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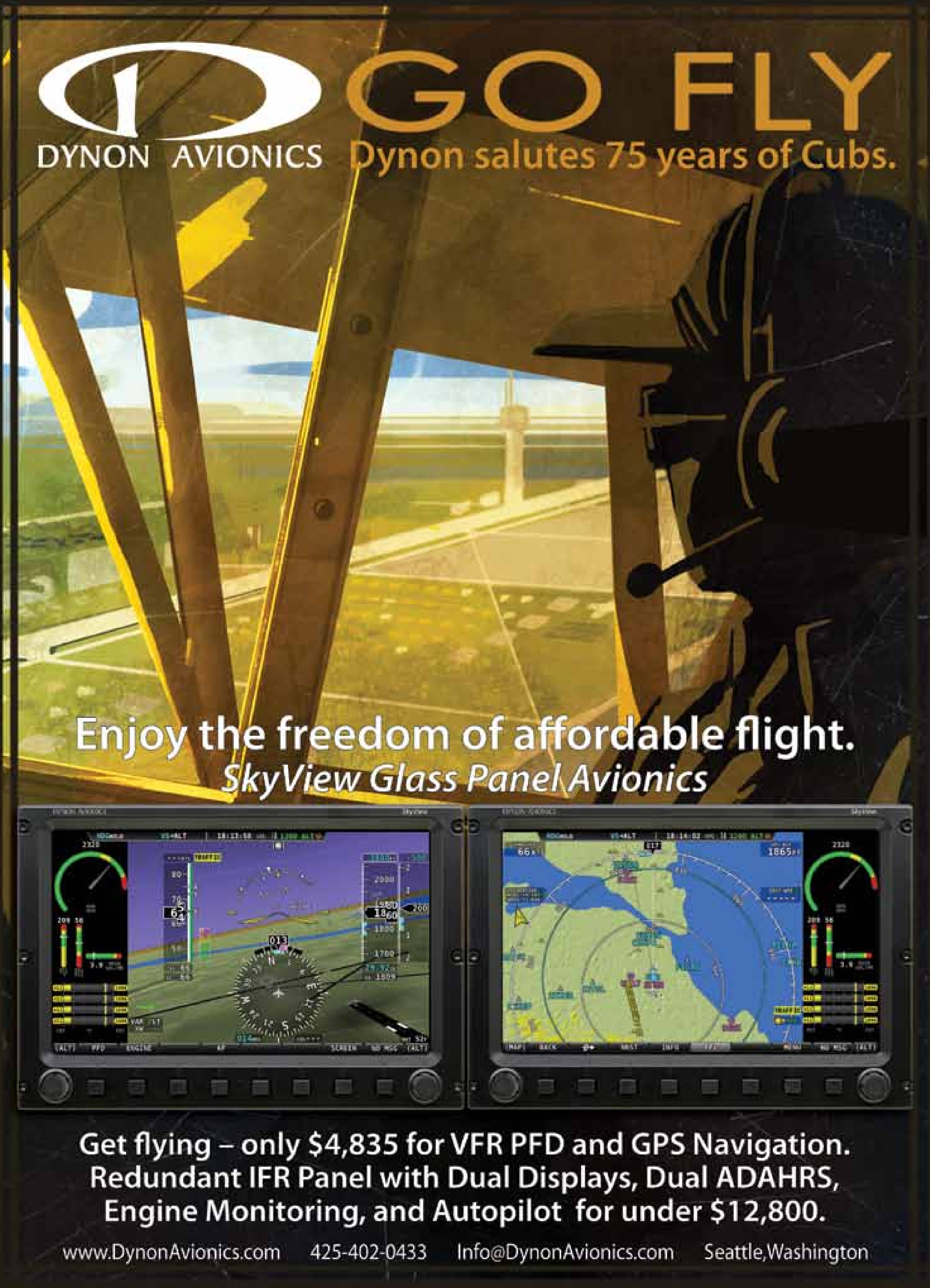
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# CONTENTS

September 2012 | Volume 29, Number 9




## Flight Reports



## Builder Spotlight



## Shop Talk



## Designer's Notebook



## Exploring



## Kit Bits



On the cover: The Arion Lightning was photographed by Richard VanderMeulen in Lakeland, Florida.

# EDITOR'S LOG

# Hope floats.

**I don't know** if you'll feel this way, but I found a lot to be hopeful about in this issue. Maybe part of it is that as I am writing this, it's graduation season, and my town is awash in the celebration that comes with young people being on the threshold of something new, something different. But I think it's more than that. It's people like Nick Otterback, whose Arion Lightning graces the cover of this issue. Here is someone who is passionately pursuing perfection, or getting as close to it as he can. Several years ago, when we last featured the Lightning, Otterback had listened to sage test pilot Chuck Berthe's suggestions about how the airplane could be improved, and he incorporated some changes. Berthe's words may still be reverberating, as Otterback continues to refine the Lightning. That approach to manufacturing is more rare than you might think.

Then there are the stories (Viewfinder, Page 4, and "Homebuilding on the Edge," Page 23) about an enclave in the California desert adjacent to an outfit you might have heard of called Scaled Composites. Elliot Seguin of Scaled invited us out for a visit about a year ago, and it finally happened (such is the nature of magazine publishing; good things take time). Editor-at-Large Marc Cook visited the facility and the local airport in Mojave a couple of months ago. Not only did he get a personal tour of the factory founded by Burt Rutan, but he also got an up-close and personal look at SpaceShipTwo, though that experience couldn't be documented with photographs. There are both ordinary and extraordinary things going on out there in the desert, including Gene Sheehan's electric Quickie project, which you can also read about in Dean Sigler's column, Alternative Energies; Sheehan made an appearance at the sixth annual Electric Aircraft Symposium in April.

There was another item in the news that prompted my good cheer, which was the successful launch into space and recovery of the Dragon capsule by SpaceX, which circles back around to Burt Rutan and all that he has been able to accomplish. Like Rutan, Elon Musk is a bit of an outlier in the aerospace world, yet he appeared on the scene and in relatively short order, and despite great obstacles and potentially fatal financial shortfalls, managed to achieve something fairly spectacular. Few would have expected him to succeed. Musk's background is in the Internet realm (he cofounded PayPal) and in the automotive world with the Tesla electric motorcar company. He is not an aerospace engineer by training. Until SpaceX, only three nations and one agency had flown a capsule to the Space Station. SpaceX's Dragon capsule is the first from a private company to complete the round trip. Musk's plans go further than wanting to just ship supplies into space; he wants to fly people there.

According to an appearance on *60 Minutes*, Musk's first tack toward encouraging enthusiasm about space travel was his attempt to buy a refurbished ICBM missile that he would send to Mars so that it could beam back photos. That project didn't fly, but it prefaced what came next: Musk invested $100 million of his own money into the Falcon Nine/Dragon project. Why? He believes mankind must become a multi-planet species to survive, and the only way to know which planets are habitable is to explore them.

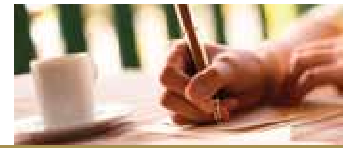
Just as many homebuilders construct parts themselves, Musk's Los Angeles factory, a former Boeing 747 plant, builds most of its own parts in order to be efficient and keep costs down. Some 1400 employees construct engines, rockets and the space capsules. Metal goes in, and a spaceship comes out, with final assembly occurring at the launch point, in this case, Cape Canaveral.

How did he learn how to do this? He read books, talked to smart people and assembled a Cracker Jack team. However, he's not about to turn his back on the U.S. space agency, NASA. In fact, SpaceX will be vying for the NASA contract to build the next U.S. manned spacecraft, a feat Musk believes he can achieve. In that sense, Dragon was a proof of concept design. Although Musk said he "wishes it wasn't so hard," he also said that short of "being dead or completely incapacitated," he won't give up on his dream. He also confessed to being disappointed that some of his greatest heroes, astronauts Neil Armstrong and Gene Cernan, both testified before Congress that they were bothered by his lack of experience and the perils of privately funded commercial space flight. Couch that in aircraft terms, and I'd bet many homebuilders have met with a similar sentiment. But most don't give up, and because of them, and people like Otterback and Musk and the Mojave group, I'm optimistic. ✈

Mary Bernard

*The product of two parents with Lockheed Aerospace careers, Mary grew up with aviation, prompting her to pursue pilot training as an adult. Her father, a talented tool-and-die maker and planner, instilled in her an abiding interest in how things are built. For more than a decade, she has been a contributing writer and Managing Editor for KITPLANES®.*

# LETTERS



EDITORIAL@KITPLANES.COM

## Push Me, Pull You

I read Marc Cook's article on the Zenith CH 650 B [June 2012] with great interest, but one part that was of particular interest to me was about the "pushrod-activated elevator." I called Zenith about that, and Caleb Gebhardt told me that Zenith has never used anything but pull-pull on the elevators for their designs. He questioned your sources, but the main reason for my writing is to offer as much time as possible for a retraction, in the event you decide that is appropriate.

I did enjoy the rest of the article, but I am still interested in pursuing a push-pull system on my CH 750 project. Any information on that subject that you may have available would be of interest to me.

**DUANE FELSTET**

*Marc Cook responds: Well, I must have spent too much timing hanging around RVs or recalling the Pulsar. Reader Duane Felstet is correct. The Zenith designs use cables to operate the elevator. My bad.*

## Props for Shrouded Props

Let me preface this letter by stating that I love Barnaby Wainfan's articles. His column is one of the major reasons I subscribe to KITPLANES®. As an engineer, I appreciate how well he communicates complex material into easily readable concepts. As a working aerodynamicist, I find his insights reaffirming to principles I already follow. Don't ever lose this gem.

Although Wainfan has a broad knowledge of aerodynamics, his recent foray into the world of shrouded propellers entered our area of expertise. For the most part, he is spot on. However, I must take him to task on a couple of points.

Although in theory an optimum shrouded prop can produce 28% more static thrust than an optimum free prop, we do significantly better in the real world. Most free props have a static thrust efficiency (Figure of Merit) of 50% to 55%. Our shrouded props typically have Figure of Merits above 80%. It's not uncommon for us to see a 45% increase in static thrust with a shrouded prop.

When a lightly loaded free prop is inserted into a shroud, the performance crossover point is somewhere in the 130-knot range. With modern CFD analysis, though, we can tailor the prop and shroud to work as a matched set. By using smaller diameter props, we also work with higher disk loadings. Wind tunnel tests confirm that a 54-inch shrouded prop outperforms a 76-inch free prop to speeds in excess of 200 knots.

Wainfan only brushes against the noise issue. Yes, the pitch of the prop noise is higher with a shrouded prop. Additionally, if you don't design the shroud lip properly, the shrouded prop can be twice as loud as a comparable free prop. But, with a properly designed shrouded prop, the noise is only half that of a free prop.

In the past, shortcuts and misunderstandings have hobbled shrouded prop performance in real-world installations. We are working hard to overcome the prejudices fostered by previous missteps. Up to now our shrouded props have been used mostly on research vehicles; in the near future, we anticipate a breakout of this technology into the world of sport aviation.

**ROB BULAGA**
**TREK AEROSPACE, INC.** ✢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# WHAT'S NEW

## KUNTZLEMAN'S Wingtip LED Light System

Kuntzleman Electronics introduces the LED Combo, a wingtip strobe anti-collision/navigation light system. This cluster of very bright LEDs uses a common controller that furnishes the heads with a junction point for synchronizing and selecting one of seven flash patterns. The system also allows for a separate power source to the navigation red, green and white LEDs.

The system includes two heads, mounting adapter plates for mounting on a radius, 50 feet of three-conductor wire, plugs, pins, one controller, miscellaneous wire connectors and mounting hardware. Also available at no additional cost (if mentioned at the time of purchase), are Combo adapters for Sonex, the BushCaddy and trikes. The introductory price is $399.

**Specifications include:**

- Navigation colors: Aviation red/green forward and white aft.
- Strobe: Synchronized with seven selectable flash patterns.
- Weight: Two heads and controller: 12 ounces.
- Power draw: Strobe and position lights draw less than 2 amps at 12 to 14 volts.

For more information, call 610/326-9068 or visit *www.Kestrobes.com*. Find a direct link *at www.kitplanes.com*.

## Zenith Debuts CH 650 QBK

A Quick Build Kit (QBK) for the Zenith CH 650 is now available from Zenith Aircraft. With the QBK, the main fuselage portion of the all-metal aircraft is assembled at the factory, and a factory-installed bubble canopy and cabin frame simplify construction and significantly reduce build time. Modern CNC fabrication technology on the standard kit includes many pilot holes, factory-finished wingspars and all hardware required to complete the airframe.

The Zenith CH 650 is a second-generation Light Sport Aircraft design developed specifically for Sport Pilots. This model offers features such as a larger cabin area and new bubble canopy. Standard features include wing baggage lockers, dual welded-aluminum wing fuel tanks and choice of landing gear configuration (tricycle or taildragger). Builders can choose from a variety of engines and firewall-forward packages.

The Zenith CH 650 Quick Build Kit is $22,950, which is $4450 more than the cost of the CH 650 standard kit. Zenith also sells component kits to builders who prefer to "buy as they build," or the aircraft can be scratch-built from plans.

For more information, call 573/581-9000 or visit *www.zenithair.com*. Find a direct link at *www.kitplanes.com*.

## RADIAL ROCKET Streamline Airframe Kits

Altitude Group LLC announced Radial Rocket Streamline Airframe Kits, which offer all of the Radial Rocket-specific airframe parts—molded composite parts, canopy and windshield, landing-gear struts, CNC and machined metal parts, the assembly manual and templates—but also allow builders to buy directly from suppliers common and over-the-counter hardware, materials and equipment previously included in the airframe kit. Builders will receive a detailed list of the materials and OTC hardware used in the airframe assembly process and sources in the kit, so these materials can be acquired as needed per the builder's schedule.

Altitude Group's Jeff Ackland sees the Streamline kit as a win-win. By acquiring common hardware and materials from vendors such as Wick's or Aircraft Spruce, builders will save about $9000 over the previous airframe kit pricing, and the company avoids having to warehouse these parts. Further, this portion of the builder's investment in the project can be spread out over time instead of being incurred all at once.

For more information, call 913/634-8531 or visit *www.RadialRocket.com*. Find a direct link at *www.kitplanes.com*. ✈

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# Gaming the system, gleefully.

**Burt Rutan is** not the kind of guy to play by arbitrary rules. And when he's had them forced across his desk, he has a long and glorious history of turning them upside down and decidedly to his favor. Where other designers see a straightforward challenge, Rutan saw (and still sees) an avenue no one else does.

Case in point? The Catbird. Also known as the Model 81, the Catbird was, in part, a response to the challenge handed down by the CAFE Foundation in the 1980s to design and produce more fuel-efficient aircraft. CAFE's signature competition, called Competition in Aircraft Fuel Efficiency, was first held in 1981 as the CAFE 250 and expanded the next year to run 400 miles, earning the new name of CAFE 400. The last CAFE 400 ran in 1990.

The goal of the CAFE races was to accurately measure aircraft performance from many standpoints, not just speed. For example, to score well in CAFE competition required a fine balance of speed, fuel efficiency and payload. The CAFE 250's formula was overall speed times miles per gallon times the square root of the payload. Aircraft with more than one seat could carry up to 200 pounds in each seat, up to the specified maximum gross weight of the aircraft. Most competitors flew with a single pilot and ballast to represent passengers (safer, less whining).

By the time the Catbird was ready to compete in the CAFE competition, the formula had been altered. Now it was speed to the 1.25 power times fuel efficiency (in mpg) times payload to the 0.75 power. An alternative way to calculate a CAFE score is: speed times mpg times payload times the square root of speed over payload. You can see the mathematical influence given to payload to offset what should be a loss of efficiency to the cabin needed to carry that payload.


The author in the Catbird seat.

No doubt Rutan saw the significance of this calculation as the Catbird came together. Although it was ostensibly designed as a personal transport to replace his twin-engine Defiant, there had to be more to the choice of five seats than shuffling people across the country.

That extra seat would do wonders to inflate a CAFE score.

Indeed, the only way to get five seats to work in the airframe size envisioned was to click over to the unconventional. The airplane gets its name from the seating arrangement, a central pilot's perch ahead of two forward-facing passengers at his elbows. Behind, entering through a separate door, are two aft-facing seats. The single canopy swings up to provide relatively easy ingress to the cabin for the front seaters, though the pilot has to stand on the outboard seat bottoms and wriggle across.

Bottom line: The Catbird, competing in the 1988 CAFE 400, trounced the competition, posting an all-time-high score of 2.75 million points. The second-place airplane was Gary Hertzler's VariEze, which made 49.25 mpg flying 152 mph; because it was a two-placer, it lost in the payload column, scoring only 2.36 million points. Gene Sheehan's Quickie Q200 and Klaus Savier's VariEze were close behind, with 2.32 and 2.28 million points, respectively. In raw numbers, the Catbird ran the 400-mile course, which included a mandatory climb to 7000 feet MSL, at an average speed of 192.3 mph using an average of just 8.9 gallons per hour.

**Marc Cook**

*Former KITPLANES® Editor-in-Chief Marc Cook has been in aviation journalism for 22 years and in magazine work for more than 25. He is a 4500-hour instrument-rated, multi-engine pilot with experience in nearly 150 types. He's completed two kit aircraft, an Aero Designs Pulsar XP and a GlaStar Sportsman 2+2.*

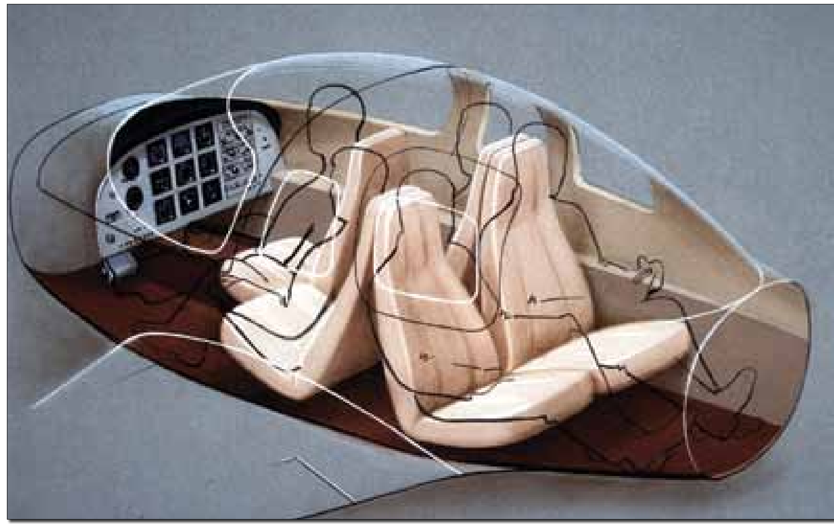
## Face to Face with Catbird

After its CAFE victory and a few airshow appearances, Catbird became Rutan's personal transportation until the Boomerang arrived. Then it was decommissioned and left to hang, upside down, from the roof at Scaled Composites. Zach Reeder, a Scaled engineer, suggested in 2010 that the airplane be brought down and restored to flying status. With Rutan's approval, the project began in early 2011 and was completed in time to make AirVenture that year, to celebrate Rutan's retirement.

I saw the Catbird for the first time at Oshkosh in 1988 and again this February during a tour of Scaled Composites and the Mojave Airport. (See "Ends of the Earth: Homebuilding in Mojave," Page 23.) I vividly recall thinking, in 1988, what an amazing conveyance the Catbird could be, and fervently hoped that the rumors swirling of a major airframe manufacturer taking it into production would come true. (I was just becoming aware of the homebuilt market at the time and wasn't terribly put off by Rutan's insistence that no kits or plans would be created.)

In 1988, the Catbird managed to seem both familiar and futuristic. It's a conventional planform airplane in many respects: engine in front, big wing in the middle, tail at the back. The bubble canopy, tough enough to withstand pressurization, seemed a bit unusual in the context of the slender fuselage—we'd grown up seeing windows, after all—though it's interesting to note that all of Rutan's space designs have simple round windows because that's the lightest, easiest way to deal with high levels of pressurization and maintain low vehicle weight.

But take a closer look. Those catfish whiskers at the cowling/firewall seam could be fixed lifting surfaces, and to some extent they are. But Reeder, who gave me a personal tour of the airplane, said their real benefit is as flow conditioners, improving the quality of the slipstream as it moves out of the turbulence of the propeller disk and toward the wings. In an airplane so focused on efficiency, nothing could be left to chance; cleaning up this airflow would improve lift and reduce drag. Look, also, at the T-tail: Its surfaces cant forward from the vertical stabilizer to reduce intersection drag at the T. The flapless wing is, as you'd expect, a John Roncz airfoil with a high degree of laminar flow. A contemporary CAFE report says that Roncz expected laminar flow to 65% of chord on the upper surface and 70% on the lower surface.



A period illustration of the Catbird's seating arrangement. The actual airplane isn't quite as luxurious.

The Catbird originally used the Lycoming TO-360 carbureted, turbocharged four-cylinder also used in the Rockwell Commander 112TC. This engine is updraft cooled, meaning the inlets are low and the outlets high, with the exhaust going out the top. A real oddball engine, in the grand scheme of things, but one the Scaled guys could get their hands on easily. (This would be a good time to mention that the Scaled *modus operandi* is expediency above all. If you look closely, really closely, at all of the Scaled projects, they seem almost a tad crude. Very effective, sure, but cosmetics and use of the latest technology are often casualties of getting it done and seeing if it'll fly.) A new IO-390 would fit like a glove.

## Have a Seat

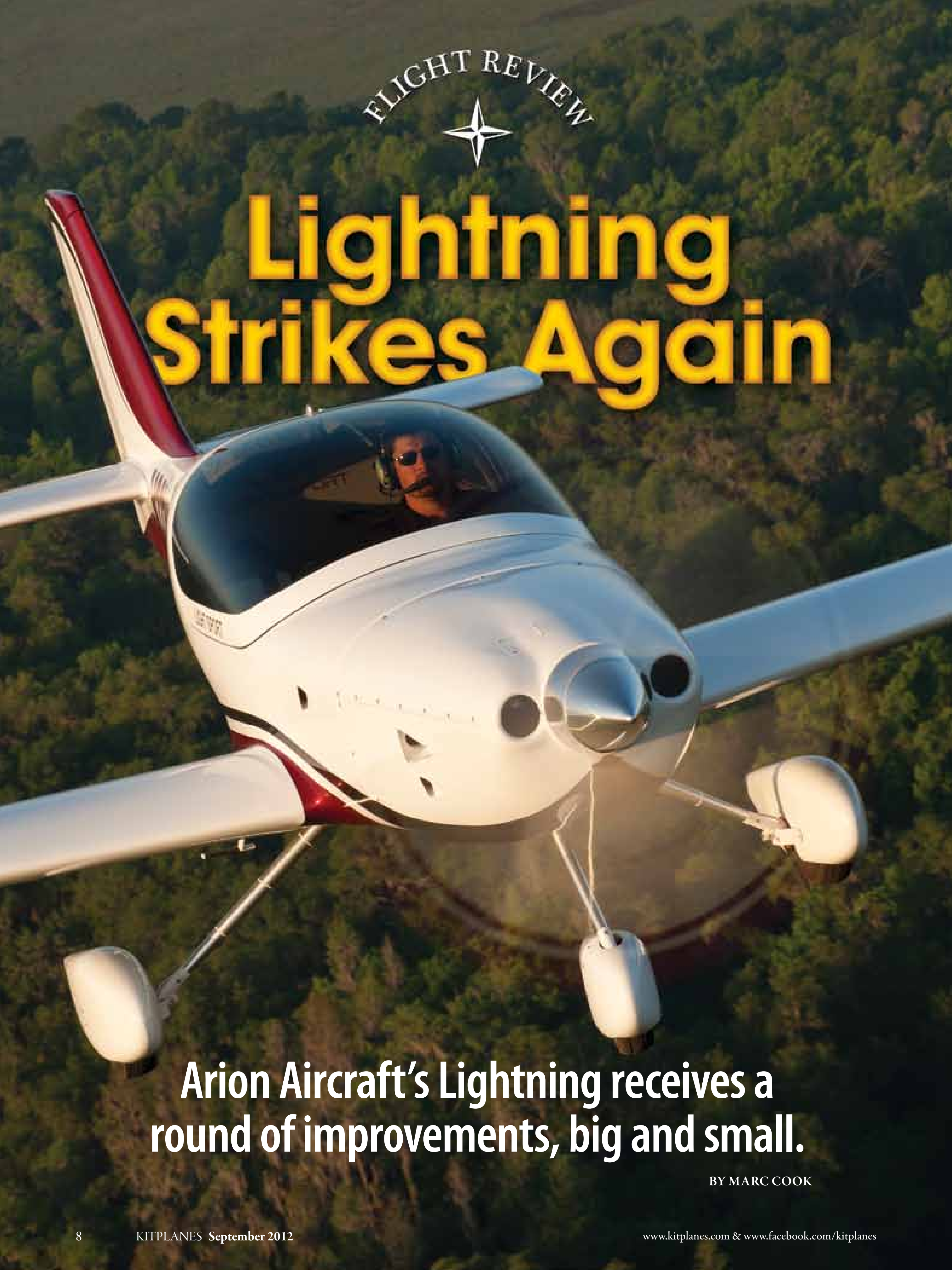
Reeder invited me to try the Catbird on for size. In today's world of electronic instruments, the Catbird's relentlessly late-1980s collection of round dials seems quaint. A few of the systems are pretty basic, including the manual wastegate and multi-step gear-retraction system. Rutan and his Scalies felt that a pilot should be a pilot, so such things as automatic wastegates and a single lever for the landing gear are just so much icing on the cinnamon roll. Isn't a cinnamon roll good enough by itself?

The single front seat is perfect, slightly reclined and comfortable. I could see spending all day, control stick in one hand, engine controls in the other. Your front-firing passengers won't be happy unless your personal hygiene is perfect, and even then only if they're pretty small themselves. Two sub-teenagers would be ideal. I didn't try the back seats, but they have a lot more room, and almost unlimited legroom, so aside from a mild case of claustrophobia, your aft-facing passengers could be pretty content.

## In Today's World

I couldn't help but think what a wonderful family airplane the Catbird could be, and if there would be a market for a kit version. I think you'd have to reconsider the one-two-two seating arrangement, and given the costs of landing gear and insurance, you might want to make it fixed gear. But the shape still turns heads, and the new ideas tried there have made it into other aircraft successfully. Could there be a place for a new-think Catbird in the homebuilt market? My totally subjective and slightly emotional vote is a yes.

*Photos: Courtesy Scaled Composites, Marc Cook*



FLIGHT REVIEW

# Lightning Strikes Again

## Arion Aircraft's Lightning receives a round of improvements, big and small.

BY MARC COOK

**You don't get** a second chance to make a first impression, or so the familiar phrase goes. That may be true on the face of it, but where light aircraft are concerned, a long-term development program can often take flawed designs—whether those flaws are large or small—and make them significantly better over time. There are many examples of kitbuilt aircraft that have improved tremendously from the first prototype, making that first impression accurate for the instant that it happened but not representative of what's on the market today.

Add to that list of improved aircraft the Arion Lightning. In fact, you could say a big update has struck twice with the low-wing Light Sport Aircraft. (It's sold as both an Experimental/Amateur-Built aircraft and a ready-to-fly Special LSA.) The last time we covered the Lightning was Chuck Berthe's flight review for the September 2008 issue. Prior to that story's publication, Berthe flew two different Lightning factory ships, the first and second prototypes.

In the first prototype, Berthe noted the Lightning's very light stick forces and low longitudinal stability. That early prototype had a number of characteristics no longer found in the design, including a spring bungee system, heavier tail surfaces and a shorter engine mount. Between Berthe's two flights, Lightning designer Nick Otterback revised the airplane, in part based on Berthe's comments. Those alterations included an engine mount 1 inch longer than before—moving the entire mass of the engine that much farther forward—as well as a separate trimtab on the elevator, revised stick/elevator gearing and a subtle repositioning of heavy airframe components, with an eye toward moving the ship's empty weight forward. Berthe thought that the original design might be running too close to its aft-CG limit with a normal load—a limit, he felt, that should have been moved forward. In fact, Otterback did specify a new, more forward limit for customer airplanes.

Berthe's second impressions were much more positive. While the airplane still had light control forces, with a stick force per G of 4 pounds, it now displayed positive longitudinal stability in all phases of flight. At the time, we roundly praised Otterback for listening to an outside test pilot and making what we felt were important improvements to his design. Even though the

Arion Aircraft's Nick Otterback continues to seek ways to improve his design.

U.S. economy as a whole was pitiably weak in this period, the Lightning kits and SLSAs sold well enough for Otterback and his dozen employees in Shelbyville, Tennessee, to keep the lights on and even commit more time to product improvement.


A GRT Avionics EFIS with synthetic vision and an integrated engine monitor anchor the Lightning's panel. Two seats are separated by a thin center console. A clever mixture adjuster (red knob) "fools" the Jabiru's Bing carburetor into reducing fuel flow in cruise.

*Photos: Richard VanderMeulen*

Upswept wingtips help improve aerodynamics and efficiency on the long-wing LSA model.


The wingroot fairing is part of the fuselage shell.

## Four Years On

I ran into Otterback at the Sebring show this January, where he hinted that additional updates were nearly ready for the Lightning. "You remember all the discussion of stability," he said. "Well, even though I kept working at the issue, I was never 100% happy with the results. Yeah, we improved it, but I thought it could be better still. So now we have what I think is the final fix: a new tail."

In truth, the updated Lightning carries over most of the major structural components, but the horizontal tail has more area: 3 square feet, to be exact. "It doesn't sound like a lot," Otterback said, "but it's very effective in increasing stability. We felt that this stability would be great for the pilots coming out of standard GA planes." In theory, a horizontal stabilizer with more volume makes the airplane more trim stable. When disrupted from the trimmed condition, the stabilizing force will be larger, all else being equal, so the airplane will tend to return to its trimmed airspeed more quickly. Such a change also means the airplane will resist maneuvering inputs, and the trick is to balance this newfound stability with good overall control balance and intuitive responses. You don't want, in the course of adding stability, to turn this lithe little airplane into a fiberglass pickup truck.

There are other changes to the tail group. "The smaller tail needed an upspring on the elevator to help with trim authority, but we've removed that spring with this tail," Otterback said. Regular readers of this magazine might recall that Berthe noted that the second prototype he flew in 2008 did not have enough

Traditional (for a homebuilt) flight controls include pushrod-activated elevator and ailerons, cable-motivated rudder.

The overall quality of the workmanship of this factory-built LSA is superb.

up-trim to fly hands-off down the final approach. And while the elevator and trimtabs have the same area as before, the maximum up-throw on the elevator has been decreased from 25° to 15°.

Finally, Otterback was contemplating some additional changes to the control gearing. Berthe felt that the stick/flight surface leverage ratios were too great, making the stick forces too low. During my visit to the factory, Otterback hadn't decided if the new system needed a similar change in gearing to improve control balance. (Subsequently, he decided to reduce stick leverage and wrote to say, "Wow. It's really nice now. The stick movement is shortened by about 1 inch at the limits. The pitch now is right on breakout force with the roll, and when making pitch changes without re-trimming, the plane really talks back.")

Both airplanes I flew were LSA-compliant designs, limited to 1320 pounds maximum gross weight and with wingtip extensions that add 12 square feet of wing a side and extend total span from 27.2 to 30.5 feet. The non-LSA version of the Experimental/Amateur-Built Lightning can go to 1425 pounds and will, according to the company, cruise at 135 to 140 knots. With standard fuel capacity of 22 gallons, an LSA variant can carry approximately 370 pounds. On the other end, a non-LSA version, with the optional long-range tanks (30 gallons), can carry about 410 pounds.

## Meet the Lightning

In case you're unfamiliar with the Lightning, sit tight for a little history. The design was penned by Otterback and Pete and Ben Krotje, who are also partners in the Jabiru USA side of the business. Arion Aircraft and Jabiru USA share two side-by-side hangars at the Shelbyville airport. (If you're there for a visit, know that the town is pronounced *shovable*. Don't forget.) The facility handles importation and repair of Jabiru engines, research and development, complete assembly of SLSA models (Jabiru and Lightning), kit mustering and customer assistance for both airplane lines.

Some have suggested the Lightning is a 3D scan of the Swedish Esqual, but that's not the case. It's true that Otterback used an Esqual fuselage to prove the Lightning's wing design, but beyond that the Lightning is its own deal. In many respects, the Lightning follows classic composite low-wing design philosophies with a large fuselage shell, split vertically, that extends from the firewall to the top of the vertical stabilizer. The wingroot fairings are integral with the fuselage shell, a detail that gave this Pulsar builder the warm glow of recognition, quickly followed by a phantom fiberglass itch.

Where the Lightning departs from convention is its use of a welded-steel

You can have any engine you want in the Lightning as long as it's the Jabiru 3300. This air-cooled, direct-drive engine makes 120 horsepower, just right for the airframe.

Light Sport-eligible versions of the Lightning run the Sensenich fixed-pitch prop to keep maximum speed in check.

## ARION LIGHTNING EXP

| | |
|---|---|
| Kit price | $35,900 |
| Estimated build time | 600 hours |
| Number flying | 56 |
| Powerplant | Jabiru 3300A, 120 hp @ 3200 rpm |
| Propeller | Sensenich two-blade, fixed-pitch |
| Powerplant options | none |

### AIRFRAME

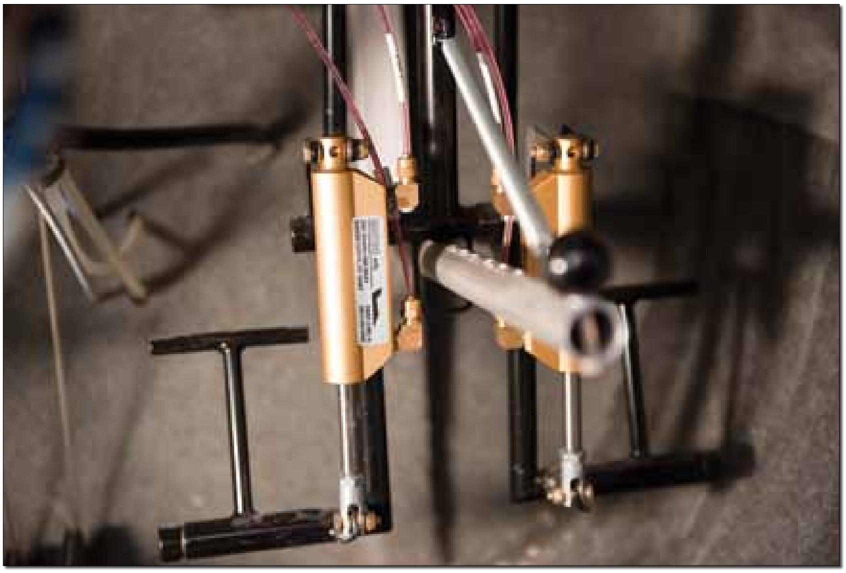
| | |
|---|---|
| Wingspan | 27.2 ft |
| Wing loading | 15.65 lb/sq ft |
| Fuel capacity | 22 gallons, 30 opt |
| Maximum gross weight | 1425 lb |
| Typical empty weight | 840 lb |
| Typical useful load | 585 lb |
| Full-fuel payload | 456 lb |
| Seating capacity | 2 |
| Cockpit width | 42 in |
| Baggage capacity | 100 lb |

### PERFORMANCE

| | |
|---|---|
| Cruise speed | 161 mph (140 kt) TAS |
| | 8000 ft @ 75% of max-continuous, 6.7 gph |
| Maximum rate of climb | 1200 fpm |
| Stall speed, landing configuration | 46 mph (40 kt) IAS |
| Stall speed (clean) | 52 mph (45 kt) IAS |
| Takeoff distance, ground roll | 500 ft |
| Landing distance, ground roll | 500 ft |

*Specifications are manufacturer's estimates and are based on the configuration of the demonstrator aircraft. Specs listed are for the Experimental/Amateur-Built version of the Lightning.*

structure in the belly that ties landing gear legs and spar attach points together. This pre-built (and powder-coated) structure defines a few really important dimensions and structural relationships for the builder, ensuring accuracy in the final product. Moreover, this structure contains the main control sticks and pickup points for the pitch and roll systems. It's pushrods and torque tubes for the elevator and ailerons, cables for the rudder, and a torque tube actuating the flaps via an electric jackscrew, also installed in this carry-through structure. Finally, this beefy weldment provides a lower support for the instrument panel and offers pickup points for the inboard seat belts. It sounds complicated, but by



Because the seat does not adjust, the rudder pedals do. Note the small-diameter brake lines, which improve braking feel.

creating this literal framework for the builder, Arion has dramatically reduced the amount of time spent creating raw structure and fiddling with mounting brackets for all these components.

### What's That Smell?

Otterback revealed another significant change to the Lightning, something I thought I detected out in the shop by smell. Where the Lightning had used an epoxy-based system, it's now using a modern vinylester resin. The epoxy/vinylester disputes go back to the Glasair/Lancair days, with each touting the benefits of the chosen method. But Otterback made the jump for good reasons. "Vinylester is very strong and light in this case," he said. "We've been working with our composites shop on this change, and so far we're very happy with it." That shop is Fiberglass Molding in Weyauwega, Wisconsin (say that 10 times fast). Vinylester has a few operational advantages over epoxy, mainly in that its cure time can be varied by the amount of catalyst, where epoxy must be mixed in the exact specified ratio to maintain its strength. Customers working in warm climates tend to fight with epoxy's short cure time on large layups.

### How'd They Do?

Otterback and I had a full day for flying just after Sun 'n Fun this year to test the big-tail Lightning and, fortuitously, had access to a recently built original Lightning for back-to-back comparisons. On the taxi out, Otterback briefed me on the Lightning. "You've probably flown a lot of different airplanes, but the one you should think back to is your Pulsar," he said. "I like to fly with my forearm on my leg and just a couple fingers around the stick. Even with the new tail, you won't need to use a lot of force to fly it."

Runup is typical Jabiru. All Lightnings fly with the 120-horsepower, six-cylinder Jabiru 3300—in fact, because that's the only choice (unless you want to totally engineer a firewall-forward installation). The company provides everything in the FWF kit, including mounts, oil cooler, lines, cables... the works. It's carbureted with twin ignition systems, so the runup more resembles that of a Cessna 172 than the high-performance airplane the Lightning appears to be. With both ignition systems working and a small drop from the application of carb heat, we were ready to go. Flaps go to half—total travel is 25°—for takeoff, verified by an indicator on the GRT Avionics EFIS.

Power applied, the Lightning accelerates well. Otterback likes to raise the nose early in the takeoff run and let the airplane fly off, as opposed to using a more deliberate unstick motion. Within 8 seconds, the Lightning had accelerated to 55 knots indicated (KIAS) and had become light on the mains. Immediately after, it flew off on its own. Placing the end of the long nose right on the horizon resulted in a slightly flat climb angle as the airplane accelerated through 60 and then 70 KIAS. Initial rate of climb was 1000 fpm with two on board and three-quarters fuel. In this high-power, low-speed configuration, the Lightning needed little right rudder to maintain coordinated flight and showed good stability. It seemed natural to allow the airspeed to creep up to 80 to 85 KIAS, which gave 700 to 900 fpm in the climb through 2000 feet MSL.

Cruise checks at 5000 feet MSL (a density altitude of 6095 feet on this day) revealed good performance. This Lightning was running the Sensenich 60x57 two-blade composite prop, the recommended setup for the LSA version. (The Experimental/Amateur-Built version of the Lightning can be built to conform to LSA rules, but if you choose to build it to a higher gross weight and allow a higher cruise speed, Arion recommends the Sensenich 62x58 scimitar-style FK-blade prop.) Set to 2850 rpm, the Jabiru pulled this Lightning up to 117 knots true airspeed on 5.3 gph, according to the GRT engine monitor. A two-way GPS run gave us an average of 118 knots. Otterback says the Lightning will gain a few knots at optimum altitude. Pulled back to 2600 rpm, the airplane does 100 KTAS on 3.9 gph.

## Manners, Improved

Otterback and I tried a simple series of stalls, clean and dirty, which showed that the Lightning has very good trim tenacity. He pointed out during our flight that the small-tail airplane needs little adjustment of the pitch with a fairly wide range of speeds; the current airplane definitely called for blips of the electric trim motor to zero stick forces. Stalls dirty give a mild burble with the airspeed needle stuck on 40 knots and no tendency to drop a wing, and recovery is a mere relaxation of back pressure away. So far, so good.

An important test for longitudinal stability is to displace the airplane in pitch and see how it reacts. A strongly stable airplane will immediately move the nose in the recovery direction (down, if the pitch input is up), gently pass through the trimmed airspeed and

The slightly wasp-waisted look of the Lightning helps give it ramp glamour.

Arion has spent a lot of time getting the Jabiru to cool well. A substantial amount of cowling exit area and small lip help keep air flowing and temps down.

eventually work toward that trim equilibrium. The modified Lightning did just that. Trimmed for 100 KIAS and displaced nose-up by 10°, the airplane responded promptly with a nose-down correction, a shallow dive through the trimmed pitch attitude and a complete recovery in just more than one cycle. I wouldn't call the response snappy, as you'd find in a certified airplane, but absolutely acceptable.

(To gain some perspective, Otterback and I took the small-tail Lightning aloft later that afternoon. In the same tests, the airplane would hold the nose above the horizon and gently, over the course of 30 to 50 seconds, begin recovery. In a nose-down pulse, the nose would stay down, and even though the airplane gained speed fairly rapidly, the nose barely started to rise.)

## Inbound to Shovable

Initial approach speed for new pilots and visiting journalists is 60 KIAS, which provides a ton of extra energy in the roundout. The flaps are effective with a mild nose-down pitch change on deployment. In general, the approach feels a bit flat and the pitch window appears narrow, but that's mainly an optical illusion. Starting from 60 knots, the trick is to manage the deceleration in ground effect, which is made easy by the strong rudder and excellent aileron effectiveness. In fact, the airplane is as

By adding 3 square feet of horizontal stabilizer, Arion's Nick Otterback gave the Lightning substantially improved pitch stability. The maximum throw of the top-hinged elevator was reduced 10° to 15° up. Electric pitch trim remains as a separate tab.

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nicely balanced at these low speeds as it is in cruise, with roughly equal pitch and roll forces, and higher yaw forces, as you'd want. Otterback was considering, again, adjusting the elevator gearing with the new tail, and it's likely that reducing the stick's mechanical advantage on the elevator will result in slightly higher pitch forces, which in turn would bring the airplane toward the more desirable control harmony—with roll lighter than pitch lighter than yaw.

Nevertheless, I found no difficulty in the landings, and in looking at the video of the flights, it's painfully clear that my control-stick movements were much less numerous in the large-tail airplane than in later flights in the other Lightning. (Amazing how much you don't recall about a flight that's right there in the video.) Even on this relatively calm day, it was clear that the pilot's workload will be lower with the improved stability. Later landings, with 55 KIAS as the initial speed, were better, with a more positive payoff at the end and the ability to put the airplane down at any chosen point.

## What's in the Box

**Arion Aircraft supplies the fiberglass components in fabricated form, including the fuselage halves that are bonded together with bulkheads installed. The wings are closed with the fuel tanks complete. Other prefabbed composite components include cowlings, spinner, canopy frame, seat and baggage floor. The base kit includes all FWF components except for the engine. The welded-steel center section and rudder-pedal assemblies are pre-built and powder coated. The builder has to purchase the engine, propeller, wheels/brakes/tires, electrical system, avionics, paint, interior and other commonly available items separately.**

***—M.C.***

### Very Nice Just Got Better

After this unusual opportunity to fly both Lightnings, it's gratifying to see how much improved the new airplane is. Otterback has once again made the effort to improve his airplane and it's paid off handsomely. Despite a high level of factory completion—the control surfaces are completed and closed, fuel tanks finished, fuselage seamed together and fitted with structural bulkheads—the Lightning kit is reasonably priced at $35,900. That's before you add the engine, avionics, prop, paint and interior, of course, but considering the amount of work done for the builder and the high quality of the components I saw, that's a pretty good deal. That the airplane continues to improve, becoming more accessible to pilots coming directly from certified aircraft, makes it even more impressive. Maybe the best first impression is actually the third time's charm.

*For more information, call 931/680-1781 or visit www.flylightning.net. Find a direct link at www.kitplanes.com.*

# The Ultimate UPGRADE


## The Solesbees' Lancair Evolution finally takes its first flight.

BY DAVE PRIZIO

**On a clear winter day** with a light breeze blowing out of the west, Lancair Evolution N7LH made the leap from project to airplane as it jumped off the runway at Chino Airport in Southern California. Two and a half years of work and a considerable amount of money came together in that moment for Wendell and Martha Solesbee as Wendell took to the air for their plane's first flight. He had long considered hiring a test pilot for the first flight, but his own desire to have that honor and his confidence born from many years of flying experience, including many hours in his Lancair IV-P, convinced him that he could handle the job, which he did with aplomb.

As we concluded the previous installment of this series, the Solesbees had their plane just about ready to fly, apart from some fine-tuning and the paperwork. Should be flying in a week or two, right? Well, not so much. The Riverside Flight Standards District Office (FSDO) wanted to see a maintenance manual for the airplane. Lancair had already produced one for a number of previous Evolutions, so it was quickly forthcoming. Almost a month and a number of minor revisions later, the Solesbees had an approved maintenance manual and permission to proceed with their application for an airworthiness certificate. The FAA requires an approved maintenance manual only for turbine-powered Experimentals, so all of us piston-powered guys never saw this one coming.

The next step was to contact a Designated Airworthiness Representative (DAR) to process the airworthiness certificate. The Solesbees wanted to use someone who was familiar with the Evolution, so they got in touch with Dave Morss, who needs no introduction to those familiar with Lancairs. He is an A&P/IA and test pilot working out of Northern California and is very familiar with the Evolution. However, another blessing from the Riverside FSDO was needed to allow Morss to come into its area and work. Another wait, but it was worth it. Morss's experienced eyes picked up a few minor but potentially critical mistakes that Wendell quickly corrected. A nut was missing from an aileron hinge bolt, and a fuel-tank vent was plugged with masking tape left over from painting. This is why an initial condition inspection by an expert, and not the builder, is so critical. It is amazingly easy to miss things like this, no matter how thorough and careful you are.

## Paper Shuffle

With the DAR satisfied, the Solesbees got their airworthiness certificate and operating limitations. They were now ready to enter the Phase I flight-test period, 40 hours in a designated test area where the plane could be wrung out and proved safe for flight. The only thing left to do was put the airplane back together after the condition inspection. Installing every inspection cover, closing every hatch, and replacing the cowl was a good day's work, and then some.

With all of this done and the decision to forgo a hired test pilot made, there was little reason not to get in the plane and see what it would do. Even though this was to be Wendell's third first flight, it was clear that he was gripped by a combination of anxiety and excitement ahead of the big moment. And who wouldn't be? This is a big, fast airplane and the result of a lot of money and hard work. There was a lot riding on it, but he did a good job of maintaining his focus and composure.

Watching from the ground, you could see the Evolution's exceptional performance. It came off the runway in what appeared to be less than 1000 feet. This plane is no runway hog, especially when lightly loaded, but then you would expect that with 750 shaft horsepower on tap. A few circuits south of the airport and a low pass for photos, capped with a firm but respectable landing, and the first flight was over. Martha was visibly relieved as their new plane taxied in, and Wendell seemed pleased with the results of their endeavor. A great start. Only 39.5 hours to go.

Wendell and Martha Solesbee are quite pleased and a little relieved that all of their hard work has finally paid off.

## How Does It Fly?

The first question out of everyone's mouth when Wendell came back from his first flight, and ever since then, is: How does it fly? "Like a Bonanza, but with super power," Wendell replies. But there is a bit more to it than that. The Evolution has a lot of power, more than twice as much as a Bonanza, and when you push the throttle forward, you get pressed back into your seat. All that power means you need a lot of right rudder to keep the plane going straight down the runway.

Comparisons to the Lancair IV-P are inevitable, and Wendell is well qualified to draw them. The Evolution rotates at a lower speed and as a consequence it uses less runway—a lot less. This is a plane for which taking off and landing from a 2000-foot runway at sea level are now reasonable things to consider. Such things would be almost unthinkable in a IV-P. The Evolution is less sensitive in pitch than the IV-P, inspiring more confidence in its handling, especially for someone just getting used to the plane. The other feature that makes short runways less exciting is beta. Pull that big Hartzell four-blade prop into beta and you slow down in a hurry. Midfield turnoffs from Chino's 4858-foot-long Runway 26R are now a piece of cake in the Evolution. In the IV-P, Wendell would almost always use the full length of the runway to land.

While these first impressions are valuable and interesting to hear, they're not the final word on the Evo's handling. In its current state without an interior, the airplane is right at the forward edge of the CG envelope. As a consequence, it runs out of elevator at around the same time as it touches down, making "greaser" landings just about impossible. Bags of sand—100 pounds' worth—in


Dave Morss performed safety inspection and DAR duties for the Solesbees. His expert eye caught a couple of important problems that Wendell quickly remedied.


Wendell taxis out for his first flight in N7LH.


The ground roll was short and the acceleration brisk as N7LH slipped the surly bonds of earth for the first time and climbed skyward.

Martha and a friend strain to see Wendell as he heads south of the airport for some brief flight testing.

the baggage compartment more than took care of that problem, making graceful arrivals much easier now. Once the interior is finished, the plane will need to be reweighed; ideally, no permanent ballast will be required. The only other complaint is that the plane used a lot of fuel during the test period, where most of the flying has been down low. The Solesbees are still coming to grips with the difference in fuel flow between the Evolution and the IV-P.

## Reflecting on the Building Process

Once the Solesbees were well into their Phase I flight testing, it was time to reflect on the building process: What went well? What didn't? What differed from their expectations? To start, Wendell says that the composite work on the basic structure was much better than he had expected, and much better than the Lancair IV-P. Everything was smooth and true and required almost no filling to prepare for paint. Considering how picky he was about the paint job, this is a fine compliment. Another positive: Lancair's willingness to make improvements to parts as the project progressed. There were a few things that needed to be redesigned and improved on the early Evolution kits, most notably the landing gear. Lancair took care of everything at no charge. In addition, factory technical reps were always available to answer questions and give support—an important resource for any builder, but especially if you are among the first.

The area in which the Solesbees experienced the most trouble was the wiring. The kit comes with a prefabricated instrument panel and wiring harnesses, but there were still some difficulties. Some were simple—like wires being reversed in their terminating connectors—but others were much harder to track down. With Wendell's strong electrical background, he was able to diagnose and repair these issues, but they would have been a real challenge for a less electrically inclined builder. This is an area where Lancair needs to improve, he noted.

When Wendell was asked what the hardest part of building the Evolution

# The Observer's Opinion

**Watching Wendell and Martha Solesbee tackle this enormous project has been a fascinating experience for me. I, like probably many of you, assumed that few people were actually going to build one of these airplanes without hiring a professional builder to do most of the work, if not all of it. I can't speak for every builder, but I can assure you that the Solesbees did the vast majority of the work themselves. I hope others will look to that example and do the same. If they do not, they will be kicking sand in the face of every amateur builder who follows the rules, and they will have deprived themselves of a tremendously gratifying and educational experience.**

**I think it is truly amazing that such a kit is available and can actually be completed by amateur builders such as the Solesbees. It is a tribute to Lancair that the company has been able to design and manufacture such an outstanding product. In about 30 years, we have evolved from the first "fast glass" airplane—the Glasair I—to the Evolution, and along the way forced a revolution in all of general aviation. At the time, who would have thought that such a thing was even possible? For less than half again the cost of a new Bonanza, the Solesbees have at once created for themselves a truly high-performance cross-country airplane and stuck their thumb in the eye of every aerospace giant that has the gall to ask the price of a new home (or two or three) in return for an airplane made from mid-20th-century technology. That's a story worth reading about, which is why I wrote it.**

**Beyond that, the Evolution represents an important segment of the amateur-built airplane market, one at the opposite end of the cost spectrum from the Pietenpol and the Breezy to be sure, but an important one nonetheless. After all, more than 40 Evolutions have already been sold, which puts it ahead of a great many other designs.**

**In this era when almost everything we see, including much of aviation, is regulated to death, isn't it wonderful that an airplane such as the Evolution can be built? Isn't it amazing that our little corner of aviation, Experimental/Amateur-Built aircraft, has managed to survive mostly unscathed in this environment? I, for one, am thrilled that such a feat is still possible, even if it isn't really feasible for me or for many of you. Congratulations to the Solesbees and Lancair for moving aviation another step forward.**

***—D.P.***

Wendell makes a low pass in front of Martha and friends at the end of a successful first flight.

Wendell taxis back to the ramp to an expectant crowd and happy wife.

was, he quickly answered, "The cowl, especially the lower cowl." Even with his considerable composite experience, he found the lower cowl to be challenging with its various baffles, along with the precise fit the cowl required. Additionally, he had complicated the matter by insisting on installing blind fasteners, but his desire to make it look as good as possible would allow nothing less.

## Can Anyone Build One?

Wendell and Martha Solesbee are experienced airplane builders whose resumes include a Lancair IV-P in addition to their now-complete Evolution. Wendell has a background in electrical engineering, as well as many years of experience running an automotive paint and body business. They used almost no professional assistance outside of the initial mandatory factory program to assemble the major structural components. Over the course of two-and-a-half years, they invested 2500 hours in their project. Considering the size and complexity of the Evolution, that seems pretty reasonable. They laugh at the idea of a first-time builder undertaking the project—unless he or she has a great deal of experience in a similar field—and duplicating what they did in any reasonable amount of time, if ever.

One reason KITPLANES® decided to follow the Solesbee project was to answer a simple question: Can an airplane as large, expensive and technically formidable as this one actually be constructed by an individual? Well, obviously it can. Even taking into account Wendell's exceptional abilities and determination—powerful qualities when combined with experience and the financial wherewithal to support such a project—it's plain to see that the Evolution is an airplane that can be constructed by a determined individual.

We're going to take a break from this series to let the Solesbees finish up their interior and put the airplane to the kind of use it was built for. Later this year, we'll rejoin them to see how the Evolution compares to the IV-P—in speed, cost, efficiency, comfort and reliability, plus a few other categories. And we'll take a closer look at the value represented by this sleek dream machine. ✈

*For more information on Lancair, call 541/923-2244 or visit www.lancair.com. Find a direct link at www.kitplanes.com.*

These acrylic aileron and flap hinge covers are one of the Solesbees' nice custom touches.


The oxygen meter and Hobbs meter fit nicely in this custom side panel by Evolution pro-builder Mike Custard.

The engine cowl proved to be Wendell's greatest challenge, and that doesn't even consider the extra work of creating a blind fastener system for the cowl.

Field Notes

# Homebuilding on the Edge

## The old joke says Mojave, California, is not the middle of nowhere, but you can see it from there. Oh, so *not* true.

BY MARC COOK

**Mojave, like so many** California desert airports, began life as a support strip for the local gold and silver mines. It became Marine Corps Auxiliary Air Station Mojave in 1942. Mojave passed to the U.S. Navy after the war and back into civilian hands by 1961. Throughout the 1970s, various forms of air racing were common at Mojave—a sort of Reno south, if you will—but changes in local roads that cut off part of the course and a longstanding issue with winds and high summertime temperatures helped hasten the end. By 2004, the airport became the Mojave Air & Space Port owing to its stature as a commercial spaceport recognized by the FAA. This acknowledgement came just days before Mike Melvill made the historic flight in Rutan's SpaceShipOne on June 21, 2004.

Mojave's emergence as the hotbed of private aerospace design and testing owes a lot to its proximity to Los Angeles (about 2 hours away), great expanses of sparsely populated California desert, generally flyable weather conditions much of the year and more than adequate facilities. Having a 12,000-foot runway (with significant open land at each end) at your disposal opens up the opportunities to test high-performance aircraft with as little risk as possible. Mojave's success is also due in part to the tireless efforts of Dan Sabovich, longtime airport manager and member of the East Kern Airport District, which managed the airport.



Photos: Marc Cook, Courtesy Scaled Composites

Rutan's Catbird under construction at Scaled Composites in the early 1980s.

Sabovich was instrumental in attracting new businesses to the airport while maintaining relationships with existing tenants. (It's not uncommon for airport authorities, in seeking to land bigger tenants, to be tempted to kick the old-timers to the curb.)

Somehow, Sabovich managed to bring in totally new industries and clients and get them to integrate into the whole. Among Mojave's alter egos is that it's a place for airliners to go to die—or at least rest while waiting for the next-life event. Some of that open land now pays for itself. Movies and television love Mojave for its flexibility. Perhaps the best show on the tube, *Mythbusters*, goes to Mojave frequently to tear apart old airliners and blow stuff up. Among the assets valuable to filmmakers: two floodable pads, warehouses, "wreckage and salvage parts," a firing range, big runway, on-field medical and firefighting capabilities and, perhaps best of all, a blast pad. Who *doesn't* want a blast pad?

But there's something else at work here, not so much stated for the record, but instead hinted at in casual conversation. For many years, Mojave as an airport of aerospace development flew somewhat under the radar, almost as though the type of person (wearing an FAA badge or not) who would insist on dotted i's and crossed t's would be less than interested in standing out in the desert sun looking for something to complain about. Not to say it was the wild, wild West, but the prevailing attitude has long been one that embraced the unknown. Perhaps, too, the proximity to the Edwards Air Force Base, where so much leading-edge technology has been tried and tested, has something to do with the attitude at Mojave. Innovation isn't the oddball around here; it's the norm.

## Rutan as Centerpiece

Burt Rutan is a big man—physically and metaphorically—but his shadow hangs so long over this desert town that he might well be 50 feet tall. Rutan's aviation accomplishments are without parallel in the modern era, and run with a particular attitude. This attitude conveniently parallels that of Mojave itself. It's an attitude that says, "I can do it better, faster and smarter than you." Whatever *it* is.

An important constant runs through Rutan's approach and is mirrored by (or, perhaps, simply mirrors) the way Mojave has evolved: a no-nonsense practicality. How can you say such a thing about a company that has created the private-sector space race and launched a slew of groundbreaking aircraft? It's easy when you look closely, which I did, thanks to Scaled Composites' Elliot Seguin, who invited me to speak at a regular event Scaled holds for its engineers—lunch and a talk. It says something about the corporate culture that it encourages outsiders to come and share their experience and

Before and after: Burt Rutan poses with the CAFE-dominating Catbird in the late 1980s. Last year, he was reunited with the Catbird as a retirement send-off.

An uncommon updraft-cooled, top-exhaust Lycoming TO-360 powers the Catbird.


The Catbird in flight near—where else?—Mojave.

point of view. Afterward, a quick tour of Scaled (sadly, no cameras allowed) and then a full afternoon of touring hangars, seeing what must be just a fraction of the exciting projects taking shape under the hot California sun.

## Company Like the Man

Burt Rutan has always been given the credit for radical leaps of concept and execution, much of which is justified. But with the formation of Scaled Composites in 1982, he created a core business structure that would support tremendous innovation.

"I think you can create an environment in which people can be innovative," Rutan told *Air & Space* magazine in 2009, two years before his retirement. "And it's an environment where you don't let people feel guilty of failure. In other words, you let them try things that may not work. And you expect that they'll try a lot of things that don't work. And once in awhile, they'll come into something that's a new, genuine idea. That environment doesn't exist at the normal airplane factory, but I try to make it exist." During our walk, Seguin makes the connection. "You can see how it happens around here. Long-EZs and Quickies turn into spaceships."

So things are tried. Wander through any of Scaled's hangars, and you'll see innovation at work. During my visit, I got to stand under the belly of the imposing Proteus multi-purpose, high-altitude research aircraft, stare up at the WhiteKnightTwo four-engine design meant to take SpaceShipTwo to altitude, and even stand a couple of feet away from SS2 itself. It was more than a little humbling to see so many aviation milestones in one place.

## A Place to Build

Seguin took me on a mini tour of Mojave's Experimental projects, which ranged from the conventional to the intense. On the saner side is Nick Sheryka's Sonex.

The Catbird was built when analog gauges ruled. So, too, did purely mechanical, high-pilot-involvement systems like a hand-crank landing gear.

With a workshop/hangar this neat, you have to wonder what Nick Sheryka's office looks like. He praised the simplicity of the Sonex as well as the clarity of the blueprints.

Sheryka started his Sonex in New Hampshire before relocating for his "dream job."

"My goal for this was to get myself into an airplane, learn how to build and to become a pilot. I wanted something inexpensive to learn on. I already have plans for the next airplane I'm going to build. The Sonex is a good design, proven, and the blueprints are fantastic."

Sheryka started the project at home in New Hampshire, but moved it to Mojave when he got his "dream job at Scaled." Sheryka said he did a lot of work in his garage but eventually had to move the project to the hangar. "I was actually out here until 11 o'clock last night putting on the ribs, but I don't mind. It's really convenient to work so close to the project. At lunch I can come in here and work for an hour.

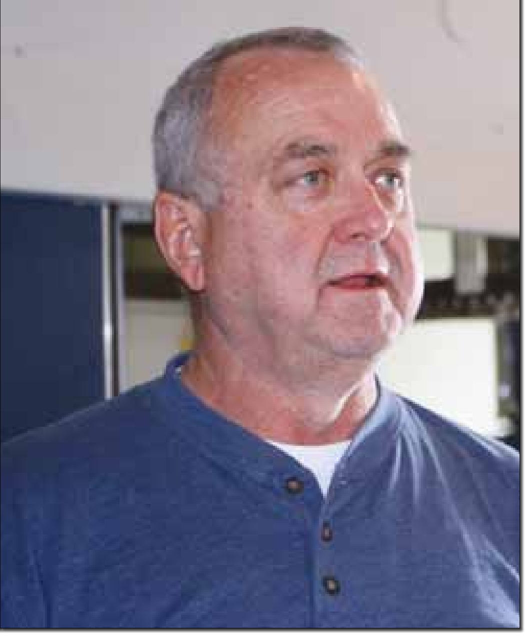
"The engine is coming next month," he said with more than a glimmer of excitement. He's going the hot-rod route with the Jabiru 3300. "My project at work is really keeping me busy, but it ends in a month, and then I plan to work on this as much as I can. The avionics have been ordered...all the big pieces. Now it's a matter of time."

When I saw the project, it was well into the main structural phase. "I built this fuselage in six months of continuous work." Skeryka had specific reasons for choosing the Sonex. "It had to be two seats because I wanted to take friends for rides," he said, "but really the deciding factor was cost of maintaining and operating. It burns a tiny amount of gas...I figure I'll make myself broke at the end of whatever airplane I own, so I might as well have a lot of hours at the end."

## Sierra Technical Services

Roger Hayes had been working at Scaled and noticed that the demand for outside vendors to produce composite tooling was strong. So, in 2008, he bought Sierra Technical Services. One of the company's strengths is its ability to create what's called soft tooling for quick-turnaround projects. Soft tooling differs from hard tooling in that it's used to make one or just a few parts and then discarded or replaced by hard tooling for series production. As so many


A road not taken: The one-and-only Skyjacker prototype lives outside at Mojave. Designed and built by Ralph Sawyer in the late 1970s, the lifting-body design has loads of novel features and bears evidence of continual tinkering to improve flying qualities.



Roger Hayes of Sierra Technical Services.

Tools of the trade: Sierra's variety of milling tools on display.

Sierra's milling machine makes quick work of large pieces of stiff foam for soft tooling.

of the projects at Mojave are one-offs, Hayes looked to be in a good place.

Business hasn't been quite as robust as predictions, but more is coming in. "We started the business in 2008 because we saw a lot of companies [here at Mojave] doing prototype work. We specialize in soft tooling because we're really good at it. We have the capabilities to do so many things," Hayes said, and that includes machining into tooling as long as 15 feet and as wide as 5 feet. Maximum depth is 3.5 feet, which makes the possibilities almost endless for aircraft parts. A single wingskin can be crafted in that space. "The machine is a five-axis type with a spindle that can turn 20,000 rpm. We can bury a 1-inch ball mill into 15-pound-density foam 3 inches deep and go 1400 inches a minute from end to end."

Given the proximity of companies like STS, it's no wonder so many projects undertaken by Scaled employees and others with CAD-CAM experience would find the company's capabilities so enticing. The days of laboriously hand-carving foam or other media as female molds are long gone. (Indeed, Rutan's whole idea for the Long-EZ and its ilk was to keep from having female molds at all. The famous homebuilts were constructed of blocks of foam cut with a hot wire across temporary bulkheads. Everything could be shipped to the builder in a flat box.)

## Bearcat in Scale

Matthew Stinemetze and his brother Justin are working on an amazing scale replica of the Grumman F8F Bearcat. Matthew explained that he and his brother are building two of the 70%-scale airplanes, "which is why we're using hard tooling. Normally you wouldn't for a one-off." The airplane will be fully composite with vacuum-bagged skins for strength and weight reduction. It'll be mostly carbon fiber.

"Part of the problem doing a scale version," said Matthew, "is that not everything scales. We had to make our own wheels. The tailwheel in proper scale just wasn't available, so we built our own. We built scale models that are mechanically

Soft tooling created by Sierra is used for the Stinemetze brothers' scale Bearcat.

Notice how the soft tooling includes the spinner half.

The Stinemetze Bearcat's horizontal stabilizer under construction in soft tooling.

Matthew Stinemetze and his brother, Justin, are building a scale Bearcat. Here is the custom-made tailwheel.

A motivational illustration hangs on the wall—the general layout of the two-seat Bearcat.

like the original Bearcat's, but we had to have our own rubber tires cast." The tires are like a large, probably fairly expensive shopping-cart's, flat and smooth.

"That's the nice thing about having Scaled here. We can do some work in the machine shop on the weekends," Matthew said. Plus the local support. The 4x8 sheets of foam used as the hard tooling was milled by Sierra Tech off the west end of the airport and then fine-tuned on weekends at the Scaled facility.

Power will come from a Lycoming IO-540, resting on the front of a fuselage that, while faithful to the Bearcat's form, shares nothing with it. "A lot of the stuff is pretty well figured out, but we're doing a lot of engineering and designing as we go. But my brother is the project manager for SpaceShipTwo…" he said, leaving more than the slight suggestion that these guys know what they're doing. In overall scale, the Bearcat will be close to an Extra 300 with just a bit less wing and, because it'll have retractable gear, slightly heavier. (An Extra typically weighs 1500 pounds empty, against a maximum-gross weight of 2095 pounds.)

The project has been in progress for a couple of years. "We've been pushing pretty hard lately, but all of us are doing a lot of overtime at Scaled, so it's hard to find the time," Matthew said. When I suggest that once the airplane is flying the brothers will be inundated by requests for plans or kits, he added, "Oh, I know. We'll see how much energy I have left by then. But we have hard tools, so we could easily rent tool time." You get the impression that he's focused on the near term, while still keeping the longer-range possibilities in focus.

## Electric Efforts

A short walk from the beefy Bearcat project is Gene Sheehan's electric Quickie. "It was built for the Green Flight Challenge, but we didn't get it finished. Tragically, I think, it's the only airplane built [for the GFC] that was made in the United States," Sheehan said. "We have three battery packs, 74-volt units, on the airplane now, but had we run the race, we would have mounted five of them. The lithium-ion batteries weigh 30 pounds each and have a capacity of 40 amp-hours, which is the largest capacity I could find."

Sheehan's carbon Quickie has more than enough performance to meet the GFC rules, which call for a cruise speed of more than 100 mph and a 200-s.m. range. "I can routinely run 120 to 130 mph for more than 2 hours," said Sheehan, who vows to continue development of the airplane because he feels that, as battery technology develops, electric

Gene Sheehan and his electric Quickie. "You want to see what's under here? OK, then." The outgoing Sheehan was unhappy about the lack of American participation in the Green Flight Challenge last year.

A compact electric motor and controller live under the Quickie's cowling.

Function is all. A pair of batteries for the Quickie live under the pilot's knees. A foam pad will do when weight is an issue.

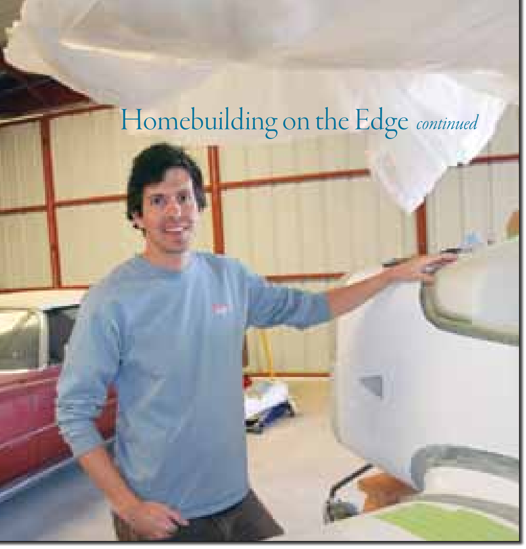
flight will become far more common. And this is from a man who, as owner of Feuling, an extremely successful supplier of hot-rod parts to the Harley world, has done well by the dead dinosaur.

## Desert Tango

Justin Gillen's Tango 2 is under construction in a hangar next to where Cory Bird's Symmetry calls home. "This is serial number 25," he said, admitting that he had some concerns about a company turning out so few kits. "But they've been great, meeting all my building needs. The support has been really good."

Gillen went back and forth about what to build, considering the RV series. "But I wanted something that went 200 mph on as little fuel as possible. I'm going to install the Lycoming O-320, and that should be economical. I also liked the low profile of the Tango. We have a Grumman Tiger [at Scaled], and flying around at 110 mph or so I figured

Even electric motors need cooling, but the Quickie's ports are really small.

Justin Gillen and his Tango 2 project.

Of the many homebuilt and Experimental projects under construction at Mojave, the Tango is perhaps one of the most conventional.

Gillen's Tango is ready for an O-320.

The Tango 2's fuselage basically "as delivered," according to Gillen.

that it was just so draggy. I liked the [Tango] design from that angle."

A good example of Team Tango's approach to support is how the company responded to some minor problems Gillen had with a lower wingskin. "As I started working on it," he recalled, "I noticed a few irregularities here and there. Nothing that I couldn't fix, but when I told the company about it, they just said, 'No problem,' and sent me a replacement skin." Gillen finds the Tango 2 a straightforward build. "The fuselage arrives how you see it. I haven't done much touchup or anything."

## Catbird, Again

Zach Reeder is the Scalie continuing his work on Rutan's Catbird. "The restoration of this airplane was interesting," he said. "The maingear was in a scrap heap over at Scaled. The airplane was hanging upside-down from the ceiling. The firewall forward was gone, the panel was gone, the wiring was gone…It was stripped."

Looking closer at the Catbird reveals some interesting design choices. The current turbocharged engine has a manual wastegate and no overboost protection because it just wouldn't fit. The landing gear is totally mechanical, with a 30+ turn crank to get it retracted. "Here's something not a lot of people know," Reeder said. "The nosegear, which is from a Beech Duchess, has no trail [the Beech has active nosewheel steering], so when the wheel spins down, it can flop over to one side or the other, and it might not line up in the well. So we pull the data plate [in the center console] and use this stick to get the tire in the right place."

Yes, it sounds crude. No, you couldn't ever get the FAA to buy off on such a system for a certified airplane. Heck, most homebuilders wouldn't tolerate such a thing.

But this one feature, if you want to call it that, is totally emblematic of the Rutan approach—dare we also suggest, the Mojave approach—to performance and innovation. Pushing the envelope and learning new things are far, far more important than coddling the pilot. In fact, Seguin told me during the tour of Scaled that it's a mark of pride among the Scalies that the aircraft are hard to fly. What they do should be amazing; how they treat the pilot is secondary in the extreme.

Innovation first. Maybe that should be Mojave's new city slogan. ✈

Approved for sustained inverted flight. The Catbird resided inside one of the Scaled Composites hangars for years.


Today, the Catbird is in the care of Scalie Zach Reeder. Can you imagine this airplane will live anywhere other than Mojave?

# Installing the Firewall

## Do it right. After all, it's the only thing between you and an engine fire.

BY DAVE PRIZIO

GlaStar builder Ed Zaleski installs an acrylic temporary firewall in preparation for determining the location of final firewall penetrations. Some builders find this technique helpful when their kit does not include firewall layout instructions.

**Firewall-forward construction** begins with a firewall. If you are working from a kit, the firewall may already be precut for you. At the very least, the material for the firewall is likely included, as is a plan or pattern to use to cut it out to size. Your kit may even include suggestions for laying out the various items that will pass through or attach to the firewall. If you are building from plans, there are a few more decisions you must make, such as how to lay it out, the material and thickness to be used and how to pass things through or secure them to the firewall. We'll look at each of these in turn.

### Firewall Materials

Most kits come with stainless-steel firewalls or material to make one, and plans builders will typically use the same material. The most popular stainless-steel alloy is 304, but 301 half-hard will also work. The 301 is about twice as strong as 304, and as a result is harder to cut, thus making 304 the preferred alloy. The minimum thickness for a stainless-steel firewall is 0.016 inches. Cutting and drilling stainless steel requires patience. Slow bit or blade speeds and higher pressures are the rule, as compared to ordinary steel or aluminum. Trying to push a drill bit or saw blade through stainless too quickly will just result in a burnt tool and little progress. Lubricating the cut with oil or cutting fluid also helps. Go half as fast, and you'll get more done.

Riveting stainless-steel firewalls should be done with solid stainless steel, Monel rivets or stainless-steel CherryMAX blind rivets, with Monel being the most common choice. Small nut plates are often installed with $^{3}/_{32}$-inch aluminum AN aircraft rivets, but aluminum rivets are unsuitable for securing major firewall components such as firewall flanges, seams or patches. The firewall must be able to contain a fire in the engine compartment, and the melting temperature of aluminum rivets is simply too low to fulfill that role. Hardware-store stainless-steel pop rivets are

*Photos: Dave Prizio, Courtesy Glasair Aviation*

Ribs were rolled into this stainless-steel firewall to stiffen it up and prevent "oil canning."

also a poor choice because the stems are not reliably secure and could fall out, leaving a hole through which hot gasses could pass.

Stainless steel is the most common material for firewalls, but there are other choices available. Mild, chrome-moly or galvanized steel can be used. These require a rust-preventative coating, but with galvanized steel that is included as part of the material. Mild or chrome-moly steel require painting on both sides. The minimum thickness for galvanized steel is 26 gauge. Plain (not galvanized) sheet steel of at least 26 gauge can also be used; it has a thickness of 0.018 inches.

When cutting sheet metal, be sure to wear gloves and deburr parts as you go. The sharp edges left after cutting are particularly nasty and hazardous to your hands. If you do not deburr parts after cutting them, you also create a potential future hazard.

## Exotic Lands

For builders who are obsessed with saving weight and have the room in their budget, titanium is an alternative worth considering. In a typical airplane project, a titanium firewall can save about 2 pounds compared to stainless. A scrap piece of titanium large enough to make a firewall will cost about $200 plus shipping. Commercial pure titanium is by far the best choice. It is much easier to cut and bend than any of the titanium alloys, such as 6AL-4V. However, it may not be as readily available as scrap. Look for a thickness of 0.016 to 0.020 inches.

Like stainless steel, titanium is more difficult to cut and fabricate, but not in exactly the same way. Titanium is prone to galling and sticking to tools, so it is important to use sharp tools and slow cutting speeds. It also dissipates heat poorly, so it is important to use sufficient cutting fluid to cool the part while drilling or cutting. If you can get titanium solid rivets, that would be best, but Monel rivets will work fine and are much easier to find. If you think that titanium is just too exotic to even consider, you might be interested to know that F. Atlee Dodge is currently selling pure titanium firewalls for Piper PA-18 Super Cubs (for an extra $220 over the stainless-steel price). See Table A (below) for a comparison of firewall materials.

Table A.

| Material | Tensile strength | Melting temp. |
|---|---|---|
| 301 Stainless Steel 1/2H | 150,000 psi | 2590˚F |
| 304 Stainless Steel | 70-75,000 psi | 2650˚F |
| Com'l. Pure Titanium | 55-70,000 psi | 3040˚F |
| 6AL-4V Titanium | 130-134,000 psi | 3000-3100˚F |
| 1008 Steel (mild) | 44-52,000 psi | 2600-2700˚F |
| 4130 Steel (Cond. A) | 85,000 psi | 2600-2760˚F |
| 4130 Steel (heat treated) | 125-180,000 psi | 2600-2760˚F |
| **Not Acceptable for Firewalls** | | |
| 2024-T3 Aluminum | 64,000 psi | 950-1180˚F |
| 6061-T6 Aluminum | 42,000 psi | 1080-1200˚F |
| 7075-T6 Aluminum | 77,000 psi | 890-1180˚F |

## Maintaining the Integrity of the Firewall

It doesn't make much sense to fabricate a nice firewall and then punch a bunch of holes in it, but that is what you have to do to get wires, control cables and cabin heat from one side of the firewall to the other. There are, however, better and worse ways to go about penetrating the firewall while still maintaining its integrity.

Any airplane with a constant-speed prop will have at least three control cables penetrating the firewall: throttle, prop and mixture. If you have a carburetor, you can add a carburetor heat cable to that list. Some airplanes will run all of these cables together and push them through one hole with a rubber grommet, goop it up with red RTV and call it good. This may get you through your initial airworthiness inspection, but if a fire ever got going in the area of that

This Super Cub firewall by F. Atlee Dodge is made of commercial pure titanium and saves about 2 pounds compared to a stainless-steel firewall.

penetration, you will have some pretty toasty feet in short order. That rubber grommet will last about 30 seconds when exposed to direct flames, as will the red RTV, which is only rated to 500° F for continuous exposure. Using a 2000° F fire-rated sealant will help, but there is an even better solution. An Eyeball Firewall Assembly, available from Aircraft Spruce & Specialty *(www.aircraftspruce.com)* and other vendors, makes a tight seal around any cable penetration, even one at an angle of up to 50°. The steel ones will last as long as the rest of the firewall in a fire and make for a neat, professional installation. This is not the lowest-cost solution, but it is the safest.

An alternative is the Firewall Penetration Kit from Plane Innovations *(www.planeinnovations.com)*, which is similar to a system used by Glasair Aviation in its Two Weeks to Taxi program. In this system, a stainless-steel tube with a flange is riveted to the firewall. Run the wires or cables through the tube and wrap it in Aeroquip Firesleeve. Seal everything with Flamesafe sealant. Plane Innovations' complete kits run $42 to $54, depending upon the size of the penetration.

Wires run through holes with grommets need their own protection. Most aircraft supply retailers sell firewall grommet shields that minimize the exposure of the rubber grommets to any potential fire. These are recommended where rubber grommets have to be used.

## Cannon in D

Some people use cannon plugs to bring wires through the firewall, and they make for a clean-looking installation, but a large plastic cannon plug is almost as bad as having an open hole in your firewall. Any serious heat will quickly melt a plastic fitting. Realize that penetrations like this mean coming to some sort of compromise, and try to minimize the size and number of these holes. Metallic cannon plug bodies and housings are available, but they're comparatively heavy and expensive. (Don't forget that unfilled sockets in a cannon plug are like open holes; for best results, populate every socket in the connector, even if the pin is unused.)

Cabin-heat valves are the biggest offenders of firewall integrity on many airplanes. In most cases, an aluminum tube with a 2-inch diameter punches a big hole through the firewall, offering almost no protection from an engine fire. Luckily, Aircraft Spruce now has an all-stainless-steel cabin heat box that should go a long way toward solving this problem. This is something every kit manufacturer and airplane builder should carefully consider. It would be difficult to land an airplane with intense heat pouring through the hole where an aluminum cabin heat box used to be.

This GlaStar firewall shows eyeball fittings for cables, added support for an oil cooler and a "dog bowl" indentation to allow clearance for a prop governor.

Fuel lines are particularly hazardous firewall penetrations. The risk they pose can be minimized by using steel bulkhead fittings, such as an AN832 straight bulkhead union or an AN833 bulkhead elbow. Either of these fittings can be secured with an AN924 nut, also in steel. All fuel lines on the engine side of the firewall should be protected with Aeroquip Firesleeve or a similar product. Running an aluminum fuel line through a rubber grommet in a hole in the firewall does not represent good practice and should be avoided, even though this has been done on some certified airplanes.

## Laying Out Firewall Penetrations

Some kits will have detailed instructions for laying out firewall penetrations, while others may come with the required holes pre-punched in the firewall. Plans-built projects and some kits may not have any information about engine compartment layout and firewall penetrations. The original GlaStar kits came with an instruction for the engine installation that simply said, "Install everything forward of the firewall." If you find yourself in a similar situation, you will need a strategy for deciding what to put where.

The big problem with laying out a firewall is that you can't see through the firewall to tell where structural supports are or where controls mount on the cabin end and attach to the engine on the other end. Still, there are possible solutions. One is that you can find someone with a similar airplane and engine installation and copy what they did (assuming they did it well). This is where builder support groups can come

Eyeball firewall fittings provide maximum fire protection at cable penetrations and allow the cable to pass through at angles of up to 50°.

The Cessna factory uses a firewall tube filled with flame-resistant caulking for the wire penetration in the new 162 Skycatcher.

Glasair Aviation uses a stainless-steel sleeve with a piece of Aeroquip Fire-sleeve attached to route cables through the Sportsman firewall. After the cables or wires are run, the sleeve is filled with Flamesafe FS 1900 sealant.

in handy. Or you can make a pattern of the structure hidden by the firewall and transfer it to the engine side, where it can more easily be seen. Another idea that works well is to make a temporary firewall out of eighth-inch acrylic sheet. You can punch holes in this until you are completely happy with the location of everything, and then use it as a pattern to make holes in the permanent firewall. The downside to this method is that you will have to remove the engine and mount from the airplane to take out the temporary firewall, but the trade-off may be worth it.

Most people will run wires high through the firewall. Oil coolers must be mounted where they have good support and where air can flow in and out of them easily. The battery is bulky, so it will usually go on the side opposite the oil cooler, where there is more room, or outside of the engine compartment, as dictated by weight-and-balance considerations. The gascolator will go low and typically on the left side, so that it is easy to drain during preflight. Control cables will usually come though the firewall low and in the center, because that is where they need to be to attach to the engine. The cabin-heat valve must be high enough to avoid interfering with the rudder pedals. It's all logical when you think about it, but it can be frustrating to make everything fit where you can still get to it for maintenance later. That's why a temporary firewall makes a lot of sense.

## Attaching Items to the Firewall

A thin metal firewall can support lightweight items attached to it fairly well, especially if a doubler is used to give the firewall extra strength. Some items that can be supported by the firewall include voltage regulators, starter solenoids and gascolators. Items that can't be supported by the firewall include such things as oil coolers and batteries. These larger items must be supported by structure behind the firewall and bolted to such supports to be adequately secured. If sufficiently sturdy elements are not conveniently located within the airplane's structure, it may be necessary to span attachment points with a framework of aluminum angle to mount heavier items in places where they will work well with the other objects competing for space in the engine compartment. Such a framework can also be a

This RV-8 came with a prefabricated firewall with major holes already in place as part of the quickbuild option.


A step drill or Unibit makes easy work of drilling medium-size holes in sheet metal.


A chassis punch makes a much cleaner hole than a hole saw. Here are the two types of holes side by side, with the chassis punch hole being the lower one. Unfortunately, chassis punches cost considerably more than hole saws.

convenient place to mount items such as oil- and fuel-pressure senders.

When attaching items to the firewall, you have the choice of using nuts and bolts or bolts and nut plates. Nut plates are more work to install initially, but they allow you to remove bolts without an assistant inside the cockpit in the future. While on the subject of nuts and bolts, all nuts used in the engine compartment or on the firewall on either side should be all-metal lock nuts (AN363 or MS21042), not those with nylon inserts (AN364 or AN365), because the heat of the engine could easily soften the nylon inserts in such nuts.

As you construct the firewall for your airplane, always keep in mind what it is intended to do—keep an engine fire out of the cockpit so that you can land the airplane. Keep holes to a minimum and protect them as well as you can. Where necessary, take the extra steps to protect any vulnerable structure behind the firewall, too. Your firewall may never be put to the test, but if it is, you will be glad you took the time to do a good job.

## Making Holes

Making holes in firewalls is not difficult if the holes are less than 1 inch. Drill a starter hole using a #30 drill and then enlarge it to a quarter-inch or so with a larger drill bit. For larger holes up to an inch, a step bit or Unibit works best. This is much safer and easier than trying to use a conventional drill bit to make a large hole in thin metal. For the cabin heat valve, where a 1½- or 2-inch hole will be required, a chassis punch makes an especially nice hole. Hole saws also work for larger holes, but they do not make as clean a hole, and cheaper ones may not cut through harder alloys well. However, a good hole saw can be used if you are careful and patient. Whenever you drill into sheet metal, be sure to


Here is a sample of the buildup of materials needed for the firewall of a wood airplane. The layers: plywood, stainless steel (0.016 inch), four layers of eighth-inch Fiberfrax and an aluminum protective sheet (0.020 inch).


A firewall grommet shield is opened up to show the grommet. Wires with factory-applied connectors often need oversized holes in firewalls. The shield protects the grommet filling in the hole.


All firewall seams and gaps should be filled with a caulking material rated for 2000° F.

secure the piece being drilled. It is easy for drills to catch on the metal as they try to break through.

## Firewalls for Composite or Wood Airplanes

A metal firewall from stainless-steel sheet 0.016 inch thick will stop a fire from entering the cockpit, but it will not stop heat from coming through the firewall. So if the firewall is attached to flammable materials such as wood or fiberglass, you need to add another layer of protection to stop the heat from transferring through the firewall and igniting, or at least charring, the rest of the airplane. Wood such as spruce or fir will catch on fire at less than 500° F. Fiberglass material will ignite at 700° to 800° F, depending on the resin used. The backside of a metal firewall can easily reach that temperature in a few minutes during an engine fire.

This is a steel AN833-6 bulkhead 90° fitting with an AN924-6 nut and an AN960-916 washer. These are well suited for running a fuel line through a firewall.

The FAA says that a firewall must withstand 2000° F for 15 minutes. Testing performed by Stoddard Hamilton (the predecessor of Glasair Aviation) revealed that the backside temperature of a stainless-steel firewall reached about 1600° F after 8 minutes, sufficient to ignite the fiberglass airplane structures. Further testing showed that a half-inch layer of Fiberfrax insulation would reduce the backside firewall temperatures to about 130° F, well within safe limits for the fiberglass supporting it. The Fiberfrax material is delicate and will absorb engine oils, so it needs to be protected with a 0.020-inch layer of aluminum on the forward side. In the event of a fire, the protective aluminum would quickly melt away, but the Fiberfrax will do its job of insulating. Some long aluminum pull rivets or #6 screws can hold the Fiberfrax and aluminum sheet in place against the composite structure. The control and wire penetrations should all be protected with fire-rated caulking. These recommendations related to fiberglass structures apply equally to wood.

Non-flammable sound-blanket material is attached to the cabin side of the firewall before it is pushed into place at the Glasair Customer Assembly Center.

Some manufacturers of composite airplane kits now provide pre-made, fire-resistant firewall protection for their customers. Lancair, for example, includes such firewall protection in its kits. If such protection is provided, it is vital that you install it per the manufacturer's instructions. If it is not provided, you will need to fabricate it yourself.

The builders of all-metal airplanes can also benefit from a Fiberfrax firewall blanket to prevent excessive heat from entering the cockpit during an engine fire. A thinner quarter-inch layer may provide welcome extra protection for pilot and passengers of metal planes such as RVs, and perhaps help reduce sound levels a bit, too. In an all-metal airplane, the Fiberfrax can be attached to the cabin side of the firewall.

Wendell Solesbee works on the engine installation in his Lancair Evolution. Note the factory-furnished firewall blanket made to protect the composite structure of the airplane.


Here's a GlaStar under construction with a transparent firewall in place, ready to begin the process of positioning items on the firewall.

## Sound Insulation

Many builders like to add sound insulation to the cabin side of their firewall. This is fine, but it is vitally important that any insulation material used is flame resistant and aircraft quality. Remember that the firewall can get extremely hot in an engine fire, and it could possibly ignite unapproved materials or cause them to emit noxious fumes that could disable the pilot.

A well-constructed firewall is an important safety feature in any airplane. Take the time to think yours out and build it carefully. You will probably never need the protection it is designed to provide, but if you do, you will be glad you took the time to build it well. Next time we will look at engine mounts. This will be one of the smaller topics we will explore, but it is still an important one. ✈


# As tablet and handheld technologies converge, there's still a place for the aviation-specific, portable GPS.

BY STEIN BRUCH

**The line between** aviation-specific GPSes and personal portable devices has blurred. Now there are many tablets and phones that are almost GPSes—they can do as much or more than the aviation-specific navigators of just a few years ago—but we're going to take a look at the devices that are 100% aviation specific.

Although tablets are fantastic for storing documents such as approach plates, charts and manuals, I consider them complementary to the purpose-built, portable aviation GPSes, not a replacement for them. One area in which the dedicated aviation units excel is in screen readability in sunlight. Even some of the newest consumer tablets are difficult to read in direct sunlight, but many of the aviation units have been developed for just this purpose; no one cares if they work well in an office or airport terminal.

While some of the units we have reviewed previously remain available, new ones are raising the bar for features and functionality.

## Anywhere Map

Control Vision is the company behind the Anywhere Map line of products. I say products because the company sells both hardware and software. Besides Garmin, Anywhere Map is the only company discussed here that offers an app (software application) for modern tablet devices. The company's software has undergone many years of refinement, and it's quite nice to use. The program can be installed on a whole host of products, from small handheld devices to laptop computers. Software and apps range in price from $79 to $199. Users report the software to be capable, bug free and highly functional. At this point, the tablet app is still new, but the company expects frequent and additional upgrades to the product, so by the time you read this, it should be as fully functional as the company's other software.

The hardware offered by Control Vision is primarily the 4.3-inch Quadra (starts at $399) and the 7-inch Septa (starts at $995) systems; an external XM Weather module is an additional $795. Both have received positive reviews from users, who report the screen clarity to be good and readable in sunlight. The company is a pleasure to deal with, and its data-package pricing is lower than most. One Achilles' heel of the Anywhere Map products has been the inability of the systems to provide an interface capable of communicating with various autopilots and other aircraft systems that many builders are now installing, which is a deal breaker for some.

AvMap's EKPV.

## AvMap

AvMap has been producing portable GPSes for some time. The most current offering, the 7-inch AvMap EKP V, starts at $1998; the EKP IV starts at $1399, and both offer the external XM Weather module for an additional $450. My experience has been that the units are well made, the display is very readable in the sunlight, and the controls are nicely placed with a good tactile feel. The EKP V is thin and fairly lightweight, but it's not as easy to panel mount (even with an AirGizmos mount) as some other units. These devices interface nicely with components such as an autopilot, and you can often find them on sale. Battery life has proved to be very good at about 4 hours.

## Bendix King (Honeywell)

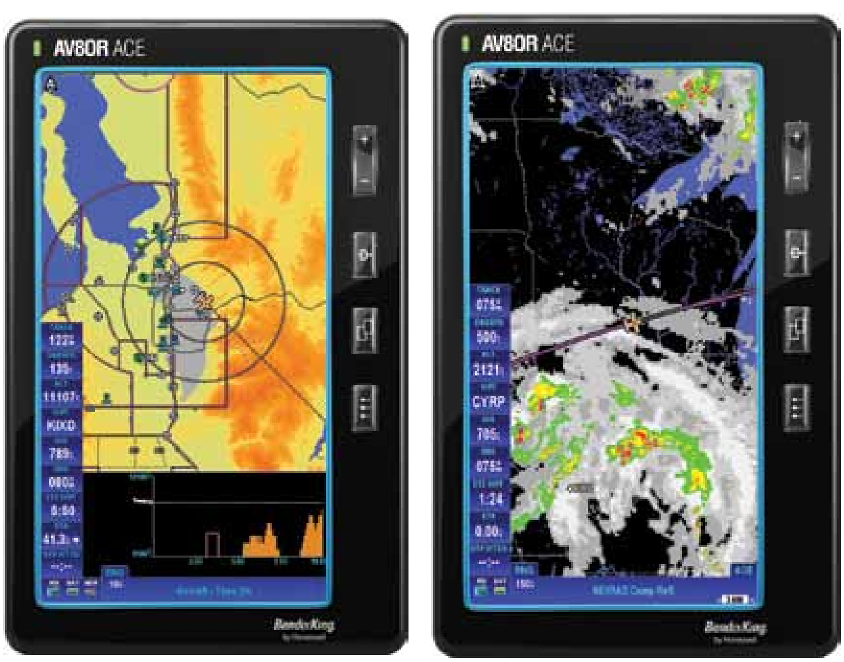
Honeywell made a splash a couple of years ago when it introduced its AV8OR line of touchscreen GPSes. They were the first major manufacturer to market this technology, so it was noteworthy. These GPSes are available in a 4.3-inch size, with a starting price of $599, or a larger 7-inch size (AV8OR ACE), with a starting price of $999. Both screens are very crisp but will slightly wash out in direct sunlight. One common complaint is the battery life with the included 800-mAh battery, which customers say provides about an hour of operation unless plugged into an external power source. A 1600-mAh battery is also available; the company says it will provide about 3 hours of operation at full luminance.

The AV8OR offers a host of interface options, such as an external XM Weather module, traffic devices and a media player; it also can download various documents. You can add optional street navigation functionality for use while driving.

We've found both units to be lightweight and easy to handle, and the functionality is competitive with others in the market, with included IFR charts, a weight-and-balance program and an external SD-card slot for moving files around. Overall, we find the AV8OR units to be good midrange devices, and they can be connected to various external devices, such as many autopilots, via an RS-232 serial cable.

## Garmin

Garmin is still the leader in portable aviation GPSes. The term "portable" is used somewhat loosely, because you'll see various Garmin units mounted in panel docks, such as those available from AirGizmos.



Bendix King's AV8OR Ace.

*Photos: Richard VanderMeulen, Courtesy the Manufacturers*

Garmin aera 796.

## All About Avionics *continued*

In the past year, the popular 296/396/496 series was discontinued, and the new aera 796 was introduced. With a retail price of $2499 ($2199 without XM Weather and music), the 7-inch touchscreen display brings some new functionality to the cockpit. The unit can be displayed in either portrait (vertical) or landscape (horizontal) mode. The screen itself is sunlight readable and nice to use, being of the same type as the new GTN boxes. The menu system is intuitive and simple to use, and those familiar with some tablet devices will appreciate the "pinch zoom" motions you can now use to manipulate the map display. New in the 796 is Garmin's 3D synthetic vision display, which depicts the terrain in "real-life" projections on the screen. A new display page that mimics the look of an EFIS screen shows GPS altitude and groundspeed as well as heading information overlaid on the terrain map, with a small airplane depicted in the center.

The 796 also includes a full set of georeferenced VFR and IFR charts along with approach plates and airport diagrams, meaning this unit fulfills the role of a Class I or Class II EFB (electronic flight bag). The battery lasts more than 3 hours, and the unit interfaces with other devices such as a mode S GPS, providing an unparalleled amount of information in a portable GPS. The 796

| Mfr./Model/Contact | Screen size (in.) | Touchscreen | Weight | Battery/Life | Terrain | Obstacles | Approach Plates |
|---|---|---|---|---|---|---|---|
| **Anywhere Map/Control Vision, 800/292-1160, www.anywheremap.com** | | | | | | | |
| Quadra (LT, Max, EFB) | 4.3 | Y | 4 oz. | Li-ion/3 hrs. | Y | U.S. only | Y |
| Septa | 7 | Y | 1.2 lb. | Li-ion/1.5 -3 hrs. | Y | U.S. only | Y |
| **AvMap, 800/363-2627, www.avmap.us** | | | | | | | |
| EKP IV | 7 | N | 1.8 lb. | Batteries for emergency use (up to hours); 6 rechargeable NiMh internal (not included) | Y | Y | N |
| EKP V | 7 | N | 14 oz. | Rechargeable Li-ion, life not provided | Y | Y | N |
| **Bendix King (Honeywell), www.bkav8or.com** | | | | | | | |
| AV8OR | 4.3 | Y | 7 oz. | 800-mAh standard, 1 hour; 3 hours w/optional 1600-mAh battery | Y | Y | N |
| AV8OR Ace | 7 | Y | 1.25 lb. | 4000 mAh standard battery & 2000 mAh life not provided | Y | Y | Y |
| **Garmin, www.garmin.com/aviation** | | | | | | | |
| aera 500 | 4.3 | Y | 9.5 oz. | Rechargeable Li-ion, up to 5 hrs. | Y | Y | N |
| aera 510 | 4.3 | Y | Same as 500 | Rechargeable Li-ion, up to 5 hrs. | Y | Y | N |
| aera 550 | 4.3 | Y | Same as 500 | Rechargeable Li-ion, up to 5 hrs. | Y | Y | N |
| aera 560 | 4.3 | Y | Same as 500 | Rechargeable Li-ion, up to 5 hrs. | Y | Y | N |
| aera 795/796 | 7 | Y | 26.4 oz. w/battery pack; 18.3 without | Rechargeable/ replaceable i-ion, up to 3 hrs. w/full backlight and GXM 40 connected | Y | Y | Y |
| **iFly GPS, http://ifly.adventurepilot.com** | | | | | | | |
| iFly 700/720 | 7 | Y | 12 oz. | NA | Co. says coming soon | Co. says coming soon | N/A |

has proved to be a popular unit, and its external XM antenna is smaller than in its predecessors. Garmin has also simplified the connection to the units, requiring only one cable for data, audio, interfaces, power and ground in a "fast connect" device. One great feature is a built-in document reader that allows a user to download various documents, pictures or PDF files, and then store and view them on the unit.

Garmin's GPSMAP 696 also remains popular due to its rectangular shape and overall ease of mounting. The 696 is available with or without XM, but it is not a touchscreen like the rest of the Garmin portable product line. Some users prefer the joystick for panning on the map page. While

Garmin aera 550.

| Satellite WX | Autopilot Interface | PC/USB interface | Suggested Retail Price | Notes |
|---|---|---|---|---|
| | | | | |
| Optional | N | Built-in WiFi or tethered (USB) updating | LT and Max, $399; Quadra EFB-$549 | Co. offers free Max upgrade w/LT purchase, which provides street nav, sectionals, low/high enroute charts; quarterly updates range from $49-$119 depending on what is included. Portrait or landscape. |
| Optional | N | USB or WiFi | $995 | Sunlight-readable display. |
| | | | | |
| Optional WxWorx receiver, functional only in North America | Y | Compact Flash 512MB memory | $1399 | Sunlight viewable LCD, portrait or landscape. |
| Optional WxWorx receiver, functional only in North America | Y | Y; optional docking station | $1998 | Portrait or landscape display. Joystick/smart wheel. |
| | | | | |
| Optional w/added WxWorx XM Weather receiver | Y (only on Experimental AC) | PC | $599 | 4GB data card w/car and aviation databases (N. America or Europe) |
| Optional w/added WxWorx XM Weather receiver | Y, w/accessory cable, Experimental AC only | PC/USB | $999 | Sunlight readable display. Hi-res airport diagrams. Annual IFR chart subscription, $399. |
| | | | | |
| N | Y | SD/USB | $799 | Can be used to load com frequencies to SL 30/ SL 40 com. |
| Optional | N | SD/USB | $1249 | Adds support for Nexrad imaging and other XM Weather capabilities. |
| N | N | SD/USB | $1399 | Pre-loaded SafeTaxi diagrams with hot spots available on 550/560. Higher res terrain/obstacle graphics than 500. |
| Optional | N | SD/USB | $1799 | Adds support for Nexrad imaging and other XM Weather capabilities. |
| Optional | N | SD/USB | $2499/$2749 | 3D vision technology; forward-looking terrain avoidance aera 796 fulfills the role of Class I or II EFB. GXM 40 smart antenna is included with aera 796, providing access to high-res weather and audio entertainment (XM subscription required). |
| | | | | |
| Planned future option | N | USB | $549/$749 | Requires external power. External battery accessory is available ($99). 720 has sunlight-readable display. VFR data subscription is $69/yr.; combined VFR/IFR is $109. |

Garmin aera 510.

## All About Avionics *continued*

the 696 doesn't have synthetic vision like its newer sibling, it retains a full terrain and obstacle database as well as the same geo-referenced charts, approach plates, airport diagrams and "safe-taxi" functions as the other devices. The battery life is about 2+ hours, depending on screen brightness, and pricing is $1999, or $1699 without XM Weather.

The aera 500 series from Garmin marked the company's entry into the touchscreen portable GPS market. The 4.3-inch display is somewhat less sunlight readable than other non-touchscreen versions from Garmin, but it's still superior to many tablet or compact consumer devices. The GPS is available in four different versions (500, 510, 550 and 560), which can include XM Weather and music, and which offer additional levels of functionality on the higher-end units. The aera 500 series is adaptable for automotive use too: The unit is lightweight, slim, compact and includes a built-in speaker. The battery lasts up to 5 hours. Prices range from $699 for the basic aera 500 to $1599 for the top-of-the-line, XM-capable aera 560. All of the Garmin units can interface to most external autopilots and other devices.

### iFly GPS

Relatively new and less well known in the aviation community is the iFly GPS. It is available in two models, the 700 and 720 ($549 and $749, respectively), both with 7-inch screens. While somewhat limited in functionality compared to others in the marketplace, we found the units to be good for the price. Some may have reservations about buying a "portable" GPS that requires an external battery or a hardwire to a power outlet, but others won't mind. Where iFly seems to really shine is in the price of its databases and updates, which are significantly less expensive than the competition's. Our experience has been with the 700, a decently priced midrange GPS in an attractive package, produced by a company that seems to be serious about competing in this market by providing a lower-cost, yet nicely featured, portable in a large-display format. At the moment, iFly does not offer the ability for the GPS to interface via serial communication to any external autopilots or other devices in the aircraft.

### What Does the Future Hold?

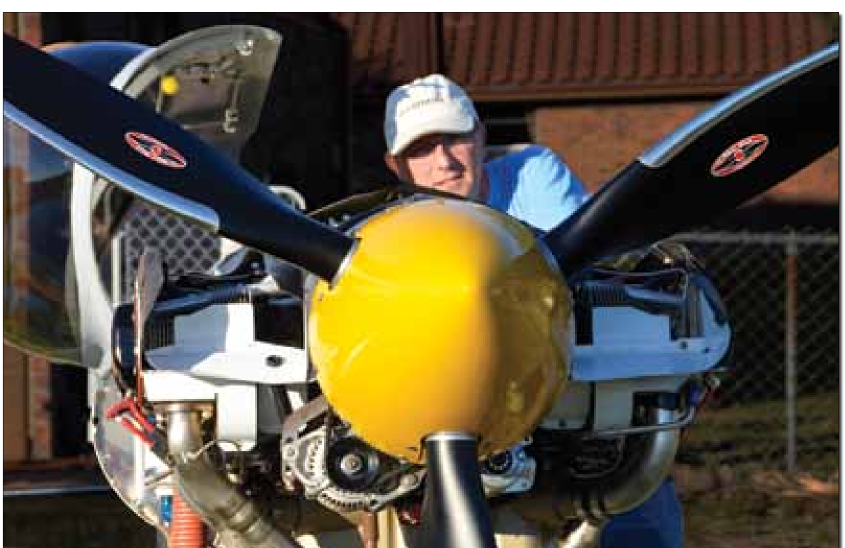
With the introduction of even more tablets on the horizon, it's quite possible that the aviation-specific, portable GPS market will contract to only a few key players. Even Garmin now offers an app for tablet computers, but the company still sees a way for these two types of devices to coexist. I own a tablet and a portable GPS, and each has its strengths; I don't foresee the dedicated portable units completely disappearing, but I do expect to see the line between them and tablets continue to blur. There will still be room for attractively priced units, and companies currently offering both high- and low-end options will probably continue to do so for some time to come. ✈

Two screen views on the iFly GPS units.

# Light and capable.

**It is fairly common** knowledge that the key to building a "sport" airplane—one that is quick, fun and maneuverable—is to build it light and simple. The lighter the airframe, the better climb performance it will have, and the more nimble will be the handling. This has held true since the dawn of aviation, and the resulting philosophy for builders of such airplanes was to keep them as simple as possible, with only minimal equipment and creature comforts. The upshot was that sport planes were generally flown in nice weather, only a few miles from their home airports. Hangars all over the world are filled with nimble little machines that get taken out on good-weather days, to be fully enjoyed by their owners and pilots. Many of these pilots own other, more expensively equipped airplanes for transportation, and they choose the right plane for that day's job when they need to get aloft.

It can get expensive, however—owning multiple airplanes, each designed and built for a specific purpose. Although I frequently tell people that the second airplane doesn't cost anywhere near as much to keep as the first, it does make sense to try and get as much out of each airplane as possible, if for no other reason than to save on the need to remember how each one flies. Fortunately, developments in modern avionics have given us more and more capability in smaller and smaller packages, allowing even the lightest of sport planes to boast real electrical systems, radios and even IFR capability, while still weighing less than their predecessors.



Constant-speed props are often thought of as heavy, but composite materials have allowed props almost as light as their fixed-pitched brethren, allowing the pilot to optimize both climb and cruise performance with little added weight.

## Light Is Might

As an example, let's look at the RV-3 that my wife and I just completed. We settled on an RV-3 as our next project to complement the two two-place RVs that already inhabit our hangar. The RV-8 is a strong performer with highly capable IFR avionics, including multiple synthetic vision screens and fully redundant navigation capability. The RV-6 is equipped more for light IFR work; it's fast and allows me to sit side-by-side with my pilot wife. We both envision the RV-3 as a highly maneuverable sport machine that we can use for independent travel at RV speeds and long ranges. We often travel individually for significant distances (for business and pleasure), so such personal transport makes sense—but only if it is equipped adequately for the kind of IFR that light planes are suited for (no ice, no thunderstorms). The trick is keeping the airplane light enough to preserve its original handling qualities without making dangerous compromises in the equipment needed for safe transportation.

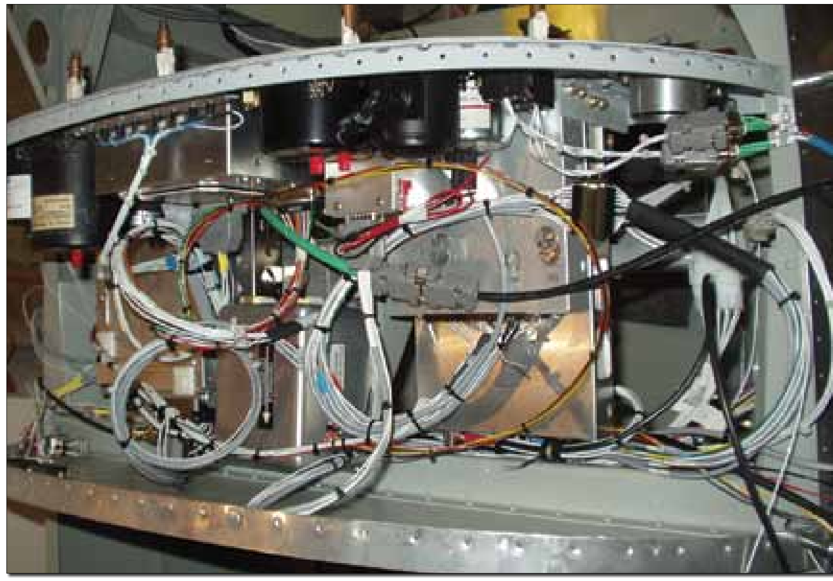
## Ever-Expanding Options

The explosion of avionics options available to the homebuilt world in the past few years is incredible to behold. When I built my RV-8 six or seven years ago, the complex EFIS units were just beginning

**Paul Dye** *is an aeronautical engineer, Commercial Pilot and avid homebuilder with 30 years of leadership experience in aerospace operations and flight testing. He is also an EAA tech counselor and flight advisor who flies an RV-8 he built along with an RV-3 that he and his wife, Louise, recently completed.*

*Photos: Paul Dye*

to make an all-glass panel possible. Today, I would wager that more traveling homebuilts are being built with glass than with steam gauges. The advantages are apparent in capability, reliability and, as importantly, weight savings. Quite simply, ripping out all the mechanical gauges (and the associated plumbing, vacuum pumps and regulators) takes a lot of weight out of the panel. Added to this savings are the latest generations of communication and navigation radios. Many of the EFIS manufacturers include built-in (VFR) GPS capability with their screens, so a builder can easily get by with a single IFR-certified navigator in the avionics stack (almost by default, the Garmin 430W these days) and comfortably rely on the backup internal GPSes for redundant, emergency navigation. A single backup communications radio weighs little and gives an added layer of safety should the "big box" fail or need to be shut down to save battery power.


Today's avionics are so much lighter and less bulky than even those produced five years ago. Here is a look behind the author's RV-3 panel; it is mostly air!

## That's Heavy, Man

During the development of our RV-3 project, it has not been uncommon for folks to see our panel design and ask, "Why are you building it so heavy?" What this question generally means is that the questioner has yet to really adjust to what is available today. Our instrument panel consists of two Garmin G3X displays, each weighing less than a pound, an autopilot head that is likewise mostly air, an electronic backup ADI and tiny ASI and altimeter backups. Add a few switches and some LED annunciator lights and that's it—a light and compact package, far more so than the "old fashioned" six-pack of gauges, and possibly even lighter than a traditional VFR panel. The radio stack does include that GNS 30W, and no one can call it particularly light. But the backup radio is a Garmin SL40, the audio panel weighs little, and the transponder—well, we really don't have much choice in carrying one of those these days anyway. Yes, there is an AHRS (a few pounds) and two autopilot servos (one in the fuselage, one in the wing) that add a few more pounds. But here we have a complete IFR machine with instrument and navigation redundancy, probably for less weight than a "sparsely" equipped RV-3.


By contrast, here is the author's RV-8, a very capable EFIS-equipped RV-8 completed seven years ago. The boxes are still modern, but they're much larger than those produced today.

Van's RV-3s get used for a lot of different things, and, historically, most of them have probably been local fliers. Weekend hamburger runs, aerobatics and formation flying have most likely filled a great number of the hours in their logbooks. I recently saw a nicely designed homemade smoke system in one—great to have if you will be doing formation work or simply want to mark your territory in the sky. A smoke system would definitely be considered a reasonable option for a true "sport plane," right? Yet let's think about the weight of the pump, tank and plumbing…not to mention the smoke oil itself. While some of these systems are built to be removable, I would be willing to bet that most of the time, they live in the airplane for convenience, and I doubt that the tank is ever empty. So whose airplane is heavy? We each choose to put our weight in at different places. (For the record, I have nothing against smoke systems. These are choices we all make.)

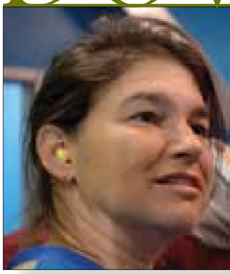
## Weight Watchers

Weight can be saved in a number of ways when building and equipping a sport airplane. Airframes are, to a large extent, hard to lighten once they have been designed. I know of at least one story of a fellow who built an RV-6, cutting every optional lightening hole that was allowed by the plans. He saved all the pieces that were cut out and weighed them at the end of the project. The weight savings amounted to less than two pounds. Good airplane designers have already taken out most of the excess weight from their structure, almost by definition if they are "good" designers. Weight can be saved by going with a lighter power plant, but since heavier engines usually have more horsepower, performance generally stays the same. Handling qualities are better at lighter weights, it's true. But you can also save by adding a lightweight propeller. Technology has helped us there as well—composite prop blades are much lighter than their metal counterparts. Lightweight props are still generally all experimental and built in limited quantities, so costs are unfortunately higher, but the total weight for a composite constant-speed propeller can often be brought down to match that of a fixed-pitch metal unit (when you consider spacers and spinners as part of the package).

The truth is that to a large extent, the all-up weight of the airplane is probably affected as much by the weight of the pilot, payload and fuel as it is by the way in which it is equipped. The RV-3B holds 32 gallons of fuel when full. Leave out 2 gallons and you can save 12 pounds. For local, aerobatic flying, leave out half of the total capacity and save almost 100 pounds! That's far, far more than the difference you can build in (or out) of the airplane during construction. And, of course, there is always the pilot. Who among us wouldn't do better with a 20-pound weight-loss program? That's more weight than all of the avionics you could find room to install—and the added benefits for the lighter pilot include better health, a longer career with an FAA medical and more cute winks from their partners…what's not to like?

A well-designed aircraft has probably already had as many lightening holes as the creator considered prudent. These wingribs are a good example of the fact that it is hard to find additional material to remove safely.

What it all comes down to is that today's airplanes can be built both light *and* capable—you don't necessarily have to choose between the two. Just as early, heavy engines gave way to the lighter, opposed-cylinder designs that saved hundreds of pounds in aircraft weight in the early days of aviation, the modern revolution in avionics allows us to build a single aircraft that can fulfill multiple roles. Sure, if your goal is to compete or exhibit at the highest level of aerobatics—to poke out there in one edge of the overall "performance" envelope—you'll have to give up capability elsewhere. But for the vast majority of pilots and builders, we can have our cake and eat it too. I am speaking, of course, about metaphorical cake…we want to keep that pilot light and healthy as long as possible. ✈



# Finding the right digital charting solution for your cockpit.

**Let's get this straight** right up front. I'm willing to experiment with new products on the aviation market—if the price is right. That's why this year I've finally done it. I've ditched paper charts in favor of digital delivery systems.

I've done this reluctantly, I must say. In the process of making the switch, I uncovered a previously unrecognized emotional attachment to my paper charts. I do like folding and unfolding, stretching them out on the kitchen table and really seeing the distances I'm about to run across the country. Drawing those long, mostly straight (but not always) lines from point A to point B with my highlighter and picking my waypoints is tactile and delightfully satisfying. I just don't get the same adrenaline thinking about an upcoming flight with a digital flight plan.

Alas, GPS and Internet flight planning has pretty much made my kitchen-table method obsolete for everything except teaching students how to fly (there is still the educational value to drawing, measuring and pondering the advantages and disadvantages of a given track). During the past few years I've gotten away from the traditional folded charts and into charts organized and bound in books—it was just more economical and compact. But this year…

It wasn't really my idea to switch. I'd have waited just a bit longer to pull the trigger on this decision (I hate being a beta-tester). The true story is that my builder/pilot husband and I had discussions in February about maybe going to digital charting. Then he got laid up for a couple of weeks, and I went out of town on assignment. When I came back, we owned a new iPad and trial versions of three different digital charting/GPS flight-planning and navigation apps. That was just the beginning.

After I digested the initial hit to our credit card for the hardware (there went my summer vacation), I began


The Jeppesen app is designed to flow and file just like the paper charts. Planning and filing a flight take just a couple of touches. Rubber-band re-routes are as simple as a firm press on the additional waypoint. The best feature of the app is its quickness. All the charts are rasterized, not scanned. Zooming in and out is immediate and sharp, as is panning.


Garmin isn't the only app that has the ability to imitate traditional HSI functions in conjunction with a moving map, and WingX Pro7 isn't alone in providing ADI information. Air Navigation Pro got its start in Europe, but it's quite capable in the new world too. Its 2D, and in some cases 3D, mapping is impressive.

**Amy Laboda** *has taught students how to fly in California, Texas, New York and Florida. She's towed gliders, flown ultralights, wrestled with aerobatics and even dabbled in skydiving. She holds an Airline Transport Pilot rating, multi-engine and single-engine flight instructor ratings, as well as glider and rotorcraft (gyroplane) ratings. She's helped with the build up of her Kitfox IV and RV-10.*

Garmin brings all of the functionality of its popular handhelds to the iPad and Android tablets with its Garmin Pilot. Best of all, if you have been a Garmin handheld user in the past, the logic for using the app will be familiar.

to explore the possibilities of the new device. I could acknowledge that the paper charts were costing us upwards of $300 a year. I knew that theoretically that meant the iPad and its software should pay for itself in a little less than three years (though the device comes standard with a one-year warranty, a minor flaw in my husband's logic).

Even so, at first I wanted to send it back. Why? Well, if we were going that route, I'm an Android user, and I felt that there were less expensive solutions out there, and I wanted to try them before going to the iPad. But sending the device back after my husband had spent a week marveling in its delights was simply not going to happen.

We began to look for the best digital charting app—one that didn't cost a lot (considering we were into the hardware for nearly $800) but met our charting and backup-GPS needs. We are two airline-transport-rated pilots with 70 years of flying between us, and we don't fly much IFR because, well, after years of flying at the whims of a boss, who wants to fly in bad weather for fun? Not us. We still stay IFR equipped, current and competent, because sometimes bad weather happens and we want to be ready. We just don't go looking for it.

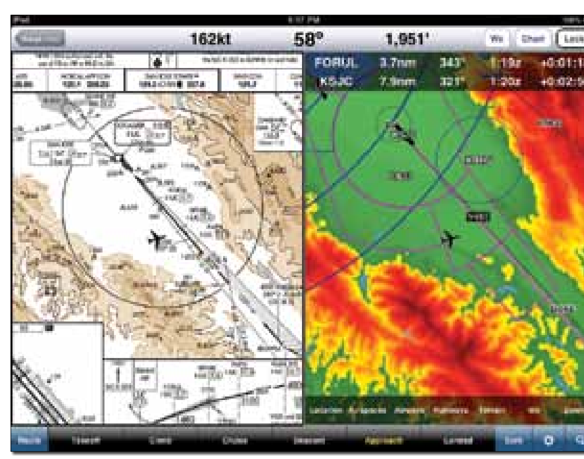
That said, the full-blown Jeppesen Mobile FD app, which is fine-tuned for airliners and sports a price to match, wasn't for us. I say that with some reservation, because it is a Cadillac of apps, hosted on the The Boeing Company's many robust servers, so it virtually never goes down. Better yet, it is intuitive, built to be familiar to those who spent years filing and searching through the leather chart books. The app is wonderful for IFR flying, but it didn't really meet our needs and was definitely going to blow our budget.

On the other end of the spectrum, *Fltplan.com* has a free app for its users (and the web site is also free for registered users). The app offers geo-referenced navigation and a robust flight-planning engine, complete with weather, FBO and hotel information, and more. There's Air Navigation Pro at $26 a year, and ZephyrCharts has a worldwide database for $3.99, period. If you believe the iTunes reviewers, it works well for basic digital navigation needs.

Sticking with names we know, it seems that nearly all of the paper-chart favorites have now found their way into apps. EFB has an app, as does the Pilots Guide. Garmin's Pilot app is quite beautiful and functional. But at $9.99 a month, it's just more than I wanted to pay for an app.

I found several of the Windows-based, flight-planning-program companies, including Anywhere Map and Seattle Avionics, have thrown their hats in the ring. Seattle Avionics FreeFlight is not a moving-map program but rather a flight-planning program, but it is completely free and quite robust. Anywhere Map's Freedom app is identical in just about every function to its


Need an app that doesn't cost much but delivers a lot? Working on an Android tablet or smartphone? The Naviator provides international capabilities, split screens and more, without busting budgets.




The terrain function on WingX Pro7 is delightful. Best of all, WingX Pro7 lets you have several different highlights over your chart at the same time, such as TFRs and weather and airspace, or terrain and TFRs and weather. We really liked the rapid swap and split-screen functionality of the program, and we are intrigued with the possibilities of having a backup AHRS (but we aren't ready to spend the money on that, yet).

Windows-based program. The downside to Anywhere Map is that, as of this writing, the company does not allow you to try out the app before you buy it. With so many choices, it is critical to be able to download the app and "try it on" to see if it works with your version of iPad and, well, your natural flight planning and execution logic.

## Test Driving and Decision Making

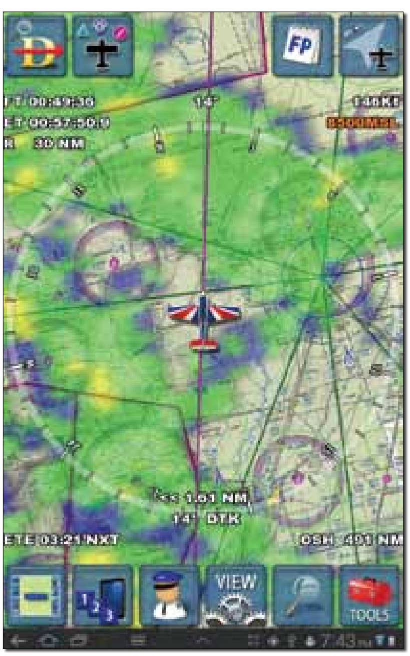
Ultimately we made our decision from an entirely new batch of apps, ones that came onto the horizon with the iPad itself. We downloaded and tried out both ForeFlight and WingX Pro7 for a month, and then we argued the virtues of both right through the end of our trial time. All of the apps mentioned offer a nice blend of VFR and IFR charting, and they work great with either the iPad's built-in GPS or an external solution. Some of them are able to communicate via Bluetooth or Wifi with an XM weather or ADS-B box, and in the future, perhaps even with your in-panel radio stack (Grand Rapids Technologies and Aspen Avionics are both working on iPad-driven solutions). But I was interested in what the iPad and apps can do today.

It turns out that my husband and I, despite our similar pilot ratings, differ completely in which app we find most intuitive. This is not surprising, as we operate very differently, even in the airplane—sort of a right-brain-, left-brain-dominant conundrum. Sometimes it amazes me that we've managed 26 years in a cockpit together. So we argued the point a bit, but then an idea hit me. First, though, I acquiesced, and he got the app he wanted for the iPad.

But here's why I did it. While we were sparring over the apps, I remembered that I have an Android-driven smartphone, and in my research, I discovered quite a few inexpensive Android solutions to our digital-charting problem. Garmin, Anywhere Map, ForeFlight and WingX all do Android apps for about the same price they charge for their iPad apps. But Naviator and Air Navigation Pro are also on the Google Play marketplace, and for much less money. I realized that I could put one of those apps on my phone and have the perfect replacement for our long-in-the-tooth HP iPAQ that has run Anywhere Map for more than seven years now.

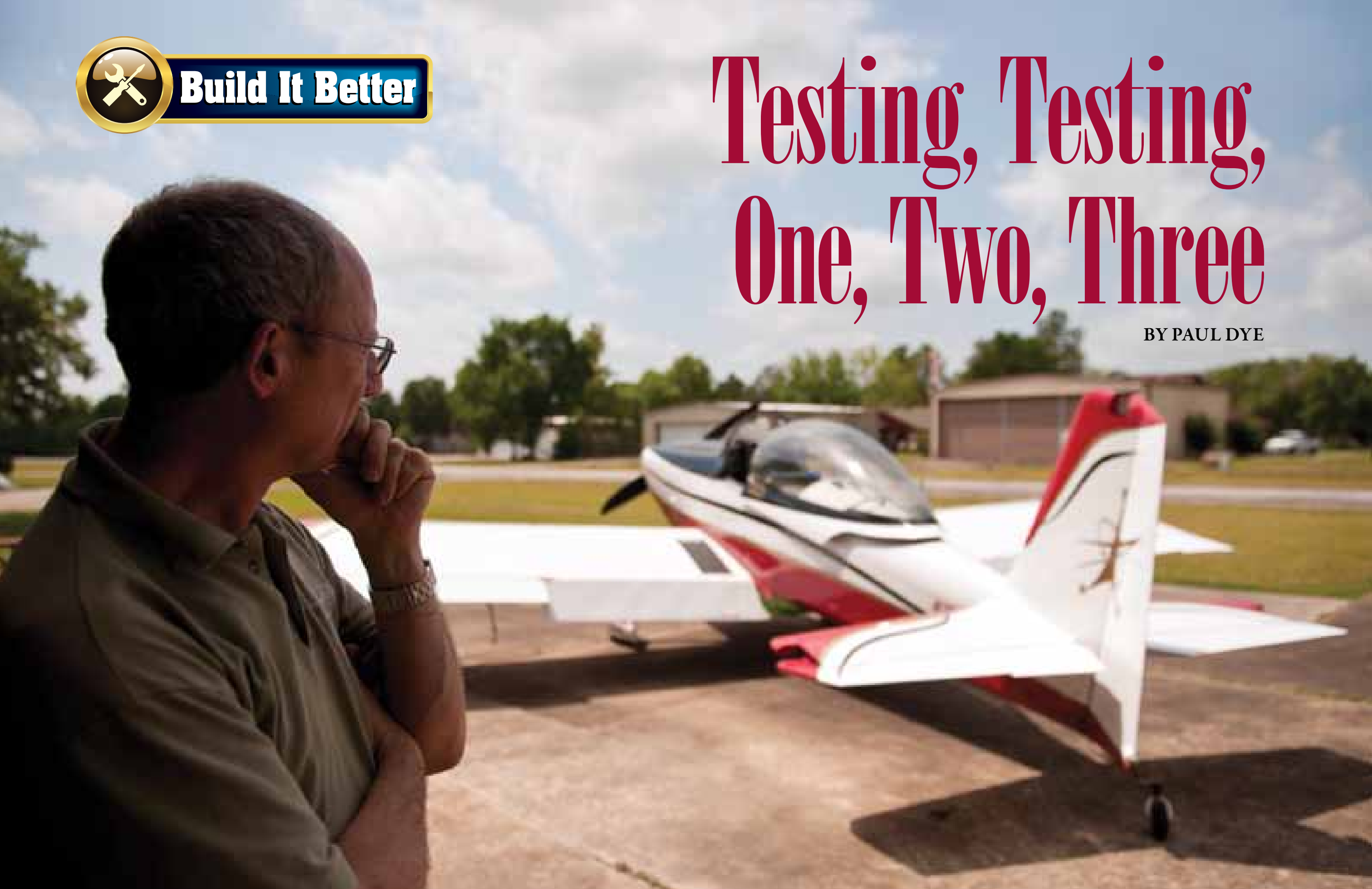
I should mention that I'm a lifetime data subscriber to Anywhere Map, and I swear, if they'd just let me sample their app, I'd probably go with them, because they offer lifetime subscribers a great deal—pay only once for the app, and all updates are considered "in plan" and are free after that. Maybe they will come around.

In the meantime, my husband and I have worked out a win-win solution to our digital charting, which, if you have two experienced pilots in the cockpit, is just what the flight surgeon prescribed. ✢




The author is a longtime Anywhere Map customer, and that means the functionality of this app comes naturally. She loves the little green safe-glide circles and the ability to layer on the data or de-clutter the screen at will. This app, as of this writing, was still acquiring function (and had a price discounted to reflect that), but its developers, Control Vision, promised it would be fully functioning with all the bells and whistles by summer.

The way the ForeFlight displays its VFR and IFR capabilities on the new high-resolution iPad screen is great. Its weather and flight-planning functions are intuitive, and for those who need it, the new ADS-B/WAAS-GPS Appareo box from Sporty's brings subscription-free inflight weather and WAAS accuracy to the app.



Build It Better

# Testing, Testing, One, Two, Three

BY PAUL DYE

**I grew up playing** with hardware, and as a boy, I was always underfunded when it came to my experiments. While I never tried to jump off a barn roof with an umbrella or bed-sheet parachute, I did try to build a free-wheeling cart out of a couple of 2x2s for axles, a thin sheet of plywood and baby-carriage wheels held on with nails. Needless to say, I didn't get very far with that contraption.

My mother predicted that outcome, and that's probably why she was confident in helping me carry my cart to the top of a hill. She knew intuitively that I wasn't going to go more than 6 inches "before the wheels came off." This early experiment in vehicle construction did, however, teach me a valuable lesson: No matter how good a machine might look on paper, you never really know what it can (or, in that case, can't) do until you test it.

## Old Lessons, New Relevance

I have carried that philosophy with me as I progressed from a teenage mechanic's helper to an aircraft restorer, a pilot and eventual aeronautical engineer. Being in the operations and testing area of aviation, I naturally tend toward the greasy-hand part of machine verification and have always cast a sideways glance at anything that hasn't proved itself in the real world—or at least a laboratory test rig. In days past, that is the only way machines and vehicles could be proved: You had to take them out and test them. Testing could be to one of various limits—operational, re-use or even ultimate conditions. In short, it was nice to know firsthand what you could do to something and still use it again—as well as where it was going to break!

With the advent of modern computer modeling, many engineering organizations have gotten away from the old testing techniques and are substituting analysis and modeling to predict when and how a piece of equipment (or an entire aircraft) is going to bend or break. They simply use the results of computer runs that say there is a certain amount of margin in the design, and since the models have been tested against real-world equivalents in the past, they trust that they will apply to the new hardware as well. While this


*Illustrations: Robrucha; Photos: Richard VanderMeulen, Courtesy NASA* approach frequently gets good results, and, if applied with caution, can save time and money while accurately verifying a design, it must be approached with caution and maybe even a little suspicion, especially in the world of homebuilt aircraft.

The reasons we have to be a little suspicious are twofold. First, the results of failures in the aircraft world can be very serious, and second, in the world of homebuilt, "custom" aircraft, the sample sizes (numbers of a particular aircraft or component) are small enough that statistical analysis might very well be inaccurate due to insufficient data points. Call me old fashioned—you can even call me a Luddite—but I am a believer in testing equipment and vehicles in the field to prove their capabilities.

## Skin in the Game

In the early days of aviation, testing was the only way to prove an aircraft, and it involved a pilot strapping on the airplane and going flying. Proving the design was pretty much done by trying a few maneuvers. If the machine came back and the pilot survived, it was on to more rigorous testing, until the airplane proved capable of its designated mission. In those days, a design didn't last very long—it was superseded in months by something more advanced, stronger and better. The pace of development was just that fast. So if there was a problem, or an aircraft was lost, it wasn't as big of a deal as it is with modern development programs costing billions of dollars and consisting of only a very few airframes. Components are likewise costly to test because of each item's accumulated cost—hence the desire to prove them by analysis rather than test.

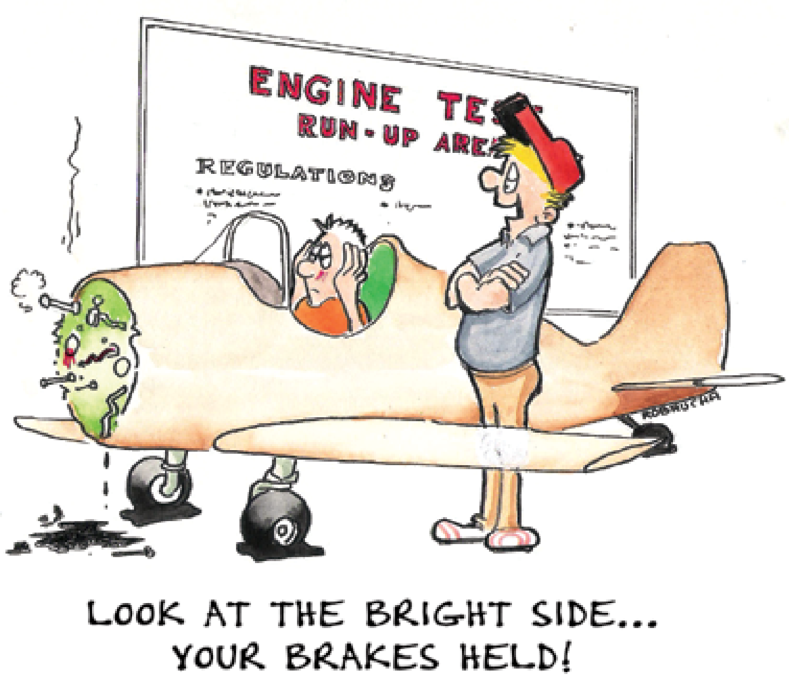
One of the reasons that the Apollo program was able to successfully land men on the moon in a short period of time was a philosophy that espoused testing. Cost was almost literally no object, and redundancy was not an option, due to weight and performance

The Space Shuttle Launch Pad Escape baskets were an "E-ticket Ride" if there ever was one. Theory said they would whisk a person from the top to the bottom safely, but until they were tested, no one was sure. They were only tested with human occupants once, and that was enough.

It has been said that the Space Shuttle Columbia was almost worn out (from testing) before its first flight. In fact, over its lifetime, many more test hours were put on the vehicle than flight hours.

limitations. That meant that every part of the spacecraft had to be very reliable—it had to work, and the people flying had to know it would work.

Many components were sacrificed on the altar of destructive testing so that the operators would know exactly how far they could push the edge of the extremely thin envelope. Modern aerospace vehicles and programs are much more limited in resources, and therefore people are less inclined to destroy equipment in labs and on test stands; hence the need for computer modeling. But the kicker is that the models are only as good as the equations used to describe the physical reality of the devices being tested, and they can only be truly trusted if those models are verified by testing! That's why modeling techniques that might be acceptable for items and systems that will eventually be mass produced, yet those used for custom gear and situations have a built-in fault—the lack of ability to prove them by testing.



## Here on Earth

So what does all of this mean to the average kit or homebuilder? Well, it prompts a number of questions that you should ask about the designs you are considering for your next build. How has the design been tested? Has the structure been loaded to destruction? How much of the design has been accepted by computer modeling and analysis versus test? A prospective builder can get an idea of the philosophy of the design team by looking at how many aircraft of that model that team has built. Is there only one in existence, or are there many built and flown? (That number is difficult to obtain. Just ask those who gather data for the KITPLANES® Buyer's Guides every year.)

This same philosophy can be used for aircraft components—engines, avionics and other equipment. I have an easy way to measure my confidence in an engine-development program: I ask how many engines of this type they have built and how many thousands of hours of run time they have on an aircraft. In fact, I generally ask to see the development team's airframe—the one they use for testing. If they don't have one and are using potential customers' airframes instead, I have to wonder just how resource-limited they are, and this leads me to believe that the test program is probably a shoestring affair.

Engine components are in a class of equipment that is ripe for extensive, methodical testing. Heat, vibration and extreme stress can all be found in an engine compartment, and hours and hours of real-world run time has proved time and again to be the only way to build robust hardware. The lowly ignition magneto has proved itself over a century of aviation, but not without many development tests and millions of hours of time in service that lead to developments such as pressurization for high altitude flight. In the past two decades, electronic ignition systems have been developing with great success, but not without a lot of blood, sweat and tears on the part of the developers and testers. I can't think of a single one of those systems that worked perfectly from the start—rather, they have matured and gone through growing pains as weaknesses were discovered, components were beefed up and/or redesigned and more testing was performed to prove the upgrades. Several of those systems are now out there on the market and fairly reliable, but it has taken years to get them there—just as it took years for those magnetos to reach the point where we don't think much about their reliability.

Avionics testing today encompasses both hardware and software. There is nothing like a good old shaker table to discover flaws in electronics boxes intended for aircraft use. It is rare that an electrical component brings the system to a screeching halt; rather, it is a connection, an exterior fastener or a loose wire or solder joint that can only be found by testing. Electronics are almost always perfect when analyzed on paper—the real world discovers that hot spots appear in a box that can affect critical components in a way no one has predicted. Testing is the only way to find this out.

In the same way, software needs testing. Run time is important (how long does it keep going between resets and/or reboots?), but a well-thought-out test program will also probe every

The Apollo spacecraft returned to earth via parachutes, and they were tested with boilerplate mockups many times before humans rode them home from space.

logic path to see if the programs can be tripped up or brought to their knees. Bench testing is good, but in-flight beta testing is generally the only way to really find the faults. It surprising to see just how many defects and errors are uncovered (and fixed) in even the most extensively designed software systems by actual field testing. It is often a simple case of the design team not being able to anticipate "field issues" until the software mixes with the hardware in the field.

New equipment, devices and components hit the market for Experimental builders almost every day. Some are from large manufacturing giants and others are turned out by homebuilders themselves in garage workshops, to be sold one at a time over the Internet. Some require little testing because their failure would have few consequences to safety or mission success. Others have a lot to do with the pilot's safe return to earth, and for this I would demand to see how well, how long and to what extent they had been tested. The old saying goes like this: If you want to know what the engineers think it will do, check the analysis. If you want to know what it will really do, test it!

Just because the equations say a piece of equipment or structure can withstand such and such a load before breaking doesn't mean as much as knowing that this has been proved true. Testing costs money—there is no doubt about it. But for critical components, testing is often the only way to be sure of where the limits really are. Whether you're going to the moon or simply across your home state, the confidence of knowing how much your equipment will take before letting you down is priceless. ✈

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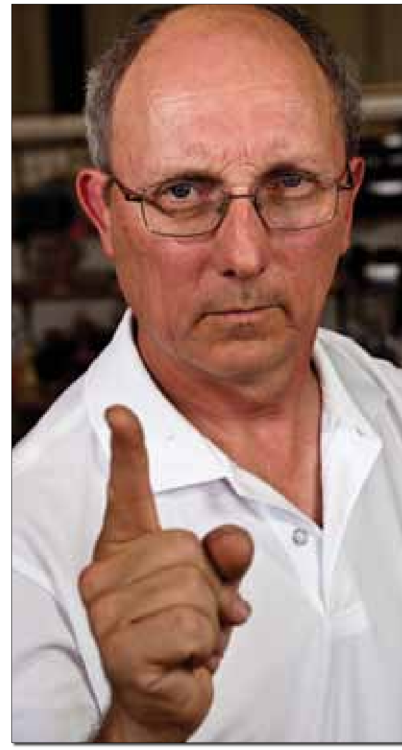
*Paul Dye is an aeronautical engineer and multi-time builder. He currently flies a Van's RV-8 and, along with his wife, Louise, has just completed an RV-3.*



Remember: If it hasn't been tested, you don't know that it will work!

# The sixth annual Electric Aircraft Symposium.

**Only seven months after** the Green Flight Challenge, this year's CAFE Foundation Electric Aircraft Symposium had a stellar lineup of presenters, some hopeful signs of progress in battery development and some challenging new visions that will apply in the kit aircraft world.

Santa Rosa, California, is Wine Country central, with abundant sunshine, nearby geysers generating electricity and a lively and supportive interest in aviation. Close to Silicon Valley, the University of California at Berkeley, Stanford University and other centers of research and learning, the symposium draws on local resources. Couple those learned presenters with experts willing to travel from Europe and Asia to be part of the program or the audience and you have a world-class gathering. The smart crowd is betting on some exciting developments this year. Highlights included new battery chemistries including IBM's lithium-air 500-mile project; the F-22 designer's 300+ mph electric homebuilt; a kitbuilt, five-seat, high-performance hybrid; and the FAA's planned regulations to regulate electric Light Sport Aircraft. Supporting that, Ron Gremban of ForSites Corporation, who developed the first plug-in Prius, suggested forming a non-binding industry consortium to promote electric-aircraft safety.

Jack Langelaan, team leader, and Tine Tomazic, designer of the Pipistrel G4, told how they built and flew the GFC winner.

JoeBen Bevirt, manufacturer of motors that Patrick McLaughlin describes as "the best," chats with Tine Tomazic, designer for Pipistrel Aircraft.

## Taking Winona for a Winged Mercy Trip

Brien Seeley, founder and president of the CAFE Foundation, had a Wobegone presentation (as in Lake Wobegone) to set the tone and agenda. Taking his cue from Garrison Keillor's popular stories about the mythical town, Seeley told of Winona, who, in a 2021 update, needs to visit her sick sister Lena in Lincoln, Nebraska. Airlines don't serve her town, buses are irregular and expensive, and Winona is beside herself. Then she sees an ad for the Anytime Ford Sky Pony, an electric-aircraft taxi alternative. It costs only 10 cents a mile, and she ends up sharing the ride and expenses with a fellow traveler. The airplane's triple-redundant GPS and auto-landing capabilities allow it to fly into Peter Pan Airpark, near Winona's home.

After a 90-foot ground roll and a steep, nearly silent climb, Winona is heading toward Lincoln, where she is eventually reunited with her sister.

**Dean Sigler**

*A technical writer for 30 years, Dean has a liberal arts background and a Master's degree in education. He writes the CAFE Foundation blog and has spoken at the last two Electric Aircraft Symposia and at two Experimental Soaring Association workshops. Part of the Perlan Project, he is a private pilot, and hopes to get a sailplane rating soon.*

Seeley emphasized that the scenario is doable with today's technology, and it takes only the will to make it real. He also promoted quiet propellers to help neighborhood airports be good neighbors.

## Cell Meetings

Three battery presentations promoted different technical approaches; all promised greater range and power for electric vehicles. First, Cary Hayner from Northwestern University spoke on "Engineered Graphene Electrodes for Lithium Batteries," explaining how wrapping electrodes with atom-thick graphene can help increase energy density in batteries. Using half-cells with a known electrode on the cathode and experimental electrode on the anode, researchers can test variables and determine best combinations of ingredients. Hayner and his researchers poke 20-nanometer holes in the atom-thick material to make "holey graphene," which diffuses ions more efficiently and increases energy density 60%—and up to 130% with a nickel magnesium cobalt (NMC) cathode. At least experimentally, Hayner has produced a 600-watt-hour-per-kilogram cell and a graphene "paper" that might allow it to be manufactured more easily.

Jack Langelaan (second from left), Pipistrel G4 GFC team leader, makes a point with Tom Gunnarson of the FAA and Mark Moore of NASA.

Bruce Katz from PolyPlus Battery Company brought back his water-immersed battery, which, in seawater, can provide nearly 1000 hours of energy—ideal for underwater Seal teams. For aerial transport, his batteries use LISICON (lithium super-ionic conductors) and NASICON (sodium super-ionic conductors), solid electrolytes to seal the electrodes and give an energy boost, which, with lithium-sulfur chemistry, could be five times


Bill Dube and Eva Hakansson (second and third from right) display the Killajoule electric motorcycle with sidecar. It has gone 151 mph and will go faster soon.

*Photos: Dean Sigler, Larry Ford/CAFE Foundation, Paul Peterson, Bill Dube & Eva Hakansson* greater than current lithium-ion cells. *Time Magazine* chose Katz's creation as one of the 50 best inventions of 2011.

Winfried W. Wilcke is the senior manager of Nanoscale Science and Technology at IBM's Almaden, California, research center. He founded and still heads the Battery 500 Project, which, with several industry and academic partners, has the goal of creating a 500-mile battery for electric vehicles. He said that if all cars in the U.S. were electric, 73% of them could be charged at night with the excess energy in the existing power-supply grid.

In a typical week for a car driven by the 500-mile battery, a 4-kilowatt home charger, used five nights during that week, would provide all the energy necessary for the week's travels, and "range anxiety" would be eliminated.

His lithium-air battery could give five times the energy storage of a lithium-ion battery. IBM's goal is to achieve 1000 watt-hours per kilogram in cells, with the theory showing this could go as high as an astonishing 6000 wh/kg.

He ended his talk with the unsurprising but sobering news that batteries are not yet anywhere near the energy density of fossil fuels. Filling his Beech King Air with 384 gallons of Jet A (2575 pounds) would only be matched by 6233 pounds of 1200-wh/kg batteries, leaving no ability to fly at all.

The happiest couple at the event, Dube and Hakansson gave a synchronized presentation spilling over with good spirits and astonishing information on the Killacycle and other projects.

With worldwide energy demands doubling every 15 years and a current lithium-ion battery market of $8 billion (projected to be $30 billion by 2017), the impetus to bring high-performance, high-quality batteries to market becomes readily apparent.

At a more "practical" level, Bill Dube and Eva Hakansson shared their secrets for wiring high-powered battery packs that take world records in motorcycles, and perhaps soon in Le Mans racers. The couple talked about building and racing Killacycle, a 500-hp two-wheeler that catapults Dube from 0 to 60 mph in less than 1 second and until 2010 was the undisputed electric drag-racing champion. Hakansson is campaigning Killajoule, an exotic sidecar racer in which she hopes to top 400 mph on the Bonneville salt flats—and she's already done 151 mph in a machine that her husband describes as "an electric drill motor with a big battery pack."

Patrick McLaughlin of Mountain High Oxygen discussed his promising motor controller, which can command any type of electric motor, and proposed an open-source organization to develop and promote the design.

Carlo Treves showed FlexSolar panels that could be wrapped around an aircraft's surface to allow electric recharging of an e-plane's batteries while it's parked.

## Charging Ahead

Two Pauls caught attendees' attention with high-speed approaches to electric flight. Paul Schlein, retired chief scientist on the Lockheed F-22 Raptor, has been getting scientific in his garage, designing and building a streamlined 4-foot diameter fuselage, inspired by Bruce Carmichael's teaching and derived from revolving a NACA 66-series airfoil. Extremely small Hershey-bar wings would carry 33 pounds per square foot, and an inverted V-tail, attributed to Molt Taylor, would slope away from interference drag. Now testing a small-block Chevrolet V-8, he looks forward to powering his two-seater with electricity.

The structure for this projectile will weigh around 230 pounds, with propulsion system adding another 800, and 150 pounds of ice water chilling the motor and batteries, possibly by melting through skin-mounted radiators, *a la* the Schneider Cup racing seaplanes of the 1930s. Cooling drag will be zero, with a fuselage drag coefficient at a phenomenal 0.02. He hopes to achieve 700 kph (434 mph) with low trim drag, high stability and little thought for stall speed—but great concern for stall behavior.

Less extreme, but extremely attractive, Paul Peterson's Volta Volaré GT4 is a four-seat (five with optional rear-bench seating) canard, hybrid electric craft that can cruise 210 knots (240 mph) on just over 7 gph. Peterson plans later versions that will be all electric, and one variant will be a twin-motor, six-seat, high-altitude business craft competitive with much more expensive turboprops at a much lower fuel burn—essentially zero fuel burn when the all-electric version is introduced with virtually maintenance-free motors.

The Volta Volaré's roomy cockpit includes room for full IFR instrumentation.

The Volaré can land and take off in 1500 feet, allowing use of various airports.

A dazzling image in flight, the Volaré shows off its twin vertical stabilizers.

With a builder assistance center in Sebastian, Florida, and a "skunk works" type hybrid and electric-power-system development program underway in Hillsboro, Oregon, Peterson's ambitious undertaking is drawing worldwide attention and orders. It will be interesting to see how the Volaré compares to Pipistrel's Panthera, another high-performance hybrid.

Peterson also plans a ViVolaré Familia (Green Flying Lifestyle Club), a limousine-type usage plan in which members would fly with a professional pilot. There's more than just aerodynamic or power-train innovation at work here.

## Smaller, Lighter Hopefuls

Gene Sheehan's motorcycle and aerodynamic expertise once produced a streamliner shell with a drag equivalent frontal area of 0.1317 square feet, about the size of a small sticky note.

The all-new e-Quickie has achieved similarly remarkable figures, both for development and performance. Sheehan and his crew crafted 41 carbon-covered molds from leftover 11-ounce-per-square-yard carbon fiber—too heavy for flight, but just right for molds. CNC-routed blocks of foam provided the forms, and the carbon fiber provided the rigidity. All parts on the airframe are a carbon-foam-carbon sandwich, with the exception of the vertical tail, made from Kevlar to allow radio waves to escape and get through to the antennas hidden within. Resin was minimized through one-step molding, and pre-manufactured model-aircraft carbon strips created a 2-inch wide, 1/15-inch-thick spar cap on the canard. (For more on Sheehan, see "Mojave," Page 23.)

A new version of a proven German brushed permanent magnet motor, which Sheehan claims is as efficient as a brushless, provides motive power, with an Alltrax controller from golf carts throttling through a slider potentiometer normally used on electric guitars. One of two battery packs is run through the controller to allow takeoffs and landings, while the other is wired straight to the motor for cruise. Sheehan cautions that changing phase when changing motor speed can cause fires because of electrical noise.

Stephan Boutenko of Alternair presented details of his two-seat electric Light Sport Aircraft now under development. The Alternair Amp-100 is designed to fight the expense of internal-combustion-powered airplanes with 2.5 hours of endurance and a 200-mile range possible on its 29-kWh, all-aluminum-encased battery pack. This is calculated, based on 2009 batteries, to allow flying to a nearby airport and returning home on one charge, with a 30-minute reserve.

With an empty weight of 880 pounds with batteries and useful load of 440 pounds, the Amp-100 fits neatly into the LSA market. Its 35-kW (47-hp) LaunchPoint motor will make it a good neighbor, with a 65-dBa maximum noise output. The prop limit is 1600 rpm, and 1400 rpm makes for quiet cruising. Wireless access will allow the iPad generation to check the health of the plane's advanced electronics. A BRS rescue parachute and five-year limited warranty should provide a sense of security. Boutenko says first deliveries will take place in 2014.

## Seriously Now?

Tom Gunnarson from the FAA and Ronald Gremban from ForSites Corporation had similar goals and different approaches to making electric flight a safe experience in both LSA and Part 23 aircraft.

Gunnarson discussed assessing emerging technology, taking a risk-based approach and considering public safety to develop regulations that will apply first in the Experimental category, then LSA and finally for Part 23.

As electric aircraft garner increased public attention, there will be added concern. An audible sigh was heard through the meeting room when he announced that new regulations could be feasible in five to 10 years, but that new rules would seek to reduce fatal accidents and certification costs by 50%. He ended by promising the FAA could fast-track these with public encouragement.

Gremban talked about new safety concerns for electric aircraft and proposed an industry consortium to help develop operating protocols and standards. ✈

*For more information, visit the CAFE Foundation's blog at www.blog.cafefoundation.org. Find a direct link for this and the sites below at www.kitplanes.com.*

## RESOURCES

Alternair Amp
*www.alternair.com*

Electric Aircraft Safety
*www.forsites.com/safety*

e-Quickie
*www.greenflightchallenger.com/thechallenger*

Graphene Battery Technology
*www.mccormick.northwestern.edu/news/articles/article_1000.html*

HighFlex Solar
*www.highflexsolar.com*

IBM's Battery 500 Project
*www.ibm.com/smarterplanet/us/en/smart_grid/article/battery500.html?lnk=ibmhpcs2/smarter_planet/energy/article/battery_500*

Killacycle (Bill Dube and Eva Hakansson)
*www.killacycle.com*
*www.evahakansson.se/#home*

LaunchPoint Motors
*www.launchpnt.com*

Mountain High Oxygen
*www.mhoxygen.com*

PolyPlus Battery Company
*www.polyplus.com*

Volta Volare
*www.voltavolare.com*

# The Coming Revolution

## Embedded speech in avionics will unburden the solo pilot by providing a virtual copilot.

BY JAMES P. HAUSER

*Much of the content of this article is based on the author's upcoming book "A Cognitive Avionics System with an Embedded Conversational Agent."*

**In multi-crew aircraft,** the pilot has considerable support from the copilot, who handles many routine tasks, such as reading the checklist, changing radio frequencies, monitoring systems and communicating with air traffic control. In single-pilot operations, when all is well, these tasks are easily performed by the pilot. But we have all seen otherwise boring flights that suddenly became very busy, sometimes critically so.

Many approaches have been pursued to lessen the burden on the single pilot. The DARPA (Defense Advanced Research Projects Agency) Pilot Associate program was one. Several articles have appeared in various aviation magazines over the years describing the idea of a virtual copilot. Brien Seeley, president of the CAFE Foundation, wrote an interesting article for the June 2007 issue of KITPLANES® outlining his concept: "Come Fly with Me—the eCFI."

The primary efforts to date by avionics manufacturers have been on improving the graphics and mode-selection button sequences. But the pilot must still manually interact with the avionics systems. If the pilot is already taxed with flying the aircraft (hands and eyes busy), then finding a checklist (paper or electronic) may become challenging.

Over time, many have come to realize that the first step to smarter avionics is a more natural interface. The use of buttons, keypads, touchscreens and knobs may seem natural to us today because of the computer revolution, but this is not an innate skill. Furthermore, remembering how to display a particular chart or checklist using key sequences may be problematic during a stressful event. This is especially true in single-pilot operations.

The most natural communication interface for technical information during times of duress is spoken language and graphics. Being able to ask the avionics to read a checklist or display a chart, and having it do so interactively, begins to approach the convenience of having an actual copilot.

By now you may be thinking, or should be, of HAL in the film *2001: A Space Odyssey*. Indeed, sans the paranoia, HAL would make an excellent virtual copilot. Technology has not progressed to quite this point yet, though the debut of IBM's Watson on the television show *Jeopardy* was impressive. But even if Watson's performance were comparable to HAL's, there are few aircraft that could carry the room full of computer servers that Watson requires. (Incidentally, Watson had no understanding of spoken language. The questions were provided in electronic format.)

Readers who have used the iPhone Siri application have surely wondered how to have something similar in their aircraft. Perhaps one day this will come to pass. But Siri has one major shortcoming: It must be connected to the Internet to function. Like Watson, Siri resides on a server farm, not in the iPhone, and the iPhone handset does little processing of the voice requests.

On modern commercial transport aircraft, a limited number of aural speech warnings are available. One of the earliest examples is the Terrain Avoidance Warning System's (TAWS) sharp announcement "Pull up! Pull up!" accompanied by a warning horn. Later, the simple advisory prompts for minor deviations from altitude, airspeed, heading, etc. were implemented. These came to be known among pilots as "Chatty Cathys," along with other less printable names.

However, the fictional HAL could both understand and speak. In the last 10 years, Automatic Speech Recognition (ASR) has made remarkable progress. It is now at the point where it can be used in a limited way in avionics. Indeed, Garmin has recently released the GMA 350 audio panel with some voice-control capability. VoiceFlight has a system for entering waypoints into the Garmin GNS 430W/530W using voice, and the F-35 Joint Strike Fighter will have some voice control of systems.

Furthermore, automobile manufacturers now have systems that far exceed the limited capability of aircraft systems. A notable example is the Ford Sync System. The system to be described here shares much of the general architecture of the Ford Sync System and other automobile ASR systems. There is a speech-recognition module, a text-to-speech module, a natural-language parser and task manager, a vehicle-system interface and the capability to display requested graphical information. The automobile designers are leading the way. One can hope that avionics manufacturers will leverage automobile designer successes into smarter avionics.

The systems discussed in this article are self-contained, and, while limited in capability, they point the way to the future of avionics.

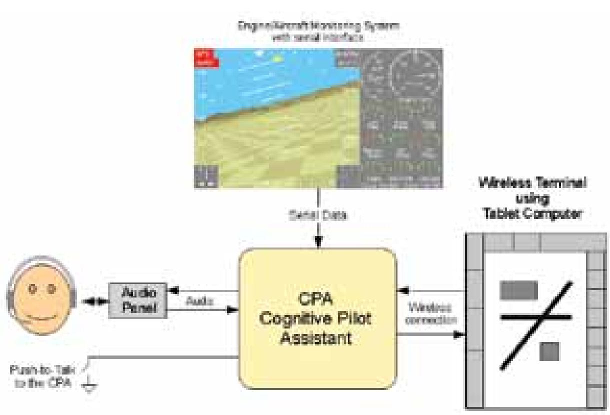



Figure 1: Cognitive Pilot Assistant overview.

## Cognitive Pilot Assistant Overview

This is a working, first-generation virtual copilot that we call the Cognitive Pilot Assistant. The CPA will interactively read checklists, provide overall system status or individual system status (e.g., fuel quantity), time, announce out-of-tolerance systems (e.g., low fuel quantity) and change the frequencies of radios that are configured for remote control. While the system is not truly cognitive, the functions it performs often seem to be. And we may expect that future systems will seem more and more so.

The device itself is a relatively small box containing a single-board computer (SBC). It is connected to the audio panel for voice input/output (I/O) and to a source of aircraft system data. The aircraft systems data is often available from the engine-monitoring avionics designed for amateur-built aircraft. Several avionics manufacturers offer a serial data output that is suitable.

Figure 1 depicts a top-level view of the installation. As you can see, the interconnection to the aircraft avionics is straightforward. Aside from power and ground, there are three other connections: two wires to a push-to-talk (PTT) switch, two wires to the aircraft audio panel and a serial cable connection to the existing engine/aircraft monitoring system.

## Operation

Operation of the CPA is through voice commands. For example, the simplest request is "Say time." The CPA will then respond "The time is hh hours, mm minutes and ss seconds Zulu." The word "Say" is not even required; the request "Time" works equally well. To minimize random responses, the PTT switch must be pressed while making requests.

Checklists are requested in a similar manner. Simply press the PTT switch and say "Engine start checklist." The CPA asks for confirmation by stating, "Engine start checklist." The pilot presses the PTT switch and says "Check." The CPA will then read the checklist interactively, checking sensor readings where possible.

*Illustrations: James P. Hauser; Photo: Bigstock*

A typical checklist session might go as follows:

| | |
|---|---|
| Pilot: | "Engine start checklist." |
| CPA: | "Engine start checklist." |
| Pilot: | "Check." |
| CPA: | "Master on. Three green." (The master switch should be on at this point for the CPA to work. Three green refers to gear lights on retractable gear aircraft.) |
| Pilot: | "Check." |
| CPA: | "Battery voltage is normal at 11.7 volts." |
| Pilot: | "Check." |
| CPA: | "Fuel on mains." |
| Pilot: | "Check." |
| CPA: | "Left fuel quantity is normal at 23 gallons. Right fuel quantity is normal at 24 gallons." |
| Pilot: | "Check." |

At any point in the dialogue, the pilot can request the CPA to say again the last response. For example, if the CPA states a different quantity of fuel than the pilot sees, the pilot may request "Say again," which will prompt the CPA to repeat the fuel quantity it senses.

It is actually not necessary for the pilot to say "Check." If the PTT switch is held depressed briefly, the CPA will assume that "Check" is intended.

While the CPA is awaiting a request from the pilot, it checks the system readings periodically. If a system reading is out of tolerance, the CPA will announce, for example, "Attention Captain! Fuel pressure is low at 1.5 psi." This may be especially useful when the pilot might be distracted by radio communications. If necessary, the CPA is readily silenced by deselecting it on the audio panel.

The checklists are created by the pilot and stored in the CPA as text files. Any text editor should be able to generate these files. The CPA comes with generic checklists that may be edited by pilots for their specific aircraft.

## Some Operational Details

*Microphone.* A good quality, noise-canceling boom microphone is important. As good as today's ASR engines are, they still do not do well in high-ambient-noise environments. Fortunately, the microphone requirement is met with a typical aviation-quality headset/microphone combination. The microphone mechanically achieves noise canceling through the use of a differential microphone element. That is, the ambient noise striking both sides of the element does not produce an output. Voice sounds impinging on only one side act differentially on the element to produce a voltage proportional to the voice sounds.

*Wireless Terminal.* Although not essential to the operation of the CPA, a Tablet PC is useful for displaying charts, the text of checklists, a backup SVS/system monitor, etc. (A laptop is more suited for CPA system maintenance such as updating checklists and other files.)

As a minimum, the tablet should have a Java-enabled browser, through which the CPA will be accessed. There are also apps that can provide access via WiFi or Bluetooth. The CPA/tablet link is secure, so a bit of setup is required before use.

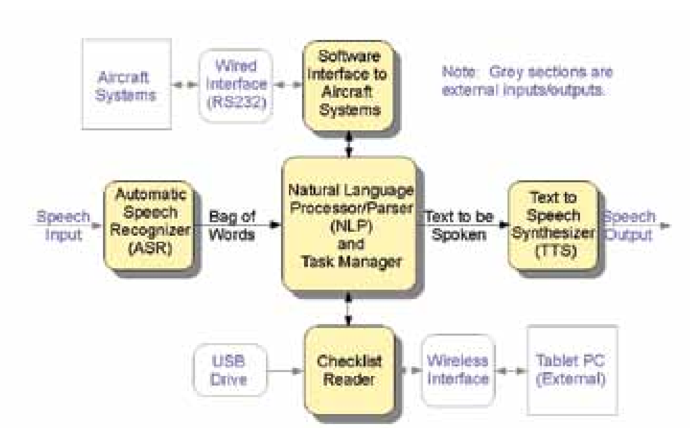



Figure 2: Cognitive Pilot Assistant software diagram.

## CPA Software Details

Figure 2 is a top-level block diagram of the CPA software.

The Natural Language Parser (NLP) and Task Manager (TM) perform the heavy lifting. The details of the NLP and TM are beyond the scope of this article, but here's a general picture.

The NLP accepts the "bag of words" from the ASR and parses them into a form for action. The action is then passed to the TM to be implemented.

For example, requesting a checklist causes the TM to send the request to the Checklist Reader module. The Checklist module then searches for a text file corresponding to the requested checklist. Next, this text file is sent line by line to the TM and on to the TTS module. The pilot must acknowledge each line with "Check," "Say again," "Skip" or "Stop." Skip marks the item as unchecked, and the pilot will be prompted at the end of the checklist for these items. Stop terminates the reading of the checklist and returns control to the NLP/TM. As mentioned, the checklists are text files created by the aircraft owner.

The aircraft systems are continuously monitored for out-of-tolerance readings. If such a reading is detected, an alert is sent to the TM for transmittal to TTS. Out-of-tolerance limits are also text files created by the aircraft owner.

## Conclusion

While the CPA is primitive compared to Arthur C. Clarke's HAL 9000, his vision is driving future development in the technology. There will come a day when talking to our aircraft will be as natural as talking to a real copilot. And this virtual copilot will handle radio communications, altitude/heading changes and more using computer speech technology. The Cognitive Pilot Assistant is just version 0.1. ✈

*For more information on James Hauser's work and his forthcoming book, visit www.aerospectra.com. Find a direct link at www.kitplanes.com.*

# COMPLETIONS

## Edward Schupp's RV-9

My Van's RV-9 took flight on October 10, 2011, after five years of highly enjoyable construction. It is powered by a Lycoming IO-320-D1A with a Sensenich fixed-pitch prop. The aircraft is based at Green Landings in wild and wonderful West Virginia. Thanks to test pilot Craig Fuller and to Jack Raun for his help and encouragement throughout this project.

**HAGERSTOWN, MARYLAND**
**ED.SCHUPP@MYACTV.NET**

## Mark Pensenstadler's RANS S-6S Coyote

I am happy to show off my newest completion—a RANS S-6S Coyote. I now have over 50 hours on it, and I am absolutely thrilled with its performance. Like most RANS airplanes, it is equipped with a Rotax 912S engine and a 70-inch KievProp. At 5000 rpm, it will cruise at 107 mph and burn 3.5 gph. At 5500 rpm, it cruises at 120 mph. The S-6S has two baggage compartments that can be packed with a week's worth of camping gear. The airplane is perfect for adventure flying.

Steve Adamczak, a skilled machinist and Kitfox builder, was a big help on this project. He machined my custom tie-down attachments for the wingstruts as well as other cool parts.

I really enjoyed the entire three-year process of building this airplane. Designing the panel and painting the airplane were the two tasks I enjoyed the most. But be careful where your exhaust fan blows! My neighbor didn't like the smell and called the police. I walked out of the paint booth and found two police cars and two fire trucks at my house! It wasn't funny at the time, but it's become a hilarious hangar story.

**WESTLAND, MI**
**S10SAKOTA@YAHOO.COM**

## Group-Built Van's RV-10

Our Van's RV-10 was built by a team of Ken Smith, Tom Smith, Tim Dawson-Townsend and Anton Nielsen. Total build time was about six and a half years. We took our first flight on July 7, 2010, and the test period was completed without major hiccups. Paint went on in May 2011, and we made the first pilgrimage to Oshkosh in July. We took a Second in Class trophy in the 2011 AirVenture Cup Race. Our paint scheme features the logo of the Fisher House Foundation to promote its mission of supplying free local lodging for the families of military members undergoing treatment at distant military or VA hospitals.

**MARSHFIELD, MASSACHUSETTS**
**YOOPER@ALUM.MIT.EDU**

# BUILDERS SHARE THEIR SUCCESSES

Submissions to "Completions" should include a typed, double-spaced description (a few paragraphs only—250 words maximum) of the project and the finished aircraft. Also include a good color photograph (prints or 35mm slides are acceptable) of the aircraft that we may keep. Please include a daytime phone number where we can contact you if necessary. Also indicate whether we may publish your address in case other builders would like to contact you. Send to: Completions, c/o KITPLANES® Magazine, P.O. Box 315, Ashland, OR 97520. Digital submissions are also acceptable. Send text and photos to editorial@kitplanes.com with a subject line of "Completions." Photos must be high-resolution—300 dpi at a 3 x 5 print size is the minimum requirement. You may also submit electronically at *www.kitplanes.com*, just click on "Completions: Add Yours" in the upper right corner of the home page.

# MAINTENANCE MATTERS

# Got threads?

**The use of cut**, molded or threaded inserts is widespread in the aviation world. Threaded fasteners such as bolts and screws depend on the integrity of threads, as do spark plugs, high-tension leads and oil filters. Would a kit airplane even be an airplane before every threaded fastener that's required is installed and tightened precisely in accordance with its intended purpose? Builders often need to add a threaded receptacle when installing a modification or restoring threads during maintenance. Threads become damaged with wear, deformed due to cross-threading or stripped from over-torquing.

## Create a Threaded Hole: Rivnuts and Other Inserts

A Rivnut is an internally threaded sleeve that has a washer-like flange on one end. The Rivnut is threaded onto a pulling tool and inserted into the properly sized hole until the flange contacts the surface of the metal. The pulling tool—which can range from a pneumatic or electrically powered production unit to a small toolbox type—pulls up the threaded lower portion of the sleeve. This pulling deforms a ductile non-threaded portion of the sleeve, capturing the metal between the flange and the deformed portion of the Rivnut. *Voila!* Almost instantly a threaded hole is installed, without the need to access the backside of the parent metal. Rivnuts were created by B. F. Goodrich in the 1930s for securing de-icing boots on DC-3 airplanes. (The rights to the Rivnut name are now owned by Böllhoff, a German corporation with a U.S. office in Kendallville, Indiana.) The edges of the pneumatic boots—which were also manufactured by B. F. Goodrich in those days—on the DC-3 wings, vertical stab and horizontal tail were captured under a trim strip that was held in place by hundreds of countersunk machine screws run down into Rivnuts.

The Rivnuts I installed were prevented from turning by a key molded into the bottom side of the washer head. This key was aligned with, and fit into, a keyway that had been cut prior to installation.

From the original keyed-type, open-ended Rivnut, the line has been expanded to include closed-ended, sealed, countersunk or large-area heads, knurled bodies instead of, or in addition to, the keyed type for increased resistance to turning. A catalog that includes the complete Rivnut design line,

Rivnuts can be identified by the large flange; nutserts and similar small-flange threaded fastener inserts by the serrated top edge.

The anti-rotation key of a Rivnut can be seen here.

**Steve Ells** *is what you call a gen-u-ine mechanic, a bonafide A&P with an Inspection Authorization. Former West Coast editor for AOPA Pilot and tech guy for the Cessna Pilots Association, Ells has flown and wrenched on a wide range of aircraft. He owns and wrenches (a lot!) on a classic Piper Comanche. But don't hold that against him.*

engineering data, strength ratings and installation torque limits is available from Cardinal Components at *www.cardinalcomponents.com.*

The original Rivnut, made of 6053 alloy aluminum, isn't meant to be used in any structural sense. Certified light airplane manufacturers used Rivnuts to secure fairings. Builders need to study the fastener specifications—in catalogs such as the one mentioned—and should contact the kit manufacturer when considering the use of a blind-type fastener that isn't mentioned in the kit materials list.

Other "instant threaded hole" inserts are often called nutserts. The inserts and installation tools are marketed under names such as Thread Setter and AVK Industrial.

Some I've seen differ from the Rivnut in that the flange is quite small relative to a Rivnut. These depend on a knurled section being pressed into the metal during the installation and setting operation to prevent the insert from turning. The much smaller flange makes these inserts desirable where a near-flush top surface is required. I purchased a small nutsert/Rivnut installation tool manufactured by AVK that I carry in my toolbox. You can find it at Aircraft Spruce & Specialty (*www.aircraftspruce.com*). It works fine for what I need.

Rivnuts and nutsert-type inserts work well for a (non-structural) hole, but what steps are needed when the threads in a structural or load-bearing hole are worn or damaged?

## Heli-Coils

Heli-Coil is the registered tradename of a special insert used to restore damaged threads or to reinforce threads in an aluminum casting. The most common application of these inserts in today's aircraft is for the threads of the spark-plug holes in aluminum cylinder heads.

A Heli-Coil consists of a diamond-shaped coil that forms threads when screwed down into threaded holes that have been cut with a special tap. (Yes, it sounds counterintuitive to install an insert that creates threads into a hole that threads have just been cut in.) The insert is hardened steel and is quite durable.

Replacing a Heli-Coil that's not used in a spark-plug hole is relatively straightforward. The Heli-Coil kit pictured in this article contains everything needed to restore a 5/16 by 18 thread. There's the proper-sized drill, the special tap to prepare the hole for the insert, a plastic installation handle (I cut the handle down due to limited access) and a tube holding six inserts. After the drill is run into the hole to prepare it for the tap, the tap is used to cut the threads for the new insert. Then the insert is screwed into position on the installing handle and, while maintaining the proper alignment and applying a slight pressure, the new insert is screwed into the threaded hole. After installation, the installation tang at the bottom of the new insert is broken off and removed. Simple. Kits like the one pictured here can be purchased at most auto-parts stores. Repairing a damaged aircraft spark-plug hole requires a few more steps—and some expensive tools.

Both Teledyne Continental Motors (TCM) and Lycoming provide guidance—TCM procedures are in each engine overhaul manual, and Lycoming's is in Service Instruction SI1043A. Neither company approves replacing a damaged spark plug Heli-Coil with a standard-sized insert. If the original insert becomes loose enough to come out, then the hole is already too large. The Lycoming bulletin provides Lycoming part numbers for the 0.010-inch (ten thousandths) oversize tap to

Heli-Coil kits contain an installation tool, a drill bit, and a special tap for cutting threads to receive the Heli-coil.

A Heli-Coil on the installation tool. After the coil is seated, the tang that catches the reinforced step of the tool is broken off and removed.

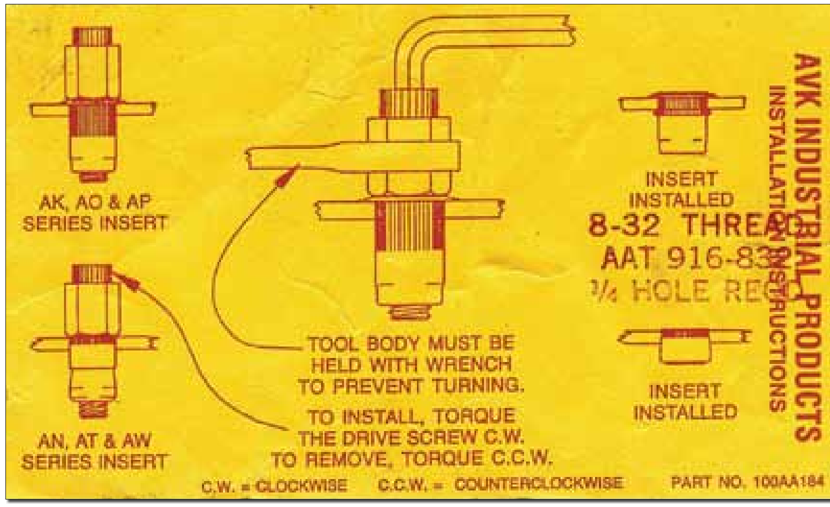
*Photos: Steve Ells*

cut new threads in the cylinder head, the inserting tool and the expanding and securing tool, as well as numbers for the inserts for both short- and long-reach spark plugs.

The spark-plug inserts required by Lycoming and TCM are quite different from other threaded inserts in that they have three marks on the tang to identify them as 0.010 oversize inserts.

Also, both the TCM and Lycoming inserts have a series of serrated teeth cut into the insert. These teeth prevent the insert from moving after installation and must be set using what Lycoming calls an expanding and staking tool. It's important to use the serrated inserts and to set them using the proper tool. The exact-sized inserts that are used (18 x 1.5mm by 13/16-inch or by ½-inch lengths) can be purchased without the serrations, but they are not approved for use by either engine manufacturer. (Lycoming service instructions state that Lycoming does not recommend the installation of standard-sized inserts when repairing a spark plug hole. Further, it does not stock nor supply standard-sized inserts to its distributors.)

Heli-Coil does sell a kit (part number 4260-18) that includes all the required tools plus a supply of serrated inserts, but the list price is over $1200. What's an owner to do? The individual inserts (part number 2-50 for the short-reach plug and 2-52 for the long-reach plug) retail for about $9, but you shouldn't attempt the replacement of a spark-plug insert without following the engine manufacturer's directions lest ye ole spark plug exit yon cylinder, creating a great noise accompanied by a sagging flight path. If a spark-plug insert comes loose or is damaged, get it repaired using the correct parts and tools. In some cases, this means you'll have to remove the cylinder and send it to a shop that does cylinder work.




AVK Industrial's "threaded insert" installation guide.

## Plug Insert Installation Tips

Tips to prevent spark-plug thread damage include cleaning all plug threads before re-installation. The Champion spark-plug service manual recommends using a rotating wire wheel or wire brushing by hand. If a spark plug can't be screwed into the cylinder by hand until no more than two threads are showing, clean the cylinder threads with an 18mm thread-chaser tool until hand-tightening is possible. Use only a small amount of anti-seize compound and apply it near the firing end of the plug, but don't apply any on the two threads nearest the plug firing end. Use a new copper spark-plug gasket each time a plug is installed. Finally, use a torque wrench to apply the correct spark-plug torque. The target values are 25 to 30 foot-pounds (300 to 360 inch-pounds) for TCM cylinders and 35 foot-pounds (420 inch-pounds) for Lycoming cylinders.

Maintaining threads and adding threads, if necessary, through the use of time-tested tools are important keys to safe and dependable flying. +

*For more information on Heli-Coil, visit Emhart Technologies at www.emhart.com. For a rivnut design guide, visit www.cardinalcomponents.com/fasteners/RivnutDesignGuide.pdf. Find direct links at www.kitplanes.com.*

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# Ask the DAR

## ELT repairs and Sport Pilot rules.

BY MEL ASBERRY

**Question: I was told recently at an Inspection Authorization seminar that I must hire an A&P to sign off the ELT annual inspection per 91.207(d) for my Experimental/Amateur-Built aircraft.**

**Is this true? I was under the impression that the holder of the Repairman Certificate for the aircraft could do this.**

Answer: I contacted the FAA people in Oklahoma City who conduct our DAR seminars, along with my local FSDO, for guidance on this matter. Both Oklahoma City and the local FSDO agree on who can perform this inspection. The following is their answer:

"There is no problem with the 'inspection' required by 91.207(d) being performed by the Repairman Certificate holder for the aircraft. Whoever performs the annual condition inspection should add the ELT inspection requirement to their inspection checklist and do that inspection.

But…if the inspection reveals a problem with the ELT installation, who can fix it? It is not the repairman (because the only thing the repairman can do is inspect). It could be any person if the problem is with the installation. If the problem is internal to the ELT, then it would have to be someone specifically approved to repair a TSO'd article. Other approved equipment is similar in that the builder (any person) may install it and inspect it, but not repair it or certify it."

**Question: I was at an airport speaking to a new Sport Pilot and A&P mechanic who he said he was going to fly into a SFRA [Special Flight Rules Area] with a friend's Cessna 172. I told him that the 172 was beyond his certification as a Sport Pilot. He argued, but I dropped it because I did not have the knowledge to counter his position.**

**I went back and looked up the regulations that I thought might apply, and the section I found that might allow him to do that said that it might meet the requirement for training, but not everyday flights.**

**Oh, and he was going to pick up parts for his SUV to fix it. (Is that commercial use because he uses this vehicle to get to different airports to service airplanes, and this is his means of transportation?) Maybe if he writes off the mileage and the repairs.**

**The part I found was part 61.31 in the 2011 FAR/AIM, pages 51 and 52.**

**I have only 350 hours since I got my Sport Pilot license in May 2009, but I am working on more.**

Answer: A Sport Pilot flying a C-172? Let's see, let me count the reasons.

Sport Pilots can fly aircraft that meet the LSA definition, which includes:

- Maximum of two seats. Last time I looked, the 172 had four.
- Maximum gross weight of 1320 pounds. I think that's closer to the *empty* weight of the Skyhawk.
- Maximum full continuous power speed of 120 knots. Your acquaintance is probably OK there.
- Maximum clean stall speed of 45 knots. Not sure here. Probably close, but I suspect on the "wrong" side.
- To use this as a training flight, he would need at least a student-pilot certificate, medical and solo endorsement as a training flight for a recreational pilot certificate or higher.

Congratulations on 350 hours. Keep plugging away and learning. ✈

*Please send your questions for DAR Asberry to editorial@kitplanes.com with "Ask the DAR" in the subject line.*

*Photo: Mel Asberry*

# Vortex generators and STOL performance.

**Maintaining attached flow** is a primary concern for the designer of any airplane. To minimize drag and maximize lift, maintaining fully attached flow is desirable. The exterior shape of the airplane is created to promote flow attachment, but sometimes separation occurs anyway.

Stall is caused by flow separation. Eventually, if the angle of attack is high enough, the flow over the top of the wing will separate, and the wing will lose lift. In addition to proper shaping of the wing and fuselage, there are several add-on devices that can be used to delay or eliminate flow separation.

## Enter the Vortex Generator

The most popular of the options are vortex generators, which are small devices used to help reattach separated flow. Installed in groups, they can help eliminate separation and solve a variety of aerodynamic problems. There are several types of VGs, but the most common is the vane type. These are small, low-aspect-ratio blades that are mounted perpendicular to the skin of the airplane. Each vortex generator is mounted so that it has an angle of attack relative to the oncoming flow, which causes it to act like a wing. It develops lift normal to the oncoming flow and sheds a vortex off of its free tip. The tip vortex of a VG stays close to the surface of the airplane as it moves aft.

The vortex shed by the VG tends to move air that is near the airplane skin up, away from the skin, while at the same time moving air from the outer flow down, closer to the skin. This mixing of air gives the VG its beneficial effect on flow separation.

When separation is imminent, the air in the boundary layer, right near the skin, is out of energy. It is moving slowly and will soon stop and reverse direction, causing separation. The air in the outer flow, however, is moving fast and has high kinetic energy. The vortex created by the VG moves some of this fast-moving, high-energy air down into the tired boundary layer and moves some of the tired air away from the surface. The net effect is to increase the speed of the air in the boundary layer and delay or prevent separation of the flow.

To work properly, the VG must be able to affect the air outside the boundary layer, and to do this it must be placed slightly upstream of the point where the flow would separate without the VG. If separation is allowed to occur upstream of the VG, it will be submerged in the separated flow and will be unable to reach clean outer-flow air to mix into the boundary layer.

## VGs for the Kit World

For many years, VGs were primarily found on large transports and military aircraft. But over the last 10 years, vortex generators have moved into the general aviation world, and retrofittable VG kits have been developed to improve the characteristics of light airplanes. These kits first appeared to tame the low-speed behavior of some production twins, including the Beech Baron and some of the more popular Cessna twins. More recently, VG kits intended to reduce the stall speed and improve STOL performance of single-engine airplanes have appeared.

The vortex generator kits generally address two areas:

**1) CLMAX improvement:** Stall is caused by separation of the airflow over a wing. Reducing separation and delaying the stall to a higher angle of attack will increase the maximum lift coefficient (CLMAX) and reduce stall speed. Properly placed VGs on the upper surface of the wing can achieve this.

Two configurations have met with success. The first uses a full-span row of VGs to increase the maximum lift of the entire wing, reducing stall speed. The VGs delay the stall of the whole wing, thus increasing CLMAX and reducing stall speed. Full-span VGs increase the maximum lift of the wing, but they do not have a large effect on where on the span the stall first appears when the wing finally does stall. Accordingly, full-span VGs will reduce stall speed but may not have any beneficial effect on lateral stability at the stall.

If the primary goal of a VG installation is to improve lateral stability and aileron control at stall, rather than to reduce overall stall speed, then the proper approach is to install the VGs on only the outer portion of the wing. This will delay the stall of the tips, giving the airplane a gentle, root-first stall.

**2) Control-power improvement:** Another place where VGs can provide a useful fix is where we need to increase the control power of an airplane, particularly rudder power on multi-engine airplanes. If, for example, an airplane is retrofitted with more powerful engines than those for which it was originally designed, the extra power may be more than the

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rudder can trim to keep the airplane straight in the event of engine failure. This causes minimum control speed ($V_{MC}$) to rise. To bring $V_{MC}$ back down, more rudder power is needed. Retrofitting the airplane with a larger rudder is often impractical or prohibitively expensive, so there is a large motivation to improve the control power of the existing rudder.

The effectiveness of a control surface is limited by how far the surface can be deflected before the flow separates at the hinge line. Deflecting the surface farther than this will cause a large drag increase, but it will not increase the amount of lift the surface is generating.

As we have already discussed, placing VGs upstream of the separation point can re-energize the boundary layer and delay separation. Adding a row of VGs just upstream of the rudder hinge line increases the amount the rudder can be deflected before the flow separates. The lift of the rudder at higher deflections is also increased. Vortex generators ahead of the rudder hinge are a feature of several of the VG kits currently marketed to tame production light twins. They also can be found on the Beech Starship, Boeing 727 and on many other production airplanes.

## VG Drag

The aerodynamic fix provided by VGs does not come entirely free: The VGs are in the airstream all the time, and they do produce some drag. How much depends on the configuration of the airplane and the size and placement of the VGs. If VGs are added to a very clean wing, particularly one that would have laminar flow without the VGs, the drag penalty can be significant. On many airplanes, the improvement in the quality of the airflow downstream of the VGs is sufficient to offset, or nearly offset, the drag of the devices themselves.

## VG Geometry

There are two common ways of installing vane-type VGs. All VGs should be mounted so that they have an angle of attack relative to the local airflow of between 15° and 20°, but they may be mounted so that all of the VGs are parallel to each other, or in pairs with equal-and-opposite angles of attack.

The first approach, with all of the VGs parallel, is called a "corotating" installation because all of the generators shed vortices that are rotating in the same sense. The paired equal-and-opposite-angle installation is called a counterrotating installation because each pair of generators sheds a pair of vortices that rotate in opposite directions.

Both types of installation are used. The Voyager and most other canard airplanes that need VGs use a row of counterrotating pairs of generators. The vortex generators on the fin of the Boeing 727 and on the canard of the Starship are corotating.

For many years, counterrotating VG installations were more widely used and better understood than corotating installations. Corotating VG installations are somewhat lower drag than counterrotating configurations, and they have become more common in recent years. The appropriate configuration depends on the details of the geometry and airflow over the surface they are being used on.

## VG Size

To effectively mix outer-flow air into the boundary layer, VGs must stick out above the edge of the boundary layer, but only a little, to minimize drag. A recommended height for a first try is about 1.2 times the local boundary-layer thickness. Boundary-layer thickness is difficult to determine accurately, but it is usually on the order of 1% to 2% of the distance from the leading edge.

## VG Shape and Placement

Typical VGs are either triangular or trapezoidal, with swept leading edges and vertical trailing edges. To work at all, VGs must be installed upstream of the point of flow separation. Before installing VGs, determine where the separation you want to eliminate starts. The VG row should be a short distance upstream of this point.

For corotating VGs, the root chord of the VG should be on the order of four times the VG height, and the distance between VGs in a row should be five to six VG heights.

For counterrotating VGs, the root chord of the VG should be about 2.5 times the generator height. The distance between the centers of the two generators in a counterrotating pair should be about the same as the root chord of one VG. The counterrotating pairs should be spaced about 10 VG heights apart.

Making a vortex generator installation work requires some experimentation with VG size, number and spacing. If an initial VG installation provides the desired effect, try reducing the size and/or number of generators to reduce drag. If more effectiveness is needed, increase the size or number of VGs. ✈

Placing vortex generators upstream of the separation point on a wing can reinvigorate the boundary layer and actually delay separation.

# AERO 'LECTRICS

# One ringy dingy… hello, Ernestine!

**When last we left this project,** we noted that the little speaker-turned-microphone would do a pretty good job of turning the cell-phone ringtone into audio we could use to drive some digital circuitry and, through a relay, power up any number of devices.

I thought the digital circuitry would be the easy part. What a surprise to find that it fought me tooth and nail for the better part of a solid week. If you see my editor at Oshkosh this year, you might want to buy her a beer for giving me the extra time to make this thing work.

I'll give you a relatively thorough explanation of why I did what I did with this project, and then next month I'll explain what goes into it, stage by stage. By the way, don't even think about starting construction on this device without a decent oscilloscope at your command. If you attempt to troubleshoot this circuit with a multimeter or by osmosis, it just won't work.

## Inputs Here, Outputs There

Let's take that 10-volt peak-to-peak audio signal and turn it into a digital pulse for processing. U1C is called a "comparator." It compares the voltage of the (-) inverting input with the (+) non-inverting input. If the voltage on the (-) inverting input is greater than the voltage on the (+) non-inverting input, the output (pointy end of the symbol) is ground (zero volts), or in the digital world, what we call a "logic low." Conversely, if the voltage at the (+) input is greater than the voltage at the (-) inverting input, the output is nearly supply voltage, or a logical high.

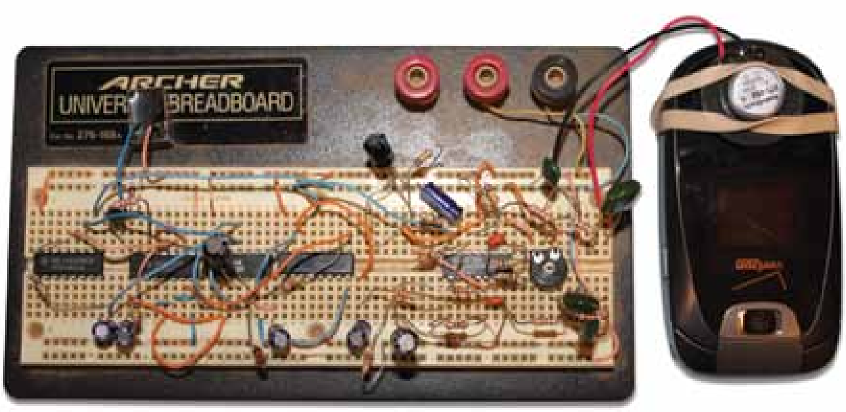
D2 takes the pulses from last month's amplifiers and charges C10 to the positive peaks of those voltages. Since last month's amplifier sits at a quiescent (no signal) voltage of half the supply, the (+) input of U1C is about half the supply, less a 0.6-voltage drop across D2. This puts the (+) input lower than the (-) input, and the output is logical low.

Along comes a "ring" signal from the hangar cell phone, and now all of a sudden the voltage across C10 rises to nearly supply volts. The output snaps from logical low to logical high, and R13 assures that this voltage does not swing back during the ring cycle. Then the ring subsides, and the output returns to a logical low. The next ring takes it back to logical high, and the process repeats itself for each ring of the phone.

R14 and C11 take these low-high pulses and remove any "trash" (spikes, noise, etc.) from them, outputting a clean one pulse per ring to the digital circuits.

U3 is a simple divide-by decade counter. At the output of Q0 ($2^0 = 1$), you have a logical high for a single pulse on the CPO input. Then a logical high for two pulses from the ring counter at Q1, and so on until you get to Q8, where you get a logical high for a phone ring of eight pulses.

U4A is what is called a pulse stretcher. When I get eight ringtone pulses from my phone, I want everything that happens in the outside world to be shut off. U4A is an "OR" gate, which says I don't care if there is a logical high on input 1 OR input 2, I'll give you a logical high output (the pointy end again) if *either* of these two is high. So along comes ring eight and sets one input high through R15 and C12 (noise filters again). Pow




This is the entire circuit, complete with output relay (just below the word ARCHER on the construction board). The LM354 op-amp is the integrated circuit on the far right, then in order (right to left) are the 4017, 4071, 4013 and the 4020. Think haywire if you will, but almost all first-cut prototypes look something like this.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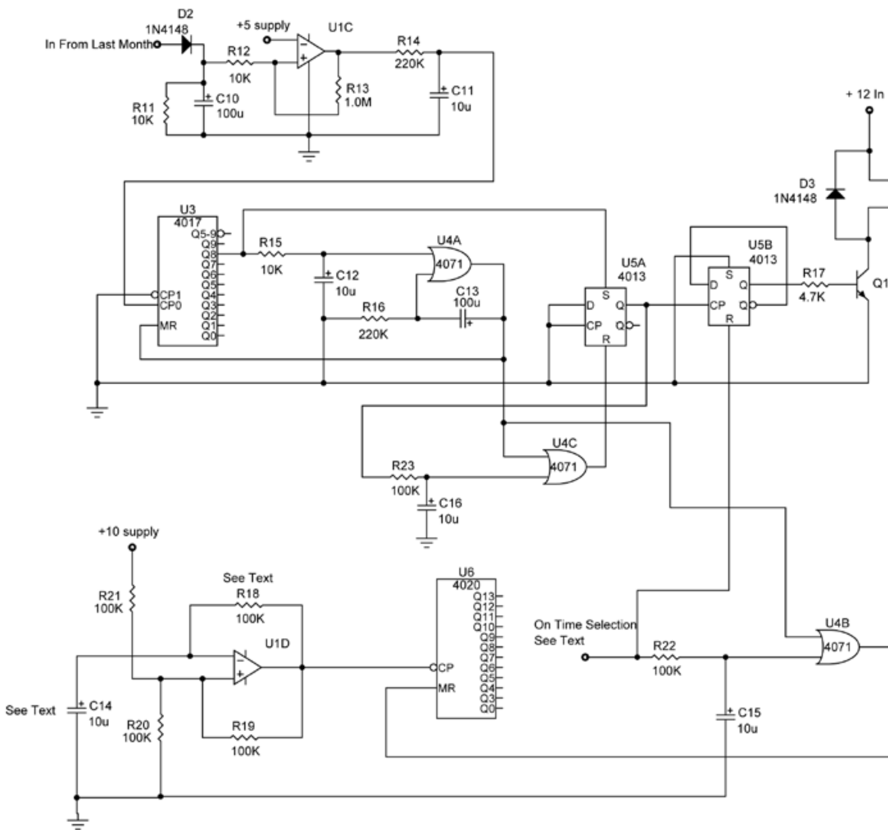



The schematic.

goes the output high and holds the other input high through C13, no matter how many rings come through the phone. It resets U3 to a zero count and sets one input of U4A to reset U5A to zero after a short time, determined by R15 and C12.

## On the Eighth Ring

Meanwhile, that eighth pulse from U3 sets (S) U5A Q output high. Since U3 has been reset (MR) through U4A and is held reset for about 20 seconds by C13 and R16, U5A has been reset (R) so that the Q output of U5A has gone low. But for the brief time that the Q output of U5A went high, it clocked a pulse (CP) into U5B and set the Q output of U5B high. This high output, applied to the base of Q1 through R17, turns Q1 on and pulls relay K1 contacts "Common" and "Normally Open" together, completing the circuit.

In another part of the circuit, U1D is a one-pulse-per-second, free-running oscillator. The output of U1D is applied to the clock pulse (CP) input of U8, which is a true binary counter where the Q outputs 1 through 13 go high when a certain number of pulses arrive at the clock-pulse input. How do we calculate how may pulses it takes to turn on a particular input? Let's arbitrarily take a Q output, say, Q11. Q11 will provide an output when $2^{11}$ pulses are counted from the CP input. How long is that? If the clock gives one pulse a second, $2^{11}$ is 2048, so it will turn on in 2048 seconds, or about 34 minutes. What is the maximum time allowed? It's $2^{13}$ seconds, or about 136 minutes (about 2.25 hours).

When U4A output went high on the eighth ring, it turned on U4B, which reset (MR) U8 to zero. When C13 and R16 discharged to turn U4A off, that in turn turned off U4B and allowed U6 to start counting up. When it reached the number of seconds the user selected by connecting the free end of R22 to one of the U6 Q outputs 0 to 13, it set U4B high again and reset U5B Q output low, turning off Q1 and allowing the relay to de-energize, and connecting Common to Normally Closed.

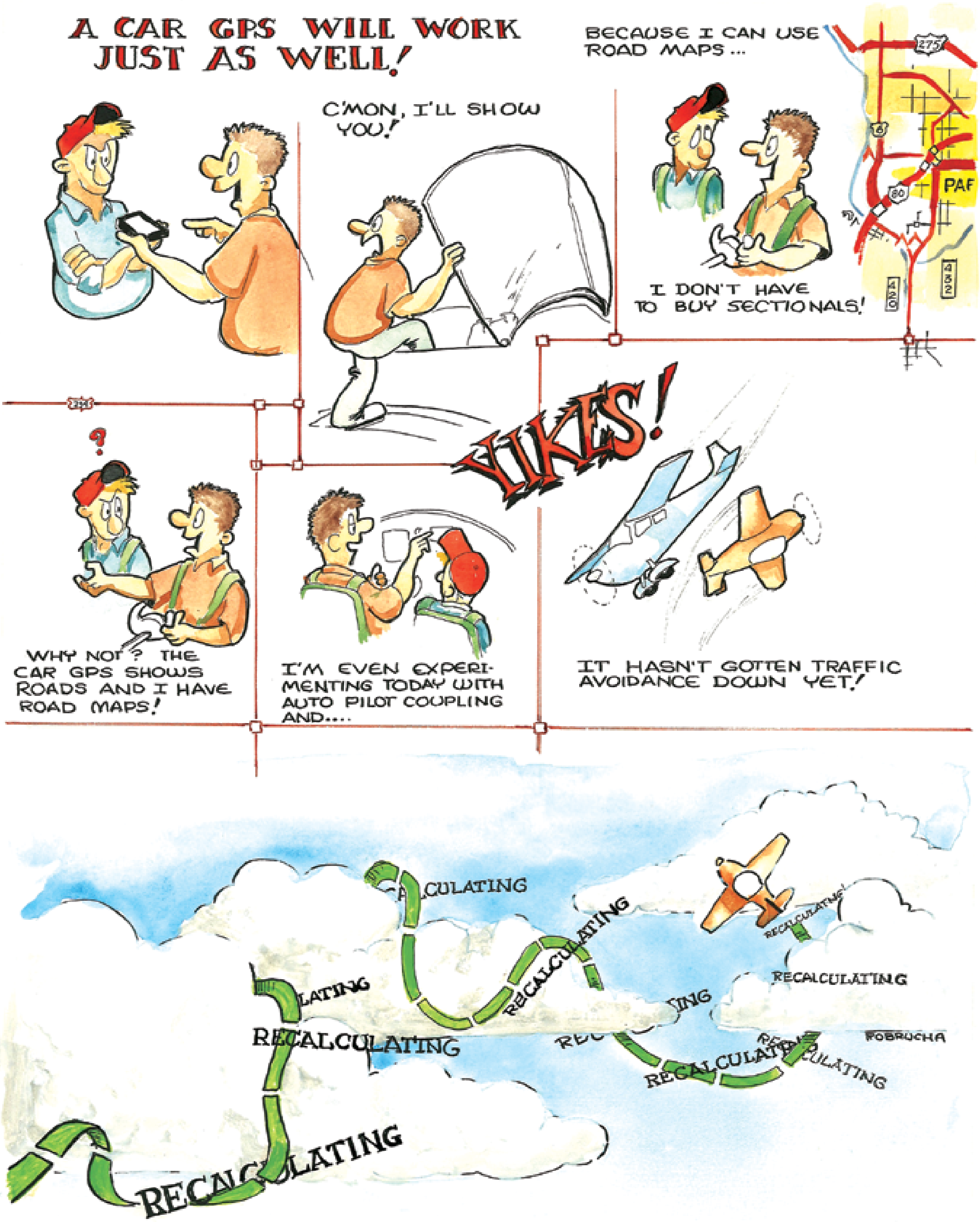
One feature, not quite obvious from the selection of the Q-bar (not-Q, or the opposite of Q), is that U5B is a true flip-flop. That is, one pulse on the CP input sets Q high, and the next pulse sets it low. If the cell phone gets another eight pulses during the timer "on" mode, it will set the Q output low and turn off Q1 and the relay K1. Thus, the operator may interrupt the timer and turn the timer on and off at will.

Say you want a longer or shorter time span. No problem: By varying the values of R18 and C14, you can vary the clock speed of U1D to nearly anything you want. How do you calculate the time of a single clock pulse from U1D? Simply multiply the values of R18 and C14 together. Using the values given in the schematic, multiplying 100,000 (100K ohms or $100 \times 10^3$) x 0.000010 (10 microfarads or $10 \times 10^{-6}$) gives the answer 1 (1 second). If you raise the value of R16 to 1M (one megohm) and leave C14 as 10 microfarads, you have increased the clock-pulse time to one pulse every 10 seconds, and now the maximum time of the circuit is $2^{13} \times 10$, or almost 23 hours (a little shy of a day). If you increase R16 to 1M and also increase C14 to 100 microfarads, you now have a timer with a maximum on time of 9.5 days.

Next month we'll look at each step of building this little goodie. I'd advise doing it the professional way…stopping after each step to see if what you did matches what you thought you should see along the way. Or you could do it like my students do at the beginning of each semester—put it all together, complete with mistakes, and then spend the rest of the semester pulling it apart, trying to find the errors and correcting them one by one. It's a lot faster my way, but it's certainly your choice. ✈

*Photo: Jim Weir*

BY ROBRUCHA


A CAR GPS WILL WORK JUST AS WELL!
C'MON, I'LL SHOW YOU!
BECAUSE I CAN USE ROAD MAPS...
I DON'T HAVE TO BUY SECTIONALS!
PAF
WHY NOT? THE CAR GPS SHOWS ROADS AND I HAVE ROAD MAPS!
I'M EVEN EXPERIMENTING TODAY WITH AUTO PILOT COUPLING AND....
YIKES!
IT HASN'T GOTTEN TRAFFIC AVOIDANCE DOWN YET!
RECALCULATING
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