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On the cover: Patrick Berry flies his Cassutt 111M near St. Augustine, FL. You can read how photographer Richard VanderMeulen captured the action on page 26.

EDITOR'S LOG

Fly low, fly fast—turn left!

If you are of the belief that the "E" has gone away from Experimental aviation, you owe yourself a trip to Reno, Nevada, in September. The National Championship Air Races are scheduled this year from the 10th to the 14th, and it doesn't take much time spent wandering around the pits to renew your faith in the creativity of true experimenters. Whether you are looking closer at the changes made to a P-51, or taking a break from the sun in one of the Sport Class hangars—admiring the latest in Lancairs, biplanes, or the venerable Formula 1 racers—you'll see ideas that might very well make your own aircraft better.

Flying the Cassutt is a thrill—even without the pylons, the feeling of speed in the tiny airplane is enough to bring a smile to the pilot's face.

This month, to get you in the spirit of the race season, we feature a review of the classic Formula 1 race plane: the Cassutt 111M. The Formula 1 class offers mere mortals (with mere mortal checking accounts) to go out and explore the challenge of speed without having to spend a king's ransom to play with the big boys in the Unlimiteds. Powered by Continental O-200 engines (many of them pulled from equally venerable Cessna 150s), these simple machines offer loads of opportunities to tinker—with aerodynamics, cooling, induction systems, and handling qualities. The owners, pilots and crews clearly enjoy the atmosphere of competition as much as they like to find out what tweaking an oil cooler duct will do.

In April, I attended the Mojave Experimental Fly-in, a low-key gathering of high-key experimenters looking to build high-performance airplanes, go fast, and do it all on less fuel. There I saw some of the fastest Lancairs and custom one-off airplanes that will compete at the high end of the Sport Class at Reno this month. These high-performance machines offer hints for homebuilders without the means to feed Lycoming O-720s—a close look will show interesting gap seals, taping techniques for seams and doors, and lots of little details, like seals between the blades and spinner openings on a constant-speed prop. How much did that airplane gain with those seals? I don't know, but I bet it didn't go slower! I recommend walking around with a camera to help remember the good ideas that you see.

But don't limit your inspection to airplanes in the homebuilder's class. The Unlimiteds are built and maintained by human beings with sometimes simple, downhome hunches and ideas. In June, I dropped in on the home of *Voodoo,* last year's Unlimited champion. Tucked away in a large hangar at Yolo County airport in Northern California, just a short flight from the race mecca of Nevada, *Voodoo* looked like a medical patient undergoing open heart, brain, and cosmetic surgery, all at the same time. Engineless (but surrounded by parts for at least two racing motors and a couple of other spares), it looked to be getting a good going-over for signs of stress from the previous season. Flaps were hanging disconnected from their actuators, access panels were removed and hung on racks all over the hangar, and new carbon-fiber cowling components were being lovingly fitted and adjusted. This wasn't an airplane—it

Paul Dye

Paul Dye retired as a Lead Flight Director for NASA's Human Space Flight program, with 40 years of aerospace experience on everything from Cubs to the space shuttle. An avid homebuilder, he began flying and working on airplanes as a teen and has experience with a wide range of construction techniques and materials. He currently flies an RV-8 that he built in 2005 and an RV-3 that he recently completed with his pilot wife. A commercially licensed pilot, he has logged over 4500 hours in many different types of aircraft. When not writing on aviation topics, he consults and collaborates in aerospace operations and flight testing projects.

How much speed is gained by adding these seals to the prop/spinner gap on this go-fast machine in Mojave? The owner wasn't saying—but you can bet he knows!

How much faster could *Voodoo* go with a low-drag transponder antenna? We don't know—but we'd like credit for the idea if they change it and go faster!

was an airplane kit, partially assembled. Bigger than the average garage project, but familiar just the same.

I noticed several parts that might have passed a casual visual inspection with big red Sharpie marks saying, "Crack here—do not use!" Looking closely, sure enough—there was a cracked web on a supercharger drive gear, and over here, a tiny, tiny start of a crack on a valve cover. As was sadly demonstrated by the tragic crash of *The Galloping Ghost* in 2011, no part is too small to be inspected, serviced, repaired, or rejected. A pair of mechanics were going over the airplane and engines the day we were there, slowly working their way through the process of getting her ready to go.

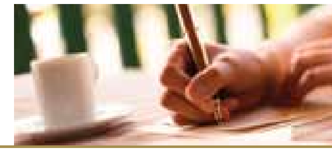
"You'd be surprised," one of them said. "By a simple adjustment to XXXX [no, I am not going to be responsible for giving away their secrets], we gained 21 miles per hour—just like that!" And you know, that stock radiator inlet was sized to cool the engine at 350 mph. "When you're going over 500 miles an hour, you end up getting a lot more molecules of air through the radiator than you need—so we're working on the idea of finding the perfect size—or maybe even a variable size, for different speeds. Of course, that means the exit area has to change as well…" I was surprised to see a little stick-and-ball transponder antenna mounted under the tail, just behind the tailwheel. Heck, it's been a long time since I actually did any true aerodynamic calculations, but I do remember that a faired blade has lower drag than that—at typical recreational speeds! I didn't get a chance to point that out, but I suspect someone on the team will look at it and say, "You know, we could lose a little drag here…"

Racing anything—cars, boats, airplanes, or bicycles—has always improved the breed, sometimes in ways that the racers didn't anticipate. Many safety enhancements come from racing, and lots of great ideas are sparked by seeing someone else's curiosity at work. Reno is a hotbed of curious ideas, and some of them I store away in my design grab bag for some future project. Even though most of us will never race, Reno is a great place to absorb the lessons of others—just like a week in Wisconsin in July, or a few days in Florida in April. Different shows, different emphasis, different lessons.

No matter what you're building, learn from the experience of others. As you read this month's issue, enjoy the thought of racing a Cassutt at Reno. It's got its plusses, it's got its minuses, and I don't think I'd like to make it my daily cruiser. But for an airplane with an O-200, it goes like scat, flies low—and turns left. ✢

See the crack in that gear? Many would have missed it. Careful inspection is a good lesson homebuilders can learn from the racing crowd.

LETTERS



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ELSA—Weight Matters!

I read your helpful piece in the June 2014 issue about ELSAs [*Born Again*] and was wondering if you have any idea why the LSA weight limit was put at 1320 pounds when there are thousands of Cessna 120s, 140s, and 150s rotting all over the United States, along with hundreds of Ercoupes, Taylorcrafts, Luscombes, and others.

When I learned to fly in 1966, there were around a million private pilots—now much less! These planes meet every qualification of the LSA rules with the exception of gross weight. I notice that Cessna announced a few months ago that they are no longer going to sell their $150,000 C-162 Skycatcher LSA; does that not tell us something about the stupidity of the 1320-pound gross weight rule?

GEORGE MILLER

For right or wrong, 1320 pounds came in an attempt to sync the U.S. Light Sport rules with those of Europe (a large source for Light Sport Aircraft). The Europeans already had a category of aircraft with a maximum gross weight of 600 kilograms, and if you do the math, that comes out to 1320 pounds. We agree with you that it is a shame that many existing aircraft and designs were excluded by this rule.—Ed.

Test First, Lesson Later

I just re-read the article about a loose screw that appeared in the February 2014 issue of KITPLANES® [*Error Chain*]. Thanks very much for sharing. It had to take some guts to reveal such a classic screw-up to the masses—no offense intended.

John King recently wrote about Mother Nature being a harsh teacher, giving the test first, then the lesson. So, test given and passed because of outstanding planning and preparation, lesson learned and passed along.

This article should be required reading for anyone building and planning to fly their own airplane. We all need to understand that, in spite of all the care taken during construction, such a simple thing can bring an aircraft down. Nobody is immune. Once again, thanks for sharing.

JEFF GORSS

You're right Jeff—no one is immune, and those with the most experience are likely to have many of these stories to tell. We encourage all of our readers to share their experiences with those who are trying to become more experienced through our regular feature, "Error Chain." We might as well help others learn from our bad experiences—no one will ever have the time to experience them all on their own.—Ed.

More from AKIA!

Dick VanGrunsven's "*Advice to Designers*" [June 2014] is yet another thoughtful and wise essay by one of the sanest and most honest voices in sport and Experimental aviation. Thank you for providing him a podium. I hope he will have additional opportunities to share his wisdom with your readers.

HUNTER HEATH III

As a member of AKIA, KITPLANES® is happy to feature such pieces by the leaders of the Experimental and kit-building world. We hope to share the views of many of the leaders of the kit industry in future issues. —Ed. ✈

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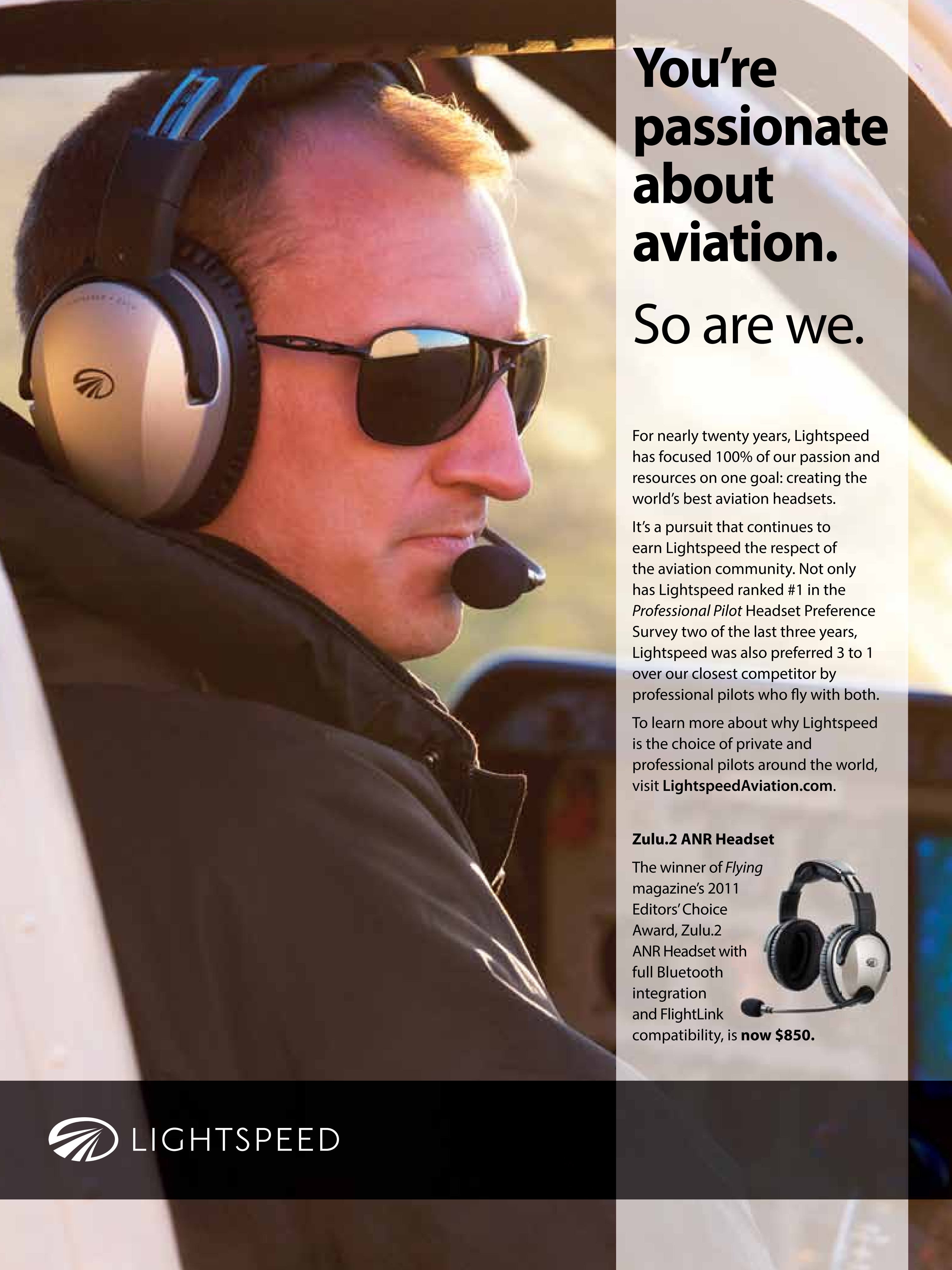
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LIGHTSPEED

FLIGHT REVIEW

Cassutt IIIM

The need for (affordable) speed.

BY PAUL DYE

The Cassutt 111M is, in every sense of the word, a classic design. Small, sleek, and fast, the little one-place airplane that first appeared as the Cassutt Special in 1954 has been built by those who want to race—or just go fast on a few dollars—for over 60 years, yet still turns heads whenever it appears on a local airport ramp. Tom Cassutt's design (based on Steve Wittman's *Buster*) inspires; it speaks of speed and freedom, with just a little bit of danger thrown in.

If you asked for a show of hands at a homebuilder gathering, a majority would probably be waving their arms to indicate that they had built and flown model airplanes in their youth. U-control or R/C, many aviators got their start well before they could afford airplanes of a size that could actually take them aloft. And if you go back a few decades, many of those U-control airplanes looked like little single-seat racing planes—complete with a plastic bust of an aviator sitting under the bubble cockpit. These fast, maneuverable airplanes had many different names, but were referred to generally as "Formula 1 racers" because they looked a lot like the airplanes used for pylon racing that conformed to the International Formula 1 Rule book.

The Formula 1 rules were created to allow normal people—those without an unlimited bank account—to compete in pylon racing. The rules specify a small, C-series or O-200 engine from Continental Motors that is relatively inexpensive and found in large numbers. The small airframe must weigh no more than 500 pounds empty (no fuel, oil, or pilot), have a fixed-pitch propeller, and a wing area of at least 66 square feet. Fixed-gear only please, and pilots must weigh at least 160 pounds ready for flight.

This fairly simple set of rules is an attempt to create similar airplanes, so that pilot skill and racing experience play a large part in the outcome of the race—larger, that is, than the simple method of spending cubic dollars to race in the Unlimited classes. Since speed goes up with more horsepower, smaller wings, and lower weight, specifying these factors to equalize the field—at an affordable level—has been a good formula for a league that has survived the test of time. Still raced at Reno every year, the fields are usually full, and spectators of all ages enjoy the tiny airplanes that zip by the stands every September. In 2013, nine of the 15 aircraft registered in the Formula 1 class were Cassutts.

The license and rights to sell plans for the Cassutt were recently purchased by Creighton King of Salt Lake City, Utah, and he hopes to continue to provide builder support, parts, and plans to keep this enduring design going for those who still have that desire to go fast and do it on a budget. We recently caught up with King at his airport facility south of the Great Salt Lake, and took advantage of the chance to fly his aircraft, look at his facility, and talk about his plans for the future.

Classic Construction

The Cassutt was designed in a day when wood, steel tubes, and fabric still ruled the homebuilding world. If you wanted to build one from plans, the first thing you had to do was enroll in a welding class at a nearby vo-tech school or junior college. When you finished welding up the fuselage, it was time to dust off the woodworking skills and start on the Hershey-bar wing, cutting all of the little bits for ribs, gluing and tacking them together, and then covering the whole thing with plywood. Finally, the entire plane needed dope and fabric—classic construction for a classic airplane.

Today there are options for pre-welded parts, and there are fiberglass (and even carbon) parts that greatly simplify the cowling and transitions. Cassutt Aircraft is committed to making the building of a Cassutt simpler, and taking care of parts that require years of skills development to make. Getting pilots into the air faster is one of King's goals.

The welded fuselage frame is covered in fabric, just as in the old days—but there are modern parts, such as fiberglass side panels (underneath the wing) and a

Photos: Richard VanderMeulen and Paul Dye

The simple cockpit has only two switches—one for the left mag, and one for the right. Basic instruments include a sight gauge for the fuel tank.

The firewall-forward design is simple and uses individual plenums for cylinder-head cooling.

glass cowl that flows around the engine. The single-piece wooden wing bolts onto the top of the fuselage structure, the spar being continuous from tip to tip. Modern racers have developed longer, tapered wings to replace the all-wood constant-chord model originally designed by Cassutt, but it is a safe bet that more Cassutts are flying with the Hershey bar than not; it is inexpensive and easy to build. Cassutt Aircraft is currently working on a carbon fiber tapered wing that will also hold fuel and should make for an interesting airplane when finished.

The tail surfaces are conventional steel tube and fabric, unbalanced with the fin extending over the rudder. There are no provisions for trim, other than adding or subtracting washers under the horizontal stabilizer attach points, so airplanes will generally be dialed in for a particular pilot weight. The ailerons are full span and slightly tapered towards the tip. They provide a brisk roll rate and good control.

The landing gear is a single-piece steel assembly that bolts onto the fuselage frame with bolt-on axles. Five-inch wheels with compact tires are standard, and the brakes on the factory demonstrator were standard Clevelands—more than adequate for the job. Removing the cowling showed a refreshingly-simple firewall forward installation. The fuel tank sits ahead of the instrument panel and behind the firewall, and the O-200 engine had nothing attached but mags, a carburetor, and an oil cooler. The oil sump was custom-welded to fit inside the small, streamlined lower cowl, and a fiberglass air box joined the little snout to the carb. Individual left and right cooling plenums covered the cylinders and joined tightly to the front cowl inlets. Sealed with aluminum tape, they ensure that all the inlet air has to go over the cooling fins.

The oil cooler was mounted to the firewall, with fiberglass inlet and outlet ducts cleverly designed to maximize cooling at slow speeds and higher angles of attack. The exit is on top of the wing on the left side, carefully faired to reduce drag. King said that, if anything, the oil is overcooled; he sometimes stuffs a rag into the outlet, or puts on a piece of aluminum tape to limit exit area in cool weather. The rag trick helps at lower power settings, and pops out when speeds (and engine energy) get to a certain point. CHTs are a moderate concern and are managed using mixture. For most normal flight regimes, they stay around 400° F, but at takeoff, they often

King's aircraft has a slightly taller vertical fin than called for in the plans for added stability. Pitch trim is accomplished by adding or subtracting washers on the stabilizer attach points.

Oil cooler air comes from a scoop on the right side that is sculpted to provide better flow at slow speeds/high angles of attack. The outlet is above the wing at the root.

This unfinished Cassutt fuselage has been modified, but shows the basic construction of steel tube structure and fiberglass cowling.

climb to near 450—this is when full rich mixture comes in handy. King's mixture control is mounted so that with your hand on the throttle, the palm can be used to twist the Vernier mixture knob to fine-tune the engine and cooling.

The fact that the Cassutt airframe is traditional and simple probably accounts for the number of airframes that have been started over the decades. However, as is often the case with early plansbuilt airframes, a majority have probably not yet been finished, which means there are finds to be made in garages and barns around the country. So long as the proper material has been used and the work is of a good quality, these bargains could easily be turned into flying Cassutts with a little investment of time, money—and an old Cessna 150 as an engine donor.

Factory Support—What You Can Expect

Creighton King is a man on a mission. The mission? Preserving the legacy of the Cassutt racer. His new company, Cassutt Aircraft, has purchased the rights to the plans, the parts inventory, and the jigs

CASSUTT 111M

Plans price	$295.00
Kit Price	$19,795
Estimated completed price	$35,000
Estimated build time	800 hours
Number flying (at press time)	400
Powerplant	Continental O-200, 100 hp
Propeller	Fixed Pitch Wood or Composite
Powerplant options	C-75, C-85, C-90, O-200, Lycoming O-235, O-290, O-320 UL Power

AIRFRAME

Wingspan	15 or 17 ft
Wing loading	14.3 lb/sq ft 12.5 lb/sq ft
Fuel capacity	15.5 gal
Maximum gross weight	950 lb
Typical empty weight	575 lb
Typical useful load	375 lb
Full-fuel payload	270 lb
Seating capacity	1
Cabin width	23 in
Baggage capacity	10 lb

PERFORMANCE

Top Speed	205 mph
Cruise speed	180 mph
Maximum rate of climb	1000 fpm
Stall speed	65 mph
Takeoff distance	800 ft
Takeoff distance (to 50 ft agl)	1800 ft
Landing distance	1000 ft
Landing distance (from 50 ft agl)	2600 ft

Specifications are manufacturer's estimates and are based on the configuration of the demonstrator aircraft at 5000 ft elevation.

Can Anyone Fly One?

So let's be frank: Can anyone fly one of these little hot rods? Well, before we answer that question, we should ask another: Does everyone *want* to fly one of these little hot rods? The Cassutt was designed for a purpose, and that purpose is air racing. Although many of us fell in love with the design when we were young (it just seemed to have the same sex appeal as that first motorcycle we saw), the truth is that in order to be a great air racer, it gives up some things in other areas—like comfort, visibility, and slow-speed capability.

But *can* it be flown by anyone? It certainly doesn't take a superman to fly, but this is not a Cessna trainer. You have to be comfortable with a high (100 mph) speed over the fence, and a higher pattern speed. Because it is so small, many pilots will have to spend some time getting comfortable going fast with their posterior only a few inches above the ground on landing. Flaring high is going to be the norm for most first-timers. Because there is no in-flight adjustable trim, you have to get used to holding stick forces one way or the other whenever you are off speed for the current weight and balance.

Of course, it is a taildragger, and experience in airplanes with the little wheel bringing up the rear will be essential. This is not a Cub or a Champ; the direct steering link is quick, and it is easy to overcontrol during the initial part of the takeoff run. We didn't sample crosswinds, but it would pay to be quicker on your feet than, say, in an RV taildragger.

If one reads accident reports related to Cassutts, it appears that they do poorly in off-airport landings, with a tendency to nose over and end up on their backs. Given the high stall speed and subsequent high landing speed, this is understandable. Several accidents with which the author is familiar have ended badly after a stall/spin—pilots need to be on top of their game in a forced landing to touch down at speed, under control, on the best surface available. There is not a lot of structure to protect the pilot at impact, and this is simply a risk that must be accepted. Care in maintenance and engine set-up is essential to make sure that the motor keeps running until you are over a suitable landing spot. It is the nature of racing machines that they get tinkered with and changed—but discipline in ground testing is always going to be important before committing to flight.

I don't think I would ever go so far as to say that anyone can be trained to fly any airplane—but you won't need to be God's gift to aviation in order to get comfortable in a Cassutt. The problem is, until you've flown one, you probably won't know if you'll enjoy it, and it is going to be hard to fly one without buying or building one first. Such is the nature of the single-seat airplane.

—P.D.

used by previous companies in order to perpetuate the factory support needed for builders to start—or finish Cassutt 111M aircraft (as well as the Owl Racer).

With the passing of the previous owner, the stock of parts and rights to the plans were in limbo until Creighton, a Salt Lake City native and airplane tinkerer from his teen years, offered to buy them in order to keep the design going. While he has yet to find time to move the entire inventory from its current Colorado location to his home in Utah, he has already been selling plans to new purchasers, and has a fair amount of Cassutt hardware taking up space in his hangar—along with a plans-built Super Cub and a Tri-Pacer. His recently-restored 111M, sporting race number 15, tucks in under the Piper wings on one side, while a long-range, big-engined Cassutt project lurks in the back, and yet another fuselage fills the last corner of the T-hangar.

Creighton is clearly committed to supporting these wonderful little toys—the "sport bikes" of the aviation world. Asked if he has any idea how many sets of plans have been sold in the decades the design has been around, he could only estimate "in the thousands." The Cassutt is a small and simple machine that attracts dreamers as well as dedicated builders, and it is hard to know just how many uncompleted airframes are scattered about in hangars, garages, and workshops across the globe. Designed in the early days of plans building, many were started, but not as many finished, and this is a market that Creighton hopes to tap. He is looking to develop firewall-forward kits for those lucky people who have inherited an uncompleted airframe from an older relative who couldn't quite get the details (those legendary last 90% familiar to all homebuilders) finished up. Even if he never sold another set of plans, the increase in flying airplanes would be tremendous if he could help get those already underway finished and airworthy.

If you find yourself with an uncompleted Cassutt, or want to start one, you can be comforted by the fact that Cassutt Aircraft plans to supply all sorts of parts and expertise to help get that machine into the air. Our visit confirmed that enthusiastic factory support is available once again.

Flying the Cassutt—the Need for Speed

Testing a single-seat airplane always presents certain challenges—not the least of which is that we have to learn everything we need to know from a

Too Big?

"Gee, that's a pretty tiny looking airplane, that Cassutt—do you have to be small and light to fly it?" I have heard something similar to that while cruising through the Formula 1 hangar at Reno, and yes, these airplanes look like you have to put them on—one piece at a time—in order to fit into the cockpit. You might be surprised then, to see that the owner of Cassutt Aircraft, Creighton King, is not exactly what you would call petite. In fact, Creighton would probably admit to being on the jumbo side of the size spectrum, yet he flies his Cassutt daily.

King's Cassutt is built according to plans, and the only accommodations he has made for his size is to remove all of the seat cushions (except for a thin pad on the floor) to allow a little more room in the cockpit. To adapt it to my 170-pound frame, we used a cushion about the size of a seat-back parachute as a back rest, and that brought me a nice distance from the controls and panel. I sat on the thin foam pad and wouldn't have wanted much more; my head had only about an inch to the canopy, and if I were wearing a helmet, there wouldn't have been any clearance left.

One of the neat things about building a plane from plans is that there's nothing that says you can't increase the cabin width a little when you weld up the fuselage, or change any other dimension a little bit for that matter. The wing is a single piece, from tip to tip, bolting to the tops of the longerons. The plans for the wing show no dimension for the distance between the root ribs, saying only "make to fit the fuselage." Yes, this is an airplane you have to think about when you build.

—P.D.

King is probably the largest Cassutt pilot around—and he fits (barely).

King is happy to accept help closing and latching the canopy, since his shoulders make it difficult to ensure that the aft latch is captured.

King added a cylindrical carb air inlet during his rebuild project to replace the former boxy-looking rectangular scoop. The fiberglass air box matches the round inlet snout. Note the custom-made oil tank, shaped to fit in the compact Cassutt cowling.

pre-flight briefing—not from a qualified pilot sitting next to us in flight. In this vein, King shared his thoughts before we took his little orange bird aloft for the first time.

"I like to maintain 120 mph in the pattern, right through turning final. Some folks fly it slower, and that's OK—I'm comfortable at 120. You'll want a long shallow approach, and slow to about 100–105 over the fence, then let it slow down as you settle to the ground. The Cassutt won't be stalled in a three point attitude, so you're really going to fly it on in a tail-low wheel landing. At touchdown, push the stick forward just a touch to plant it, then let it slow down so the tail can touch."

"The tailwheel is connected to the rudder with a solid link—no springs. So that is going to make it very sensitive on the ground. Then when the tail comes up on takeoff, there is a little bit of motion as you transition to rudder control because the rudder is small. It will fly away when it is ready, and you'll want to climb about 120—just remember that speed, 120."

King has his mixture and throttle mounted on the left side, but the push-pull controls are in slightly unfamiliar positions: the throttle is *below* the mixture. He did this because, he says, he does a fair amount of mixture manipulation during flight to keep CHTs where he wants them to be. He does this with the palm of his large hand while manipulating the throttle. I found this a bit of a trick with more normal-sized hands, but one of the good things about the Cassutt is that it can be customized for the pilot by the builder—especially if they are one and the same.

King briefed me that the stall is fairly benign and straightforward; it shouldn't be feared. Reading back through a previous review of the Cassutt in KITPLANES® (many years back), I found that the pilot considered it to be well-mannered in stalls, spins, and aerobatics. Since I was not planning on sampling spins, this gave me significant comfort that it wasn't going to suddenly depart on me. With a good, thorough briefing on how to latch the canopy, I felt I was ready to go.

We repositioned the aircraft from its home field just south of the Salt Lake City International Airport to Bolinder-Tooele Valley airport, one mountain range to the west, situated in a smooth, flat valley on the south shore of the Great Salt Lake. This freed us from the constraints of the Salt Lake Class B airspace, and gave King a chance to warm the airplane up and make sure it was ready to go. Besides, remote fields without witnesses are always welcome when flying a hot-landing airplane for the first time.

Getting into the airplane requires a little bit of flexibility. Because the cockpit is forward of the trailing edge of the wing, and the trailing edge is actually full-span ailerons, you have to hoist your leg up and all the way into the cockpit in one big step. Fortunately, the lack of upholstery means you don't have to worry about the seat, and assuming that you can get that first leg up, lowering yourself down into a seated position is not too difficult. These airplanes are generally custom-fitted to their occupants, so there is no seat adjustment, other than cushions. I found the relationship between rudder pedals and stick to be comfortable, so when I got my butt in the right place, all was fine.

I wouldn't exactly call the cockpit comfortable; it's more than adequate

The oil cooler installation on King's airplane is so effective that he has to partially block it off in order to get temperatures up to operating values.

The canopy latch system consists of forward and aft latches that operate independently—care must be taken to ensure they both catch.

for racing or playing around in, but a long cross-country might be a challenge. The visibility is more limited than in many single-seat airplanes, partly because the canopy was designed to use a sheet of Plexiglas bent to shape, and partly because the pilot sits ahead of the shoulder-mounted wing. You kind of get the feeling you are peering out of a turret, rather than sitting with your head and shoulders above the airplane, as you would in a bubble-canopy aircraft. Frontal area means drag, and this is a racer, so some things have to be a compromise. In a race, you are probably more concerned about seeing who is ahead, and how you can get around them than you are with someone you have already put behind.

There are only two switches in King's cockpit: one toggle for each mag. Along with the flight controls, there are mixture, throttle, and carb heat knobs, a handheld radio, and the canopy latch. No flaps, trim, or other complications get in the way. Starting it is a matter of having someone swing the prop—and if he is alone, King has rigged a small tow hook/release that can be used to hook the tail to a stake or post while starting. Once the engine is running, he can hop in the plane, pull the release string, and away he goes—clever, and far safer that trying to hand prop without being held back.

The O-200 started up on one pull after a couple of blades with the switches

Resurrection

Creighton King loves Cassutts—so much so that not only has he owned this same one twice, the second time he bought it, the airplane was buried under the rubble of a collapsed hangar. Regretting his original sale, he made the trip to the scene of devastation where the little airplane was mightily trying to hold up its end of the structure. The gear was flattened by the strain, the door header of the broken hangar lying across the nose of the airplane, just ahead of the cockpit. There was damage to the cowl, the fuel tank, the gear—and a few holes here and there, like in the top of a wing.

Extricating the machine took the work of several friends and a few power tools. Hauling the machine back to his shop, King realized that the damage was not deeply structural—mostly cosmetic, but would require a new fuel tank, new cowling, and a lot of covering and paint. Fortunately, he has the shop, the tools, and he had recently purchased the assets of Cassutt Aircraft, so the repairs were simply a matter of taking the time to get it right.

The long lead time item proved to be a new set of gun-drilled landing gear (better to hide the brake lines). While this was on order, he did the necessary re-cover and worked on getting the cowling right. The poor wheelpants needed some surgery and TLC after being crushed under the hangar debris. He took the rebuild as an opportunity to update the air intake, clean up the oil cooler ducting, and touch up a few cosmetic issues. When KITPLANES® showed up to fly the airplane, it had about five hours on it since its resurrection, and all of the repairs looked to be top notch. The only work not done was a final paint job on the wheelpants—but that certainly didn't affect the flying qualities.

It was clear to see that King loves the airplane by the enthusiasm he showed as he described what it is like to have his airplane back and in flying condition. He's a true believer, and ready to help others see the Cassutt light.

—P.D.

After it collapsed, the hangar had the tough little bird pinned down.

The landing gear was smashed flat, and the wheelpants damaged—but the primary structure was in good shape.

King stripped down, inspected, and re-covered the airplane in a few short weeks to get it back in the air.

off to prime. King pointed out an important aspect of the O-200s used in racing: since they are turning very fast, the stock oil pump has a tough time keeping up, and the oil pressure runs extremely low at cruise power (or faster). I was glad he pointed this out, or I might very well have put it back on the runway on that first takeoff when I glanced at the gauge. Class rules require a stock oil pump, so there is not much that can be done, and the engines seem to tolerate the low pressure just fine.

The engines also seem to tolerate rpms that would drive a Cessna-150 instructor to drink. Because the props are so short, tip speeds are not as much of an issue, so it is not uncommon to be turning 3500 rpm in flight. Numbers like that are becoming more common to pilots who fly behind Rotaxes—but the Rotax has a gearbox to reduce the rpm seen by the prop. In the Cassutt, what you see on the tach is what you get at the prop—and it is fast! Idle was about 1400 rpm after start, and we secured the canopy carefully; there are two separate latches, one forward, and one aft, and it pays to take the time to get them both properly secured—and to have someone else verify that they are captured.

Taxiing takes a couple of seconds to get used to—the tailwheel being linked directly to the rudder gives very sensitive steering. Those who like tight, stiff tailwheel springs will feel right at home. Those pilots who prefer loose chains will have to get used to the instantaneous response. I adapted in just a few airplane lengths, but it pays to sample the steering cautiously the first time. The brakes were effective, but not overly so—a good match for the size of the airplane. I didn't feel a tendency for it to get light on the tail during braking, even though our CG was at the front end of the box.

(The forward CG was primarily due to the fact that there is a heavy crush plate on the prop of King's airplane to offset his size. Cassutts are set up for their primary pilot, and all others must adapt. In my case, we taped a small cylinder (it was half a ball-point pen) to the trailing edge of the elevator to act as a trim tab, and this worked fine in flight, but did little at low speeds. It was perfectly adequate for such a small airplane to fly it with constant stick forces, but if you had your own, you'd set it up perfectly with a little experimenting.)

With run-up complete and controls checked free, I taxied onto the runway, rolled the tailwheel straight, and pushed the throttle to the stop. The acceleration is not remarkable; the airplane's fixed-pitch prop is designed for speed, not climb. Being used to constant-speed props, I was initially surprised at the lack of "get up and go," but then, we got up and went! When the tail came up, there was just a slight bobble in yaw as I learned the feel of the rudder, but it probably wouldn't happen the third time; the response is easily learned. Liftoff and initial climb/acceleration were flat, and once I had achieved the magic 120 mph number, we climbed out of the pattern to go sample the handing.

I could tell right off that the airplane is quick in roll response—the full-span ailerons give plenty of control in that axis. The airplane rolled significantly quicker to the left than to the right, and it felt more comfortable in a left turn, holding the bank angle very nicely. To the right, opposite stick was required in a 45° bank to keep it from significantly overbanking. But then again, there is no dihedral to the wing, so roll stability is going to be unusual. It was hard to judge pitch harmony with roll because of the nose-heaviness—the resulting forces tended to make it less responsive in the pitch axis, and it would be unfair to judge it in that condition.

Control was never a question, however, and the airplane is quite flyable. I slowed it down to about 100 mph a couple of times, just to see what it would be like during the descent to landing, and it still had positive control in all three axes. The rudder is effective, and pilots need to remember to coordinate their turns. A couple of wingovers proved again that the airplane was more comfortable going left than right, and the seat of my pants kept saying, "rudder, rudder, rudder...."

The large rpm range available was odd to someone used to operating a Lycoming (or Continental) between a flight idle of 700 and a redline near 2650. There was so much more throttle travel that it was almost disorienting when trying to set power for maneuvering. Minor changes in pitch without a throttle adjustment resulted in significant rpm changes due to the fixed-pitch prop, and an unfortunate in-flight failure of the tach drive cable left me blind to what the engine was doing, so I nixed the aerobatic and stall portions of the test card and returned to the pattern for a landing.

On our way back in to the field as a two-ship, I had gone to school on King's altitudes and speed around the field. He suggested a pattern speed no lower than 120 mph, slowing to about 110 over the fence with a very low, shallow approach. I had difficulty getting myself that low before the threshold, but seeing as how we had 5,000 feet of concrete over which to float, it was not a significant problem. The float of the Hershey-bar wing was considerable—especially once I got close to the runway—and ground effect at speed became significant. The airplane was easily controllable, however, and we touched down in a nearly three-point attitude, after which control was quite positive, and braking was good. I didn't look down at the airspeed at touchdown, but I expect that it was in the 80–90 mph range.

The gear seemed well-tuned to the airplane's flight characteristics, and there was no significant bouncing or bucking—it just settled in nicely. The first landing I make in a new airplane is, unfortunately, usually my best, but in this case, that worked to my advantage, as I really didn't want to continue without a tach (seeing as how the engine is turning so much faster than factory design speed), so my one landing was good, and I could quit while I was ahead.

Overall, the Cassutt is well and truly matched for what it was designed to do. It flies fast, and goes where you point it. It turns left with ease (the Reno Racing motto is "Fly low, fly fast, turn left"), and while I certainly wouldn't call it a short-field airplane, it is easily manageable on a reasonable runway. Pilots who are willing to adapt to its speeds and quirks will find it fun in the way that anything with a little challenge is fun. It is honest in the true meaning of the word—it delivers what it promises, and doesn't promise one thing and then do another.

The handheld radio antenna is simply stuck through the canopy vent—we assume that it would be stowed for racing.

The tailwheel is a modified Rollerblade wheel mounted to a spring. Steering is through a rigid rod bolted to the rudder—no springs here.

Treated with respect, it certainly would be a fun airplane to race.

Do You Want One?

Well that's a silly question—of course you do! The question is, do you need one, and will it serve a purpose? You don't have to plan on racing at Reno to enjoy building and flying a Cassutt. The existence of many unfinished airframes makes this a bargain for potential builders who simply want an airplane to fly. Granted, it is not going to be a daily cruiser—it is a performance machine that demands a higher level of skill than many might want to maintain—but this classic design is out there and waiting for those who want to give it a try.

Cassutt Aircraft is dedicated to helping people build and fly these machines, and while King admits that it is a niche market, it is a market that he believes in, and wants to support. If you already have another airplane with multiple seats to fly, and are looking for a unique project, the Cassutt is worth a look. Who knows, you might accidently have so much fun that you find yourself in the Formula 1 hangar at Reno some September, waiting to line up for the next heat.

For More information, contact Cassutt Aircraft at www.cassuttaircraft.com. For International Formula 1 Rules, visit www.if1airracing.com/index_htm_files/IF1_Technical_Rules_Rev2011.pdf. Visit the Cassutt Racer Owners Forum at www.Cassutt-Racer.com.

The Red One

The red airplane on our cover, Cassutt N119RC, was built by Bruce Hammer. It is now owned by a partnership headed by J.W. Mills, with Patrick Berry (flying the airplane in the photos), Drew Hughes, and David Kicklighter. The airplane is hangared at Fernandina Beach Municipal Airport (KFHB) in northeastern Florida.

KITPLANES® chose this Cassutt for the cover shot because the factory airplane was still undergoing final restoration after an unfortunate hangar collapse that smashed the cowling and landing gear. Both aircraft use the stock wings, but the red Cassutt has the standard tail, while the orange and blue factory aircraft flown for the report has a slightly enlarged vertical fin for additional stability in yaw.

Although the red Cassutt has stock dimensions, there are several modifications and other touches that make this aircraft unique. Probably the most notable is the long, sloped windshield/canopy that gives it a more streamlined appearance and a bit more room in the cockpit.

The engine is a Continental O-200 with high-compression pistons and a spin-on oil filter. It maintains a low-profile "Ratray" style cowl with a custom set of spark plug shielding "pots" manufactured and installed by Mills. Powerplant performance is sent to an engine information system (EIS) on the panel. A lightweight starter and alternator have also been installed.

The engine turns an Ed Sterba 58-64 propeller. At 2500 rpm the aircraft cruises at 160 mph IAS. At 2700 rpm cruise is 170, and at full throttle 205 mph.

Fuel is carried in a nose tank with 20 gallons usable. There are wing root bays that once held auxiliary fuel tanks, but are empty now and provide extra baggage space. With the speed and duration, legs of 350-400 miles are possible.

Sitting in the tiny cockpit for that length of time can be an ordeal, but N119RC came with a dished seat bottom and back that holds thick, comfortable cushions. The carbon-fiber panel is very clean, with most of the information presented through the EIS. There is an airspeed indicator, an altimeter, a compass, and a fuel tube indicator. The throttle quadrant is on the left sidewall. The "avionics suite" consists of a hand-held com radio and portable GPS.

The exterior fit and finish is beautiful, comparable to an Extra aerobatic aircraft from Germany. The fuselage is clad in fiberglass from the spinner backplate all the way back to the seat. The spring steel gear is streamlined with aluminum fairings and the Cleveland wheels and brakes are housed within very clean and close-fitting wheelpants. The steerable tailwheel is mounted on a tapered tube, and breaks loose for tight taxi maneuvering—different from the direct steering of the plans tailwheel.

As equipped, N119RC weighs in at about 680 pounds empty. It stalls around 80 mph IAS, climbs at 120 mph at more than 800 fpm, and has that legendary Cassutt maneuverability. If you think the pictures are gorgeous, you need to see this airplane in person.

—Keoki Gray

To learn how N119RC was photographed, see page 26 of this issue.


GARMIN


Team X

Record *Breaker*

Setting the round-trip USA aviation speed record in an RV-6A.

BY JEREMIAH D. JACKSON

On a clear day in January 2010, I took-off from Montgomery Airport in San Diego, California, in my highly modified RV-6A (christened *The Feral Chihuahua*) for Jacksonville, Florida. Twenty-four hours later, I landed back at San Diego, having successfully criss-crossed the United States. It was an official NAA round-trip transcontinental aviation speed record. This is my story.

My quest for a record flight started with an idea: Why not rebuild my Van's RV-6A to make it go faster, higher, and farther? With such a plane, I reasoned, why not have as a goal the round-trip transcontinental speed record?

I already had a fine RV-6A with about 1,300 flight hours on it. It had flown me safely and efficiently for over twelve years, and had taken my wife and me to many places in the western United States. But I had just sold my other completed kit plane, and thus had some extra time and cash on hand. So, I decided to use these resources to go after my new goal.

To modify the RV-6A for more speed, I decided to increase the plane's horsepower, as well as improve its aerodynamics. For increased power, I replaced the Lycoming O-360 with a modified fuel-injected IO-360 built by Aero Sport Power of Kamloops, British Columbia. The engine was modified by installing a more efficient exhaust system designed by Clinton Anderson at Custom Aircraft Parts, and by adding Light Speed Engineering's dual electronic ignition in lieu of magnetos. Going with fuel injection, along with electronic ignition, increased the plane's power by 20 horsepower and allowed a more efficient fuel burn at the higher altitudes flown during the record attempt. (This better efficiency would also help extend the plane's range.)

For better aerodynamics, I used the more tucked-up feature of the IO-360's horizontal air intake to justify replacing the stock Van's engine cowling. I decided to replace it with the more elongated James cowling, with its three induction ring intakes. (Two are for cooling air, and one is for engine combustion air.) The use of these rings promised less air-intake drag, thus saving more power for thrust. The lower third ring also smoothly joined a conical ram-air intake which I reasoned should work "a la Mooney" to increase engine manifold pressure at altitude.

I also added a fiberglass plenum to cover the engine's air box for cooling, rationalizing that it would help effect laminar airflow over the engine's cooling fins, and also provide a more efficient connection to the induction ring air intakes.

The last thing I did to reduce drag was to replace the original wheel fairings with Van's newer design, which more smoothly covered the tires, wheels, and brake systems. I also took advantage of the rebuild to replace the old wood-and-fiberglass-tape nosegear fairing with Van's improved gear and hollow fiberglass fairing. The new nosegear fairing was obviously lighter, but also adopted the newer "fat" teardrop shape now prevalent on all Van's products.

I flew my RV-6A both before and after the modifications, recording speed, fuel burn, and engine manifold pressure at various altitudes. For each altitude, I flew a heading then reversed it, recording my groundspeed for each leg so I could compute an average no-wind airspeed. The resulting data (see Table 1) shows that the modifications in engine, ignition, and aerodynamics were well worth it. At 18,000 feet, my rebuilt RV-6A was 21 knots (24 mph) faster, while burning one gallon per hour less fuel. My first goal of flying *faster* had been met.

My second goal was to get the plane to fly higher. Over the years of enjoying my RV-6A, I've found that it's especially good traveling in the "teens," and I routinely filed for cruise altitudes between 12,000 and 16,000 feet. The impediments to flying higher included the loss of power (and speed) inevitably from the lower performance of the engine in the rarified upper atmosphere. But they also included the engine's oil overheating due to that rarified air's inability to carry off heat. The new IO-360, with its greater horsepower, improved ignition, and increased manifold pressure, would address the first impediment. But what about excessive oil temperatures? Indeed, the higher-horsepower engine's greater heat might make that problem *worse*.

Engine detail showing IO-360 with cooling air plenum, electronic ignition, and ram-air horizontal intake.

During initial flight testing after the rebuild, I regularly had to stop my climb and wait for the engine's oil to cool. I also found that by about 19,000 feet, the engine's oil remained uncomfortably hot in cruise. Fortunately, I became aware of a new oil cooler developed and sold by Airflow Systems, which suggested improved performance. I eagerly ordered and installed one. After extensive flight testing, the data showed I could easily climb to 19,000 feet without the oil rising into the yellow, and cruise at a cool 180° F. With the new engine configuration and oil cooler, my second goal of flying *higher* was realized.

I next turned my attention to the question of extending the plane's range. At first this seemed rather obvious: add more fuel capacity. But at the altitudes (17,000 to 21,000 feet) planned for the record, I also needed to extend the range of my oxygen system. Its solution was not so obvious.

For increased fuel capacity, I did what ferry pilots do, and added a rubberized fuel bladder, plumbed to the plane's existing fuel tank selector. I initially installed a Turtle-Pac "Drum 66," which I placed lengthwise in the cockpit, replacing the passenger seat. The cockpit's lateral bar behind the seats prevented the bladder from becoming full, and limited its on-board capacity to 42 gallons. However, with the plane's two main tanks in the wings, I now had approximately 76 gallons of usable fuel, enough for almost 11 hours of flight without reserves.

I had been using Mountain High's Oxymizer cannula and 540-liter aluminum oxygen bottle for years, and found I could generally count on about six hours before running empty. For a record flight, I needed to at least double that duration. Fortunately, Mountain High recently had started offering a new product, a "black box" called an Electronic Delivery System (EDS). Intrigued, I ordered one, along with an oxygen mask and built-in microphone to keep me legal above 18,000 feet. The EDS arrived, and flight testing showed that it *quadrupled* my oxygen bottle's duration. I now had a fuel range of 11 hours, with an even greater range for on-board oxygen. My third goal of being able to fly *farther* was thus accomplished.

During the rebuild period, I added a fourth goal to my list: fly more *safely*. Thus, I upgraded and added equipment to also accomplish this goal. To improve my ability to obtain real-time weather information (including winds aloft and airport conditions), I installed a moving map GPS that connected to an XM

Table 1. Net Effects of Speed Modifications

Configuration	Speed @ 18,000 feet	Manifold Pressure	Fuel Burn
O-360 engine, stock cowling and fairings	135 kts (155 mph)	14.2 inches Hg	8 gal/hour
IO-360 engine with electronic ignition, James cowling, new fairings, and ram-air intake	156 kts (179 mph)	15.4 inches Hg	7 gal/hour
Improvement	21 kts (24 mph)	1.2 inches Hg	1 gal/hour

Photos: Jeremiah D. Jackson

FAQs

In the months since I flew the record, I've been asked by both pilots and non-pilots a number of questions which can be grouped into "What was it like?" and "How did you…?" Let me share my answers here:

What was it like? **Simply put, it was cold and surreal. Cold-weather mittens and insulated clothing improved my endurance, as did a better strategy of doing most of the high altitude flying during daylight hours. The surreal sensation of being suspended in a small aluminum bubble, motionless in an infinite black void, was very much the norm for hours at night as I crossed vast empty expanses of the United States.**

How did you eat and drink? **I took a tip from marathon runners and ate and drank per my normal regimen on record day. I brought along my "normal" breakfast of cereal and a banana, and a "normal" lunch of a bagel and an orange. I also brought along coffee and energy drinks, but didn't use them. I did, however, bring along and consume a bottle of water, two protein drinks, and a Milky Way.**

How did you fight sleep and boredom? **I found I was surprisingly alert, even after 24 hours at the stick with no sleep. The eight hour rest the night before certainly helped. As for boredom, I mimicked what Lindberg did on his trans-Atlantic flight: I filled-out a flight log by recording performance details at regular intervals, just to monitor engine systems and give me something to do.**

How did you navigate? **I initially received a special VFR departure out of San Diego to point me east, and then flew under an IFR flight plan with direct routing across the USA and back. The FAA was extremely cooperative in granting my requested flight plan.**

And the question never asked but certainly wondered about: ***How did you relieve yourself?*** **My wife came up with the brilliant idea to sew a zipper completely around my pants, from belly to backside. This, and some special "pee bags" solved that problem nicely.**

—J.D.J.

radio. The GPS also had a mapping feature to improve my terrain awareness at night and under instrument meteorological conditions.

Anticipating at least one night landing during my record flight, I also decided to upgrade the plane's landing lights, and retrofitted high intensity discharge (HID) lights. I also replaced the old 121.5 MHz emergency locating transmitter (ELT) with the newer 406 MHz satellite-based ELT. Lastly, for good measure, I added a SPOT satellite tracker, so I could let people know I was either OK or not.

Satisfied with these improvements, I concluded that *The Feral Chihuahua* was now also safer and ready for the record attempt.

My strategy for setting the record was fairly straightforward:

1. Select a flight day when the jet stream was aligned west-to-east, and followed the southern border of the United States, connecting one coast to the other.
2. Leave San Diego at sunset to take advantage of cooler air for the climb to 19,000 feet.
3. Use the jet stream's push to increase my groundspeed and allow a non-stop crossing to Florida.
4. Land in Jacksonville at dawn to refuel.
5. Fly back to California during the day at low altitudes to duck the jet stream's headwind.

That was the plan, anyway—but it didn't work.

On a clear February evening in 2009, I took off from San Diego. Unfortunately, I hadn't accounted for being tired at the start and was dangerously fatigued only six hours into the flight. I also found a number of systems to be inadequate, including my clothing's and cabin heater's ability to warm me at 19,000 feet in February; the instruments' lighting effectiveness; and the bladder fuel tank's usability. To make things worse, the forecast tail winds didn't materialize, making a non-stop crossing impossible with the amount of fuel I had onboard.

So, at around the Texas-Louisiana border, I made the difficult decision to quit and turn-back. From 19,000 feet, it took about 40 minutes to descend, so I asked the controller for the nearest 24-hour towered airport an hour *behind* me. He advised Abilene, Texas, so I took it, turned, and descended.

After refueling and taking a short nap until sunrise at Abilene, I limped my way home to San Diego, using the easier daylight flying conditions to reflect on my failed attempt and learn from it. After all, Henry Ford once said, "Failure is only the opportunity to more intelligently begin again." And I was certainly in need of more intelligence.

As I flew west to home, I jotted down the things that hadn't worked on the failed flight. And beside each item, I listed

Nose view of Jerry's plane showing modified engine cowling with induction ring air intakes.

View of cockpit showing the auxiliary fuel tanks that allowed an extra six hours of flight.

Jerry, shortly after landing at dawn, having completed twenty-four hours of flying and setting a new round-trip transcontinental speed record.

what I could do differently next time. My list included the following changes:

1. Take off at *dawn*. I'm a morning person, and leaving at sunset was simply stupid on my part. It was totally against my biological clock. Plus, leaving at dawn would give me a night's sleep before the flight, so I'd disembark fresh instead of tired.
2. Fly high east across the United States in *daylight*. Since I would be leaving at dawn, a large part of my high-altitude flight would now be in daylight, giving me at least some passive solar heating in the cabin to ward-off the 4° F outside environment.
3. Replace the flexible fuel bladder with *rigid-walled* fuel tanks. I had found that the flexible bladder was difficult to fuel and—due to its irregular shape on the floor—didn't have a consistent "unusable" amount of fuel, thereby making a wild guess of fuel duration calculations. A more traditional rigid fuel tank would also allow me to calibrate and better plumb it to the aircraft's fuel system.
4. Improve cabin lighting by installing an LED strip under the glareshield. This was probably more psychologically needed than real, but it would make it easier for me to monitor engine systems, and would make me feel "at home" as I travelled surreally surrounded in blackness nearly four miles above the earth.
5. Land halfway across the United States, *both* while heading *east* and west. I didn't want to again gamble on having a perfect tailwind to make it non-stop to Jacksonville. So, I would purposely plan to stop halfway while heading east. The next time it would happen in daylight, so I could also study the approach, taxiways, and FBO location, and confirm they'd be open for refueling when I would be coming back 12 hours later. Ironically, halfway across the USA is Abilene, where I'd stopped during the failed attempt, so it was already familiar to me. Stopping halfway also would allow me to depart with less fuel and weight, and thus climb more quickly to cruise altitude.

With the changes listed above, I awaited the next perfect winter day and took off at dawn, January 30, 2010.

The result was success, and I beat the old record by three days. As is the case in many revised plans, I found that my successful record flight was actually an easier experience than my previous year's failed attempt. Henry Ford was right!

Lessons learned

I learned a few important lessons during the whole record-setting experience. They included:

1. Mistakes are an opportunity to improve, so always have a timely debrief to learn from them.
2. Spend some time in your cockpit before you depart, and visualize your full flight to help identify weaknesses.
3. Use checklists to aid your memory. (I had one for remembering essential equipment and supplies, as well as a special pre-flight checklist modified for the record flight.)
4. You'll need the support of many people, so be good to them. My friends and family were always supportive, and I can't say enough good about them, my equipment suppliers, and the FAA.
5. Trust your inner voice. I'm glad I paid attention to those nagging doubts that always enter one's mind. In all cases they were right, and I was safer as a result. ✈

JERRY JACKSON

Jeremiah ("Jerry") Jackson is an instrument-rated private pilot and experienced skydiver with over 1,800 parachute jumps. He's been on eight successful world-record skydives, and holds the official NAA round-trip transcontinental speed record in his modified RV-6A. Jerry has published two aviation books: "The Flight of the Feral Chihuahua," about the pursuit of his NAA speed record, and "Four Minutes," about the crash of his RV-10. He and his wife live in San Diego, California.

How to Build Your Own Engine (Or Maybe Not)

Adding a rotary engine to a Q2 is easier said than done.

BY LEWIS BJORK

The Q2 aircraft in my garage was designed to be efficient—most speed for the lowest fuel burn. To begin with, the designers made it small. It barely seats two people and a little baggage. There is room for a small VW engine and a little fuel. As designed, the plane is capable of 140 mph cruise speeds and might reach 180 mph at maximum effort. These are remarkable numbers for only 65 hp.

The plane barely debuted when builders clamored for a bigger engine. It's great with 65 hp, so what could it do with 100? After much continued development and the installation of a Continental O-200, the plane demonstrated 200 mph top speeds with a cruise of 175 or so—all this while burning around five gallons per hour. Throttled back to 120 mph, the plane travels nearly 45 miles per gallon, matching the best automobiles at nearly twice the speed.

Almost 1000 kits were sold before the company folded. A few hundred became flyable. Many more still sit in garages and shops throughout the land—like mine. You see, that question still nags at me: If it can do that on 100 hp, what could it do on 120 or more? I know, it's probably at the point of diminishing returns already, and why reinvent the proverbial wheel?

For me, the story began with an outright rejection of the VW. Not that it's a bad engine, I just never liked them in airplanes. I appreciate and trust the Continental O-200, on the other hand, and selected the Q200 airframe with that engine in mind. That is, until I saw

The rotor comfortably nestled in its toroidal chamber. No valves, lifters, cams or timing chains. In theory, fewer parts means less chance of failure.

A peripheral intake above and slightly modified exhaust port below. Peripheral ports almost double the horsepower at the expense of a rough idle.

the price. A decent used O-200 sells for just under $10,000—two thirds of my total allotted budget for the project, and the engine design is over 50 years old. In an effort to bring reality to the cheap/practical airplane pipe dream, I bypassed the O-200 in search of an engine of comparable reliability and perhaps greater horsepower, at a much cheaper price. Looking back, this has been vastly more difficult than I thought at the beginning.

On the Hunt

Shopping for a suitable engine is fascinating. After reading everything William Wynne posted online about the Corvair conversion, I became somewhat intrigued, especially in regards to how that engine compares favorably to the O-200. Discussing my newfound interest with a local mechanic found him pleading with me to find something else. He spun a long tale of endless fights with his Corvair automobile, said he would barely risk driving it to work, called it a bunch of colorful names, and told me certain death awaited me if that engine ever found its way onto an airplane. I didn't like the VW; he really hated the Corvair!

Further investigation brought me to the AeroConversions VW. I loved the idea of a big box of parts and instructions to build my own engine. It looked terrific, seemed at least several steps above the original Revmaster engines in the Q2, and made a claimed 80 hp. Additionally, the AeroVee would not increase the weight over the original engine. Maybe 80 hp would be enough? A phone conversation with the owner of a beautiful Sonex in Logan, Utah revealed a problem. Two big people, hot day, 6000-foot density altitude, and he felt pleased to be climbing 300 fpm. He said that 80 hp is about all I could ever expect out of the engine, too. Although the Q2 is a bit smaller and perhaps lighter than a Sonex, it appeared my goal of 1000 fpm climb would not be possible with that engine.

Then I found a terrific engine coming out of Europe called the Gemini diesel. It burns jet fuel, weighs about the same as an O-200, and makes 120 hp. My excitement lasted until the price sent me running the other direction. With the exchange rate on the euro, that engine would double my total budget all by itself.

I looked at several more engines, all either too heavy, too expensive, or too dubious for serious consideration. The Mazda Rotary, for example, promised great potential for power and reliability, but weighed almost twice what the little Q200 airframe was designed to carry.

At this point, I became somewhat resigned to coughing up money for an O-200 and inflating the overall budget for the airplane.

Eureka!

A short time later, a single-rotor Mazda conversion came up for sale. The engine had been custom built, specifically for mounting on a Q2. In fact, the engine was mounted to a Q2 airframe that was offered with it. After a brief negotiation, I bought the engine and reduction

This shaft is the only part remaining untouched from the original engine.

Photos: Lewis Bjork

The assembled block weighs 68 pounds, about the size of a large battery. Not bad for 140 horsepower.

drive, for $2300, well within budget, and a claimed 120 hp, to boot. The seller bragged the engine, as installed, weighed less than 200 pounds—about the same as an O-200.

My project proceeded rapidly for a while after. Then, after installing the propeller (an Ivoprop), I noticed that light downward pressure on the spinner could lift the tailwheel off the ground. Things were not as light as they seemed. I continued with the installation, building intakes, plumbing, radiator, and oil cooler, very curious all the while to see it run.

With the tail weighted down, the engine coughed, spat, and began a fitful idle that shook the airframe into soft focus. After less than a minute, the exhaust pipe shattered, and the engine mount cracked from the vibration. Although initially elated to see it work, I felt dismayed at the fact that it worked quite poorly. At the very least, I would have to tear the engine down to see what caused the vibration. Pulling it free of the firewall and dangling the whole mechanism from a scale verified my suspicions—it weighed 273 lbs, way too heavy to use in the airplane!

Throwing Good Money after Bad

My dismay turned to brooding. This cycle has repeated itself many times since. Hope with the project becomes excitement, then elation, then dismay and a grumbling return to square one. At this point, the O-200 would cost $12,300 due to my foray into alternative engines.

I decided to throw good money after bad, figuring money spent so far still left room for Experimental development, and to be honest, I felt somewhat attached and intrigued by the little rotary engine. Piece by piece, noting the weights of each component, I dismantled the engine as it hung on the scale.

It is important to note that I have no experience building engines. Tracy Crook, of Real World Solutions, sells a nice conversion book for the rotary, and Paul Lamar, of *rotaryengines.net,* publishes a wealth of information to lend confidence to the neophyte (read foolish) builder. A great deal of reading and the enthusiastic comments of other builders involved with the discussion did much to build my confidence. Through these avenues I learned of several ways to shave weight and increase the power of a rotary engine.

Hope Springs Eternal

No way could my engine make 120 horsepower; the intake ports were untouched. In the Mazda RX-7, a two-rotor engine produces 150 hp, or 75 hp per rotor. My inexpensive single-rotor engine weighed nearly 50 percent more than an O-200, and might make 25 percent less power—if it were running well. Fortunately, increasing the power of a rotary engine is as simple as changing the ports. I decided to peripheral port the engine and hired Jeff Dodridge, a machinist and rotary enthusiast, to make it happen.

Jeff began milling the center housing and stopped short. My housing came from a very early model of the engine and would not allow an intake of the usual 2-inch diameter without cutting into some critical hardware. He offered to sell me a newer housing with the machining already completed, and I accepted at once. The new housing looked terrific, but did not quite match the cast iron end plates. I replaced these anyway, with aluminum end plates manufactured by Racing Beat, of California. The new end plates shaved 30 pounds off the engine weight, but cost an additional $3000.

Assembling the new parts revealed several subtle changes throughout the engine. Nothing else fit together. Even the toroidal chamber of the center housing had been changed over the years as Mazda sought to improve the engine from my original model. As such, I needed a new rotor, seals, oil pump, water pump, and engine mount. I sent

The engine weighs 168 pounds at this point. Oil cooler, radiator, fluids, and prop will send it just north of 200 pounds, and it will produce about 140 horsepower.

Fourth radiator; third oil cooler, engine mount, and overhaul; second oil tank, ignition, gear reduction, rotor, bearings, etc. This is the final iteration, the author hopes!

the rotor and all spinning components to Mazdatrix in California for rotational balancing. They found the old parts to be way out of balance and suggested that was the source of the initial vibration. Upon assembling the engine block, the only part retained from the original engine was the shaft.

Moving ahead, Jeff altered the reduction gear to accept thrust bearings while I looked for every opportunity to shave off weight. I hadn't had so much fun in the shop for many years. Despite all the frustration and cost, the learning curve in selecting parts and building the engine was a blast. When fully assembled, the basic engine, mount, reduction gear and prop weighed 188 pounds. With radiator, oil cooler and fluids, the 200-pound figure looked quite doable. Power output is yet to be determined, but with the peripheral port and about 8200 rpm, 140 hp might be possible. I began to get excited.

Will It Work?

After a few test runs in the shop, I tied the plane in the driveway and advanced the throttle. It ran smoothly, but seemed to hesitate at higher rpm. There seemed to be some errors in the oil pressure sender and several discrepancies throughout the engine monitoring system. I throttled back after a few minutes to check the engine directly. It idled for a moment, then the prop came to a sudden, jolting halt. Cue the dismay.

Disassembly revealed a complete lack of oil pressure and a couple of destroyed bearings. Thankfully, the shaft and expensive housings were undamaged. I rebuilt the engine again with improved bearings and retainers designed to improve oil flow at high rpm. Approaching the next test run with great caution, we lubricated the engine with a hand pump as it ran, and still noted zero oil pressure. We went through the whole oil supply system, verified the senders with a voltmeter, then noticed a fool's mistake. I'd plumbed the entire output of the oil pump into a dead end. This is easier to do than you'd think, and replumbing the system required a slight modification to the engine mount. At last, I felt ready for another try.

With the engine idling smoothly, I was elated to note an oil pressure of 90 psi—about right for a rotary, when a geyser erupted from the propeller speed reduction unit. The low-pressure seal at the back of the PSRU blew out, and high-pressure oil sprayed the starter ring gear. Like the proverbial substance hitting the fan, oil found its way past the wingtips, all over the driveway, and spattered the wall of my garage. I could have been the poster boy for "grease monkey." Some quick replumbing involving a restrictor, and an alternate drain path for the PSRU prevented the seal from blowing again. The next run shot a geyser of oil straight up, about 8 feet, out the oil tank breather. I had to relocate the breather and buy a lot more oil. At least the problems could be solved, and I found great enjoyment in this, as well. Even more fun than collecting and assembling parts was the thrill of seeing them work together and make some noise.

Subsequent testing revealed the cooling system to be inadequate. I bought Paul Lamar's book, *How to Cool Your Wankel*, and studied it carefully. Essentially, my radiator had to double in size, and sure enough, the engine temperatures stabilized. What a delight to watch the temperatures rise with increasing power, then cool again as the power is reduced. I fixed several leaks, adjusted ignition circuits, fuel flows, and generally tinkered until satisfied that the whole thing looked workable. In the end, I've spent enough to buy an O-200 anyway, but I've had a lot more fun and learned a great deal more than simply bolting on another engine.

Of course, the engine won't fit under the old cowling, so I have to make a new one—but that's the subject of another article. ✈

No geysers of oil, billowing steam, exploding parts, or shooting flames, all parameters normal. The engine is very smooth—cue the delight!

Air-to-Air Adventure

A photo mission with the pros.

BY DAN HORTON

It's late morning, and I'm at 9500 feet near Tallahassee, on my way to school. As the magazine's new guy, I can't afford to miss a learning opportunity, so when I heard professional air-to-air photographer Richard VanderMeulen would be in Florida to shoot features for KITPLANES® during Sun 'n Fun week, I cleverly proposed a "reader ride-along" article. Editor Paul Dye gave his blessing, VanderMeulen agreed to a temporary apprentice, and now I'm southbound in my RV-8. It's a beautiful day, warm and bright blue, with a brisk wind at my back. Hmm…the XM says windsocks are popping smartly all along the coast. I wonder if it will calm down this evening?

Arriving at George Baker Aviation in New Smyrna Beach, I find Beechcraft expert Curtis Boulware removing the rear doors and most of the club seating from his faithful A-36 Bonanza. Boulware is one of VanderMeulen's regular photo ship pilots. Chatting about the upcoming photo mission, I learn that the A-36 is a favorite air-to-air platform, with a wide speed range and an excellent field of view. Although not strictly required, removing the seats will allow VanderMeulen to sit on the floor and move about the door opening.

The annual New Smyrna Balloon and Skyfest is going on as we prepare. Patti Wagstaff is making her turnarounds

While chatting with VanderMeulen about the upcoming photo mission, Boulware removes the rear doors and most of the club seating from his faithful A-36 Bonanza.

VanderMeulen has learned from experience that it pays to check every corner of the interior for loose objects and dirt.

overhead, followed by the AeroShell T-6 team. Boy, this is fun!

Preflight

I notice VanderMeulen carefully checking every corner of the interior. He says he is looking for loose objects and dirt, then tells a funny story about renting a dog-owner's Bonanza and spending hours vacuuming, rather than suffer a dog hair storm on takeoff. He also tells about getting some aluminum drill swarf blown into his eye, which was not so funny.

The seat rails and supports remain bolted in the airplane. We'll use them as safety harness anchors. VanderMeulen, the professional, has a real harness, custom made for him by a parachute manufacturer, and he adjusts his anchor strap so he can't quite fall out the open door. I don a climber's seat harness, a relic from former adventures. I am advised that photographers have been known to slip out of them, so I pull it real tight and clip into an anchor well away from the door.

VanderMeulen's harness incorporates a back pad. That's because hardware (like exposed seat rails) will jab and poke without mercy, not to mention tearing your pants or performing an ad hoc vasectomy. Such concerns are valid, because so far, the wind has not abated very much, and we're starting to wonder if it might be a wee bit bumpy up there.

Eventually we strap in and Boulware fires up the mighty Continental. He shuts it down again when VanderMeulen notices the hat shelf flopping in the propwash aft of the open door. A few feet of tape cures the problem, and we head for the runway.

To St. Augustine

Our destination is St. Augustine, 58 miles up the coast, where we'll meet our photo subject. As soon as we're off the ground, VanderMeulen grabs each of his cameras and fires off a few. Experience again; no point in burning gas only to find a problem later. It's windy in the back, but not any more than expected. However, fifteen minutes into the leg, the AA batteries in my Lightspeed Zulu2's crap out, and I learn that the open door generates a low pitch harmonic boom strong enough to rattle eardrums. Naturally, my spare batteries are back in the RV-8.

Up front, Boulware hunts for a smooth altitude. He finds none, but we cross our fingers and tell each other it will calm when the sun gets low. Still plenty of time; the evening's "golden hour" of perfect light is still more than three hours distant. There is not a cloud in the sky.

In due course Boulware greases Runway 31 at St. Augustine. We can hear

The Pro

Richard VanderMeulen has been shooting air-to-air for more than 20 years. His work has appeared in dozens of magazines (in four countries!), including Air and Space, Air Force, and, of course, KITPLANES®.

VanderMeulen may shoot 500 to 1500 images in a photo session, including static ground shots. The number can go up dramatically when working with larger, more complex aircraft, or when flying in rough conditions. Extra images compensate for those lost to camera or subject movement.

Typical GA missions take about an hour in the air. The best photographers rise early and stay out late, and you will too if asked to be a subject. It's all about the light. Soft, warm, low angle lighting makes every airplane look better.

Favorite cameras are a Nikon D-4 and a D-800, with staple 70-200mm and 24-120mm lenses. In general, a shutter speed of 1/60 of a second is enough to blur propellers into the desired disk. The key issue is rpm; while 1/80 may work with a fast three-blade, a geared warbird prop may require a longer exposure.

In terms of time spent, the actual photography is just the tip of the iceberg. VanderMeulen shoots in RAW format rather than JPEG. It offers total control over every aspect of the final image, but all images will require post-processing. Viewing and sorting to make the initial selections can take a day or two, after which working with the best images can burn as much time as an artist is willing to invest.

Want to try shooting air-to-air? VanderMeulen says Rule #1 is safety first. He has called "Knock it off" and sent subjects home without regret. Rule #2 is finding a photo plane with removable doors or windows, or an open cockpit. Really good photographs are hard to capture through Plexiglas. Rule #3 is to always remain aware of lighting.

Readers may view a gallery of VanderMeulen's work at *www.aviationimaging.com*.

—D.H.

Photos: Dan Horton and Richard VanderMeulen the Cassutt we've come to photograph calling the tower from the other direction. Pilot Patrick Berry amuses everyone when a grouchy tower controller orders a premature turn during rollout. Berry ignores him, and then responds (quite rightly) with, "Sorry, I was busy flying the airplane."

VanderMeulen works on static shots of Berry's Cassutt, gathering frame after frame from every imaginable angle.

Ground Shots and Briefing

The Cassutt is an eye-popping ripe-tomato red, and very well finished. After introductions, VanderMeulen goes to work on static shots, gathering frame after frame from every imaginable angle. We all watch awhile, then I borrow the FBO courtesy car to fetch new headset batteries. The others find shade, and like pilots everywhere, start telling stories.

The golden hour draws near. With thirty minutes until liftoff, VanderMeulen calls us together for a briefing. We discuss frequencies, break procedures, expected maneuvers, hand signals, and a host of other items. It's a refresher for the photo plane crew, but new to Berry, and he is looking very serious. Each participant has a specific job. Boulware will mind the Bonanza and fly as directed by VanderMeulen. He will also be the communicator, handling ATC issues and relaying instructions to Berry in the Cassutt when necessary. Safety pilot Fred Vyfvinkel will be the eyes of the group, responsible for traffic spotting, buzzard avoidance, and backing Boulware. Berry will place the Cassutt where needed, working from hand signals and the radio. I will shut up and stay out of the way.

The Mission Begins

Everybody climbs aboard and we taxi out. Grumpy is still in the tower and needles Berry, pointedly canceling a taxi clearance before answering a request for clarification. Eventually we line up on 31 and launch to the north.

Boulware doesn't climb far. It's immediately apparent that the air has

The View From the Hot Seat

I started watching the weather forecasts a few days before the shoot, hoping for what my friends and I call "Cassutt air," a perfectly smooth evening. Instead, Sunday arrived with clear skies and wind. The launch call came just as I was pulling the airplane out of the hangar. No problem; it is fun to play catch-up with a Cassutt. After takeoff I set 2900 rpm on the O-200, and soon the GPS said 160 knots and 15 minutes to KSGJ.

The Cassutt is a great airplane to fly. The handling is pretty straight forward, although there is not a lot of positive stability. I rarely take my right hand off the stick, instead using my throttle hand to manipulate the EIS, GPS, and the handheld radio in the right wingroot. The tailwheel is usually a few inches above the runway at touchdown, and it is best to let it come down by itself. Aft stick to lower it right away can put the Cassutt back in air, and when that happens the pilot gets to log two or three more landings. On Sunday I had just touched the mains, and as I was correcting for the wind and waiting to feel the tailwheel rumble, the controller ordered, "One One Niner Romeo Charlie, make next left on Runway 20 and contact ground on 121.17." "Sorry," I say to myself, "You'll have to wait until I get this thing down to Grandma's walking speed, then after I get a spare hand we can talk."

When I pulled up in the parking area, I saw the club doors removed on the A36. At the briefing, VanderMeulen and Boulware were very thorough. They made it clear that my comfort level would set the limits. If I could not do something, all I had to do was say so, and anyone could call "Knock it off" and quit at any time...no pressure.

As we formed up to begin shooting, I just hoped I could fly well enough to not waste everyone's time. They wanted me in a 45-degree trail, off the right side of the Bonanza. It was a good place to begin; my formation instructor (and Cassutt mentor) Keoki Gray had started my training with the same position. You're below and not overlapping wings, and with a canopy airplane, you can fly under if you accidently close too fast, all while keeping the other airplane in sight.

The air was rough, but not too bad. For me, the go-to maneuver was to power back when things got crazy. It gave almost immediate separation, while keeping the lead in plain sight, and in a good place to close again. We used about 130 mph and 2500-2600 rpm, which left plenty of power to catch up.

After a while, the guys in the Bonanza could see my power-backs were more and more frequent. They called for a break, which let me get my neck unstuck from the 45-degree-left position. Next came the right turns, which put me on the inside. That was challenging; I was working my butt off to stay where they wanted me to be. Later, after a few runs up and down the beach, I did a final breakaway pull for the camera and said goodbye, making the short flight back to Fernandina with daylight to spare.

It was a great experience. I learned a few new things about formation flying, and I got to hang out with some serious airport guys... two of my favorites in one day!

—Patrick Berry

Using hand signals and the radio, VanderMeulen directs Berry to move upward, forward, backward, and down, each in turn.

not calmed even a little bit. VanderMeulen says conditions are marginal, but the light is nearly perfect. We all hate to see the opportunity wasted, and agree to let Berry be the deciding factor. If he can safely hang in formation, we'll proceed.

Light, Camera, Action

One hour before sunset over the Tolomato River salt marsh: Showtime. VanderMeulen starts Berry with gentle circles to the left. Circling means the sun angle is always changing, thus offering the photographer an infinite variety of lighting angles. A left turn puts Berry on the outside, generally more comfortable in difficult conditions. VanderMeulen doesn't push, allowing Berry to work his way in closer as he settles down and gains confidence. Both airplanes are moving around a good bit, the Bonanza bouncing in the solid Beechcraft way, while the Cassutt looks more like a Duncan yo-yo in the open door. VanderMeulen braces his back on the spar carrythrough, presses his toes to the rear wall, and bobs the long lens up and down like a man in a rocking rowboat.

After 10 minutes or so, Boulware tightens the circle, and VanderMeulen begins directing Berry to move upward, forward, backward, and down, each in turn. Berry is clearly working hard, but seems fine, showing no distress in his flying or in his voice.

The steep left turn and high position frames the Cassutt against the bare blue sky. A low shot places the airplane on the horizon, banked artfully toward the camera. VanderMeulen holds Berry in each position through one or more full circles, gathering images as the sun angle sweeps through a full 360 degrees. Eventually he declares a break, and Berry slides away some distance to unwind.

VanderMeulen uses a harness custom made for him by a parachute manufacturer. He adjusts his anchor strap so he can't quite fall out the open door.

The Crew, left to right: photographer Richard VanderMeulen, Cassutt pilot Patrick Berry, Bonanza pilot Curtis Boulware, and safety pilot Fred Vyfvinkel.

Moving Down

When we rejoin, Boulware starts a right turn to put Berry on the inside, upping the game for everyone. In addition to framing, focus, and light, VanderMeulen is now working to capture background, the whole point of the right turn. Boulware is being very conscious of altitude and position. To get detailed background we're at 500 feet, and the subject is slightly lower. Drifting downward, or back toward civilization, is not an option. Even Vyfvinkel is under pressure. We're at helicopter and bird level, and spotting is more difficult each time we circle west into the setting sun.

Conditions remain bumpy. In the Bonanza we're not quite floating off the floor, but sometimes it gets close. Berry must be getting tired, although he isn't showing it. Each time the gyrations get too radical, he slips aft a bit, takes a breath, and slides back in. VanderMeulen eyeballs the pines, marsh grass, and open water, directs Boulware to sweep past a few specific backgrounds, then declares another break.

With the standard shots in the bag, we move out to the beach, rejoin, and fly low, gentle circles. VanderMeulen studies the sun and the sea. The shooting seems both random and carefully planned, much as a seasoned gambler plays the cards he is dealt. The gambler appreciates luck, but never expects it. VanderMeulen works hard for his luck.

The winds are finally dying, and the light is gentle. We relax and enjoy the flight, until we have no more time. Berry is based at Fernandina Beach. The Cassutt has no lights, and he has 30 miles to go before sundown. He rolls for a last pull, and we turn for home. ✈

The professional product: great framing, lighting, and background.

Building Again

A plans resurgence?

BY CHAD JENSEN

I've been asking myself a few questions over the last couple of years. Since completing my RV-7 and subsequently selling it, I've wondered if I'm a builder or a flyer, and if I do build again, what kind of project will I undertake? I love to fly. I love to build. I thoroughly enjoyed the kit experience, but what about that set of rolled up paper plans I have sitting in the corner? Would that be a better way to go? What am I really looking for in my next build? Can the community I've been part of for the last decade help with the decision? There is nothing simple about deciding to build, and the financial and time impacts can reverberate throughout a person's life. It is definitely worth it to put some thought into the process—and elicit some help.

Help from My Friends

Looking back on the last ten years of being an airplane owner and eventual builder, I immersed myself into something that has become my passion in life. Experimental aviation has opened my eyes to many new things. I originally started looking at building a plansbuilt airplane when I began my research in 2004. I was new to the local EAA Chapter 129 in Bloomington, IL and had plenty of opinions coming my way about what to build, how to build, and which method of everything was best. I knew I had to be budget minded, and a plans-built airplane would certainly check off that column. I looked at finding plans for Long EZs, Cozys, Tailwinds, Thorp T-18s…you kind of see where my mind was regarding my airplane mission: I wanted to go fast! Why, I didn't really know, but most builders in Chapter 129 were fast airplane guys—RV, GP-4, Glasair—so that's where my biggest influence came from. That's not the way to choose an airplane to build, but as a newbie, that's what happened—and that's a story for another article.

Photos: Chad Jensen

Even if you build a Sonex from scratch, you'll still need to order upper and lower spar caps (visible on the spar on the right) from the factory. These parts are proprietary extrusions that are CNC machined to final size and shape.

Building main wingspars from scratch is slower than ordering pre-built spars from the factory, but the end result will be just as functional.

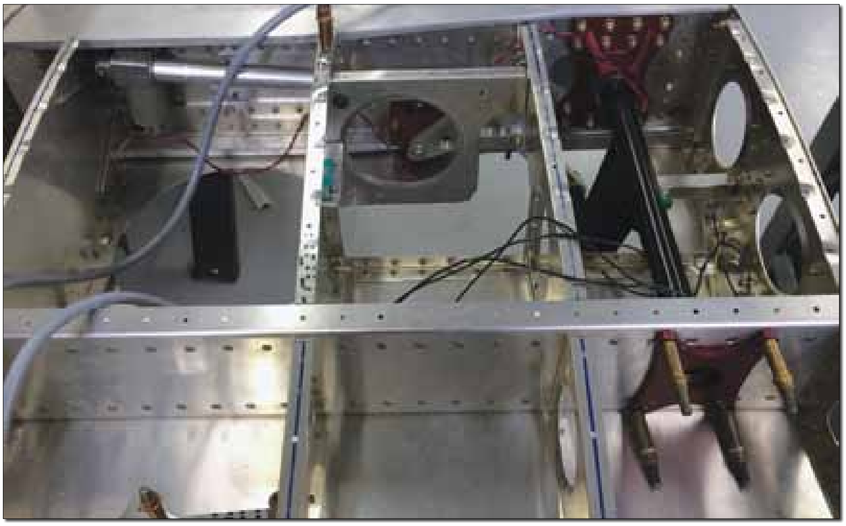
My EAA chapter was absolutely wonderful in helping me along the way. Over the course of a year, I used every tool at my disposal, including the annual KITPLANES® buyer's guides, to make an informed decision. What it came down to eventually was an RV-7. My first choice was a Velocity SE-FG, but my shop space simply wasn't set up for a fiberglass airplane at the time. So, how did I go from plansbuilt thinking to building an RV-7? Well, I basically took a leap of faith and just did it, with the notion that I would work out the budget constraints along the way. Somehow that worked out. But I couldn't have done it without another huge resource: online forums.

Help Online

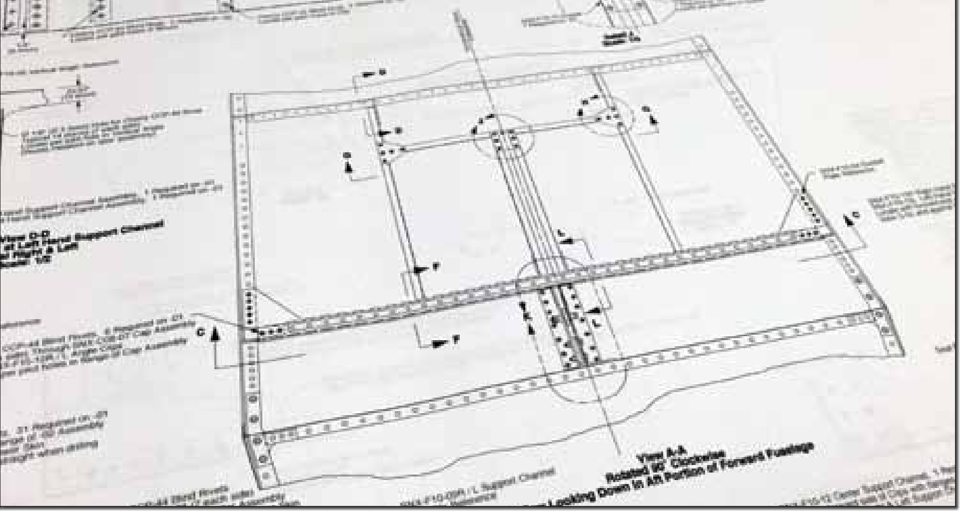
If one was thinking of building a plansbuilt airplane back in 2004, there was, and still is, a fantastic forum called *homebuiltairplanes.com*. I spent hundreds of hours on that site, making just a few posts here and there, not knowing at the time what large influence E/A-B forums would have on my life and career in the future. As I got to know a few of the online personalities, one person stood out to me: John Sannizarro, aka "Captain John." He was a fairly prolific poster there, and when I mentioned RVs one day, he told me to check out an RV forum called *Rivetbangers.com*...and that's where my online "family" began. *Rivetbangers* led me to *VansAirForce.net* and the VAF forums, and then to the canard forums, the Kitfox forums, and so on, and so on. The forums really became a part of my life. I couldn't go a day, or even a few hours, without checking into one of them for some reason or another. Friendships were made; we'd meet up at AirVenture, Sun 'n Fun, or some regional fly-in, and hang out like we had just seen one another a week ago. John is nearing completion of his RV-7 and is still an active forum poster and great friend of mine.

The forums are now a place that I go to check in on friends, conduct business, watch as new builders come into the fold, and find out what those who built before me and alongside me are now doing with their time. I've noticed something over the course of the last ten years of forum participation: Specifically in the kitbuilt forum world, builders who have completed an airplane are now venturing into new waters by starting projects that begin by following lines on paper—not opening big boxes that come filled to the brim with pre-made parts.

As a successful kit builder myself, having finished and flown an RV-7 in 2010, I found out that I was one of those folks who decided, perhaps unknowingly, that I was really more of a builder than a flyer. If I had to put a percentage on it, I'd say I'm right at 51% builder and 49% flyer. I had a successful beginning to a flying career working for Image Air, an FBO in Bloomington, where I had become the aircraft sales manager and a charter pilot in a King Air 200. As much as I loved flying at my day job, I couldn't wait to get home, or for the clock to strike five,



One sign of a scratch-built part is the centerline indicating where holes should be drilled on these rib flanges. If you're going to build from plans, be prepared to drill and deburr a lot of holes.



Are you good at following directions and searching for clues? Both are required skills for building an aircraft from plans.

so I could leave and start another work session on my airplane project. Maybe—just maybe—building from scratch would make a second project even more challenging and interesting.

Paper or parts?

What I'm seeing today, even with a strong kit market, is an increased percentage of repeat builders going for the paper rather than the parts. I associate this with increased courage to tackle something new after learning the ropes on a kit project. Some kits are obviously more involved and challenging than others, but what all kits provide new builders is a knowledge base with a bit of hand-holding along the way. There is absolutely nothing wrong with that, and it's something that I will always be thankful for. The skills I learned while building my RV-7 and the courage that experience gave me along the way can't be taught or gained in any other way. The fact that I completed the project shows me that I can tackle something a bit more complicated and challenging.

Plansbuilt airplanes are not for everyone, and not every repeat builder is going to go down this path. But it's a path that I have chosen several times after my -7 was completed. As I write this on a cold, snowy February day in Oshkosh, I have plans for no less than six different airplanes sitting in the garage. I've also gone so far as to start three different plansbuilt projects over the last two years—and I still have four sets of plans I haven't tried. When I worked for EAA, I led the staff build of a Zenith 750, a kitbuilt airplane that is on the leading edge of plans quality and ease of construction. That project delayed my own projects, but I am always thinking about those plans at home and getting back to them someday.

Perhaps when the time comes to build another airplane at home, it

Four ways to build the same airplane: Sonex builders can choose from a quickbuild kit, a complete airframe kit, sub-kits, such as wings, tail, and fuselage, or from scratch.

Even if you're building from plans, there are some parts that just aren't worth the trouble to make from scratch. This throttle and trim control are good examples.

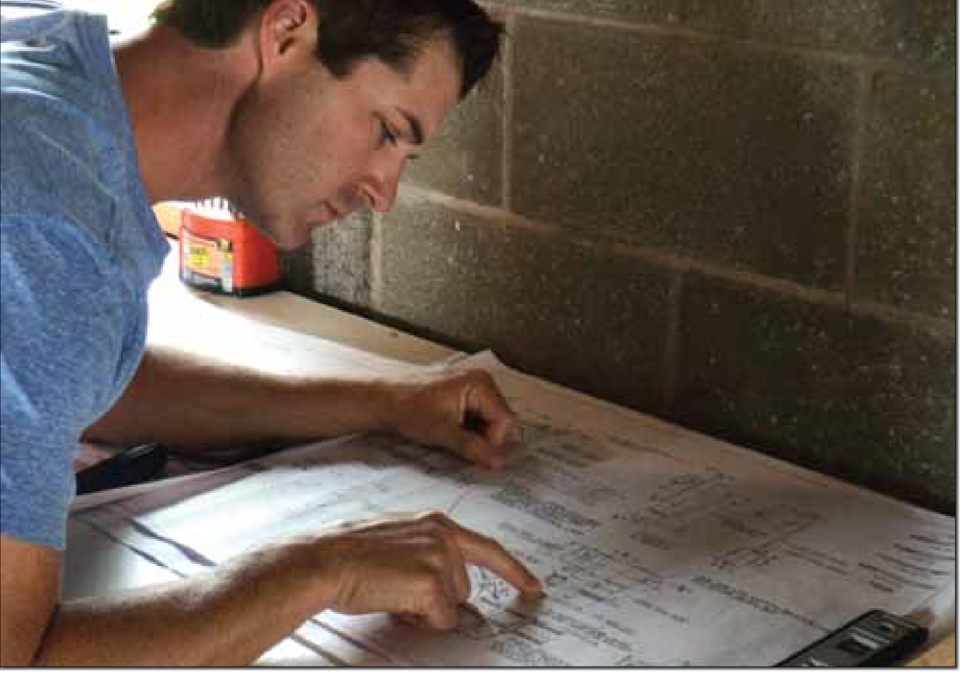
might be a kit again, but the fact of the matter is, I'm a builder at heart—and the challenge of starting with raw materials and a set of drawings is inviting. The plans are still going to be there, and I would be willing to bet that if you have completed a kit airplane, a plansbuilt airplane has crossed your mind a time or two. There are too many examples to list, but among the kit builders that I know (both personally and as online personalities), a plansbuilt resurgence is underway. Whether you've completed a Lancair with some builder assistance, spent five years building a Velocity in your garage, or 20 years building a Mustang II kit, a plansbuilt airplane has at one time or another crossed your mind, hasn't it?

What is truly interesting to me in this scenario is the type of airplane being chosen for a subsequent project. Many builders are going for almost the exact opposite of the type of airplane they built first. I don't observe a Velocity flyer plugging away at a Cozy Mk IV project, or a Wag-Aero Cubby kit pilot gluing together joints on a Hi-Max. This may certainly be happening, but what seems to be most prevalent in my casual glance at this, is the accomplished Lancair builder working on a plansbuilt Bearhawk or a Kitfox builder working on a Falco F.8. In my own experience, the first plansbuilt airplane I looked into and bought plans for after my RV-7 was completed was a Legal Eagle XL. I went through a slew of plans that included a Hummelbird, Cubby, Zipster, Hi-Max, KR Super2, and Tailwind. The Tailwind and KR came about after I sold my RV-7 to get that mission profile back, but the others were all on opposite sides of the map from my original mission. I suppose the easy reasoning would be that this would be a second airplane, and why have two airplanes with similar missions? I needed one to go places and one to get breakfast on a Sunday morning, right? The simple fact of the matter was that I just wanted to build something and, while having an airplane available at any time, the slower plansbuilt route was just the ticket to keep my mind in the game and improve my skill set another notch.

Doing it Again?

Every once in awhile, I come across a builder who has completed a kit and

As you might expect, prototype aircraft like this SubSonex personal jet are always built from scratch, even if the design will only be available as a kit. In the foreground is a SubSonex molded fuel tank.



The author studies the plans for a potential next project. To date he has acquired plans for no less than six different airplanes.

when asked, "Would you do it again?" will say, "Nope, I did it once, had a great time, but it's time to fly now." I'd say more often than not, though, the answer is just the opposite. And that answer has led many to think about that next project. The kitbuilt airplane is done, sitting in the hangar looking great. You love to fly it, but you can't always fly. Weather, work, finances, family, and many other things take the ability to fly and make it less available. Why not have another project in your garage? Weather is bad? Go build. Time is too tight to fly? Run out to the garage and cut some tubing or bang out a couple of metal ribs. Finances a bit short? Doesn't cost a dime to cut that tubing, assuming you have some on hand, which, of course, may be what made the finances short in the first place. Family time and needs? What better way to spend a Saturday afternoon than in the garage with your spouse or kids building an airplane?

I'm a Builder

At least 51% of me is a builder. I love to fly, but I am always thinking about building again. Whether it happens to be a kit or a set of plans on the bench, the next time I'm 100% in on a project, it will be because of the skills I learned and the courage grown from building a kit airplane in the first place. Who knew the kit industry could possibly spark a resurgence of plansbuilt airplanes? It's not something I really gave much thought to until recently. I will forever be grateful for the experience of building a kit airplane, and I may well do it again. Plans are on the mind, but kudos belong to the kit companies for designing and engineering the kits we build today that got me here in the first place.

Sonex Plans and Kits

The fact that I live in Oshkosh, WI, gives me a very nice opportunity to keep tabs on the local kit manufacturer, Sonex. The company is full of wonderful people who are welcoming to my visits, and Jeremy Monnett is always accommodating. I took a drive over to Sonex recently to talk to Jeremy about their plans and kit sales.

There are very few kit manufacturers out there that offer their designs in paper plan form. As far as I know, they can actually be counted on one hand, with Zenith Aircraft Company and Bearhawk Aircraft being the other mainstream offerings. Sonex has four models available today in kit form. They only offer one, the original Sonex, in plans form. I asked Jeremy about their kits versus plans sales, and I got a surprising response: "We sell, on average, two sets of plans for every Sonex kit we sell every year."

A two-to-one ratio of plans to kits from one of the top kit manufacturers in the US? That sounds like it supports my notion that kit manufacturers actually help drive the plans market. Imagine if all of the kit manufacturers offered a model or two in plans form.

Jeremy says that if the company only offered plans for their airplanes, there would be no Sonex Aircraft, but the supplement that the offering of plans makes to the bottom line certainly helps. The fact that the kits do sustain the business, and plans add to it, pretty much assures that the plans will be available for a long time to come. If you haven't seen the plans set from Sonex, you are missing one of the best laid out and most easily understood sets out there. The

D-sized drawings come in a huge roll of pages and are so easy to read, it inspires starting a part almost immediately.

Unfortunately, the majority of plans available on the market today aren't quite this good, but many of them are getting better and better. I've reviewed at least 50 sets of plans over the last couple of years, and I have to say, I was pretty impressed with most of them. But others leave a lot to be desired. That's a good challenge for some, but not something to take lightly. If you've had that successful kit experience, eyeing a set of plans, well laid out or not, is something that should be on your to-do list to keep those creative juices flowing and acquired skills nice and sharp.

—C.J.

SEAT FOAM

DIY for comfort and cost.

BY ERIC STEWART

The cost-benefit tradeoff of DIY is that, typically, the more of a project you do yourself, the cheaper it will be—but also the longer it will take. Sometimes, if you'll only be making pennies on the hour for your labor, it pays to pay a professional (you'll often hear this said about drywalling of owner-built houses, for example). In other cases though, you can save a substantial amount of money for a minimum investment in time and materials. Depending on your mission (and derrière) profile, DIY seats can definitely fall in the latter category.

I DIY'd just about everything on my RV-4, but when it came to paint and seats, well, I was willing to splurge a little and farm out some of the work. But just a little; I did the grunt work of pin-hole filling and prime-and-sand on the fiberglass to keep the paint bill down. Likewise with seats, I figured I could take the work to the penultimate step myself, learn some new skills, and then let a professional put on the exterior that I (and my passengers) will actually see.

Last year KITPLANES® featured an article by upholsterer and pilot Mike Manning about working with Axel Alvarez to custom design the interior for Alvarez's RV-4. Manning's article mostly focused on design and collaboration concerns. In this article (consider it a sequel to Manning's), we'll take the next step and explain how to fabricate the actual cushions before heading off to the upholstery shop. In addition to saving a fair bit of money, you can be sure the seats will fit you and your plane perfectly, and you'll even have a chance to sit (or fly) in them to make sure they feel just right before actually having them upholstered.

However, before embarking on this project, do read Manning's article ("The Owner Assisted Interior," KITPLANES® June 2013), and find yourself an upholsterer who is willing to collaborate and can give you advice and suggestions regarding your intended design. In a future article, we'll cover making a control stick boot, so be sure to tell the upholsterer to save the scraps from your job—those should be sufficient to make a couple of boots.

Materials for DIY seat. Foam (L to R): Medium-density "rubberized" urethane foam, high-density "tractor" foam, and high-, medium-, and low-density CONFOR foam. Large roll of pink CONFOR foam in the back. Foam-compatible spray adhesive, as well as brushable Pliobond for touchups. Velcro may be necessary to hold cushions in place on some planes. Materials are resting on a sheet of 3mm birch ply used as a backing frame.

Overview

The majority of Experimental aircraft seats consist of various layers or sections of foam bonded together and upholstered in leather, fabric or synthetic materials. A backing frame may be used, although it appears as though most E/A-B vendor seats are more like cushions, in the sense that they lack a rigid frame and instead fit snugly (often secured with Velcro) into a pre-existing airplane seat structure that provides support. The upholstery may be permanently attached, or removable with zippers and/or Velcro. Some builders also choose to wire their seats with aftermarket automotive-type seat heaters.

Since this job is primarily about building with foam, let's define three common types of foam available to a builder:

1. **Closed-Cell Foam:** Fabric stores (Jo-Ann Aviation, as a friend calls one chain) typically carry both closed- and open-cell foams. Closed-cell foam tends to be tougher and heavier than open-cell foam and is impervious to liquids. Neoprene and polyethylene foams are used for camping ground pads, flotation devices, etc. but are not typically used in upholstery, so you can ignore these.
2. **Open-Cell Foam:** These foams are typically urethane/polyurethane based, come in varying densities, and some have a distinctly sponge-rubber feel to them.
   - **Tractor/Motorcycle Foam:** Not an official name but it seems to be used often enough by vendors to describe a rigid, high-density, non-rubbery open-cell foam. It is commonly yellow, black, or "chopped" (i.e., a rebonded mix). If you've ever sat very long on an old tractor or motorcycle, you'll know that you don't want to be sitting on a seat made of this stuff. However, the rigid nature of the material makes it excellent for providing structural shape to the seats in the form of bolsters (wedges), lumbar supports, etc. Think of it as a base contouring foam.
   - **Sponge-Rubber Foam:** Not a real foam rubber, but it feels that way. It has a bouncy, pleasant sponginess that is OK as a veneer layer, or for bolsters and lumbar support, but it should not be used as the primary cushion itself (see sidebar "Safe Seat Science"). Note that it is less rigid and more cushy than tractor foam, but not as easy to shape.
3. **Viscoelastic Foam:** Commonly called memory foam, an endless variety of viscoelastic foams are available, with CONFOR foam generally used for aviation purposes. It's admittedly expensive, but for the safety of my spine, I don't mind paying a premium for CONFOR foam. It comes in a variety of colors, with green, blue and pink being the standard colors used in aviation seats. Green is quite firm, blue less so, and pink relatively soft. All colors become increasingly hard the lower the temperature.

Green plays the biggest role in mitigating G-loads in an impact, while pink conforms most easily to the body and provides comfort. A typical layup schedule is one to two inches of green on the bottom of the seat, followed by one to two inches of blue, and finally, one to two inches of pink on top. If canopy clearance is an issue, and you want the thinnest seat/cushion possible, consider one inch of green as an absolute minimum—it won't be particularly comfortable, but it's better than nothing. However, based on TR79-22, an aircraft crash survival design guide, and other research, I personally would not feel safe with anything less than two inches. At the other end of the spectrum, some builders like to have several inches of pink on top for maximum comfort.

Photos: Eric Stewart

The simple rectangular rear bottom seat cushion backing frame is checked for fit. Seat back has already been completed in this photo.

In contrast, the forward backing frame is a more complex shape due to the wingspar that passes below the pilot's legs. A frame is especially helpful in cases like this where the cushion is not sitting flat. Lightening holes optional.

Angled backing frames should be reinforced with fiberglass.

All of these foams are available from online vendors. However, I'd suggest sourcing your open-cell foam from a local fabric store, since they'll often have remnants for cheap, and by actually handling various types of foam, you can choose one that feels best to you. They should also be able to sell you a foam-bonding adhesive. I recommend either Keyston #4011P General Purpose Spray Adhesive or 3M FoamFast 74 Spray Adhesive. Regular spray adhesives not designed for foam, such as 3M77, are *not* recommended—they appear to bond at first, but after a few days the foam will delaminate.

CONFOR foam is available from the usual aviation hardware vendors, although they typically sell relatively small pieces. I found Rubberite Cypress Sponge of Santa Ana, California, to offer excellent full-sheet prices; they are happy to sell to individuals, but their salespeople want a company name, so be prepared to call yourself "Bud's Aviation Palace" or whatnot.

Corners should be rounded and edges radiused to minimize possibility of frame rubbing through upholstery.

A thin layer of laminating epoxy is applied to the seat back to protect the wood from moisture. Squeegee excess epoxy with a credit card.

STEP 1: Rigid frame Construction (Optional)

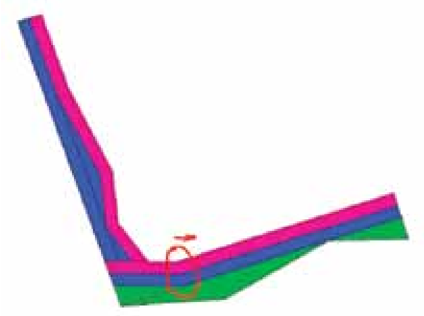
Although not necessary, a lightweight frame provides a rigid structure that can make assembling your foam layers a bit easier and provides a backing to which the upholsterer can staple the fabric if the upholstery is to be permanently attached. Use a high-quality, lightweight ply such as 3mm 5-ply Finnish birch. If you add lightening holes or make other cutouts to accommodate structure under the seat, be sure to leave at least a 1.5-inch perimeter for the upholsterer to staple to. Application of a thin layer of laminating epoxy to the exposed (i.e., opposite the foam) side gives a nice finished look and helps protect against any liquids that might end up spilling under the seat.

Safe Seat Science

Safe seat design is primarily about managing G-loads to the human body in the event of a crash. Of the three axes (up-down, left-right, fore-aft), the human body has the lowest survivable tolerance limits for downward G's (due to spinal compression). Higher tolerable G's for other axes, as well as the fact that airplanes often continue sliding forward or laterally, but not vertically (the earth is incompressible, after all) once they hit the ground, mean that the down-axis G-load is the driving parameter of safe seat design. This is reflected in FAR23.562, which describes the requirements for aircraft seat crashworthiness and uses 19G as the maximum survivable downward acceleration.

To explain why foam has such a strong effect on survivability, remember that although we often speak of G-force, a G is actually a unit of acceleration, not force. The important thing here—without getting overly technical—is that acceleration has a time component. In other words, if we can slow things down, we can reduce the G's. So how do we do that?

We do it through giving the body time to decelerate by compressing a layer of foam. But beware—not just any foam will do. Under certain circumstances, the wrong type of foam (like urethane) can actually increase G-loads on the spine. How? Imagine the foam as a spring: the spring compresses under load, but once the maximum point of deceleration is past, the foam begins to spring back upwards. The seat pile-drives the lower spine (which is now fully compressed and thus rigid) up into the upper spine, neck or head, which are still moving downward, thus compressing the spine from both directions. As hard as it is to believe, the wrong kind of seat can actually be worse than no seat at all.

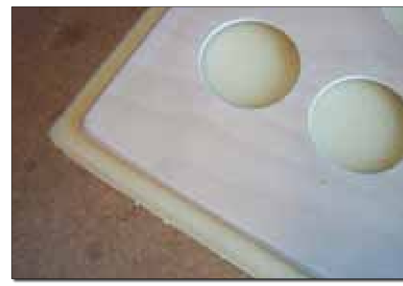


Preliminary layout of the foam schedule. A CAD program can let you easily play with dimensions and thickness as in this picture, but a hand-drawn sketch will work just as well. *(Illustration courtesy of Tom Wruble)*

Either high-density tractor foam or medium-density "rubber" foam can be used for bolsters and lumbar supports.

Urethane foam cuts best with a scroll saw. Use it for both initial cuts and final trimming.

Yet another reason to get a shop fridge—to freeze your seats! Frozen CONFOR foam is much easier to shape than room-temp. Once frozen, even pink CONFOR will slice paper thin.



Cut your foam oversize and trim when all layers have been final bonded together.

STEP 2: Assemble Foam Schedule

Make a sketch of how you'd like to layer the foam, including any bolsters, lumbar support, etc. This diagram should give consideration to your desired head clearance, safety factor (the more CONFOR foam the better), comfort, and weight (CONFOR foam is moderately heavy).

A variety of tools may be used for shaping open-cell foam. For high-density tractor foam, I prefer to use a bandsaw. In situations where this is not possible, I use an electric carving knife or serrated bread knife. I have also used, with varying degrees of success, a die-grinder with cut-off wheel or grinding bit, belt sander, and X-ACTO knife. Different foams shape differently—experiment and see what works. *Be careful*—band saws and die-grinder attachments can both suddenly grab at the foam if you are not careful. Wear the appropriate safety gear.

For shaping CONFOR foam, one of the neat things about memory foam is that it becomes increasingly hard with lower temperatures (well, not so neat if you are climbing into a cold plane—it can take a while to warm up and conform to your body if you don't have seat heaters). This makes shaping a piece of cake

However, CONFOR foam closely resembles a theoretically ideal shock absorber: that is, it provides both a constant rate of deceleration as well as a very low rate of spring back. This buys time for the body to decelerate more slowly, as well as avoiding the pile-driver effect mentioned above.

We should point out that flammability and smoke toxicity are also important elements of safe seat design. Certified aircraft are only allowed to use approved foams and coverings. The methods outlined in the above article do *not* necessarily conform to the safety regulations for certified aircraft (we're Experimental, remember?). It is the builder's responsibility to determine the fire-worthiness of any non-aviation-approved foam, adhesives, upholstery, or wiring they might use in DIY seats, especially when seat heaters are used.

—E.S.

Human Acceleration Tolerance Limits

Direction of Accelerative Force	Tolerance Level
Downward (pushes pilot up in seat)	15G
Upward (pushes pilot down in seat)	20-25G
Lateral Right (pushes pilot left in seat)	20G
Lateral Left (pushes pilot right in seat)	20G
Forward (pushes pilot into seatback)	45G
Rearward (pushes pilot away from seatback)	45G

Ref: *Crash Survival Design Guide,* Technical Report 79-22; 0.10 sec duration of crash pulse, full restraint if you have access to a freezer big enough to put your seats into (either that, or do your seats in the winter!). Once frozen, the CONFOR foam cuts easily with a knife or saw, and shapes beautifully with a vixen file or 80-grit sanding block.

Initially, I'd suggest cutting all your layers slightly oversize. Then before final assembly of your seats with adhesive, stack them per your schedule (you can tack-glue with a glue gun to keep things from shifting if necessary), and either sit in the plane for a few hours (taildraggers propped to the flight angle) reading a book, or go fly. This can provide valuable ergonomic feedback about the comfort of the seats. Due to my height (6 feet 2 inches) and the rather small size of the RV-4 cockpit, I flew for a few months before I finally had a foam schedule that felt right.

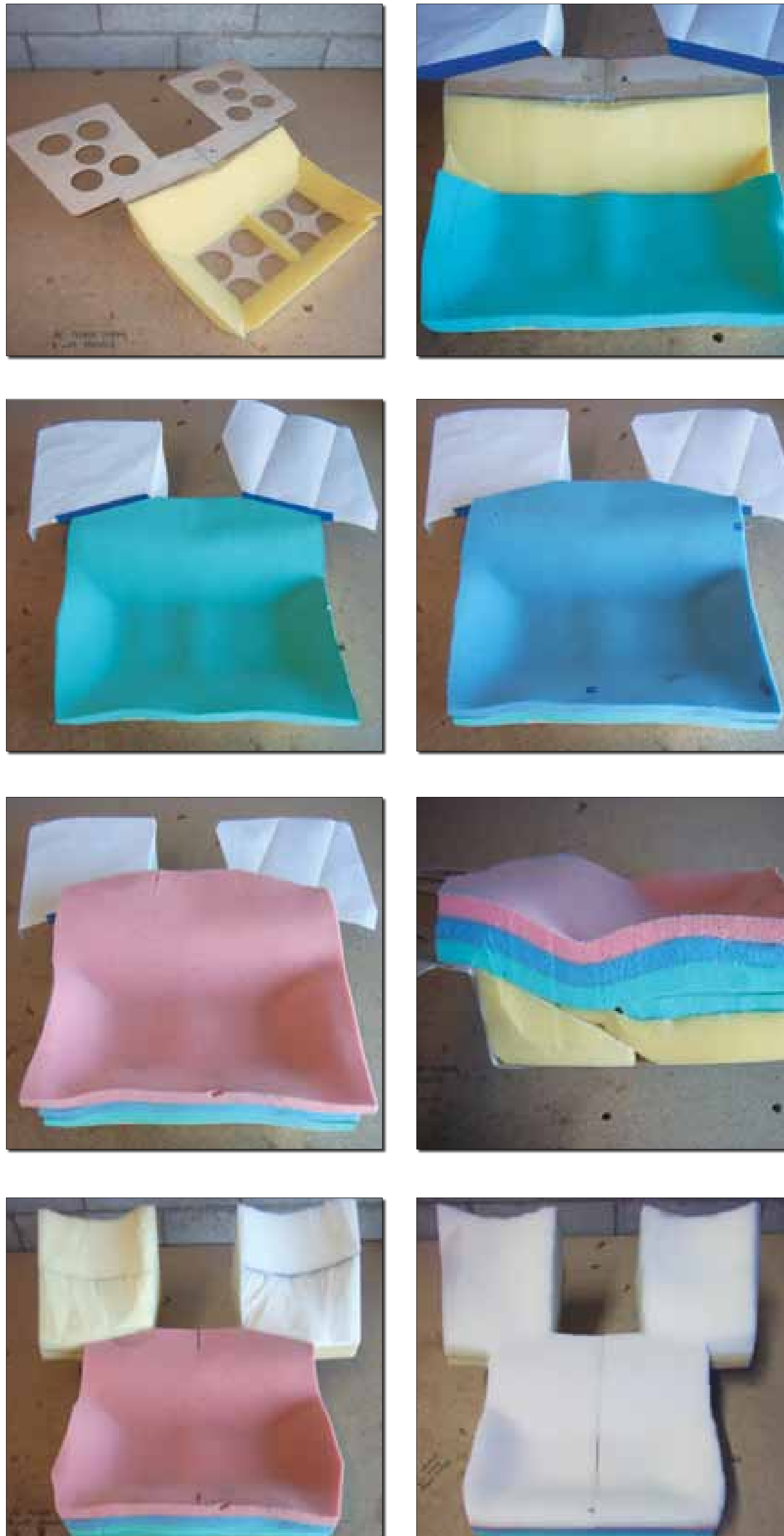
Once you are happy with your schedule, go ahead and bond it together, beginning with green to frame and bolsters, blue to green, and finally pink to blue. Occasionally you'll miss a spot with the spray adhesive and an edge might lift, or corners pull apart. In that case use a bit of Pliobond or a glue gun to re-adhere the delamination.

If using a seat heater, be sure to plan out the placement of pads and routing of wires ahead of time. Wiring, harnesses, Molex connectors, etc. should be installed at the time of wiring the airplane and before the floor is installed. Note that the adhesive for some seat heat pads is not activated until heat is applied. Check with your upholsterer before permanently attaching the pads—some may prefer to adhere the pads themselves later in the process of upholstering.

Most kits come with dual pads, and there's no reason you can't run one pad to each seat—just make sure that the pilot and passenger can both reach the on/off switch. If you want separate seat heaters for pilot and passenger, make sure your alternator can handle the load; some of these heaters draw a considerable amount of current.

STEP 3: Trim (Optional)

The final step is to trim the layup (and seat heat pad, if applicable) to the final dimensions. Before doing so, I'd



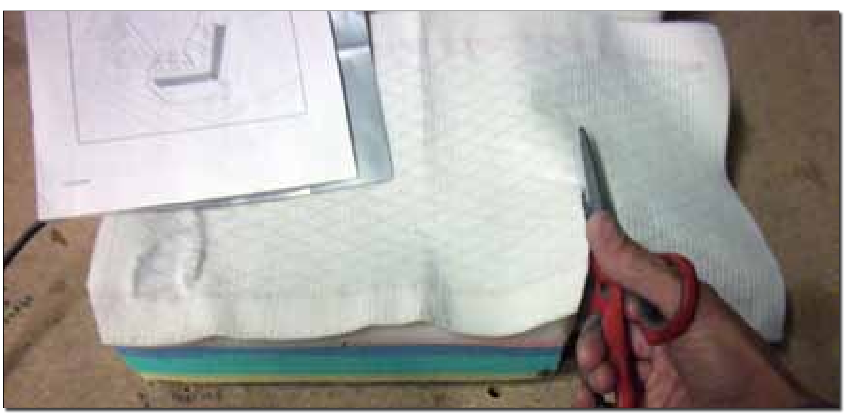
Foam bonding sequence: Urethane bolsters are bonded in first, followed by high-, medium-, and low-density layers of CONFOR foam (white "ears" are simply paper masking the forward frame from spray adhesive). Forward thigh supports are sponge-rubber type urethane foam, followed by a final top layer of ½-inch urethane over the whole cushion.

Final check before delivery to upholsterer: Seat bottoms and seat backs fit together without interference, cushions are marked for stick cut-out, and seat heat pad location is checked for adequate power unit harness length.

suggest taking the untrimmed seats to the upholsterer to see if they want you to add or subtract an allowance for the finished size. This will also give the upholsterer a chance to let you know if anything needs to be changed or corrected.

That's a Wrap

DIY-seats are another great way to combine learning with economizing, and unlike other areas of homebuilding, the raw materials are cheap enough that you can practice making a seat or two without a big investment in time or money. In fact, you'll probably have a fair amount of scraps left over after you cut out your foam patterns—why not use them to practice, and make a cushion for your (or better yet, your spouse's) car seat or office chair? ✈



Seat heat pads are designed to be trimmed to the size of your seat.

Materials List for Pair of Seats

Materials	Source	Cost
Urethane Foam remainders	Local fabric store	$44
CONFOR foam (½″x36″x80″ sheet, x1 each green, blue, and pink)	Rubberite Cypress Sponge, Santa Ana CA	$85*,**
Keyston #4011P Spray Adhesive x2	Local fabric store	$14
3mm 6-ply Finnish Birch 48″x48″	Aircraft Spruce (online)	$65*
(Optional Dual Pad Carbon Fiber Seat Heater Kit)	Online auto parts vendor	($38*)
TOTAL (*= cost of shipping not included) (**= ½ sheet price, sufficient for 2 seats)		$208

Alternator and voltage regulator problems.

In the days of steam gauges, an alternator failure was inconvenient. In the age of glass panels, it is much more serious. Now if the alternator stops producing power, it is just a matter of time—and maybe not very much time—before you no longer have any instruments at all. Keeping your charging system happy and tracking down problems needs to be in a high position on your list of priorities—even if you are a day/VFR pilot.

What Do the Gauges Tell You?

Two instruments can tell you something about your charging system: the ammeter and the voltmeter. Depending on how your plane is wired, the ammeter will tell you how much current is going in and out of your battery or how much current your alternator is producing. The voltmeter will tell you the voltage at the main electrical bus. A voltmeter is required equipment if you have electronic engine gauges: tachometer, manifold pressure, oil pressure, etc. These two gauges tell you quite a bit about the state of your alternator in particular, and your electrical system in general.

Normal voltage readings should be around 14 volts for a so-called 12-volt system. This is because if the voltage output of the alternator is not greater than the battery voltage, current will not flow into the battery, which on its own should produce about 12.8 volts when fully charged. If you normally see system voltage that is above 14.5 or below 13.8 when flying, you need to find out why. Too little voltage will not charge the battery properly, and too much voltage can damage it permanently. When the alternator fails, system voltage will drop to battery voltage, which will be at 12.8 or less, and declining as the battery loses charge. Somewhere around 9 to 11 volts, your electronic instruments and radios will fail. This will vary from one device to another and is a number that you should know for your equipment, especially if you fly IFR. In the case of radios, transmitting will fail before receiving because just keying the mike will cause system voltage to drop a bit. This is why a voltmeter is required with electronic engine monitoring systems.

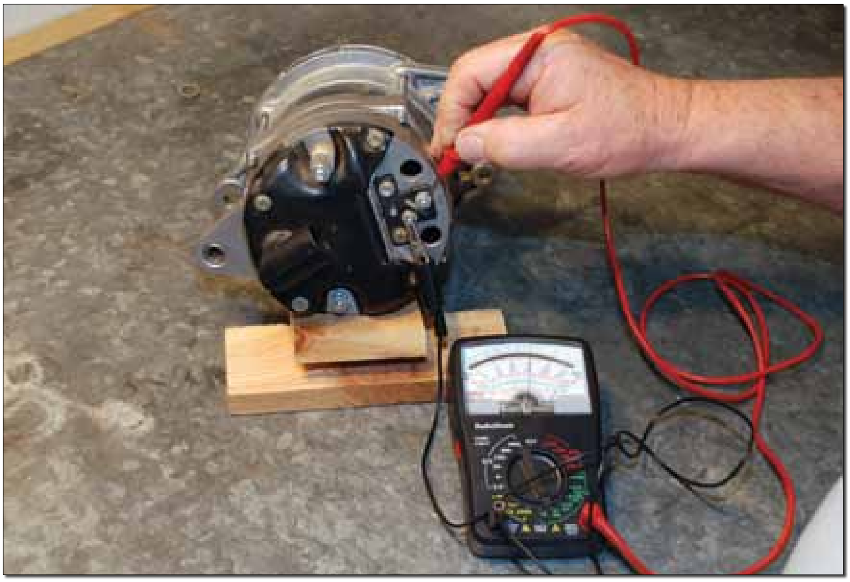
A slight increase in voltage may indicate resistance building up in the field circuit for some reason. A corroding connection or a partially-broken wire could be the cause. The failure of one of the stator coils could also cause voltage to rise. The important point is that just as decreasing voltage is bad, so too is increasing voltage. If it changes, there must be a reason.

Normal ammeter readings will vary depending on what you have installed and turned on, and depending on how you have wired your ammeter. It is very

The insides of an alternator are pretty standard. The field windings magnetize the rotor shown in the left half, and the stator windings, diodes, and brushes are in the right half. The field windings get their power through slip rings shown on the exposed end of the rotor. The crankshaft pulley is on the other end.

Dave Prizio

Dave Prizio is a Southern California native who has been plying the skies of the L.A. basin and beyond since 1973. Born into a family of builders, it was only natural that he would make his living as a contractor and spend his leisure time building airplanes. He has so far completed three—a GlaStar, a Glasair Sportsman, and a Texas Sport Cub—and he is helping a friend build a fourth, an RV-8. When he isn't building something, he likes to share his love of aviation with others by flying Young Eagles or volunteering as an EAA Technical Counselor. He is also a member of the EAA Homebuilt Aircraft Council.



On alternators with F1 and F2 terminals, you will need to connect one lead of the meter to each terminal. The resistance reading is a little high because this alternator has been sitting on a shelf for several years. Some regular use should remove the oxidization from the brushes and slip rings.

wise to have a good idea of how much current each device draws, just in case you need to shed load in a hurry to preserve your battery. When flying sometime, try turning off each device in your plane and see how the current changes. Then make a note of it in case of an emergency. Pitot heat, landing gear, and landing lights are typically the big power hogs in most planes.

Why the Lights Go Out

Failed alternators cause relatively few electrical failures. The various alternators likely to be used by amateur airplane builders will last for 2000 hours, the life of a typical aircraft engine, and will require no service during that time unless abused or improperly installed. Of course, relatively few is not the same as none, but look elsewhere first unless the alternator displays obvious signs of distress. Wires and connectors are the most likely culprits when things stop working. Just as with starter problems, track down each wire, switch, and connector to see where resistance is high—above 0.2 ohms across any switch or connector—and/or where voltage drop is excessive—more than 0.5 volts. Get a good multimeter that will reliably measure tenths of ohms and learn how to use it.

There are some mechanical problems that could also cause your alternator to underperform or fail. If you hear a high-pitched squealing sound when you place a heavy load on the alternator, you may just have a loose belt. Lycoming has a service instruction that tells you how to properly tighten your alternator belt. Keeping your alternator belt properly tightened helps ensure a long life for

Alternator Belt Tension

New		Used	
Size	Tension	Size	Tension
3/8-inch belt	11-13 ft-lbs	3/8-inch belt	7-9 ft-lbs
½-inch belt	13-15 ft-lbs	½-inch belt	9-11 ft-lbs

Use a torque wrench on the pulley belt and adjust the tension so that you get the specified torque just as it starts to slip. Turn the pulley nut in the tightening direction so you don't risk loosening it. Reference: Lycoming Service Instruction 1129A.

Photos: Dave Prizio and compliments of B&C Specialty Products, Inc.

the belt. Since replacing a belt means taking off the propeller, getting a long life out of it is really important.

Troubleshooting

With any kind of troubleshooting, there are a couple of rules of thumb that are worth considering. First, start with the simple stuff, then move to the complex items. And second, which is similar, start with the cheap stuff first, then move to the more expensive things. It is just easier to fix simple things, even if it is not always easier to find simple problems. And if, in desperation, you devolve from mechanic to parts changer, you sure as heck want to start changing the less expensive things first. These are not hard and fast rules, but really more like guidelines. Sometimes the problem is obvious, and it is obviously expensive, but when you are having a hard time figuring things out, these rules can help you keep things in perspective.

Common Alternator Problems

If you have a mechanical whining that increases in pitch with increased rpm, you may have a bad bearing in your alternator. If so, sending it back to the manufacturer or a repair shop for overhaul is probably your best bet. Mechanical noise is different than radio noise, so turn your radio off if you aren't sure of the origin of the noise.

This airplane uses a B&C solid state voltage regulator. It will work better if it is installed inside the cabin instead of in the engine compartment. One advantage of the B&C regulator is that the voltage is easily adjustable.

If the alternator just stops charging, the first thing to suspect, assuming it isn't making some terrible noise or hasn't blown the main breaker, is the field. If you are not getting 12 volts or more to the field terminal of the alternator, you are not going to be making electrical power. Check the connector at the alternator, the wire, the voltage regulator if you have an external voltage regulator, and then the ALT side of the master switch. If you don't have 12 volts at any of these points when the master switch is turned on, find out why and fix it. Loose connectors can be the toughest problems to find, so be sure to tug on each one to make sure it is secure. If the field breaker has popped, suspect a chafed wire making contact with the airframe somewhere. Trace the entire path of the field wire until you find the short.

A short from the field to the alternator case inside the alternator can also cause the field breaker to trip. Disconnect the wire from the field post of the alternator and use your ohmmeter to check for a short by placing one lead on the field terminal and the other on the alternator case. If there is no, or almost no resistance, you have a short inside the alternator. You should expect to see at least four to six ohms resistance, assuming a 12-volt system. In some cases the field is not internally grounded. You can tell this

It can be quite difficult to access some field connections on alternators installed in airplanes. Here a pigtail has been made to make checking resistance easier.

When testing an alternator with only an F terminal, one lead goes to the case (ground) and the other to the F terminal. This B&C alternator shows 5 ohms field resistance, which is exactly right.

A quick test to see if the field is working is to power up the field and see if the rotor shaft is strongly magnetized. A tester made up of two paper clips shows that it is.

by the existence of two field terminals on the alternator (usually marked F1 and F2). In this case measure resistance between F1 and F2.

In other cases you may have a poor connection between the field brushes and the slip rings inside the alternator. To track this down disconnect the field wire and the alternator belt. Then turn the alternator over by hand while checking resistance between the field post and the alternator case (or F1 and F2). If resistance is consistently high, the contact between the slip ring and

Make sure that all battery wires and terminals are clean and secure before worrying too much about your alternator. Note the ground bus bar in front of and below the battery. Good grounding eliminated many potential problems.

the brushes inside the alternator is not good, which again means the alternator needs to be repaired. You may be able to cure this problem by using a fine Scotch-Brite pad on the slip rings. If you have an open circuit across the field (infinite resistance), you may have brushes that have fallen apart or a broken wire in the field winding—time for some major alternator repairs.

Because of their extremely low operating current, digital multimeters do not do a good job of measuring resistance in the field circuit, so it is best to use an old-style analog meter for this. Even if you get a reading of 50 ohms or so, there is no reason to panic. Spin the alternator a few times and see if the resistance goes down. You may also notice that the reading varies as you spin the alternator. This is pretty common and not necessarily a reason for concern if the alternator is otherwise working well. A thin layer of oxidation on the slip rings can easily produce some extra resistance. Higher resistance indicates a possible problem worth further investigation.

If the field wire and the alternator wire short against each other, you will get a potentially very damaging overvoltage situation. A partial stator failure can also cause the field to trip if it has caused an overvoltage spike. Make sure wires are properly routed and secured, and that they can't rub against each other. The price of this mistake can easily run into the thousands of dollars. To guard against this you should install an overvoltage protection module available from B&C Specialty products or other sources for about $35. It is quite easy to install, so there is no reason not to provide yourself with this protection. Rapid loading or unloading of the alternator can also cause overvoltage surges. Some of the current models of Plane-Power alternators have internal overvoltage protection, but others do not. Be sure to find out if this is included in your alternator, or if not, add it to your electrical system.

If you have an overvoltage situation, and you have overvoltage protection, it should trip the field circuit breaker. In such a case you will need to turn the power to the field off (ALT side of master switch) to reset the overvoltage module. Of course, the next thing to do is find out why you had a voltage spike, so it won't happen again.

Be sure to check the tightness of your alternator belt yearly and whenever you are having alternator problems.

Rotax Alternators

The Rotax charging system is a special case and calls for its own diagnostic and repair procedures. There are some simple resistance checks that you can perform to check the alternator. First disconnect the alternator at the plug. Check resistance between the yellow wires and between each yellow wire and ground. Yellow to yellow should measure 0.1 to 0.8 ohms. Yellow to ground should be open (infinite resistance). Next check the resistance between the red wire and ground. This should be in the range of 3.2 to 4.5 ohms. The two colored wires are for the ignition system. If the unit does not pass these basic checks, it most likely needs to be removed and further checked and/or repaired. For more detail on these procedures, please refer to the Maintenance Manual (Heavy Maintenance) for Rotax Engines Types 912 and 914 Series, which is available online. Troubleshooting is also covered in the Rotax maintenance training courses, which are highly recommended to anyone who works on Rotax engines and are required for SLSA Rotax mechanics.

If your electrical system and/or alternator do not already have overvoltage protection, this module available from B&C is inexpensive and easy to install. It is pretty risky not to have overvoltage protection in your electrical system.

The nice thing about the Rotax troubleshooting procedures is that they are very straightforward and can be performed with a good multimeter.

Radio Noise

If you are getting radio noise that seems to be alternator-related, you can use your multimeter to do a quick check of the alternator output voltage. Set your meter to AC voltage and measure from the main bus to ground while the engine is running. If you see more than one volt in the AC scale, suspect a blown diode inside the alternator, or possibly bad brushes. Remember, the alternator is only supposed to output DC voltage. This isn't a perfect test, but it is quick and easy. A ripple meter is an even better way to check stator and diode condition, but most amateur builders will not have one in their tool box.

Suddenly occurring and persistent radio noise is probably caused by a bad diode or a broken stator wire in the alternator. This means a trip to the alternator shop. Intermittent noise is more likely caused by a ground loop, which in turn is likely caused by a bad connection to ground somewhere. Electrical systems that employ a central ground bus are seldom plagued by ground loop problems, but using the airframe for a ground leaves you more vulnerable. These problems can be tough to track down, but simply making sure every single ground connection in your plane is secure and corrosion-free is where you need to start.

Where to Find Help

As with most items made for aviation, the manufacturers of these products are ready to help you sort out your particular problems with their products. Use these resources to speed up the troubleshooting process. Another great resource for all things electrical in aircraft is Bob Nuckolls' *AeroElectric Connection*. There is no other one single source that has so much good information about aircraft electrical systems in one place. For $20 plus shipping it is hard to think of a better investment for an amateur airplane builder.

Leading manufacturers of alternators for Experimental builders include B&C Specialty Products and Plane-Power. Hartzell Engine Technologies now handles the legacy brands such as Prestolite and Kelly Aerospace. In addition they now have a lightweight product line suitable for amateur builders. ✈

RESOURCES

AeroElectric Connection
www.aeroelectric.com

B&C Specialty Products
www.bandc.biz/

Hartzell Engine Technologies
www.hartzellenginetech.com

Plane-Power
www.plane-power.com/troubleshooting.htm

Rotax
www.rotax-aircraft-engines.com/portaldata/5/dokus/d05014.pdf

Cabin Heat Plenum

Inexpensive solution to heat distribution.

BY GARY JONES

When we are building our airplanes, we sometimes overlook items simply because we are excited about flying our handiwork. It is my hope that in spite of that, we never overlook safety. For me it was bypassing the construction of a cabin heat plenum. I had a 2-inch hole in the firewall with a cabin heat box mounted to the firewall. There was a shutoff valve that was controllable from the cockpit. My feet would melt, but the rest of me and the passenger were cold. After a recent winter flight to Nampa, Idaho with my wife, I decided to do something about it. Funny how a freezing, nagging wife is all it takes to motivate change.

One of the great things about owning a kit/Experimental airplane is we don't have to go through expensive STCs to make a change. As long as the change is safe, functional, and easy to use, owners are good to go. To get started, I removed the seatback from my Glasair so I could get up-close and personal with the area where cabin heat entered the cabin. After taking a good look and taking measurements, I was able to formulate a design.

Cabin heat plenum. A 90° elbow (not shown) attaches to the 2-inch flange duct and keeps the plenum away from rudder pedal movement and brake lines.

I ordered the following parts from Aircraft Spruce and Specialty: one flange duct for 2-inch tubing, six feet of 2-inch SCAT hose, one 2-inch aluminum "Y" tube (non expanded), one foot of 2-inch diameter aluminum tubing, and one ACS air vent. Total cost was $162.48.

My Glasair came with an engine heat muff, but the inlet and out ducts were 1.5 inches in diameter. I fabricated a new heat muff and increased the duct openings to 2 inches. This did two things: It increased the airflow through the heat muff, and it kept the exhaust pipes a bit cooler, reducing the chance of cracking. I kept the cabin heat muff the same size (15 inches long, 3-inch diameter). The aluminum sheet metal (.032 inch) was taken to a local sheet metal shop for shaping. Two wooden plugs were made (3-inch diameter), so the sheet metal was the exact radius it would be on the airplane. With that done, it was easy to shape the 2-inch aluminum ducts that would later be welded to the cabin heat muff.

The plan was to have three cabin heat outlets, with one installed in the instrument panel. Next was to have the outlets

The system includes three cabin heat outlets. Two were installed near the floor on the pilot and passenger side, and one installed in the instrument panel.

To increase the outlet pressure of cabin heat, PVC reducers were installed that decreased the outlet from 2 inches to 1 inch.

The new heat muff. Two 3-inch wooden plugs were used during fabrication to keep the sheet metal the exact radius it would be on the airplane.

positioned to blow on the occupants. PVC tubing was used for most of the runs aft of the firewall. I used PVC because the cost is far less than $7.00-per-foot SCAT hose, and I wanted something rigid. PVC can handle 140° F and will start to deform at 160° F. Most hardware stores will have a wide assortment of PVC fittings and tubing. To increase the outlet pressure of the cabin heat (pilot and passenger side), PVC reducers were installed that decreased the outlet from 2 inches to 1 inch.

Not shown in the cabin heat plenum photo is a 90° elbow that attached to the 2-inch flange duct. This was required to keep the plenum away from rudder pedal movement and brake lines.

So, how did it work? If there is such a thing as 100% improvement, that's where the cabin heat plenum with its three heat outlets falls. On a recent IFR flight at 11,000 feet, the OAT was 10° F. We were comfortable with just a long sleeve shirt and jeans. ✈

Photos: Gary Jones

Those pesky inspections.

The initial airworthiness inspection for builders and the condition inspection for non-builders of Experimental/Amateur-Built aircraft seem to cause a lot of concern. While there's no doubt that for some the concern is justified (I'll add some color to that comment a little later), both inspections are quite similar and not all that difficult. Each has the same objective: to insure the aircraft is in a condition for safe operation. From the phone calls I receive, it appears the trepidation of the initial airworthiness inspection stems more from a lack of knowledge as to what is required, and the condition inspection for non-builders stems from possible unexpected costs. Both rank up there with a visit to the flight physician or dentist.

In this column I will cover the initial airworthiness inspection, and in a future column I'll tackle condition inspections.

So, let's discuss exactly what "condition for safe operation" means and how to best verify that. Preparing for the initial airworthiness is really quite straightforward these days. There are certainly lots of resources such as online help and local EAA chapters. There's even a complete packet with all of the required forms that is available from EAA for $15. As I mentioned in an earlier column, I recommend that you find a DAR early in the process, and you will probably get all of the help you need, thereby eliminating surprises or delays. All of the inspections that I have seen delayed have been due to paperwork issues, so let's discuss the most common causes.

Prior to the initial airworthiness inspection being authorized, the aircraft has to be registered, and for that to occur the FAA needs three things: an application for registration, a bill of sale traceable back to the kit manufacturer or original builder, and an affidavit of ownership. If these three requirements are incorrectly done, they get sent back to you, and when you resubmit them, you go to the bottom of the stack again. This can add some very lengthy delays right when you are anxious to get flying.

The application for registration, form 8050-1, is one of the few FAA forms that cannot be downloaded. Most FBOs will have one, especially if they are an active aircraft sales operation. This one has carbon copies, and while prior-certified aircraft can use the pink copy as a temporary registration certificate, it is not allowed for the initial registration. You should fill this one out with your reserved N-number (if you have reserved an N-number, write a short note asking them to assign it to this aircraft). Otherwise, leave it blank and they will assign you a number.

The bill of sale seems to snag a few builders as well. Most of the kit manufacturers have learned that everyone loses these, so they now send them out upon

Here's a great example covering a number of things: Torque Seal on B-nuts and jam nuts, cotter keys on bolts subject to rotation, and metal lock nuts in the engine compartment.

Vic Syracuse

Vic is a Commercial Pilot and CFII with ASMEL/ASES ratings, an A&P, DAR, and EAA Technical Advisor and Flight Counselor. Passionately involved in aviation for over 36 years, he has built nine award-winning aircraft and has logged over 7400 hours in over 65 different kinds of aircraft. Vic had a career in technology as a senior-level executive and volunteers as a Young Eagle pilot and Angel Flight pilot. He also has his own sport aviation business called Base Leg Aviation.

Photos: Vic Syracuse

request at the end of the project to the kit owner. The problems seem to occur primarily where there have been multiple owners. It is not sufficient to submit only the bill of sale from the last builder to you. All of the prior bills of sale must be included back to the original manufacturer. So hang on to them when you purchase a kit. Put them in a safe place with all of your other valuables. By the way, a bill of sale can be the downloaded FAA form 8050-2 or a bill of sale/sales contract that you and the prior owner have signed and dated.

The affidavit of ownership is downloadable as form 8050-88. This one needs to be notarized, so don't forget to have that completed before you send these three documents, along with $5, to the FAA Aircraft Registration Branch in OKC. Normally, it will take three to six weeks, depending upon their workload (or sequestration), to get your registration card back to you. For those who wait until the last minute, there are a couple of companies located in OKC that will hand carry the paperwork through the FAA process within a day or so.

Once the aircraft is registered, you can begin your application for airworthiness. This is another downloadable form, 8130-6. Where appropriate, such as builder, owner, N-number, etc., it should *exactly* match your aircraft registration card. Your DAR will help you with this, along with any other documentation that is needed, such as a program letter, eligibility statement (FAA form 8130-12), weight and balance, 3-view drawings, etc.

Yep, some think the paperwork is bigger than the project itself! Eventually we do get through it, and we can get on to the nuts and bolts (pardon the pun) part of the inspections. This is where the fun starts. (Remember in an earlier column I wrote that we were supposed to be having fun.) I really do have fun performing initial airworthiness inspections because for first-time builders, it is a lifetime event. And sometimes the situations themselves can have some levity.

I like to see the aircraft completely open, meaning I have access to the entire control system. The cowling should be removed, along with the tail fairing and wheelpants. It is not necessary to remove wingtips or gear leg fairings.

See the drilled holes in the bolt heads? These will require safety wire.

The most common greeting I get when I arrive is, "I've had my A&P, IA, Tech Counselor, etc., look it over and we are ready for you." I love the fact that the builder is willing to have others look at his/her aircraft, but in seven years of inspections I have found that some of these have the most discrepancies. The funniest one was hearing this exact statement as I was walking towards the airplane from the right side, with the *red* nav light staring me in the face. Very politely I said that I thought we usually placed the *green* light on the right side. The look on everyone's face as they stared at the light, then at each other, and then back at the light was unforgettable.

I'm usually doing a cursory look as I am walking towards the airplane. On another aircraft I noticed that neither of the main wheels had cotter keys on the axle nuts. When I mentioned it to them, I was firmly told that they had them "cranked down as tight as they could and they weren't going anywhere as they had already completed taxi testing!" Needless to say, the rest of the airplane received a very thorough inspection and required multiple trips to rectify the discrepancies. Intentions were good, but unfortunately, they didn't make use of available resources during the build process.

On an RV-10 I discovered more than 40 rivets missing from the vertical stabilizer mainspar. On a meticulous plans-built and spotless, show-quality Pitts, I discovered a loose B-nut on the main oil line from the sump back to the inverted oil system. I could turn it with my fingers. On this same aircraft the oil temp sender was missing the safety wire. Both of these could have eventually caused catastrophic results. I really recommend that everyone check each jam nut and B-nut with a wrench and then add Torque Seal. I still check them, but at least I know that supposedly someone else did the same.

Here are some of the more common discrepancies I've found on initial Airworthiness Inspections:

- **Loose jam nuts on control rods and rod end bearings:** I find more of these loose than any other single item, so much so that if I don't find one, I recheck. I believe that the recently issued service bulletin from Van's pertaining to elevator spar cracking is due to this very cause. Torque Seal works well here, too.
- **Missing cotter keys:** Wherever the bolt is subject to rotation, castellated nuts along with cotter keys are required. I have seen more than one aircraft without cotter keys on the engine mount bolts and mainwheel axle nuts.

Here is an engine mount bolt with a missing cotter key.

- **Data plate compliance:** This is really a simple area, but gets confusing for some. There are only three things required on the data plate: make, model, and serial number. All three of these are on your registration card and should be on the data plate in the exact same format. And the data plate needs to be of stainless material.
- **Baffling:** Many builders forget to tie the under-cylinder baffling together, as well as sealing the baffling to the engine with RTV or some other sealant.
- **Safety wire:** Common areas are the brakes (not required on all brakes), engine compartment (oil temp senders with AN-900 gaskets, oil filters, gascolators), and flap actuators on RVs.

In all of the inspections I have ever completed, only one builder disagreed with my findings, and that was regarding the need for safety wire on the oil temp probe. (Once I showed him the hole for the safety wire, he agreed.) They have all been really fun for me. I love seeing the ingenuity by some of the builders, and I have taken away some ideas and incorporated them myself.

In the end, we all have the same focus, letting the real fun begin. Safely. ✢

Motor controllers: making DC into AC.

For most motors (we can't get too detailed or complex with the myriad possibilities), the motor controller converts the direct current energy in the battery into alternating current that goes to the motor and makes it rotate. Because different motors run at different voltages, amperages, and different frequencies, the controller and motor must be carefully matched to allow best possible performance and (as an e-bike site put it) "keep the magic smoke *inside* the batteries and electronics!"

Part of the magic in making DC into AC is the controller's pulse-width modulation (PMW), a process that cuts the direct current into a series of carefully timed pulses of selected duration—a kind of Morse code to the motor.

This digital encoding of the analog battery current changes the always on battery "signal" into a series of "on" and "off" signals to the motor. The more time analog current is "on," the greater the amount of current gets through.

Modulation is a good term for what the controller does, though. If the pulses were shut off entirely, no current would flow to the motor. If the pulses were opened up to overlap, so that a constant current flowed to the motor, the motor would probably "freeze" and overheat. Modulation in moderation is a very good thing in this case.

In the greatly oversimplified drawings (the only kind I can make), note that, like all digital signals, things are either *off* or *on*. When a controller shuts the current *off*, nothing energizes the motor. When it opens the circuit for the current, that current is at 100% of the battery's energy, but only for the time it's flowing—which can be in milliseconds.

Your music CD or movie DVD does much the same, sprinkling clusters of *on-off* signals of different frequencies that end up emulating the analog wave patterns that make up sound or light.

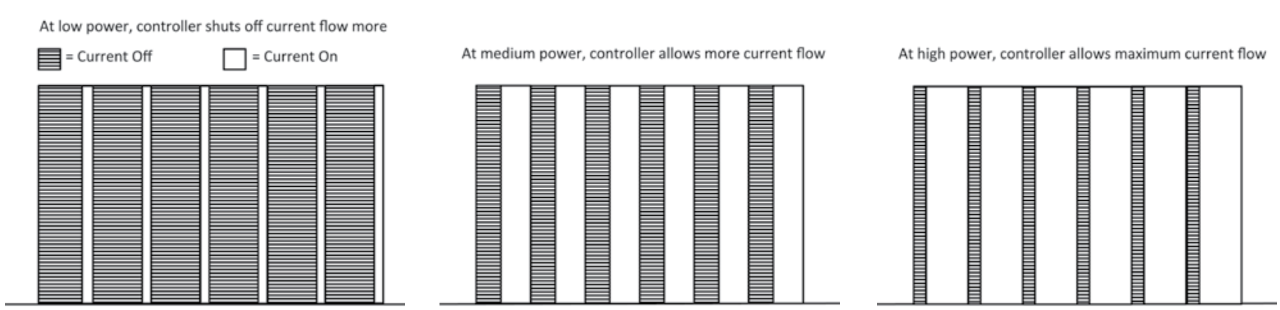
Getting Real

I asked several builders who've successfully flown their own electric creations (or are preparing to do so) what their experience has been and whether they had good advice for those who wanted to try this new form of aerial transit.

The motor is integrated with an electronic speed controller (ESC), which acts as an interface between the batteries and the motor. This controller can be anywhere from the size of a small matchbox to a breadbox (in the ranges we're considering) and controls the motor speed by sending high-speed switching signals to the coils that ring the perimeter of the motor. Be sure to take into account the physical size of the controller and whether it can be fitted into the available space near the motor.

With a three-phase motor, these signals are phased at 120 degrees. The voltage that gets passed to the motor is based on the amount of time that the switching allows for each phase. By switching in microseconds, the controller permits a lower or higher voltage to drive the motor and increase or decrease its speed.

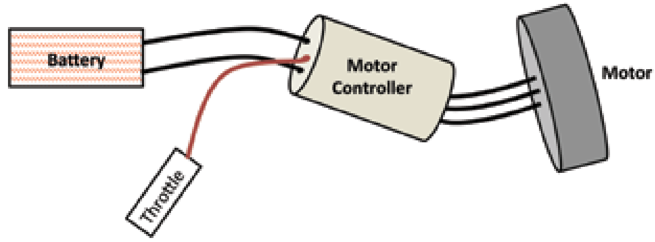
The speed controller is sized to manage the largest amperage that will be passed to the motor, plus an additional (and nominal) 10 to 20 percent or more to permit



Pulse width modulation turns on and shuts off current flow to the motor. Wider openings (more time that current flows) creates more power at the motor.

Dean Sigler

A technical writer for 34 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 six Electric Aircraft Symposia and at several Experimental Soaring Association workshops. Part of the Perlan Project, he is a private pilot, and hopes to craft his own electric aircraft.



Battery motor controller hookup super simplified: Two lines from battery pack to motor controller and three lines from controller to motor show "conversion" of two-phase to three-phase power. Note additional line to controller for "throttle."

occasional excess loads and not damage the controller. Anecdotal evidence shows that wires between motor, ESC, and batteries should be kept as short as practical to prevent damage to the controller. One electric bicycle builder blew three controllers before discovering that sizing and line lengths are important factors.

Getting Similar Answers from Several Experts

I asked these questions as a starting point for discussion:

1. What are your guidelines for a successful motor/controller combination?
2. What contingencies do you take into account in sizing the controller to the motor, other than the correct voltage and maximum amperage that will be drawn by the motor?
3. What line size and length limits do you apply for connecting cables? Between the controller and battery pack? Between the controller and the motor?
4. Are there any special characteristics that you want in a motor controller? For instance, regenerative capabilities?
5. What safety features do you want in a controller?

I received excellent answers from Anne Lavrand at Electravia in France; Mark Bierele, who has flown his e-Gull at Arlington and Oshkosh; Danal Estes, who is developing a motor program for Brian Carpenter's Rainbow Aviation, Scott Macafee at Joby, and a Chinese representative for Kelly Controllers.

Identifying him or herself only as Fany, Kelly's Chinese rep let me know that one of their devices has been successfully used on Mark Bierele's e-Gull. "The controller is our KHB12401. The motor is 30KW BLDC type.

"Our KHB controller is designed by opto-isolated technology. We specify 8-30V for the power supply, which must be isolated from main battery pack. We used dual microprocessors for the KHB controller. The KHB can do regen brake by default."

Fany noted Kelly's KBL12401BC has been used on another airplane. It includes CAN bus linkages used for the display on the dashboard. (We will discuss CAN bus and other connecting elements in the next installment.)

Scott Macafee at Joby Motors explained, "We mostly use Castle HV160s as our controllers. In high power setups (> 6 KW), we've had the most luck running the motors in a 6-phase configuration with two controllers per motor.

"We've got a guy working on a controller right now. I'm not sure how close it is to being flight-ready, but he spins a JM1S at his desk with it regularly."

Mark Bierele, designer, owner and pilot of the e-Gull, gave a little more detail.

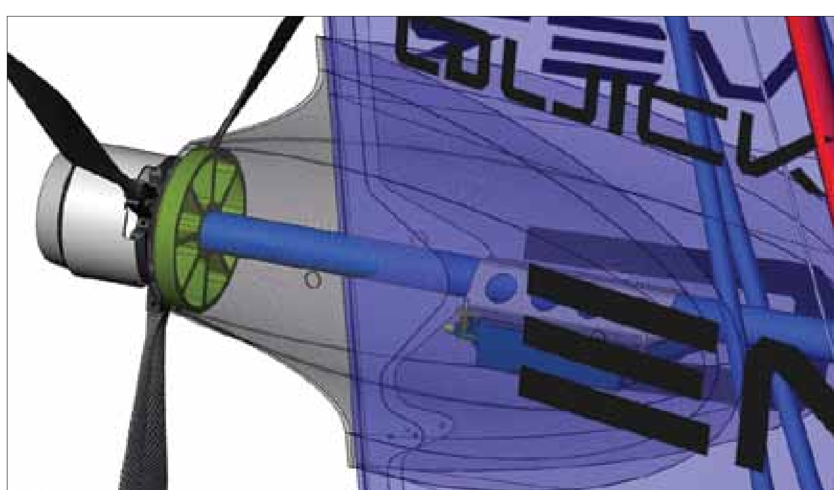
"Each style of motor has its own needs when it comes to the controller. The controller needs to be able to put out its power at the frequency that the motor needs to run at its required rpm. A Joby motor has more poles, so for the same rpm it would need a higher frequency controller. The Joby also runs at a slower rpm because of its larger diameter; this larger diameter allows it to run a prop without a speed reducer. This is an advantage for simplicity."

He noted cost, availability, and the unit's track record as prime considerations.

In connecting things, he explained, "It is vitally important to have short cables between motor and controller; the length of cables to the battery is critical due to voltage drop and weight." Connections require bolting, crimping, and Anderson plugs.

In the most controversial area, Bierele thinks, "Regen is important but not mandatory," and, "reversing is handy for backing into the hangar." (Wow your friends with that.)

Low-voltage cutoff is mandatory, according to Bierele, along with a high-voltage cutoff, over-temperature, overspeed, motor over temperature monitoring, and limiting. All these controls protect the batteries and motor. He advises having a high-throttle



Exploded drawing of Brian Carpenter's motor installation on EMG-6 shows ducting to direct cooling air to controller and motor. Cooling is necessary, even with the motor's high efficiency. A 10-kW motor with 95% efficiency would give off 500 watts waste heat. Try touching a 500-watt heat lamp to understand how hot that is.

Photos: Dean Sigler

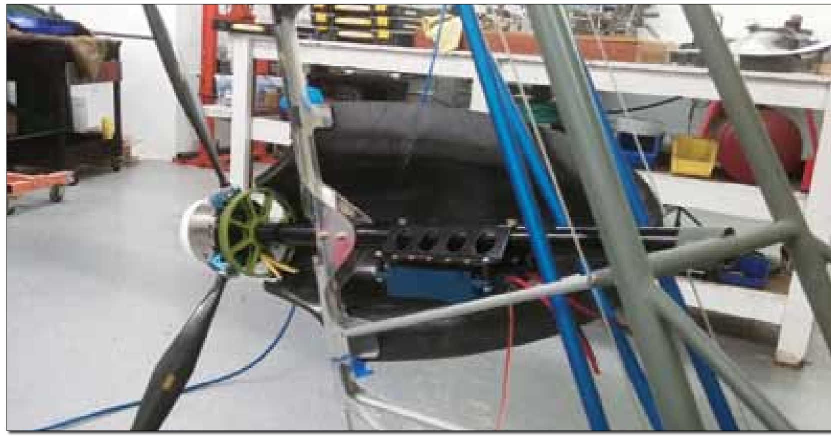
block to prevent the motor running if the key is turned off when the throttle is advanced. This requires pulling the throttle back to a fully-closed position before the key can be turned back on and the throttle advanced.

Anne Lavrand responded, "Concerning the controllers for electric engines: It is important to have a controller especially for each motor. The characteristics of each electric motor are very different, and the controllers have to be adapted.

"We tried to put a controller for a 25 horsepower motor on another one (same power, quite same characteristics), and it was not a good idea: [resulting in] radio interferences, several problems with power, etc.

"The controller has to be put as close as possible to the motor (within a maximum of 50 centimeters, or 19.7 inches). Then the batteries can be farther. There are no reasonable limits on airplanes. We had about two-meter wires on the E-Light2 between the controller and the batteries." (Author's note: this also helped with the center of gravity. However, Electravia no longer provides electric motors, controllers, and batteries. As we went to press, the company announced it "has decided to suspend development, integration and marketing of electric motors in order to concentrate on production of carbon E-Props." For that reason, we do not include them in our resources section.)

Richard Csuk, vice president of operations for Alltrax controllers, gave a good overview of how to go about matching all the electrical bits and pieces.



Real-life version of EMG-6, to be flying soon on electric sustainer power.

"The best advice for choosing a motor controller and motor is to properly size them, not only to the size of the plane but to each other.

Motors:

"Too small of a motor for the plane/prop won't get you the power you need to get off the ground, too big and it's a waste of money and extra weight. There are three main types of motors available: the series wound, the shunt wound, and AC motors. Each has its benefits and drawbacks. In the grand scheme of things, they are a wash, and it really comes down to the budget.

"The current ratings on motors come in two flavors: peak and continuous. There is no standard for what needs to be on the nameplate, so one company might put peak down and another will use continuous. When in doubt, check with the motor manufacturer. A good rule of thumb is that peak is about 3x the continuous rating. I would recommend a motor with Kevlar banding on the commutator bars. In the event of the motor cutting out and the prop free spinning really fast, it will greatly reduce the risk of centrifugal forces ripping the motor apart when the commutator is spun too fast.

Without streamlined cowling, Electravia's record-holding Cri-Cri shows close connections between motor, controller. Note longer lines going to batteries inside fuselage.

Controller:

"Size the controller for the motor. Check that the controller's and motor's continuous rating are in the same ballpark. Don't use a controller with a 100A continuous when the motor has a 300A continuous rating; the motor will never get enough torque to do what the pilot needs it to do. If the ratings are close, or fit in between two controller's ratings, always err on the side of bigger is better.

"Almost all controllers on the market have the ability to be programmed; expect to spend some time dialing in the settings. Each aircraft will be unique, and each pilot has his or her own preferred feel. When laying out the motor/controller/battery system, if the choice comes to having a long run of wires between the controller and the batteries, and the controller and the motor, go with a long run between the controller and the batteries. Distances of more than 20 wire feet between the controller and motor can cause some ringing in the line that will mess up how the motor works; try to keep the motor/controller wire lengths to under 10 feet. [Way under, based on others' experience.]

Safety:

"I am a firm believer in multiple redundant safety systems on some applications. An aircraft is one such application.

All the standard safety systems seen on drawings provided by the controller companies are a good baseline. Install a properly-sized contactor between the batteries and the motor/controller. There is a lot of energy stored in the batteries, so if something were to go south on the motor or the controller, the pilot will want to disconnect the batteries before anything bad happens. I would also recommend a secondary manual disconnect that is easily accessible to the pilot in the cockpit: one of those red emergency mushroom buttons, for instance. That way if the solenoid gets welded shut, the pilot can just hit the button and disconnect everything. All of the wiring should be properly sized—when in doubt go bigger. The only wires we worry about sizing are the battery and motor wires to the controller. Smaller wires can't carry as much current and can overheat.

"Otherwise, a lot of this is common sense. If something doesn't look right, ask or go to the next size up."

Summing Up

General sizing guidelines, both physical and electrical, are remarkably similar for the different users. We'll look at a few more guidelines in the next article and look at some combinations that have flown successfully, including a "plug-and-play" system that could be a model for all vendors of electric aircraft systems. We'll also look at a way readers might participate in developing a next generation motor controller. ✈

RESOURCES

Alltrax Controllers
www.alltraxinc.com

Castle Creations
www.castlecreations.com

Kelly Controllers
www.kellycontroller.com

Piktronik Controllers
www.piktronik.com

Schulze Controllers
http://tinyurl.com/l5t8gel

Sevcon Controllers
www.sevcon.com/

Unitek Industrie Elektronik GmbH
www.unitek-online.de/en

Home Shop Machinist

The lathey guy's guide to work holding.

Most home shop lathe work is done using a standard three-jaw scroll chuck, but there are about as many different ways to mount and hold turnings as there are lathes, or airplanes for that matter! This month, we'll cover the "standard" methods of work holding, as well as some unusual techniques that might come in handy for those occasional jobs that might well leave your friends scratching their heads wondering, "How did you do that?"

Chucks

Everyone is familiar with a drill chuck, right? The three-jaw chuck is basically the same idea, just scaled up and made a bit more useful with clever design. Like a drill chuck, a key (or T-handle) turns a mechanism called a scroll to expand or contract the jaws in unison. Three-jaw chucks usually come with two sets of interchangeable jaws to allow the widest possible range of diameters for a particular chuck body. A scroll chuck is also called a self-centering chuck and can be found with as few as two jaws and up to six jaws or more.

Independent jaw chucks are typically of the four-jaw variety and they probably are the most versatile, but least used, of all chucks. As the name implies, each jaw can be adjusted independently by means of a jackscrew. This allows many interesting possibilities, including holding irregular objects such as rectangles or off-axis turnings like a crankshaft or a bellcrank. Make note that any object that is mounted off-axis is likely to be out of balance and can cause potentially destructive vibration. The spindle speed must be set to the absolute minimum rpm and tested for balance before turning. It's a good idea to *always* stand clear of rotating parts when flipping the "on" switch, but especially when testing potentially out-of-balance turnings.

Independent jaw chucks come in really handy when you need to re-chuck a previously made part. Even though they are called self-centering, all regular scroll-type chucks have some off-center error called runout. Manufacturers typically guarantee their chucks to be within a certain spec. For example, when describing their Model 2337 five-inch chuck, *LittleMachineShop.com* says: "The radial runout of a test bar held in this chuck, when the chuck is mounted true, is 0.003 inch." This does not mean you can't use

L: A typical three-jaw self-centering chuck. R: Independent jaw chucks hold odd shapes.

Bob Hadley

Bob Hadley is the R&D manager for a California-based consumer products company. He holds a Sport Pilot certificate and owns the VW-powered Victory Stanley Fun-Kist.

The D1-4 cam-lock system: three studs in the back of the chuck mate with the spindle. A 90° turn on each of the three cams secures the chuck.

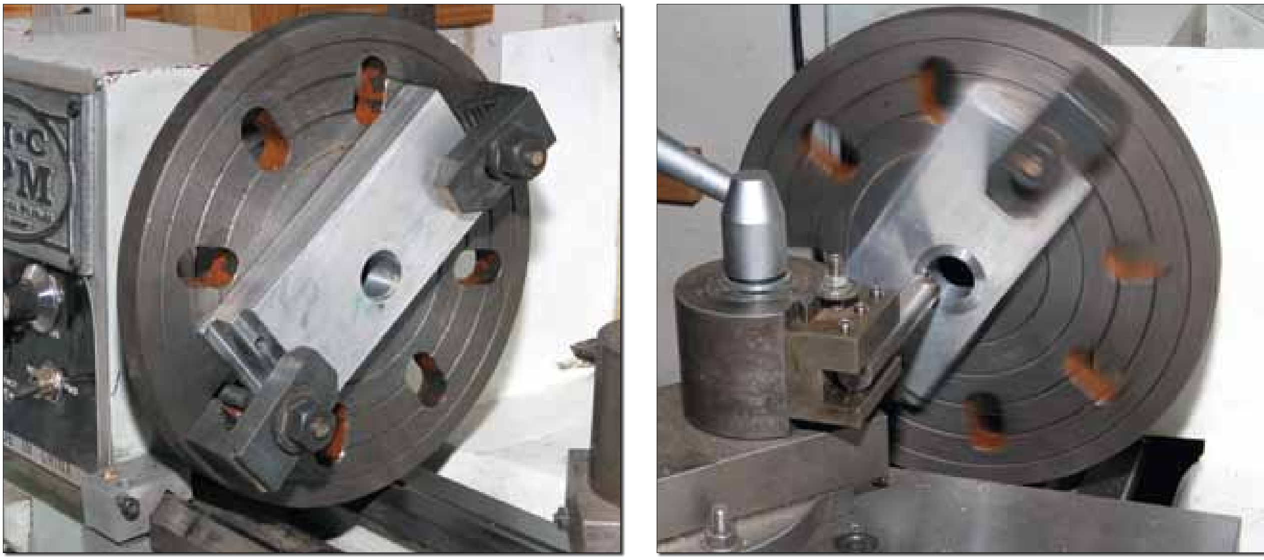
A 5C collet system mounted to the lathe. This particular model uses a scroll system with a T-handle to tighten the collet.

this chuck for precision work. Most lathe work is about reducing (via turning) raw bar-stock into parts, so some small run-out in the chuck is not an issue. The parts will come out round and true to the spindle axis from which they originally were turned. It's only after a part is made and you need to rework or re-machine it does runout become a problem. The spec tells you what to expect in terms of runout in the event you need to remount a previously turned (and concentric) part. That's where the four-jaw chuck comes to the rescue! By using a dial-test indicator and carefully adjusting each jaw independently, you can bring most previously turned parts into near-perfect "zero" runout. The only drawback to the independent chuck is that dialing them in takes some experience and even then, they can be quite tedious and time consuming to use.

Chucks are mounted to the lathe spindle in a variety of standard ways. Most shop and tool room lathes use a cam-lock mount that conforms to a series of standards (D1-2, D1-3, D1-4, etc.) that define parameters such as nose taper, stud location and backplate diameter. Chucks on most mini and hobby lathes bolt directly to a drive flange that is integrated into the spindle. A self-centering recess in the back of the chuck mates with the flange. Many older lathes, and wood lathes in particular, have an external thread on the spindle (usually 1x8 TPI or 1¼x8 TPI). Chucks for these lathes are either threaded or have a matching thread adapter bolted to the back.

This comparison shows the relative size difference between the "standard" 5C collets and the mini-lathe 3C collets. Collets are precision tools that should be stored in an appropriate tool holder.

Photos: Bob Hadley



Faceplates give you a way to mount and turn parts that otherwise would be problematic, if not impossible, using a chuck.

Cam-lock chucks provide convenience of rapid change-out, good precision, and solid mounting for both forward and reverse rotation. Bolt-on chucks lack the convenience of cam-lock systems, but are lower cost, offer good precision, and provide solid mounting for both forward and reverse rotation. Thread-on chucks are as fast and convenient as cam-lock chucks, but can't be reversed, at least not too aggressively, as they will try to unscrew themselves. Most have one or more setscrews to provide some lock to the spindle, but it's a marginal approach at best.

Collets

Collets are split sleeves with an outer taper that are used in conjunction with a drawbar, scroll system, or compression nut to grip a tool or work-piece. The ubiquitous Dremel uses collets to hold a variety of bits, as do all wood routers. Collets for lathes generally hold the parts instead of the tools (there are exceptions, such as when milling on a lathe—Google it if you are curious). What makes collets stand out over chucks is their precision. Collets, when directly mounted to the spindle nose, allow you to re-chuck a part in the lathe with high precision and minimal fuss.

Naturally there's a downside to using collets, and that is you need a large collection of them to cover the smallest to largest diameters. Although there are dozens of configurations, most bench and tool room lathes are adaptable to the "5C" type collets, which go up to a maximum of 1 1/16-inch diameter. The 8x14 lathe I have at home is considered a mini lathe and, as such, it uses "3C" collets, of which the largest diameter is 9/16 inch.

Faceplates

Faceplates are a traditional lathe accessory from way back in the days before chucks. The general idea is you can use a faceplate to fix odd shapes for turning by using clamping blocks, hold-downs, or by directly bolting the work to the slots in the faceplate. Remember, odd shapes usually are out of balance and can cause potentially destructive vibration. The spindle speed must be set to the absolute minimum rpm, and the setup tested for balance before turning. *Always* stand clear when flipping the "on" switch!

Between Centers

When you need a shaft or tube to be perfectly concentric, the preferred method is to turn it between centers. A "dead" center (dead = non-rotating) mounts directly in the spindle (replacing the chuck) and a "live" center (live = free-rotating) is mounted to the tailstock. A lathe dog is often employed to slave the workpiece to the drive spindle to prevent slipping, especially for heavy cuts.

The dead center fits into a taper adapter, which fits directly into the spindle nose. Precision is assured because all the tapered parts are precision ground.

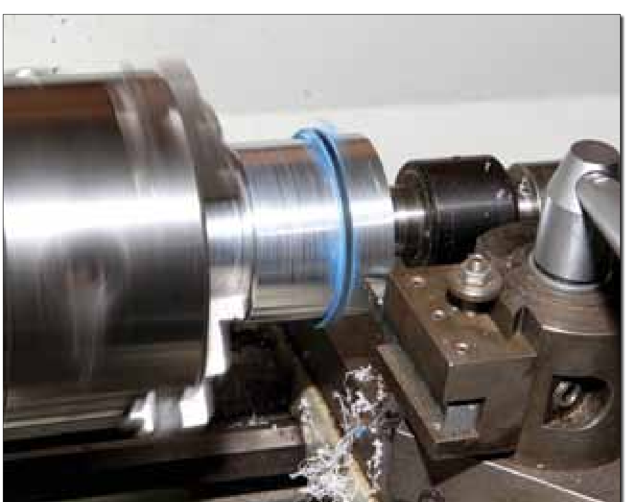
The clamping force of the tailstock live center (right) is often enough to engage the drive center for taking light cuts.

It's also possible to use the compression force of the tailstock to maintain engagement with the drive center. But this only works in limited circumstances where the piece is not too long, too thin, or at all flexible. Even then you are limited to taking very light cuts. The advantage to compression clamping is you can turn end-to-end in a single pass because there is no lathe dog in the way.

Although between centers turning is usually for shafts and spindles, you can turn disks and plates between centers as well. I recently had to make a repair lens for a Hobbs meter. It was the weekend and I couldn't order a new glass lens in time for a Sunday flight. But I did have some ⅛-inch Plexiglas that would be perfect for a temporary replacement. Using my bandsaw, I roughed out a slightly oversize blank from Plexiglas sheet. I then turned a sacrificial faceplate to mount in the three-jaw chuck and a matching tail plate, each out of aluminum (wood or a free-machining plastic like Delrin would also work). Both were slightly oversize from my final target lens diameter. I center-drilled the tail plate so it could be interfaced with the rotating tailstock center. Turning the lens to size was a simple matter of positioning the plastic blank between the two faces, applying sufficient pressure with the tailstock ram to clamp the part, and then turning both the faceplates and lens to size.

Summary

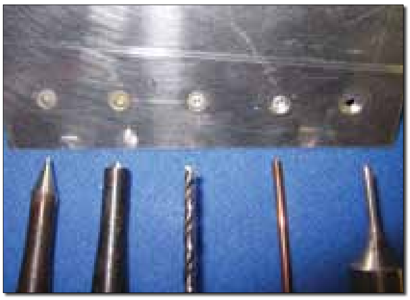
Chucks, collets, faceplates, and between centers represent the most basic methods of work holding on the lathe. For certain shapes that won't fit in a chuck or defy even a faceplate mounting, lathe work can sometimes still be accomplished by building a special fixture to hold the part in a chuck or even between centers. These are outside the scope of basic methods, but it's worth mentioning because it shows the possibilities are nearly endless when it comes to things one can do in the home shop! ✈



In this variation of between centers turning, a small sheet of Plexiglas is turned to a perfect disk (the tape is to prevent scratches). This method can be used to turn any material that is too thin or fragile to machine any other way.

Flush Rivet Removal

BY DAN HORTON



There can be more than 10,000 rivets in an aluminum kit aircraft. Given that many opportunities for errors, you'll surely need to replace a few. Don't worry…removing AN426 flush rivets is easy if you follow these five simple steps.

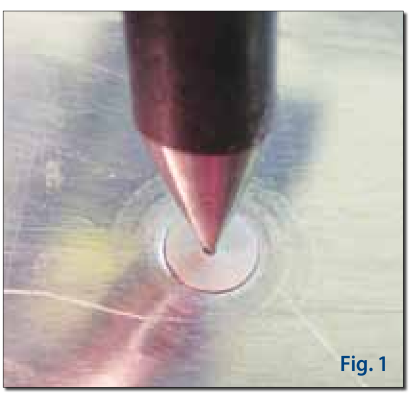


Fig. 1

First, use a sharp prick punch to mark the exact center of the rivet. (Fig. 1).

Fig. 2

Use a low angle center punch to form a wide dimple for drill guidance (Fig. 2).

Fig. 3

Use a new, sharp drill bit. Drill only to a depth equal to the thickness of the head. *Never* drill all the way through the work. (Fig. 3).

Fig. 4

Break off the head using a rod or punch with a sharp squared tip (Fig. 4). The tool here is just a short section of scrap welding rod.

Fig. 5

Now use a punch to push out the rivet shank (Fig. 5). Note the undamaged dimple.

Fig. 6

If the workpiece is thin-gauge aluminum, the material around the hole may be deformed or bent when you strike the punch. To eliminate damage, drill 0.1875-inch and 0.250-inch holes in the end of a spare bucking bar (Fig. 6).

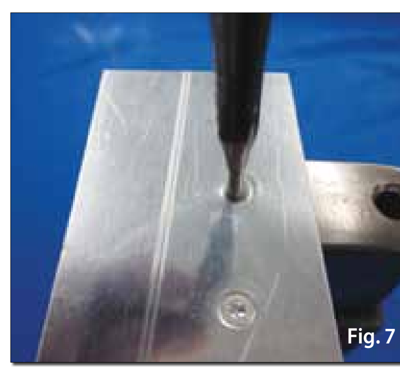


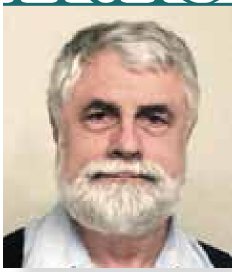
Fig. 7

Simply place a suitable hole under the shop head of the rivet before you strike the punch (Fig. 7). Given good support the aluminum will not be deformed and the rivet shank will pop right out.

Don't have enough hands to hold a backup bar, a punch, and a hammer? It doesn't take much force to pop the rivet shank out of thin material, so try using your spring-loaded prick punch instead.

With a clean, undamaged hole you're ready to set a new rivet. Have fun! ✈

PRACTICAL ELECTRICAL



Battery facts and fables: lithium lead-acid equivalency.

For the past few months I've conducted a market-study on lithium ion batteries offered as replacements for legacy lead-acid engine starting batteries. Lithium iron-phosphate in cylindrical jelly-roll cells seems to be the front-running favorite combination for chemistry and form factors. This combination has demonstrated the lowest risk with the greatest utility in the manufacturing of engine-cranking batteries. I've written several purveyors of lithium batteries requesting engineering data and operational features unique to their products—data that would be mandatory were the supplier seeking to get their product installed on type certified aircraft.

Responses ranged from "That data is not available," or "Sorry, company proprietary," or "Don't know about the numbers, but we sell a lot of them and customers are happy with them." A few suppliers did respond in a cooperative way. However, even the most knowledgeable and cooperative suppliers did not understand the special role that batteries play in many owner-built and maintained aircraft. I'm engaged in an ongoing dialog with the most promising participants and will work with them to refine their marketing approach to owners of Experimental aircraft.

The latest lithium iron batteries, like this one from Shorai, are incredibly light—but the cautious homebuilder should weigh the pros and cons of this weight saving carefully.

A popular marketing term amongst lithium vendors is "Pb-Eq," or lead-acid equivalent. I've come to understand that this term is intended to claim that Lithium Battery X cranks an engine as well as Lead-Acid Battery Y. Another popular phrase is "drop-in replacement" for a legacy lead-acid device. These terms are not quantified…i.e., they have no side-by-side numbers of overall performance that describe the differences between the two chemistries. In an earlier episode, I described a tiny lead-acid jelly-roll cell from Bolder Technologies being offered about 15 years ago. That product cranked an engine right smartly, but in no way was it a "drop-in replacement" for any example of an airframe systems battery. Some suppliers have offered the notion that lead-acid batteries are less tolerant of deep discharge than the new kids on the block. These assertions are in error.

Lithium batteries are offered in three general categories. (1) Arrays of 4 cylindrical-cell modules with no provisions for electronic cell management. (2) An array of said modules with cell management connections brought to the outside. (3) Arrays of said modules with an integral battery management system. Understand further that lithium batteries crafted for user-friendly incorporation into aircraft do have integral battery management systems (BMS).

I was able to peek inside a TSO'd lithium product from True Blue Power. This battery is fabricated from a large array of LiPo jelly-roll cells, along with a boatload of electronics. Further, much of the solid-state circuitry carries or switches the load demands of a turbine engine starter motor—generally 1000+ amps! This is not a trivial achievement in meeting design goals. Given that this battery is qualified to fly on TC aircraft, it might be said to feature the ultimate battery management system.

Product literature from EarthX cites built-in BMS that prevent damage due to high-fault currents, overcharge protection, and over-discharge protection.

Know that the Tesla all-electric car uses thousands of the 18650 cylindrical cells in its battery arrays in combination with sophisticated (read complicated) battery management systems.

Compared with lead-acid, the lithium cell is not nearly so robust. Maximizing service life demands that a cell not be charged to more that 90% of its chemical capacity. Further, a cell will last much longer if not discharged to less than 30% of its chemical capacity. The BMS for some models of the Prius are programmed to

Robert L. Nuckolls, III

Bob Nuckolls retired from Beech Aircraft in 2007 after more than 45 years of work in certificated aviation and over 25 years of support for the homebuilt aircraft industry. Bob publishes "The AeroElectric Connection" from his web site at http://aeroelectric.com.

He also hosts the AeroElectric-List on Matronics.com. This special-interest forum serves approximately 1600 participants.

operate the battery within similar upper and lower boundaries. Products with advanced BMS claim and probably deliver on the longest service life, but battery management intelligence designed for automobiles doesn't sound particularly attractive for airplanes! Does the BMS contained in EarthX products exert similar control of stored energy? Don't know yet.

Consider a product fitted with connectors for an external charger/BMS. Most airplanes are put away with the battery fully charged. Assuming that one attaches a BMS to a hangared airplane, exactly how is this already-charged battery expected to benefit from the nurturing of a really smart charger? Yet some vendors of lithium products claim that battery life may *double* if the battery receives routine maintenance from the external BMS. Doubled you say? Gee, this battery cost me $250! Anything I should do to recoup that investment seems almost a mandatory.

Consider this offering wherein technical details in the advertisement are limited to two lines:

"Technical Details:
(1) 480 Cranking Amps—(Cranking Amps are the power the battery has)
(2) 16Ah (PB Eq)—(Amp Hours are the Capacity of a Battery)."

This no-frills device cites no BMS. The line of chargers offered for use with the Antigravity line of batteries use a simple 2-wire interface not unlike those we've used on lead-acid batteries for 100+ years. The technical details for this product are most noteworthy for what is not said.

The interesting thing is that all of the batteries cited above are assembled from commercial off-the-shelf lithium iron phosphate jelly-roll cells. Some years ago, I did a study on a wide range of brands in AA-alkaline cells *(http://tinyurl.com/kvdm9tx)*. I discovered that there was little difference in performance, in spite of a wide range of pricing and marketing for the alkaline AA flashlight battery. It's not clear that differences in popular LiPo cells of the same size are very great either. It follows that broad variation in claims for performance and operating recommendations may be grounded more in lack of knowledge than well-considered application of the physics.

Just because a supplier says, "Yeah, we have a BMS," doesn't tell you everything you need to know about how that battery will perform. For example, some versions of the 18650 jelly-roll cell are fitted with a simple self-resetting, over-current protection and claim to have a BMS. Other suppliers of the same cell offer sophisticated electronics on an etched circuit board within the battery *(http://tinyurl.com/kwtm34e)*. Suppliers on eBay *(http://tinyurl.com/peby54w)* are offering battery management modules that target 4-cell series strings of various sizes.

The industry does acknowledge the value of electronic battery management features throughout the spectrum of lithium applications. It follows that OBAM aircraft owner/operators should consider the value of capable battery management.

This begs questions that go to understanding how any product offered may (or may not) be applicable to the electrically dependent OBAM aircraft. These questions go beyond the siren call of weight savings and acceptance of present levels of risk for battery fires. These questions go to electrical performance for energy content. How about potential for battery damage due to aggressive, dumb-charging by the typical 40-60 amp alternator? Will service life be commensurate with breathtaking acquisition costs? Are there BMS-induced behaviors that were never a concern with the lead-acid battery?

Another line of questions go to deducing how many watt-hours are available to run critical systems without placing the battery at risk for damage. If I leave the master switch on and the battery stands fully depleted for a day, two days, a week…at what point do I come back to a trashed battery? If I use ground power to start my airplane and then connect the depleted battery to a normally operating 14.2V bus fed with a 60A alternator, how well does the battery recover…or should it be removed for charging by a specialized charger? Finally, what is the rationale for the wide variation in recommendations across the product lines for operation and maintenance of the battery? The latter question is significant, given that the majority of offerings are fabricated from commercial off-the-shelf lithium-iron phosphate jelly-roll cells.

The True Blue battery cited earlier is as close as you can get to a drop-in performance replacement for its lead-acid counterpart in bizjets. Except for a design goal of lowering weight, the electrical performance has to be equal to or better than SVRLA (sealed, valve-regulated, lead-acid) batteries it replaces. The electronics wrapped around that task are astounding. I just bought a really nice, low-mileage minivan for half of what that battery costs. I hoped I was going to discover at least one or two products that are truly drop-in replacements for something like an Odyssey PC680 in airplanes. Some purveyors of lithium products do claim that marketplace position. However, data backing such claims are not yet in hand. Based on what I know about the LiPo jelly-roll cells from which the majority of these batteries are made, I am skeptical of claims for "drop-in equivalency."

EarthX does use a proprietary prismatic (box shaped) battery. For the aviation user, "equivalency" speaks of issues beyond engine cranking and fitting into a battery box. Until data on contained energy, along with limitations for access to that energy, are published, the question of "equivalency" is not fully answered.

As my relationship with the lithium battery industry matures, I'll bring new discoveries to the pages of KITPLANES®. In the meantime, consider joining us on the AeroElectric-List *(http://tinyurl.com/rp8st)*, a forum for exploration, discussion, and discovery of all things electric. If any KITPLANES® readers are experimenting with lithium in their low-risk, day-VFR airplane with gravity feed fuel and magnetos, please join us on the List and share your observations. If any readers are experimenting with lithium in electrically-dependent airplanes, I implore you join the List and let us all sift through the figures and facts together.

Fly comfortably. . . ✢

Ask the DAR

Applying for a repairman certificate, replacing a missing airworthiness certificate.

BY MEL ASBERRY

Question: How do I get a repairman certificate for my E/AB aircraft? What is involved?

Answer: Getting the repairman certificate for your amateur-built aircraft is actually very simple. You will first need to fill out the application, FAA form 8610-2. If you download this from online, make sure you do it double sided.

Check the "Repairman" box in the upper left corner and enter "Experimental Aircraft Builder" in the "rating" box.

Fill out section I. Notice that this form is different from most Federal forms in that it asks for first name first.

Block "M" asks for any other FAA airman certificates. This means pilot, mechanic, instructor, or any other certificates you hold or have ever held.

In Section III under "Type Work Performed," enter the make, model, and serial number as shown on the registration and airworthiness certificate, and the date of certification.

Make an appointment with an airworthiness inspector at your local FSDO. Take the following documents with you and be prepared for a short interview: FAA form 8610-2 (application), a signed and notarized FAA form 8130-12 (eligibility statement), a copy of your airworthiness certificate, your aircraft logbook showing the airworthiness sign-off, and an inspection checklist showing how you will perform the condition inspection on your aircraft.

The FAA inspector will ask you a few questions to determine that you are qualified, and that's pretty much it.

Now, this is the normal procedure. Since the year 2000, I have been issuing my clients a "letter of recommendation" stating that they have satisfactorily shown evidence of their qualifications. This seems to give the FSDO a good feeling, and they typically issue the certificate with very little questioning.

I have known of some FSDOs that will mail the certificate without the personal interview, but that is up to them.

Question: I purchased an Experimental Mustang II from an individual in El Paso, Texas. The airplane had been heavily damaged in a windstorm, so I removed the wings and trailered it to my shop in South Carolina to make repairs. After I got to thinking about it, I realized I never received the orginal airworthiness certificate from the previous owner. I contacted the FAA for a replacement, but they told me that I must first get the airplane ready to fly, and then it needs to have a condition inspection. I have registered the aircraft in my name, and the FAA has told me verbally that it won't take long to get an airworthiness certificate after the plane has passsed an inspection. What are your thoughts? Do you think I will have a problem getting the airplane back in the air?

Answer: It sounds to me as if the FAA has told you that a new airworthiness certificate will not be a problem, and I agree. Most likely the reason that they aren't issuing a replacement certificate is due to the history of the aircraft being significantly damaged and repaired. If this aircraft were referred to me, I would suggest a recurrent airworthiness inspection. Not only would this give you the most up-to-date operating limitations to include your current location for phase I operations, it would also give you the peace of mind of another thorough inspection. I'm sure this is what your local FAA has in mind. +

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

Photo: Mel Asberry

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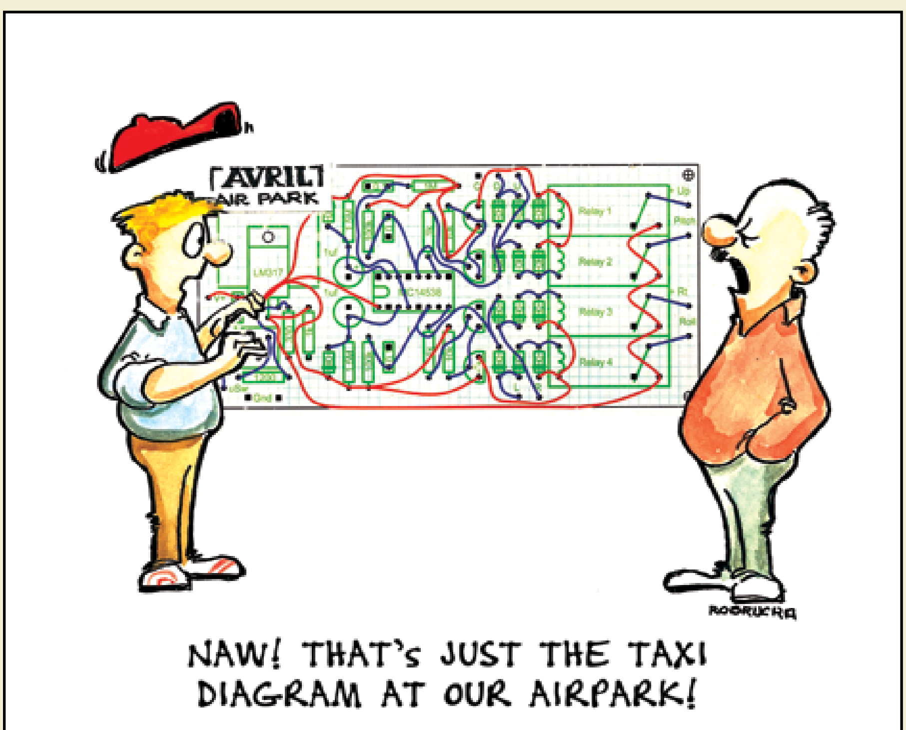
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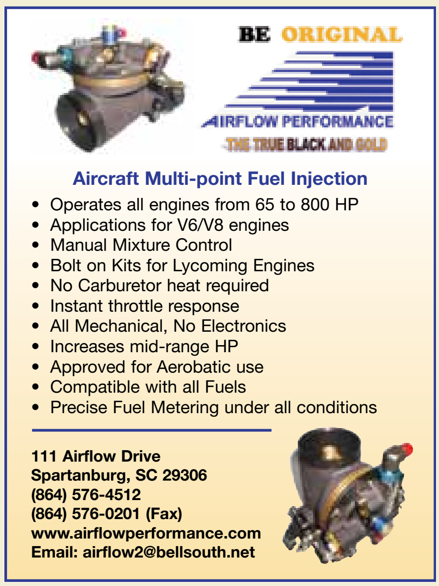

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COMPLETIONS

Jerry Loeffelbein's Sonex

Sonex N1320X took to the air March 29th, 2013 after 3 years (1500 hours) of cutting, drilling, asking, learning, and riveting. N1320X is the culmination of a life-long dream of building and flying my own airplane. Sonex plans are great, and easy to use once you learn to read them properly. The factory builders' workshop was a tremendous help; factory assistance was fantastic after the sale, too. The plane flew great from the first flight, the AeroVee moving it smoothly at about 125 mph. Many thanks for the help and encouragement of friends, family, and EAA Chapter 424 (Home of Miss Veedol) in East Wenatchee, Washington. The graphics are freehand by Dead End Graphics. If you are thinking of building your own plane, I highly recommend a Sonex. The Sonex will be hangared at Cashmere, Washington. You are welcome to come by to see it, or contact me with any questions.

CASHMERE, WASHINGTON
JLOEFFELBEIN@JUNO.COM

Charles McCluggage's RV-8

I finished N188DW and the inspection was completed in the fall of 2012. First flight was November 6. All went well and the plane has been a delight to fly now for over 100 hours. It is powered by an Aero Sport Power IO-375 with dual P-Mags turning a WhirlWind 200RV. An all-Garmin IFR panel, including the G3X, makes navigation and engine management straightforward and adds to the fun. My first cross-country was to Oshkosh 2013, fulfilling a goal I have long held: to fly a plane built with my own hands and park it at the show.

Thanks to the great sport aviation community here in Houston, with a special shout-out to Doug Knab for his help and encouragement. And a final very special thanks to my wife Susan, who is always supportive of whatever I want to do. When a task produced less than pleasing results and I was a bit down, it was her encouragement that kept me going.

HOUSTON, TEXAS
CMCCLUGGAGE@COMCAST.NET

Vernon Little's Harmon Rocket

Harmon Rocket C-GVRL is my second completion. The first was an RV-9A C-FVRL. The VRL twins are hangared at Victoria International Airport (CYYJ). On August 21, 2013 I flew the Rocket for the first time. Perfect day, almost perfect flight with just a few snags.

The Rocket is a test mule for several avionics devices that I designed and put into the public domain through MakerPlane. Flies like a racehorse, not a mule!

Special features of this aircraft include modifications to use the sliding canopy from the F1 Rocket, oversize tires for rough fields, IO-540-D4A5 with roller lifters, Raven 1/2-inverted system, propeller shaft seal to reduce air leakage around prop, plenum, single mag plus Electroair ignition, single SkyView VFR panel, centralized electrical system using breakers and automotive relays for all loads.

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COMPLETIONS

Richard Yerian's GlaStar

I started building the GlaStar in 1996 with the help of my wife Judy. The time to complete it was 17 years. The project started in a two-car garage in Phoenix, AZ, and when it outgrew the garage, a hangar was purchased at a local airpark. From time to time, the project took a backseat to other things, which explains the long build time. The kit was purchased before quickbuild kits, therefore, all the work except the paint and upholstery was completed by the builder. I stopped counting at 3000 hours. The engine is a Lycoming O-320 with a three-blade wood prop. Top speed is about 135 knots.

INDEPENDENCE, OREGON
AZYERIAN@COX.NET

Larry Long's Sonex

My first-time project N635LL was flown on December 5, 2012 by my mentor/hangar mate, Wayne Andrews, at Siler City, North Carolina Airport. The kit was started even before my first ride in a Sonex. I soloed a J3 Cub in 1957, however life got in the way, and I am just now working on a Sport Pilot Ticket at $77\frac{1}{2}$ years old. The Sonex is powered with a Jabiru 2200 engine and has dual controls. The paint is Sun Yellow Krylon from a rattle can! I received great help from all my RC buddies, especially Chris Bobo and Wayne Andrews. Great kit, plans, and support from Sonex!

CANDOR, NORTH CAROLINA
LARRYLONG@EMBARQMAIL.COM

Tom Robertson's Glasair

This aircraft combines the lighter airframe of the Glasair IIS/R aft of the firewall, Glasair III components forward of the firewall, and a modified Lycoming IO-540. At 300 pounds lighter than the Glasair III, it approximates the performance of the Lancair Legacy with 6G+/4G- stressing.

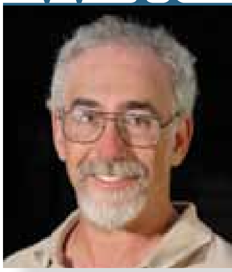
The wing airfoil was modified to approximate the NLF airfoil on the P51D Mustang with consulting assist by Ed Horki, chief aerodynamist of the Mustang in WWII. Other consulting contributors were Jeff Viken at NASA Langley, and Roy Lopresti.

Over the last 15+ years, N25SX has accumulated over 1300 hours on numerous long cross-country flights, including one stop across the U.S., and Guatemala to McAllen, Texas, nonstop over Mexico averaging 215 KTAS at 11,500 msl.

ROBERTSONTHOS@GMAIL.COM

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 1295, Dayton, NV 89403. 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.



Critical flutter airspeed.

Over the past few months we have been discussing various aspects of aeroelasticity. This month we turn our attention to the vitally important subject of critical flutter airspeed. This is of particular concern in the world of homebuilt and Experimental airplanes, where many builders are making modifications to increase the performance of their machines. These modified airplanes are often flown higher and faster than the original design was intended to go. In so doing, the pilots are going onto flight regimes where the flutter characteristics of the airframe have not been determined.

As we have already seen, flutter can be extremely dangerous because it can come on very rapidly and cause catastrophic failure of the airframe. There are misconceptions about flutter speed that have become quite common. This article is intended to expose and discuss these misconceptions, and provide some perspective on their effect on safety from catastrophic flutter.

The mathematics of flutter is very configuration dependent. It is so complex that it is daunting to all but the most expert specialists in the field, and far beyond the scope of anything I could discuss in these pages. It is critically important that the reader should take the principles I am about to discuss as a warning of danger, and not an assurance of safety.

> *"Some fear flutter because they do not understand it and others fear it because they do."*
>
> —Theodore Von Karman

Flutter Factors:

Mechanism

A structure has multiple degrees of freedom, or ways it can distort. Each type of distortion gives rise to a mode of vibration. When two modes have the same natural frequency, the motions of the modes can couple, allowing one mode to directly affect the other.

If two modes couple, and the mode shapes are such that deflection in one mode causes forces that amplify motion in the second mode, there is the potential for flutter. For example, wing twist changes the lift of the outer portion of the wing, which in turn changes the bending moment on the wing. Accordingly, a change in wing twist (one mode) causes a change in wing bending (other mode). If the natural frequencies of the first wing bending mode and the first wing torsional mode are the same, there is a potential for flutter.

Flutter Onset

As airspeed increases at constant altitude, the magnitude of the aerodynamic forces on the airplane increase proportional to airspeed squared. The natural frequency of some of the deflection modes also change, typically increasing with increasing airspeed.

If the natural frequency of the right two modes come together, and the airspeed is high enough for the aerodynamic forces to overpower the damping in the system, then the structure may flutter. In perfectly smooth air, an airplane flying above this critical flutter speed may not start to flutter immediately. Flutter can be triggered by a gust or a control input that produces a force that excites one of the critical structural modes. Once started, the flutter will continue or build in magnitude until it is either stopped by a physical constraint of the structure or a sufficient reduction in airspeed. If neither of these happens soon enough, the flutter will amplify until the structure fails.

This possibility of exceeding the minimum speed for initial flutter onset without fluttering right away is extremely dangerous because when the flutter starts, the airplane will be flying fast enough for the flutter to be violent and sometimes destructively divergent. It could prove difficult or impossible to slow the airplane down enough to stop the flutter in time to avoid structural failure.

Forces

If the proper mode shapes of structural deflection exist, and the frequencies couple as discussed above, there is the potential for flutter. Whether flutter happens or not is dependent on how the forces driving flutter, and the forces opposing it, develop.

Driving forces

In a potential flutter situation, the structure deflects in a way such that the

Barnaby Wainfan *is a principal aerodynamics engineer for Northrop Grumman's Advanced Design organization. A private pilot with single engine and glider ratings, Barnaby has been involved in the design of unconventional airplanes including canards, joined wings, flying wings and some too strange to fall into any known category.*

Photos: Paul Dye

change in shape causes aerodynamic force to develop that tends to increase the motion of the structure in at least one of the critical modes. These aerodynamic forces are driven by the external airflow and add energy to the developing structural oscillation.

Damping

There are also aerodynamic forces and mechanical forces that arise as a result of the motion of the structure rather than its distortion. These damping forces oppose the velocity of the moving parts, and absorb and dissipate the energy added to the system by the aerodynamic forces caused by shape changes.

The winner of the battle between these two sets of forces determines whether the system will flutter. As long as the damping forces absorb more energy than the "propelling" forces add, the system is stable and any oscillation started by a perturbation will die out as the damping dissipates the excess energy.

At some point, the propelling forces grow so large that they add more energy to the motion than the damping forces can absorb. At this point, the oscillation starts to grow, until it either reaches a stable amplitude, or until the forces it generates get so large they cause structural failure. Once it starts, the flutter can grow very quickly.

Flutter Speed

The reason this interplay between propelling forces and damping is so critical in understanding flutter speed limitations is that the propelling forces and the aerodynamic damping vary differently with changing airspeed.

Types of Airspeed

Two airspeeds are important in the development of flutter.

The first is indicated (or equivalent) airspeed (EAS). This is really a measure of dynamic pressure, rather than actual velocity. The equivalent airspeed, which is what a pilot would read from a perfectly-calibrated airspeed indicator, is the speed that would produce the same dynamic pressure at sea-level conditions.

The second is true airspeed (TAS). True airspeed is the actual velocity the airplane is travelling relative to the air.

As altitude increases, and the air density decreases, TAS and EAS diverge. If we fly constant true airspeed, equivalent airspeed will drop with increasing altitude.

If we fly constant equivalent (or indicated) airspeed, then the drop in air density requires that we fly at ever-faster true airspeed as altitude increases.

This is important for flutter safety because most pilots only have indicated, or equivalent, airspeed information in the cockpit, and the onset of flutter is a function of both true and equivalent airspeed.

Airspeed effects

The propelling forces, which are caused by the interaction between the geometry of the aerodynamic surface and the air, are strictly a function of the geometry itself and the dynamic pressure in the airstream. Dynamic pressure is a function of equivalent (or indicated) airspeed. Accordingly, for a given-shaped surface at a given angle of attack, the aerodynamic forces will be the same at the same indicated airspeed regardless of the true airspeed.

Aerodynamic damping is a function of both equivalent airspeed and true airspeed. Some insight into why this is comes from looking at aerodynamic damping of wing bending. As the wing bends, or flaps, the outer portion of the wing is driven vertically, either up or down, by the motion of the wing flapping. The vertical velocity of the wing, combined with the true forward airspeed, give rise to a change in angle of attack. This angle of attack change increases the lift of a down-flapping wing, and decreases the lift of an up-flapping wing. This opposes the flapping motion and tends to cause it to die out.

What is important here is that the angle of attack change caused by the flapping vertical velocity is the vector sum of the flapping motion and the true airspeed. For a constant flapping rate, the higher the true airspeed the lower the angle of attack change. This has large effects on flutter.

Constant Altitude

At constant altitude, as true airspeed increases, dynamic pressure increases

Most modern EFIS displays can adjust the redline to represent the current IAS that corresponds to a fixed TAS redline. This often makes the yellow arc (or band) become very small or disappear completely on the airspeed indicator, as is evidenced in this high-flying picture.

proportionally to the square of the speed. The propelling forces thus increase with airspeed squared.

At the same time, the angle of attack increment caused by a given flapping oscillation is decreasing as true airspeed increases. Since damping force is determined by both the angle of attack increment and dynamic pressure, aerodynamic damping also increases, but it is roughly proportional to airspeed, rather than airspeed squared.

Since the propelling forces rise more rapidly with increasing speed than the damping does, at some critical speed, flutter sets in.

Constant Dynamic Pressure

The situation is dangerously different if we maintain constant equivalent (or indicated) airspeed and increase altitude.

As altitude increases at constant EAS, true airspeed increases. Because the dynamic pressure is constant, the magnitude of the forces that propel flutter stays constant.

Damping, however, drops as true airspeed increases with altitude because the angle of attack increment caused by a given flapping velocity is less at higher true airspeed. Since the damping force is a function of dynamic pressure and angle of attack increment, the damping decreases as altitude increases at constant indicated airspeed.

This can be dangerous because if the damping drops sufficiently, flutter can set in at an indicated airspeed below what is believed to be the critical flutter speed of the airplane.

Critical Flutter Speed and Flutter Clearance

There are two "absolutist" ideas about flutter speed that seem to have gained some prevalence in the homebuilt community, particularly among those who are seeking to improve performance of their airplanes.

One school holds that as long as the airplane is flying at or below the *indicated* airspeed for which it has been flutter cleared, it is safe.

The other school holds that flutter is strictly a function of true airspeed, and that the "real" critical flutter speed is a true airspeed.

Both of These Assumptions are Wrong

As we have seen above, the idea that a single indicated airspeed is valid as a flutter limit is dangerously wrong, since increasing true airspeed at constant indicated airspeed can easily lead to a situation where aerodynamic damping can no longer prevent flutter.

The variation of flutter speed with true airspeed is more complex. We have discussed the effect of true airspeed on damping here, but true airspeed also affects several unsteady aerodynamics phenomena that define how the forces on a rapidly-moving surface develop. These are far too complex to attempt to discuss in these pages. Keeping the airplane at or below the maximum true airspeed for which it has been flutter cleared is more conservative than limiting indicated airspeed, but it is not an absolute guarantee of safety if the airplane is outside the altitude envelope that has been flutter cleared.

An airplane is flutter cleared to a specific flight envelope during testing. This cleared envelope defines the range of speeds and altitudes in which the airplane is safe to fly. If the airplane is flown outside that envelope, either at higher true airspeed or at higher equivalent airspeed (or both), it is flying in an area where its existing flutter testing does not apply, and there is significant danger of a catastrophic event.

Any expansion of an airplane's flight envelope outside that which has already been tested requires additional flutter testing to ensure safety.

One Final Warning

Flutter testing is probably among the most dangerous of flight tests, particularly for light airplanes that lack the sophisticated instrumentation, telemetry, and ground technical support available on big commercial and military airplane programs. If you do choose to test to expand the flutter envelope of an airplane, follow proper testing procedures, and proceed with extreme caution. ✈

Can you hear me?

When Brother Bell (Alexander Graham, that is) was doing his experimental work on the telephone back in 1875, he accidentally spilled battery acid on himself and the first words spoken over the telephone were his call for help, "Watson, come here, I want to see you." History does not clearly record what Watson said back, but I'll bet it went something like this: "Hi, this is Watson; I'm sorry I'm not here right now, but if you leave a message at the beep…"

Back in the March 2013 issue of KITPLANES®, I did a whole column on how aircraft headset circuitry worked. I also had a very simple circuit for go/no-go testing of the headset. That circuit was about the simplest thing I ever designed, and I'd like to do a brief review of that column and then launch into a two-part series on making a *real* headset tester. This design will not only let you do qualitative measurements, but the third iteration of the circuit will let you set the microphone level so that all your headsets will match one another.

Let's do a short review of how headsets came to be what they are. Mr. Bell's invention was the inception of how we turned voice into electricity, and the carbon sacks he used as variable resistors had somewhere between 100 and 300 ohms of resistance (depending on how you shook them, how you held them, and who was leading the National League at the time). Later work with the carbon (and its progeny, the dynamic and the electret) microphone standardized the impedance at 150 ohms with a nominal output of half a volt (500 millivolts) peak to peak.

The caveat here is that military microphones don't follow the civilian rules. A lot of military microphones do *not* have amplifiers in them, and they standardized the impedance at around 5 ohms, with an output of roughly 50 to 100 millivolts. The question then becomes, can we convert a military headset for civilian use? Sure, given enough circuitry, anything is possible, and I just might do that in a future column.

But for now, let's get back to the story. Bell needed just a little bit of sound pressure into his earpiece and found that a 300-ohm winding gave him what he needed. The first telephones used 150-ohm microphones and 300-ohm earpieces. However, when we went to use his invention on an airplane, we found we needed both ears covered if we wanted to preserve our hearing. The choice was to wire the left and right ear from Bell's 300-ohm earpieces in series or in parallel. For whatever reason, the military decision was made to wire them in series (probably because the vacuum tube

The source of the microphone plug used in civilian aircraft. This switchboard was typical of the tens of thousands such switchboards in common use by large companies from the 1920s through the 1950s.

Jim Weir

is the chief avioniker at RST Engineering. He answers avionics questions in the Internet newsgroup at www.pilotsofamerica.com. His wife, Cyndi Weir, was his high school sweetheart 50 years ago and now she keeps Jim from making stupid blunders in spelling and grammar. Check out his web site at www.rst-engr.com/kitplanes for previous articles and supplements.

amplifiers of the day could more easily drive the higher impedance), which gave us 600-ohm headphones. From shortly after WW-I to about 1975, 600 ohms was the standard headphone impedance.

Then somebody had an earpiece open up on them, and just like the old Christmas tree lights that were wired in series, the entire headphone was dead. Rethinking the process (and now that we had the wonderful transistor that could handle the load), the standard became to wire the 300-ohm earpieces in parallel, giving us headphones with a 150-ohm impedance. And so we come to today's standard headset with a 150-ohm headphone and a 150-ohm microphone.

"But Jim, the plugs…" Again, a sop to 1920s technology. Civilian aircraft plugs have a standard ¼-inch plug for the headphones, but a smaller diameter 3/16-inch diameter plug for the microphone. Why? Because all the telephone company switchboards from the 1920s to the present day use 3/16-inch plugs for their connectors.

If you will recall from that 2013 column, we made a headset tester using only the headset itself, a 9-volt battery, a 470-ohm resistor, and a 100-microfarad capacitor. Simplicity itself, and that schematic is reproduced here. The problem is that simply connecting the microphone to the headphone directly creates a lot of distortion. If we are checking for distortion rather than go/no-go, this isn't the design that we should be using.

The author's Sierra College Mechatronics class putting together and testing the advanced headset tester. The total time to construct the prototype board on the desk in the background was less than an hour, and it worked the first time.

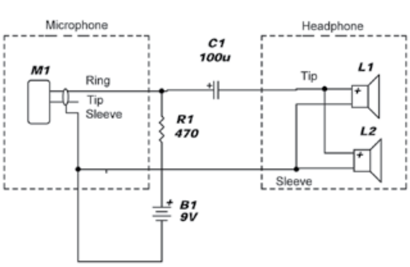
Not only that, but I'd like to be able to have a second headset on the tester at the same time, so that I can listen and talk in comparison to a known good headset to the one under test.

Shucks, that's pretty easy, too, especially for those of you who have been reading this column for a while. You know that I particularly love the little LM324 four-amplifier-in-one-chip device, but they came out with a single amplifier version of that device called an LM386 that drives power up to and including 8-ohm speakers. With a 9-volt battery, we should be able to get over 60 milliwatts to those 150-ohm headphones, and that amount of power that close to your head will ring your chimes. We will actually wind up toning that output down to something reasonable to listen to.

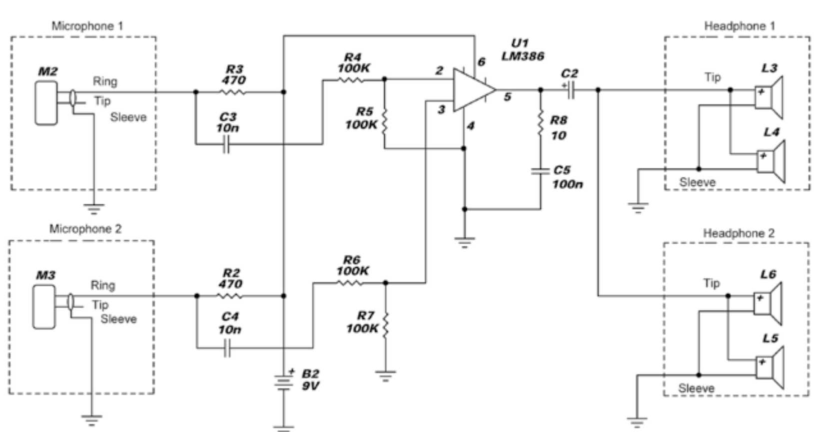
Same bias scheme, but now we are going to be able to use small plastic capacitors to couple the microphone signals to the amplifier, as well as use much smaller electrolytic 10-microfarad capacitors from the output of the LM386 to the earphones.

That's not bad. Another $2 worth of parts and we can now reasonably evaluate the quality of two headsets side by side. Next month we'll come up with some super-spiffy stuff that will let us use either the little 9-volt battery *or* a regular 12-volt aircraft/automotive battery or power supply.

Until then, stay tuned… ✢



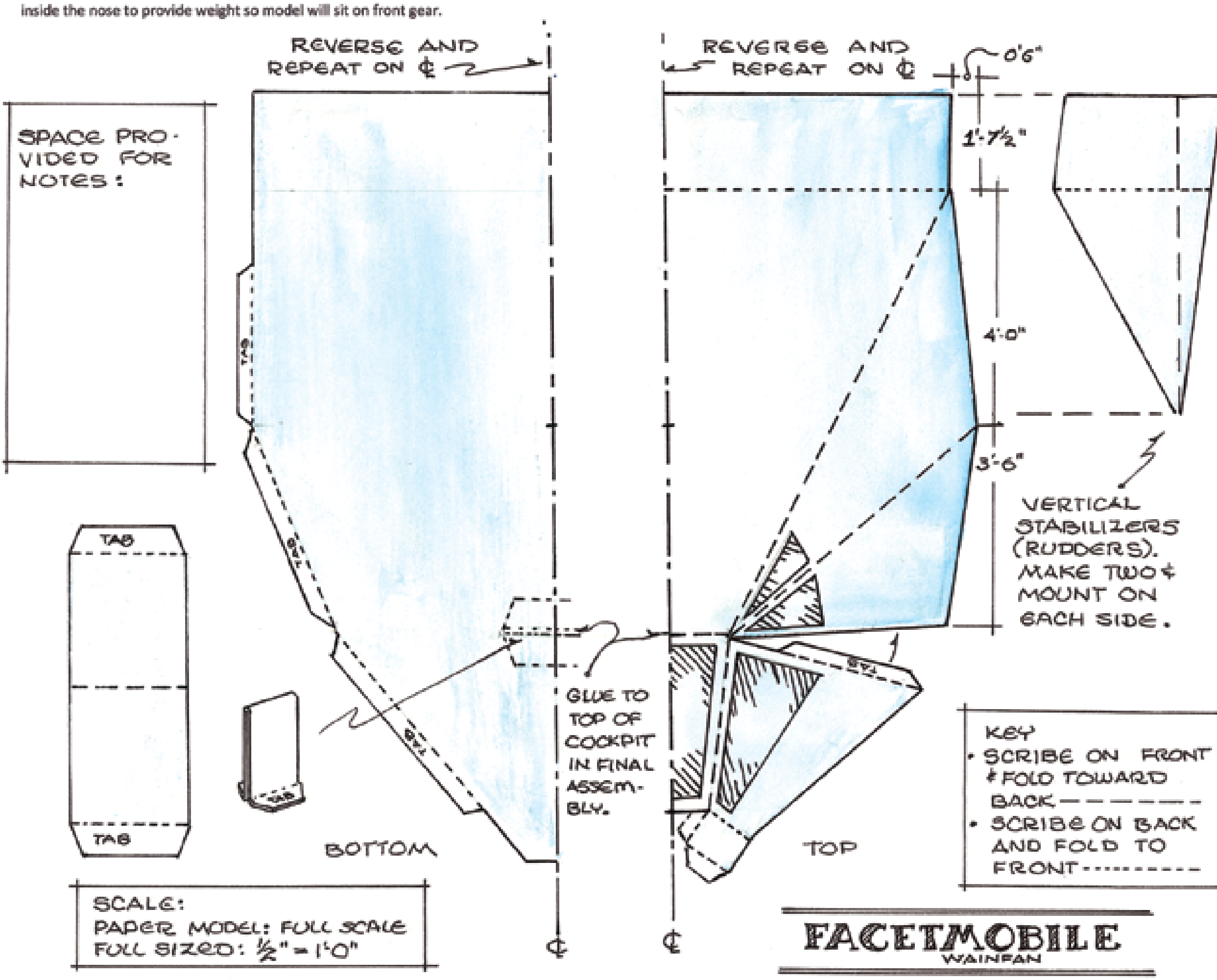
This is the original cheap and easy but limited-quality tester.



This is the new and improved "quality" headset tester.

ANOTHER FACET

Paper Model: Step 1: Layout plans, full size on a piece of 2 ply Bristol paper. Reverse and repeat each side of top and bottom and join in the middle to make a solid piece of Bristol for the top and one for the bottom. No joint is necessary. Step 2: Carefully cut out the top and bottom with an X-ACTO knife (including tabs). Step 3: Note scribing lines (front or back) and scribe and fold pattern and tabs. Step 4: Cut out and fold the support post. Glue in place on the bottom piece where indicated. (Note: **It might be advisable to cut the pattern of the top slightly large to allow for last minute adjustments.**) Step 5: Beginning at the back of the model, **on the elevators only**, glue the top elevator to the bottom elevator being sure that the nose of the top layer is lined up with the nose of the bottom layer. Step 6: Now work your way forward up each side, folding the top to fit the line of the bottom and folding the bottom tabs up and gluing them to the underside of the top panels. **From here on you are on your own.** If you do wish to add the gear be sure to put a piece of clay inside the nose to provide weight so model will sit on front gear.



Full Sized airplane: (fuggedit!) Step 1: Please remember that this is a high performance aircraft, modified in the fertilized (not fertile) mind of a cartoonist, not an aeronautical engineer! Step 2: If still intent on reproducing the full sized airplane from these instructions please schedule an appointment with your psychologist and get a certified, written release (which must be posted in a conspicuous spot on the finished aircraft.). Step 3: Sober up completely! Step 4: Acquire sheets of .125 Stainless Steel. Contract with a large metal forming company to cut and bend the full size pattern and weld the joints. (If you haven't changed your mind by this time it might be a good idea to have them weld the cockpit shut!) Step 5: There will be considerable manufacturing and designing on parts as you go. Step 6: Stay sober! Step 7: Obtain heavyweight, high speed tires and wheels for the gear and work out the retract engineering (ref: B-36). Step 8: Engineer and install air to air re-fueling probe. This baby will suck up gas like there is no tomorrow. Step 9: Hang a supercharged IO-540 on the nose. (Don't worry about FADEC. If you insist on trying to fly this thing you won't be around that long.) Step 10: Taxi test on any 10,000' hard surface runway at sea level or at Edwards Air Force Base.

Note: If you have actually gotten this far, the editor and designer will disclaim all knowledge of the endeavor! (Sincere apologies to Barnaby Wainfan!) ROBRUCHA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