portability through robotics. The robot has successfully flown a DA-42 and Cessna Caravan. Aurora has simulator tested it and expects to fly it on a UH-1 Huey next. The idea behind the Alias is to coordinate tasks in a manned cockpit, permitting pilots to perform tasks best suited to humans, while the Alias technologies perform tasks best suited to robots, Aurora said.

Sikorsky has been testing the Alias under a Darpa contract, integrating its Matrix automation technology in a Cessna Caravan and the Sikorsky Autonomy Research Aircraft (Sara). Langford believes these concepts will make their way into cargo operations first.

NEW ELECTRIC DESIGNS

Electric and hybrid propulsion also offers the promise of not only environmental gains, but reshaping aircraft and their operation. Electric aircraft are already making their way into the lightest end of the market, and experts predict that by 2030 a hybrid of electric and traditional fuel-powered business aircraft will be on the market, Bowles said. All-electric is anticipated to become possible on larger aircraft by 2040.

Electrical power inspires new designs. Under another Darpa contract, Aurora has been developing the XV-24A LightningStrike VTOL aircraft, powered by a “hybrid electric distributed propulsion system” that could allow the aircraft to hover, as well as fly forward. The aircraft integrates aerodynamics and propulsion with electric motors built into the wing. The motors move energy through wires instead of drive shafts. “There is no way to say where the

engine stops and wing begins,” Langford noted.

The XV-24A is expected to fly next year. Langford conceded that he isn’t sure whether the program will lead directly to an aircraft, or whether it will develop technology incorporated into future aircraft. But the concept is capturing significant attention, particularly as companies eye the market for VTOLs for commuter transportation.

Langford estimated that there are half a dozen serious organizations at the low end of the market, and “we have had varying levels of conversation and interaction with almost all of them.”

“Talk about the on-demand mobility model is beginning to take off,” agreed Bowles. “It is another new realm.”

Uber recently outlined a vision for an electrically powered urban VTOL network and hired a NASA engineer who will be dedicated to the Uber Elevate project. Uber acknowledges certification, battery and other challenges, but notes that as many as a dozen companies are looking at the VTOL concepts.

XTI is one such company, with the TriFan 600, but it is taking a hybrid approach with three ducted fans powered by two turboshaft engines. This project has attracted aviation industry veterans, among them the late Jeff Pino, who led Sikorsky; and Charlie Johnson, former Cessna Aircraft president and COO. More recently, former AgustaWestland North America CEO and AgustaWestland Tiltrotor president Robert LaBelle has come on board as CEO. XTI hopes to fly a prototype powered by Honeywell HTS900s within two years.

“This stuff is 100-percent real,” Bowles said of the evolving technologies. “The question is ‘Is society ready?’ We really do believe that with automation on the roads and other kinds of automation, society will be willing to go in that direction.”

—K. L.

Wing technology: morphing into the future

by Matt Thurber

With composites now well established, there is little new in the way airframes are designed and manufactured, and most aircraft still part the air with shapes that have changed by small degrees over the past few decades. For the most part, a wing is a wing with flight controls attached, typically flaps, ailerons, spoilers and sometimes slats. However, change is coming in the form of wing shapes that can morph into optimal configurations without the need for separate surfaces hinged onto the primary structure.

One application of wing shape-changing technology—Tamarack Aerospace active winglets—is not quite in the morphing category, but it represents the application of modern electronics to manage loads on a wing for greater efficiency. Tamarack's active winglets are an adaptation that improves the way the winglets work by lowering the structural burden they introduce.

Certified on the Citation CJ, CJ1, CJ1+ and M2, Tamarack's active technology load alleviation system (Atlas) winglets add a small active



Aviation Partners and FlexSys have formed a joint venture to bring wing-morphing technology to market. The first application is a KC-135 inboard flap, and talks are under way with many OEMs.



camber surface (Tacs) next to each winglet. The electronically controlled Tacs move in a way that alleviates bending loads caused by the winglets, so the devices can be designed with less structure added to the wing to compensate for the higher load. By relieving the load, the winglets can be optimized for maximum efficiency instead of designed as a less efficient compromise to minimize the amount of structural reinforcement needed to handle worst-case flight loads, according to Tamarack.

The Atlas winglets on the M2 take the wing's aspect ratio beyond 12 from its original nine, the company explained, "which translates to a 10- to 12-percent reduction in fuel burn, 400 pounds more zero-fuel weight, a 600-pound hot-and-high performance boost and the removal of a yaw damper INOP limitation."

Tamarack is working on Atlas winglets for other airplane types.

TRUE WING MORPHING

NASA is furthering research into wing morphing with its Mission Adaptive Digital Composite Aerostructure Technologies (Madcat) team at the Ames Research Center in Northern California. The team is collaborating with students from the Massachusetts Institute of Technology, Cornell University, UC Santa Cruz, UC Berkeley and UC Davis.

The Madcat project uses composite building blocks to make an ultralight wing, but the blocks are arranged in a lattice shape and the way they are placed affects how the wing can change shape. Computer-operated actuators control the morphing. Some flight-testing has been accomplished at a test airfield near Modesto, Calif., according to NASA.

FLEXING NEW WINGS

At the 2015 NBAA Convention, Aviation Partners and FlexSys announced a joint-venture company (Aviation Partners FlexSys or APF) to commercialize wing-morphing technology, and at last year's show the two companies demonstrated APF's FlexFoil technology on a 15-foot wing section.

The seamless, continuous flight-control surfaces can morph from -9 to 40 degrees, and FlexSys has flown the FlexFoil technology on a Gulfstream III during NASA tests. Among the possibilities for wings: active flaps, ailerons and leading edges, and a combination of morphing leading and trailing edges that can deliver high-lift, turbulence mitigation, de-icing and active load-alleviation configurations.

This research is leading to clean, unbroken flight surfaces—wings and stabilizers—that can change shape in ways that designers seek for maximum efficiency and performance. This should be far more efficient than changing the wing's shape with mechanical hinge- and track-mounted devices with all their added weight and complexity.

Since the last NBAA show, said Aviation Partners president Tom Gibbons, “we’ve been fielding inquiries, and we’re engaged [in discussions] with four major OEMs.” Large airframers are not the only ones interested in morphing technology; drone and rotorcraft OEMs are intrigued as well, the latter for morphing rotor blades. The most benefit will be realized with new aircraft designs, but morphing tech could also be retrofitted and also with all types of materials, not just composites. “FlexFoil technology takes advantage of the absolute normal process of flexing current aviation materials,” said Aviation Partners COO Hank Thompson. “We can flex titanium, aluminum and composites.”

While the applications for FlexFoil technology are many, there remains much engineering work

to bring products to market, not least certification. One of the first applications has already been announced, a FlexFoil replacement for a KC-135 inboard flap covering the last 26 inches of chord and spanning 142 inches. “We’re taking the section and morphing it to create a mission-adaptive profile that improves fuel efficiency,” Thompson said, “estimated by computational fluid dynamics analysis to be 4 percent. We’re building the static-test article now.”

“Everybody’s first frame of reference is the control surfaces on aircraft today,” explained Gibbons. “They have been pretty static for decades. You can apply this technology in new ways, given that computers now let us do far more sophisticated design work, and materials have evolved that can do much more than before. We find there are interesting applications to enhance existing wing architecture. At the same time, once we spend time with these manufacturers, they start to understand that this gives them the opportunity to redefine wing architecture. You don’t necessarily need different sections; you can flex different parts at different rates and degrees, without hinge lines and gaps, and get a general improvement in aerodynamics. If you can do that across an infinite number of points—today flaps travel at fixed percentages to a fixed position—if you use the power of computing to dynamically adjust that, you can get an improvement in performance.

“There is a benefit to applying this to current wing architectures, but it is a big step, as designers can create a new architecture for wing structure. That’s long term, and new airplanes [gestate for] many years. We’re just getting started.”

“Morphing technology is disruptive,” agreed Thompson. “It’s cutting-edge technology.” □