PILOT LOG: DOES JUDGMENT TRUMP SKILL *EVERY TIME?*

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KITPLANES
THE INDEPENDENT VOICE FOR HOMEBUILT AVIATION

EDITOR'S LOG

Long and winding roads.

As this issue goes to press, images of AirVenture 2011 are receding in the rearview mirror. However, some highlights remain vivid. By far, the outlook of vendors and attendees at the show was surprisingly upbeat. This is not Pollyannaism on my part, and I wasn't alone in this observation. Sure, there were a few no-hopers (there always are), but they were definitely in the minority. Whatever the reason, people were focused on their plans for the future, and most seem determined to carry on and make the best of it. We picked up a number of ideas for articles at the show, and we'll be bringing them to you in coming months.

I was eager to meet and/or reconvene with some of our contributors face to face as opposed to communicating with them long distance as I usually do, and I wasn't disappointed. I came away impressed that, to a person, they are stalwart and genuinely want to make a positive contribution to this publication. We're lucky to have them. Speaking of which, a new column debuts this month from Steve Ells, formerly on the "Engine Beat" beat. We hope you enjoy reading "Maintenance Matters."

By Way of Background

On to our cover story this month, and it's one that has been a long time coming. Marc Cook and Paul Bertorelli visited the Glasair Aviation factory in Arlington, Washington, for a photo session in the fall of 2010. And here we are in the fall of 2011. There are some good reasons for the timing. Glasair's Sportsman TC was readied for an Oshksoh debut in 2010, its test time flown off, determined to be safe to fly. But cooling systems and fuel trim had not been tested extensively at that time, and the lean-of-peak performance wasn't where the company wanted it to be.

The problem was that General Aviation Modificatons, Inc., which had spec'd the engine installation for Glasair, wants a max cylinder head temperature of 380°, and you can only add so much fuel before running into that limit.

So after Oshkosh 2010, Glasair sent the demo plane back to GAMI to have them help fine-tune the turbo installation. (GAMI had done the same thing on a contract basis for the turbo Cirrus SR-22.) GAMI made minor changes to the cooling flow and baffling, and retarded the ignition timing, and then recommended that the fuel flow be increased. This last bit happened (courtesy of Precision Airmotive) on the morning Marc was there to fly the airplane last July, and was necessary because the engine was generating excessive heat during climb, starting at a deficit before even reaching altitude.

Glasair's original thinking about the TC, says Marc, was that it would be a good thing for all pilots because a number of Sportsman 2+2 owners had been clamoring for better performance at altitude despite perfectly fine climb performance with either the IO-360 or IO-390 Lycoming. But as Marc so aptly points out in his flight review, turbocharging complicates everything, and the cost is high for the performance gain. I'll let you read his article to get the rest of the story.

The road of the title is a metaphor for the difficulties common to small companies that aspire to greater heights: an admirable goal in theory, but one that presents significant challenges in practice. Such companies often don't have the resources to complete the required engineering, which means that they farm it out and pay for the privilege. Ideally, to mate the engine and airframe successfully, extensive in-flight testing would be done, but if there is only one demo plane, taking it offline may be prohibitive. Few outfits have dedicated test pilots who can devote themselves full time to the fine-tuning effort. And even small changes can have a big impact, so testing must be done methodically to isolate specific causes and effects.

The result, in this case, as Marc says, is an airplane that while entirely capable, may ultimately appeal more to those with a specific need than to the "masses." Still, companies like Glasair are to be commended for doing something new and advancing the industry in the process.

About Those Sub Alerts

Thanks to everyone who has notified us of fraudulent subscription offers. As a heads-up, KITPLANES® customer service has moved from Palm Coast, Florida, to Big Sandy, Texas. You can find the complete contact info on our masthead on Page 5. If you receive correspondence from Big Sandy, fear not. We'll continue to provide the quality customer service you expect from this new location.

Also, we got a name wrong in the September "Learning to Weld" article. The TIG welder pictured on Page 38 is Becky Breckenridge not Bonnie.

Mary Bernard

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

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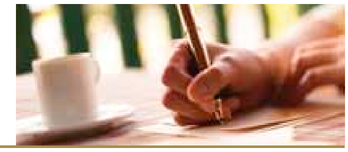

EDITORIAL@KITPLANES.COM

Old-Timer, New Ideas

I would like to offer a comment on Stein Bruch's article "All About Avionics," which appeared in the August 2011 issue of your magazine.

As an old-timer homebuilder I am following the progress of technology in different areas of our industry. I totally agree with the author that electronic flight instrument systems (EFISes) have come a long way in the past few years. With the advance of this technology, availability of reliable systems is improved, and their price and footprint make these systems a viable solution for even the smallest homebuilt.

I own a RANS S-6S, built as a second project of mine in 2001. Besides the fun this airplane provides me when I'm flying it, I enjoy the never-ending little projects of improvements, modifications and maintaining the plane. The next project in line is rebuilding the instrument panel, so it's no wonder I read this article with lots of interest.

As an old-timer, my hesitation to move from "steam gauges" to digital was, and still is, there. On the other hand, the digital systems have so much to offer and at such a (relatively) low price....

With my technical background in the area of data communication, it is easy for me to see that for companies such as Dynon, Advanced Flight Systems and others, it is only one short step to develop another line of products. Consider the following: an LCD screen shaped like a traditional instrument panel where "steam gauges" are displayed on it "electronically." Or how about discrete instruments—altimeters, airspeed indicators, attitude indicators, and directional gyros (heading indicators)—operating in the same mode, i.e., digital display of steam gauges while the data to drive these devices comes from the same source as the digital systems?

My question is very simple: Am I the only intuitive old-timer who sees the need for such a line of products? The question is directed to the readers and to the companies involved with these technologies.

NATI NIV, EAA 749796

Nati:
Indeed, you are not the only one who has asked this question and are not the only one who would like to see this sort of layout. In fact, even some major airlines have used this type of layout. Southwest Airlines has used a similar layout on its EFIS displays, where standard round gauges are represented on digital displays. Additionally, and recently, Advanced Flight Systems saw the benefit of a similar layout and has implemented it on the company's new larger screens with terrific results. The AFS version is extremely nice when you see it in person.

I think as time progresses you'll see more and more options that allow pilots who are familiar with older-generation systems as well as new-generation systems to utilize technology in whichever way works best for their own preferences. As with many things in this business, other companies are likely to follow Advanced Flight Systems' lead at some point (as various companies have borrowed from each other in the past).

Thanks so much for reading my article, and thanks for the excellent question!

STEIN BRUCH

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WHAT'S NEW

TWO NEW PRODUCTS FROM TCW

TCW Technologies is known as the company with the products that can save your airplane's avionics in case of a crippling power surge, sag or complete loss of electricity. The company has just added two new products to its lineup: a 24-volt Intelligent Power System (IPS-24V-5A) and a revision of the signature integrated battery backup system (IBBS-12V-2AH).

The 24-volt IPS fills out TCW's line and helps customers who are running with the higher-power radios in their panels. The IBBS, at 2 amp-hours, is a smaller system than its sibling, and is well-matched for single-instrument systems and very light aircraft (it weighs 1.5 pounds). It also serves as an independent power source for four-cylinder electronic ignition modules.

For more information, visit *www.tcwtech.com*. Find a direct link at *www.kitplanes.com*.

ADS-B for the Budget Minded

ChartFlier connected to a Zaon traffic system.

Options abound for pilots interested in free government-sponsored ADS-B weather. One of the least expensive market entries is the ChartFlier by Essential Flight Technologies (EFT). The ChartFlier system includes VFR and IFR charts (low and high), airport diagrams, instrument procedures, and an aviation database for airports in all 50 U.S. states, Puerto Rico and the U.S. Virgin Islands.

ChartFlier is PC-based for economy's sake, according to EFT President Colin Bitterfield. "We wrote the code for the program so that it would be extremely small—about 1.5 mb total—to enable it to run on legacy netbooks and tablets that were sitting dormant on so many shelves." The company offers one package, including a Fujitsu Lifebook computer and the software, for $399. Bitterfield says the program, which costs $149 per year, will run on a $199 netbook with ease.

Essential Flight Technologies offers several different bundles and packages, including options for a Bluetooth GPS that start at $39, and the ADS-B "In" box starting at $995, as well as a Zaon PCAS connection for those who are not ready to invest in an ADS-B transceiver.

For more information, visit *www.essentialflight.us*. Find a direct link at *www.kitplanes.com*.

SubSonex Jet Makes First Flight

The SubSonex jet aircraft prototype, JSX-1, made its maiden flight in August at Wittman Airport in Oshkosh, Wisconsin. The flight, piloted by Bob Carlton, lasted approximately 14 minutes and focused on low-end speed, including stalls and low approaches in the landing configuration, Sonex said. Carlton, whose experience pioneering light jet aircraft made him a natural choice, remarked after the flight, "It was great—flies like an airplane. The faster I went, the better it felt." Carlton is known for his airshow performances with the Super Salto jet, and he is the developer of the Bonus Jet two-seat glider.

"It's an exciting day for Sonex," said SubSonex designer and Sonex Aircraft President John Monnett. "We have a test-flight plan to expand the envelope of the aircraft, and we'll see where the project takes us from here."

For more information, visit *www.sonexaircraft.com/research.subsonex.html*. Find a direct link at *www.kitplanes.com*.

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Rationalizing LSA rules, today and tomorrow.

At Oshkosh this year the ASTM working group announced that efforts to update the Light Sport Aircraft rules were under way. The two main topics were the allowance of electric motors for propulsion and a clarification on use of LSAs in instrument conditions. That's a good start. I hope they don't stop there.

First the electric motor issue. In trying to keep LSAs simple and affordable, the initial rules for the segment restricted engine choice to piston power. This move was to ensure that small turbines and other technologies (like what, steam or solar?) would not be used in the category. The unintended consequence is that because of the restrictive language electric motors were not specifically allowed. (This is not the first such faux pas for the LSA rules. Remember that the net prohibiting retractable gear caught a few fish in the amphibian category, with a few specific aircraft getting exemptions before the whole rule was changed to allow a pilot to take off and land on the water without injury.)

Is there really any good reason the Cessna 150 can't be an LSA?

Electric Sheep

As we ride the ever-steepening curve of electric-aircraft development, the American Society for Testing and Materials (ASTM) and the FAA and the European Aviation Safety Agency (EASA) must recognize that a simplified path to production is the only way this still-fragile subset of general aviation can hope to succeed. What's more, because of the present technology levels, smaller and lighter aircraft (right in the LSA wheelhouse) are the ideal candidates for electric propulsion. My colleague Dean Sigler (Alternative Energies, Page 50) has been following electric-aircraft technology closely, watching the technology lurch through its formative years. He points out that the interim generation of electric aircraft will have to be very efficient aerodynamically, which points to light, simple sailplane-like designs.

Perfect for LSAs, in my view, because now you have the opportunity to engage those who aren't interested in flying "ancient technology" and who, by temperament as younger tech-heads, will be attracted to the potential of faster training for the Sport Pilot certificate. (I won't engage the argument that, for many, the SP rating isn't much more direct than going straight to Private Pilot.) It has *new, new, new* written all over it.

Without question, the one component holding electric aircraft back is the battery. We're making big progress—and by *we* I actually mean the many companies with exceedingly smart engineers—but the power density of a commercially available battery is still way behind the equivalent from gasoline. Understanding that, I think the ASTM needs to lobby hard for an increase in the maximum weight of LSAs, which are, in my view, arbitrarily set at 1320 pounds for land planes and 1450 for amphibians. After all, the Terrafugia "flying car" has received an exemption to a higher gross weight to offset the required road-going safety devices. Why shouldn't we acknowledge the difficulty of breeding new technology and give the electric aircraft a similar (actually, larger) break? What do we risk?

Weighty Issues

I admit that when the LSA rules were being written and during their initial implementation, circa 2004, I didn't think much about the 1320-pound weight limit. Actually, it seemed like a good idea at the time: You can create a new breed of light, agile aircraft that won't crowd the existing designs and would force designers and manufacturers to work harder at getting weight out of the structure. Look

Marc Cook

Former KITPLANES® Editor-in-Chief Marc Cook has been in aviation journalism for 22 years and in magazine work for more than 25. He is a 4200-hour instrument-rated, multi-engine pilot with experience in nearly 150 types. He's completed two kit aircraft, an Aero Designs Pulsar XP and a GlaStar Sportsman 2+2.

at the progression in long-running certified aircraft. Each generation has become heavier, forcing the use of larger, thirstier engines to keep performance from degrading. Bigger engines use more fuel, which calls for larger fuel tanks, eating up more of the useful load, which can only be regained by increasing the gross weight until the performance falls again and you need more power. A vicious cycle, oft repeated.

Without the benefit of proximity to the leading designs, I figured 1320 was good enough. But then you start to see the airplanes themselves, and what they're trying to do. For a reasonable payload and decent range on approximately 100 horsepower, you need to carry 20 gallons of fuel or more in an aircraft that weighs about 800 pounds empty. That's for two 200-pound occupants and no bags.

For a small, well-designed airframe, that's an engineering challenge and a half, one that designs such as the RANS S-19 and the Van's RV-12 have met very well. However, think about the Cub-style airplanes. Their natural method of construction is really hard to make light, no surprise when you consider how much the big wings weigh and that most of these designs come with engines other than the expensive (but light) Rotax 912. When I visited the CubCrafters facility to see the Carbon Cub, I was taken aback by the degree to which the company had to reinvent the venerable Cub just to make weight. A carbon-fiber floorpan helped, but every single component was considered for weight reduction. That's fine from an objective point of view, but the engineering time and materials cost have made the Carbon Cub a fairly expensive proposition.

Moreover, the 1320-pound limitation placed many airplanes that should be LSAs out of the class. Can you honestly tell me that a Cessna 150 would not be a great LSA? It's the perfect low-cost, simple, extremely safe, durable and available airplane. Can you truthfully suggest that this beat-on-me design, which taught so many pilots how to fly, is now somehow inappropriate for someone concerned about keeping a medical, or a newbie wanting the most affordable path to pilotdom?

You could make an argument that including a large body of existing airplanes does nothing to spur innovation or create demand in a new market. That's true, but it ignores the fact that the great divide between a new LSA and a used Cessna 150 cannot be bridged by desire; the pilot selecting the Cessna is not turning down a $100K+ new LSA instead. He's a player in the market at $40,000 but not even interested at six figures. I've heard this from enough of our readers who really want the perfect $30,000 kitbuilt.

Think Again

It's time to call the arbitrary weight limitation a failure. Bump it up to 1600 pounds. Don't debate, just do it.

In my column, I'm king, so I can make these rash proclamations. But think of what you'd get. A good number of homebuilt designs that are currently too heavy for LSA suddenly become chariots for Sport Pilots. Even those aircraft specifically designed for 1320 pounds will likely have enough margin in the structure to go up 100 pounds or more. Now you can carry two Bubbas (as my Southern friends say) as well as some baggage. Or you could increase fuel capacity. Or you could fit a nicer, quiet interior. Or use landing gear less prone to breakage in the training environment. The 1320-pound limit seemed fine but has proven to be too low out in the real world. Fix it.

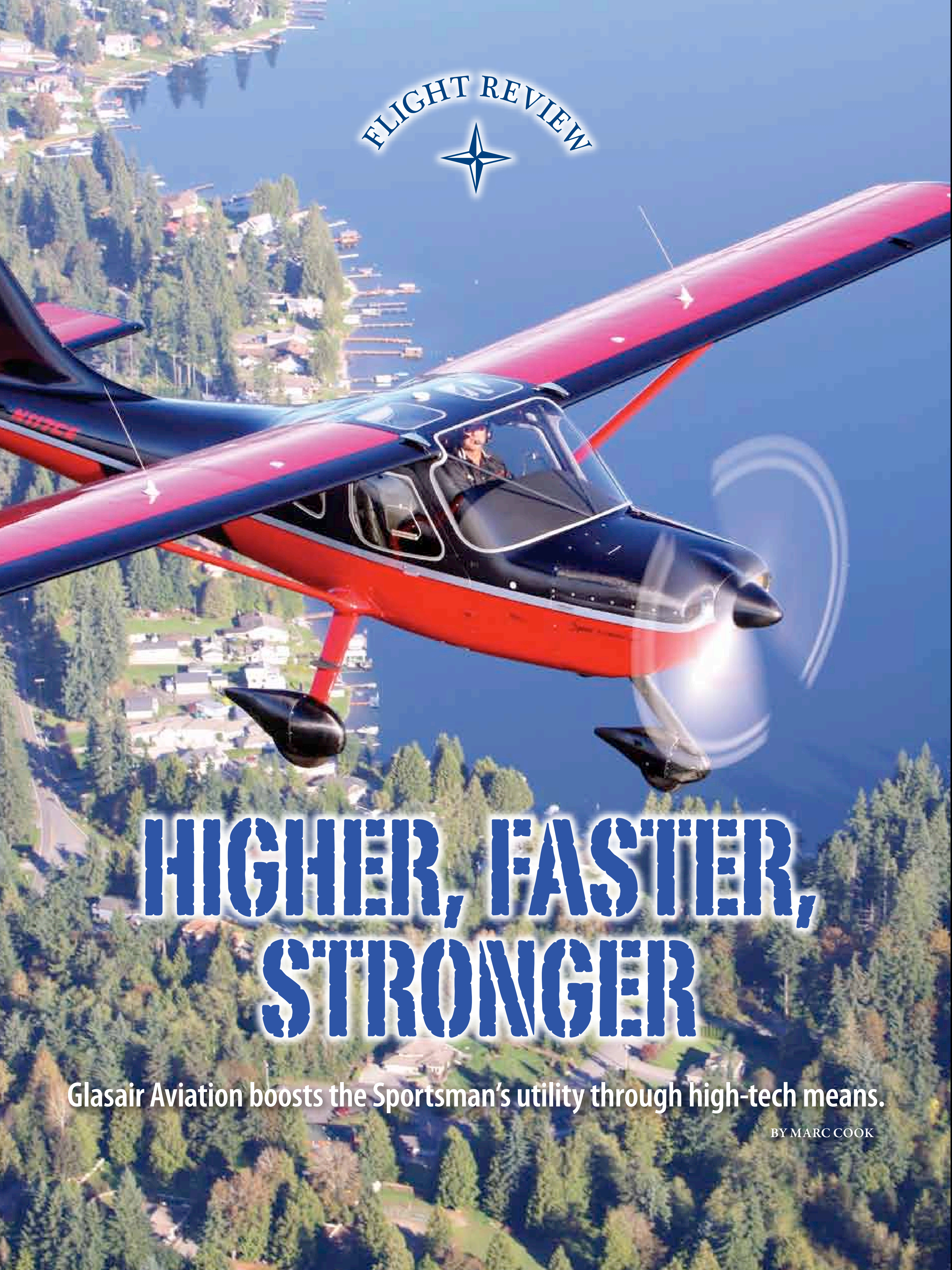
Now that we have new limits, there's one other wall I'd like to kick out, and that's the 45-knot stall speed. Actually, I agree that keeping the stall speed low is one of the best ways to improve safety, but the way the ASTM rules are written, this applies to the *clean* stall speed. Most of the designs have flaps, which can be (and should be) factored into this equation. I'd be perfectly content with a 45-knot landing-configuration limit, or even 50 KIAS dirty. After all, the 61-knot stall-speed limit for single-engine certified aircraft is considered with the use of flaps. Why is this any different?

When you raise the effective stall-speed limit you can then reduce wing area (or maintain it at the higher gross weight) and thereby increase wing loading. If there's one complaint to be leveled at LSAs, it's that they tend toward the "kitey." In fact, pilots transitioning from Beech Bonanzas and Cessna 182s have had a lot of trouble with these slow-landing, responsive aircraft, pranging them on landing with some regularity. A little bit of wing loading will go a long way.

I'm sure there are other aspects of the LSA regulations that could benefit from a tweak here and there. Given the fragile state of general aviation and the failure of the LSA "movement" to attract great numbers of new pilots, it's foolish to call these rules good enough to leave alone. Sure the manufacturers want stability, but they need sales, too. ✈

Our next-generation aircraft using electric propulsion will look more like sailplanes than traditional gas-powered designs. Shouldn't the LSA rules be forward-looking?

FLIGHT REVIEW



HIGHER, FASTER, STRONGER

Glasair Aviation boosts the Sportsman's utility through high-tech means.

BY MARC COOK

You're a kit airplane manufacturer. You're staring troubled times in the face. (Well, who isn't?) You would love to produce an all-new model to spur sales, excite the marketplace and show off your engineering prowess. But you've heard that only fools and the grossly overfunded drop an expensive new toy into a soft economy. It could be the best new thing ever, but if the phones aren't ringing and the buyers aren't lining up at the airshows, what's the point?

Next best? Take your current product and apply what you've learned over the last decade of building the kit to improve its performance and utility without running the engineering department's budget deep into the red. The questions remain: Can it be done, and will it be worth the effort?

This high-end IFR panel includes dual Advanced Flight Systems EFISes along with analog backup gauges and an AFS-branded, TruTrak-built autopilot.

Case in Point

Submitted for your consideration is this answer: the Glasair Aviation Sportsman Turbo Carbon, TC for short. Introduced at AirVenture 2010, the TC would seem like a mild "re-skin" (to use automotive-industry parlance) of the popular and enduring Sportsman 2+2 utility high-wing design. After all, stand beside the demonstrator, even with the carbon-fiber weave proudly displayed under clear-coat paint, and you might be excused for thinking not much was new. The key items that set the Sportsman apart from the pack remain in place—composite shell over a steel-tube "safety cage" plus an all-aluminum wing and multifarious landing-gear configurations.

All things considered, the Sportsman's performance is more than adequate. With the larger of the two most popular engines, a 210-hp, four-cylinder Lycoming, the 2+2 can cruise at 150 knots true airspeed (KTAS) on 11 to 12 gph. The takeoff roll uses 400 to 500 feet of asphalt, and the initial climb that follows peaks at 1200 fpm at maximum-gross weight.

A good power-to-weight ratio helps the climb, and good aerodynamics benefit the cruise speed, but the Sportsman doesn't give away utility. (Most very fast airplanes also have high stall speeds, which push takeoff and approach speeds up, in turn increasing runway requirements.) A reasonable amount of wing, 131 square feet of GAW-2 airfoil in a constant-chord, untwisted configuration, keeps stall speeds low. The full-flap, max-gross stall speed is 44 knots indicated airspeed (KIAS), which makes approaching to land at 60 to 65 KIAS comfortable and safe.

Yeah, So?

These characteristics have been with the Sportsman from the start, the speed amplified by the factory's decision to support the new Lycoming IO-390 in 2006. Seeking yet another performance bump, Glasair Aviation took a two-prong approach: reduce weight and increase power.

The first half of that decision is where the carbon-fiber comes in. In the normal way of things, the Sportsman uses

Photos: Paul Bertorelli, Marc Cook

From the outside, you can't tell this Sportsman has high-altitude power. The stock cowling is used with minor changes that are almost invisible.

conventional E-glass (and vinylester resin to hold it together) in a molded construction for the main fuselage shell that includes the vertical stabilizer. That's right around 20 of the airplane's total length of 23 feet in semi-structural composites; in other words, a lot of glass. One advantage of the glass-over-steel-tube design is that the composites are not highly stressed. Yes, the shell is structural for tail loads (both aerodynamic and as part of the landing gear in taildragger configuration), but these aren't the difficult pinpoint loads you'd get from the wingspars and engine mount, for example. That fact, in turn, provides some flexibility in materials, which Glasair Aviation fully leveraged.

So in the Sportsman TC, everything that once was E-glass is now carbon-fiber—main shell, landing gear fairings, engine cowling, wingtips and various other bits. The price to upgrade is a healthy $15,000 strictly on the difference in raw materials costs. For that cost you get a weight reduction of more than 40 pounds.

But the benefit is actually greater, because Glasair elected to further improve the airplane's already good load-carrying capabilities by making detailed structural changes to increase the maximum-gross weight from 2350 pounds to 2500. That's on wheels. For floatplane use, Glasair Aviation approves a max-gross of 2650 pounds. When you think that the Sportsman isn't so far removed from the 1950-pound GlaStar, that's a pretty amazing number.

Existing Sportsman builders who haven't yet certified their ships shouldn't assume this is a pencil-whip exercise. In fact, a number of the tubes in the fuselage cage had to change, mostly by increasing their wall thickness. Plus there are detail changes in the wing structure to handle the increased max weight. A good portion of the fuselage alterations had little to do with aerodynamic or in-flight structural loads; certain tubes locating the landing gear sockets were changed to help increase resistance to deformation under "drop" loads.

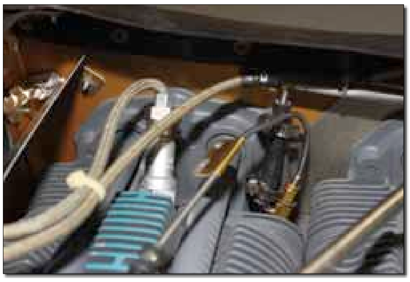
Heavy Breather

While the outside of the Sportsman TC doesn't betray many of the substantial changes, one peek under the cowl changes your outlook. A bone-stock IO-360 parallel-valve Lycoming sits in standard engine mounts, but it seems to have a bad case of hose-itis. Additional oil lines to serve the automatic wastegate and to keep precious fluids flowing to

A standard Lycoming IO-360 underpins the turbocharged option. The only internal change was to add nozzles that squirt oil at the bottoms of the pistons.

Carbon fiber, you think?

From across the ramp, the Sportsman TC belies its new skin through a cosmetic treatment. Although it's lighter, the carbon-fiber skin appears the same as the regular fiberglass it replaces.



New fuel injectors include pressurized shrouds to ensure that the injector body is always at a higher pressure than the intake manifold.

Although the better turbo systems use automatic wastegates, they all need a so-called popoff valve to prevent overboosting of the engine in the event of a controller or wastegate failure.

the Garrett turbo mounted low and to the right side of the engine are obvious. Somewhat less so are the air lines leading to the otherwise stock Slick mags (to pressurize them in preparation for high-altitude work) and the hoses feeding the special turbo fuel injectors.

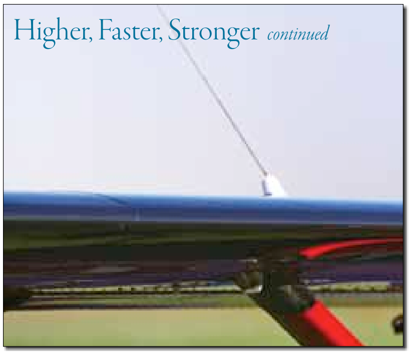
Because this installation is turbonormalized, the Lycoming compression ratio is the stock 8.5:1, though the magneto timing is retarded from the normal 25° BTDC to about 20° to 22°. (The final setting was not fixed when we flew the airplane.) But this engine has been fitted with piston oil squirts: passages drilled in two oil galleries that direct oil to the bottoms of the pistons in an effort to reduce cylinder head temps.

Overall, the installation is quite neat. Induction air enters the turbo on the lower right side of the cowling through a K&N filter. From the turbo, a solid tube carries compressed air behind the engine to a large intercooler mounted on the firewall just at the left edge. Air to cool the intake charge is picked off from behind the No. 4 cylinder and exhausted toward the cowling exit. Induction air continues from the bottom of the intercooler forward to the waiting mouth of a Precision Airmotive RSA injector throttle body. A firewall-mounted oil cooler receives air from behind the No. 3 cylinder. This installation maintains almost all of the standard Sportsman cowling and baffling.

Twin louver sets increase the flow of cooling air for the turbo installation.

Bubble windows improve the Sportsman's already good visibility.

A new optional opening window can be used as a camera port.



The one problem with carbon? It's conductive, so all antennas must now be external.

Detail changes to the steel-tube "safety cage" allow an increase in maximum-gross weight. The design of the structure was not changed, only the size and/or thickness of some tubes.

An aerodynamic clean-up kit streamlines the strut-to-fuselage junction and the flap tracks.

What's in the Box

The basic Sportsman 2+2 comes several ways. One is the Two Weeks to Taxi program, which includes preset avionics packages centered on Advanced Flight Systems EFISes and a narrow choice of stock Lycoming engines as well as the cost of the workshop experience; the basic airplane starts at $168,520 with basic VFR avionics.

Those who want to build on their own can take the Sportsman all at once or in three basic kits. Included in all versions are all of the major airframe components including the fiberglass (or carbon-fiber) fuselage shell, pre-welded and powder-coated steel-tube frame, aluminum wings, horizontal stabilizer and elevator, and aluminum rudder. A pre-built fuselage option includes several bonding steps done by the factory and the important mating of the fuselage cage to the shell. Pre-built wings come mostly assembled, just open at the top to install systems; pre-built tail kits are available as well.

Items the builder must supply: engine, avionics, paint and interior, though a fairly extensive accessories catalog includes such items as interior packages, speed-fairing kits, different cowlings and exhaust systems, and many more smaller items you can use to customize the build.

—M.C.

While the cooling inlets and main exit are the same as for the non-turbo Sportsman, a pair of louvers are added to the lower cowling to help extract hot air. In addition, the single exhaust pipe exits slightly toward the copilot side from where it normally would. But many small tweaks to the baffling—mostly to ensure a complete seal—and ramps that smooth the transition from the upper edge of the inlets to the inside of the cowling help accommodate the increased heat load of the turbo installation.

Cost and weight are the two dings against any turbo setup. The total upcharge of the turbo package has not been set, but will be in the neighborhood of $35,000. That's on top of all the other things you have to buy like engine, prop, airframe. And those 40 pounds lost thanks to the carbon-fiber skin?

GLASAIR SPORTSMAN TC

Price (including turbo and carbon-fiber fuselage)	$95,502
Price as Two Weeks to Taxi *	$207,902
Estimated completed price	$130,000 - $225,000
Estimated build time	1500 hours
Number flying (includes all Sportsman variants)	210
Powerplant	Lycoming TIO-360, 180 hp @ 2700 rpm
Propeller	Hartzell two-blade constant-speed
Powerplant options	Lycoming IO-360, IO-390

AIRFRAME

Wingspan	35 ft
Wing loading	19.08 lb/sq ft
Fuel capacity	50 gal
Maximum gross weight	2500 lb
Typical empty weight	1450 lb
Typical useful load	1050 lb
Full-fuel payload	758 lb
Seating capacity	4
Cabin width	46 in
Baggage capacity	250 lb

PERFORMANCE

Cruise speed	190 mph (165 kt) TAS 20,000 ft @ 85% of max-continuous, 9.0 gph
Maximum rate of climb	1200 fpm
Stall speed (landing configuration)	50 mph (44 kt) IAS
Stall speed (clean)	61 mph (53 kt) IAS
Takeoff distance	400 ft
Landing distance	650 ft

*Specifications are manufacturer's estimates and are based on the configuration of the demonstrator aircraft. *Two Weeks to Taxi is a factory-based customer assistance program. Performance numbers are preliminary for the turbocharged option.*

Virtually all eaten by the turbo. Nevertheless, the estimated empty weight of a Sportsman TC is about 1450 pounds, certainly in the mix of actual Sportsman weights when using the IO-390. But don't forget the higher maximum-gross weight. Even with the 50-gallon tanks (48 usable) full, you still have 750 pounds for the cabin. Moreover, the combination of the turbo engine and lighter fuselage moves the empty CG forward, so in an airplane not prone to bumping the aft-CG limit you have even more loading flexibility. Hunters, fishermen, er, sportsmen will appreciate both the weight and cubic carrying capacity of the TC.

Flying It

Waking the turbo Sportsman isn't much different than bringing any injected Lycoming online, and the taxi-out and runup are completely conventional. The surprises come when you throttle up for takeoff. This turbo installation has no lag and no bad manners in this regime. The throttle responds smoothly, the turbo comes up predictably, and the manifold pressure hunts down and sticks to a steady 34 inches. Wait, isn't that more than it should be as a turbo-normalized engine? Yes, but General Aviation Manufacturing, Inc. (GAMI), the forward-looking company that refined turbo kits for Bonanzas and created the system for the Cirrus SR-22TC, is accommodating the increased inlet temps present even with an intercooler. To get the expected 180 hp (or even a bit more), you need more than 30 inches for takeoff.

The second surprise is the fuel flow. Just before this flight, a technician from Precision Airmotive had altered the Sportsman's injection to increase maximum fuel flow. The Advanced Flight Systems display's fuel-flow figure rolled right up to 23 gallons per hour during the initial takeoff roll. That's 3 gph more than the 210-hp Lycoming IO-390 takes

Vortex generators inboard and ahead of the ailerons help condition local flow to improve low-speed handling. The Sportsman, given its size and wing area, has exemplary low-speed manners.

High-intensity-discharge (HID) landing lights are a new option for the Sportsman, now fitted into the wingtips, where they have half a chance to survive.

down, and up by 5 gph over the non-turbo IO-360. It's the price you pay for turbocharging. To maintain detonation margins, you need to run either quite rich or moderately lean. Mixture settings at 40° rich of peak provide the highest cylinder-head temps. Turbos, when run rich of peak, like a goodly amount of fuel.

Going Up

The good news here is that the image of $150 per hour of fuel going through the pipe is offset by impressive takeoff and climb performance. In our flight, with partial fuel and two full-size men aboard, the demonstrator aircraft got off in 500 feet, hit an initial climb rate of more than 1000 fpm with 10° of flaps at 75 KIAS. Stow the manual flaps, leave the power full in, and you'll see 1200 fpm at 95 KIAS, well above the best-rate speed but a good compromise for engine cooling and over-the-nose visibility. We continued the climb at full power, with the manifold pressure gradually tailing off above 12,000 feet MSL (and the fuel flow going with it), and still maintained better than 1000 fpm through 8000 feet MSL at 95 KIAS; we were still moving along at 850 fpm past 14,000 feet MSL. The climb to our test altitude of 16,500 feet MSL took approximately 20 minutes including some maneuvering and a bit of experimentation with different airspeeds for engine cooling. While the per-hour rate of 23 gph (tapering to 21 as we climbed) seems gluttonous, we used just more than 8 gallons to get to altitude because we weren't at that setting for long. A normally aspirated, 180-hp Sportsman would have done the deed on less fuel but taken much more time; it's common to see climb rates above 12,000 feet MSL taper to 500 fpm or less.

Throughout the climb, the Turbo Sportsman was well mannered. After fiddling with fuel flows and speeds, we were able to raise a cylinder above the arbitrary 380° F limit. (Lycoming says 475° maximum with a recommendation "for better life" to maintain 435° F or less.) The 380° rule comes from GAMI,

Talk of the Turbo

For some pilots, "turbo" is a mysterious term, suggesting dark arts or other unnamed internal-combustion magic. In fact, turbocharging as a concept is straightforward. It's the details that often define the success of any installation.

In the simplest sense, a turbo installation is merely the addition of a turbo-supercharger device with two main components. Think of the turbine as an encased pinwheel that faces a stream of hot exhaust gas from the engine. In engineering terms, exhaust gas is considered wasted in non-turbo engines. Normally, the fuel/air mixture, after ignition, is used to push the piston down and rotate the crankshaft, but the heat generated from the chemical reaction goes largely unused. Our exhaust pipes dump the flow into the atmosphere. Heat is energy, and it makes the pocket-protector crowd nuts to see that energy wasted.

Turbocharging takes the energy of that exhaust stream and spins a turbine with it. Naturally, immersed in 1500° F, corrosive engine effluent, the turbine endures a tough life, which is why turbochargers are made of high-temperature alloys that cost a fortune. Harnessing this otherwise lost energy makes it free. Almost.

As in so many things, it's what you do with it that counts. In a turbocharger, a shaft connects the turbine to a compressor wheel. Its job is to take ambient air and compress it, raising its pressure and, as a result, temperature. Fed to the engine, this compressed air allows more fuel to be combined in the cylinder, which results in more power.

The Garrett turbocharger resides below and behind the engine on the copilot's side. A heat shield keeps the oil cooler (on the firewall) from picking up infrared heat.

That's the block diagram: Exhaust spins the turbine, which spins the compressor, which raises the pressure of the air fed to the engine. Depending upon the style of turbo and associated systems, an engine could receive the same manifold pressure it would consume at sea level even up at 15,000 or 20,000 feet. Where a non-turbo engine would be wheezing along at, say, 15 inches of manifold pressure (the normal value at 15,000 feet) and making barely 50% power, a turbo engine could be at its max-continuous rating. For some installations, the critical altitude (the highest altitude at which a predetermined cruise power setting can be maintained) can be 20,000 or even 25,000 feet.

Our goal is to increase high-altitude power, and we've done it by simply splicing a turbocharger into the exhaust and inlet paths, right? In reality, there's more to it, and that fact helps explain why turbos aren't the default choice for light aircraft engines. A turbo installation will be heavier and more complex than a normally aspirated example on the same engine. It taxes the engine's and airframe's cooling systems, and it adds to the pilot's workload.

One complication is the wastegate. Turbo sizing is a complex science, but let's just say that for any given engine a turbo ideally sized for low altitude won't also be as efficient at high altitude. The reverse is true. And there's more: Under many normal operating conditions, there's sufficient exhaust flow to spin the turbo faster than its maximum-rated rpm (often above 100,000 rpm) or to create more-than-desired manifold pressure (boost). One solution is a wastegate, which redirects the exhaust path around the turbine to moderate turbo-impeller speed. The better systems are automatic and are set to maintain a certain maximum manifold pressure, allowing the pilot to firewall the throttle without worry. It's up to the designer to ensure that the turbine doesn't overspeed even when the manifold pressure is in range. (A turbo is like

which has seen an increase in top-end life in big-bore Continentals by adhering to this limit.

Level Headed

High-altitude cruise is where you expect a turbocharged airplane to really shine. The Sportsman does well; we'll explain that verbal asterisk in a moment.

We tried two basic cruise settings: rich of peak and lean of peak. Rich, you leave the throttle full in, reduce rpm to 2500 and leave the mixture up to the firewall. At 16,500 feet MSL (barometer of 30.03 inches, OAT of +3° C), we tried 30 inches of manifold pressure, 2550 rpm, full rich (19 gph) to get true airspeeds between 156 and 158 knots. Fast, substantially faster than the non-turbo version, but unreasonably thirsty. At this speed, too, the cooling mods needed for climb caused the engine to run too cool, with cylinders in the 330° to 355° range.

Lean of peak is where turbos become much more fuel efficient, but there's a catch. Remember that caution about maximum head temps occurring near 40° F rich of peak? Good. Understand as well that power falls fairly quickly as you move leaner from peak EGT, so that the sweet spot is anywhere between 40° and 60° F LOP. Head temps track a similar line, and the gradient is similarly steep. As a result, small changes in mixture setting LOP can have a large impact

In many turbos, induction air can take a circuitous path. Here, ambient air enters the K&N air filter (left side) first, and then flows to the turbocharger, which discharges it through another white pipe running across the back of the engine. The air goes through an air-to-air intercooler on the pilot's side firewall face and then to the fuel injection throttle body just behind the white elbow.

Turbo installations require more oil circuits, especially if used with an automatic wastegate. Accessory-case access is often compromised.

a wing in the sense that it has to work harder at higher altitude, so it'll be spinning faster to make 25 inches of manifold pressure at 20,000 feet than it will for the same value at 10,000 feet.)

Auto wastegate systems can either set the output of the turbo to a fixed value (usually an inch or two of mercury over the redline manifold pressure) or to "float" the turbo's output (called the upper deck pressure) to some small value above the pilot-requested manifold pressure. The floating types are more efficient because they allow the turbo itself to work a bit less hard at higher altitudes when the pilot is setting less-than-maximum manifold pressure.)

Wastegates are typically just butterfly valves located in the exhaust stream near the inlet side of the turbine, and are usually operated by servos that employ oil as the motive force. Normally we'd hate to have a more complicated oil system than necessary, but here it's OK because the turbo itself also needs an oil supply. Moreover, because the turbo is usually mounted below the engine, a suction pump draws the excess oil up from the turbo, returning it to the engine case. Look at the back of any turbo engine, and you'll see a few grand worth of oil hoses and a special pump taking up a vacuum-pump pad.

Oh, and you're not done yet. You probably remember that standard fuel injectors have a set of bleed holes around the central fuel circuit; they draw in a small amount of air and help with fuel atomization. They work fine when the engine manifold pressure is never above the ambient pressure inside the cowling, but when you add boost, those vents would allow fuel to spray out. As a solution, turbo installations need shrouded injectors connected to the upper deck to ensure that the air pressure in the shroud is always higher than the engine's manifold pressure.

So there you are at sea level, 30 inches of manifold pressure and 2700 rpm. Your turbocharged IO-360 Lycoming is making the same 180 horsepower as a non-turbo version showing the same numbers on the gauges. Right? Nope. Two problems here: One is that the exhaust system and turbocharger represent compromises in flow and typically have more back pressure than an idealized system. That steals a bit of power. Two is that by raising the inlet pressure, you also raise its temperature, so induction-air temps will be higher on the turbo, even on a cool, sea-level day. This less-dense air robs some power, too. One solution is to add an intercooler—a radiator for the inlet air. Now you've added more complexity, cost and weight. But you've reduced some of the power loss at sea level and increased the ever-important detonation margin.

Turbocharged engines increase the likelihood of detonation because of the higher combustion pressures. A cooler induction temp helps widen that margin, but engine manufacturers have used other means to prevent destructive detonation. One is to reduce the static compression ratio from the normal 8.5:1 to something like 7.5:1. Of course, that sacrifices power, so the turbo gets cranked up to produce, say, 35 inches of manifold pressure at sea level.

Another approach is called turbo-normalizing. This scheme leaves the stock compression ratio in place and limits maximum manifold pressure to 30 inches. With the growing popularity of running engines on the lean side of peak exhaust-gas temps (LOP, EGT), turbo-normalizing has become the configuration of choice.

Turbocharging has been popular in production aircraft since the 1960s. The technologies are well proven but there's no free lunch. Want to fly fast at high altitude? Prepare to have a heavier, more complex and more expensive bundle of noise ahead of your homebuilt's firewall.

—M.C.

on both speed and cylinder head temperature (CHT). You have a comparatively narrow range in which to work: Too lean and the airplane slows down, too rich (but not rich of peak) and the airplane speeds up, but the CHTs rise quickly. If you have set a modest working limit for CHTs, you can run into temp limits that really determine how fast you can go LOP.

Such a characteristic appears in this particular turbo installation. After considerable experimentation, we determined that the Sportsman TC would, on this hot day, tolerate mixtures at or leaner than 10.1 gph without busting the 380° F limit. Our speed was now 146 to 148 KTAS at the same 16,500 feet MSL. While that range doesn't seem impressive, an IO-390-powered Sportsman would be doing well to make 135 to 138 KTAS at the same altitude despite having a 30-hp sea-level advantage; a 180-hp Sportsman would be slower than 130 KTAS at the same altitude.

A side note on the numbers. We flew this airplane twice, once early in the development process, where the cooling system had not been refined. On the second flight, an unexpected variable had been introduced because Glasair Aviation was testing the 74-inch-diameter Hartzell composite prop; the earlier flight was with the 72-inch metal blended-airfoil prop normally specified for this airplane. Data on both props on the Sportsman airframe suggest that the larger, composite prop is a bit slower at altitude.

Had we allowed the CHTs to run to, say, 390° or even 400° F, and had the metal prop been mounted, it's likely the measured cruise performance would have been better. It's not unreasonable to think 150 to 152 KTAS is possible, running low-consumption fuel flows under ideal conditions. What's more, there may be still more to be found by improving this engine's cooling so that slightly more fuel could be used at altitude, with a resulting increase in true airspeed. But there may not be much more. An advantage of the parallel-valve engine is its low weight compared to the angle-valve brethren, but its cylinder design simply can't shed as much heat as the angle-valve type no matter how much cooling air you run around it.

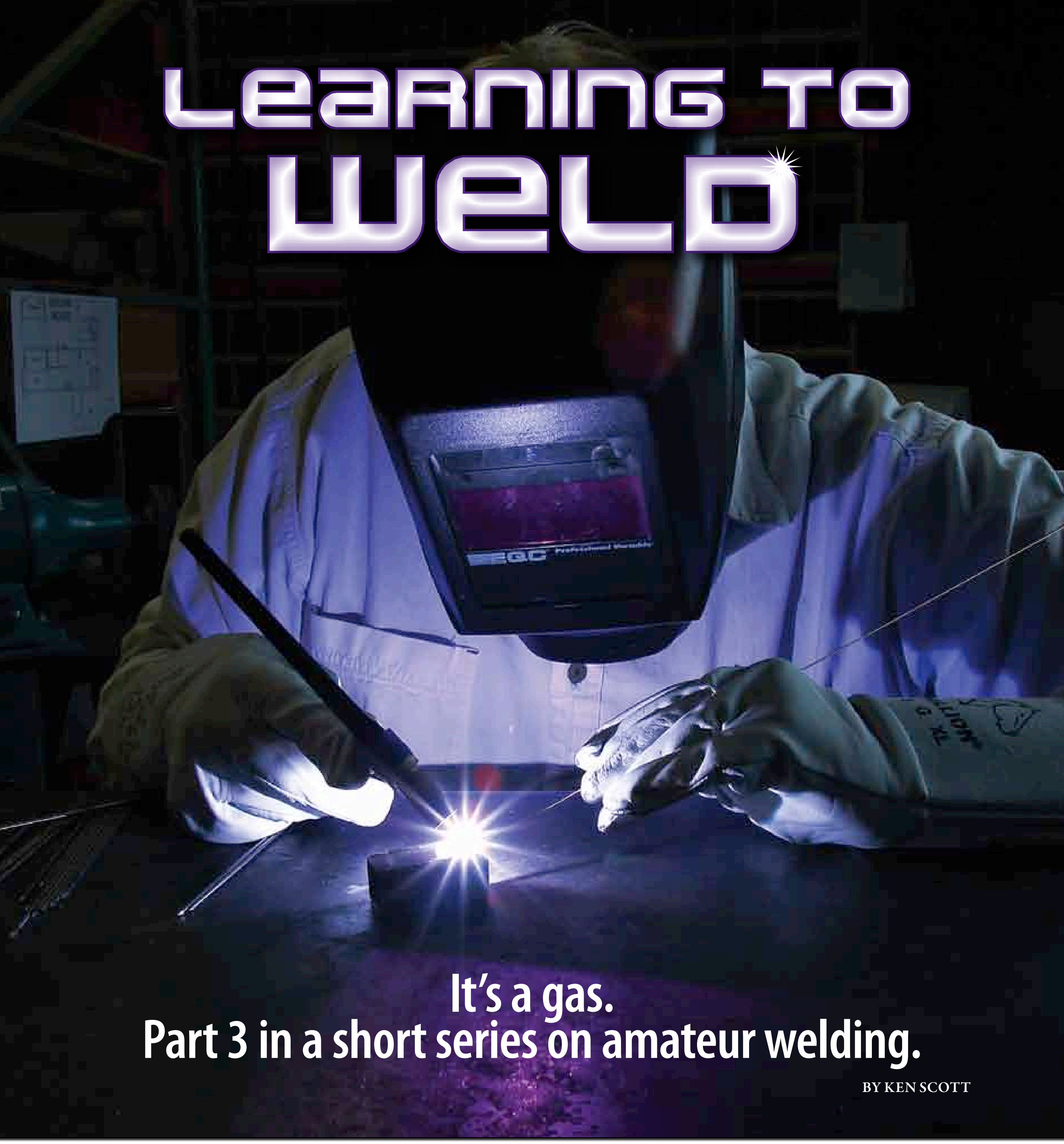
The Bigger Picture

There's more to it than numbers. Think of two situations where you want to run at high altitude. One is trying to traverse the desert southwest during the summer months. It's possible you won't find smooth air, or get above the popcorn-cloud cumulus, until you're at 14,000 feet or more. An airplane that climbs energetically to that altitude and maintains a reasonable airspeed there makes that flight profile possible. The other is getting above weather. Again, the climb rate at altitude is a strong ally.

And there's this: Turbocharging the Sportsman does nothing to harm its utility rating. It has excellent payload and its comfortable handling qualities remain unaltered. In fact, the airplane is so conventional in almost every respect that its handling hardly bears mention. Think of a slightly heavy, much more muscular yet considerably more maneuverable Cessna 172 with sticks. The stall is a non-event, even with full power on; it slips like an off-duty clown who wandered into a banana-peeling facility. The control forces and airplane responses are so easily learned that the biggest risk is probably sheer complacency.

Bottom line: Is the Sportsman TC the hot new thing for everyone? Not quite. A conventional E-glass model with a big-inch engine has good "everyday" performance. But for the pilot who needs to get off that short strip even in the back-wetting heat of summer, lives where density altitudes are always high, or simply wants the considerable operational flexibility provided by turbocharging, the TC is absolutely worth considering. +

Learning to Weld



It's a gas.
Part 3 in a short series on amateur welding.

BY KEN SCOTT

After attempting wire-feed and TIG welding in the first two installments of this series, it was time to try the old standard: gas welding. Even in the age of sophisticated electric welding techniques, gas welding—or oxyacetylene welding—has its strong points and its proponents. One such proponent is my neighbor Philip Groelz, who was kind enough to wheel his gas welding equipment down the street to my shop and show me the basics.

Gas welding is accomplished by melting and joining metal with a very high temperature flame, formed by burning the extremely flammable gas, acetylene. Normally, when we think of burning, we think of combining some fuel with air. But really, we're combining the fuel with oxygen, which makes up only about 20% of air. To completely burn acetylene

Photos: Kevin Wing, Ken Scott

and get the hottest flame possible, it is combined with pure oxygen. That is why you almost always see gas welding setups with two tanks: one contains acetylene, the other pure oxygen. These are packed into the tanks and stored at high pressure. The gasses are released through a regulator on each tank and travel down hoses to a pair of thumbscrew valves. The valves are mounted on the torch—a brass colored tube several inches long with an almost right-angle bend to a tip. In the tip is an orifice; tips and orifices are interchangeable and sized to provide the correct amount of heat for the job at hand. Welding thicker metal naturally requires more gas and oxygen.

Getting ready to weld doesn't require a grim expression and a bit of welding rod clasped in clenched teeth as builder Philip Groelz demonstrates here.

So We Begin

Open the regulator and the acetylene thumbscrew valve slightly, and gas flows into the torch and out of the orifice. Strike a spark with a flint igniter and *poof!*—a soft yellow flame springs to life. Slowly opening the other thumbscrew valve introduces oxygen. The gasses combine inside the torch, and the soft yellow flame turns bright blue and burns with a steady whisper. A blue conical flame with just a touch of "feather" at the pointy end seems to work best.

Although it's too bright to look at with a naked eye, the flame is nowhere near as bright as the electric arc formed by wire-feed and TIG welders. A simple set of dark goggles is enough to provide protection. Because the flame is not throwing off intense ultraviolet rays, there's no need for a full face mask, long sleeves and the other protective clothing electric welding requires.

The Melting Point

Bringing the flame to the work quickly raises the temperature of the metal. Steel

When the torch is first lit on acetylene alone, it generates a soft yellow flame.

When the oxygen valve on the torch is opened (slowly) the flame turns into a lovely blue cone.

moves rapidly through red to orange and then to bright yellow as a puddle forms near the end of the blue cone of flame. In a TIG welder, you can vary the amount of power and heat applied to the weld by modulating it with the foot pedal. In gas welding, the flame burns at a steady intensity. The amount of heat applied to any one spot is adjusted by moving the flame either closer or farther from the work, and by the duration the flame is held to any one spot.

Once a puddle forms, you can move the bead along by moving the torch in a small circular motion, advancing along the edges you want to join. Just like wire-feed or TIG welding, the puddle's the thing. You must learn to really *see* that puddle and keep it moving. Stay too long in one place and you risk burning a hole right through your work. Move too fast, and the puddle either cools and won't flow, or it never really forms. The result is intermittent globs perched on top of the metal, rather than a bead that blends the work pieces. (I found that my bifocals made it almost impossible to really see the puddle well enough, so I ended up taking them off altogether and moving my face closer to the work. Without the big helmet, I could find a place where my aging eyes could focus and see the details in the molten puddle.)

Material Evidence

While you could join two pieces of metal by simply welding their edges together, gas welding usually requires adding new metal to the puddle. This is accomplished by dipping a thin rod of metal, held in your other hand, into the puddle. Of course, when you dip a cold metal rod into a puddle of molten metal, it extracts heat and cools the puddle, which means you must bring the torch slightly closer to add heat and keep the puddle molten.

I found that holding the torch at an angle of about 40° to the work and letting the puddle form slightly to one side worked best. I'm right-handed, so I'd cant the torch to the left and work from right to left, letting the puddle form in front of the tip. This let me hold the rod in my left hand and dip it into the puddle without interfering with the torch or the flame.

After three or four hours of practice, spread over several 20-minute sessions, my hands and eyes were finally learning to work with one another in a little rhythmic dance. Get the puddle started, and then simultaneously move the torch and rod in a bit closer. As the rod melts into the puddle, pull it back ever so slightly while making a tiny advancing circle motion with the torch, then back in with the rod until the puddle widens, and repeat. At first, I could only get one or two iterations before I stuck the rod too deep into the puddle and froze it there, or I advanced too quickly and let the puddle get away. After many attempts I could eventually get the bead going and continue it for minutes at

Torches come with different orifice sizes. Thicker metal requires more heat and more fuel to create the weld.

Interchangeable torches mix the oxygen and acetylene and fit comfortably in hand.

One of the beauties of gas welding is that it's self-contained. Everything you need—gas, goggles, igniter, torch—is on one wheeled caddy.

A pair of regulators with gauges controls the flow of gasses to the torch. Red is acetylene, green is oxygen.

It doesn't take much to practice gas welding: a vise, a firebrick and a couple of scraps of steel.

a time. The hands move in, the hands move out, the puddle expands, recedes and moves on. As the dance acquires fluidity, muscles relax, breathing stays steady, and the bead starts to form the little series of overlapping puddles that are the mark of a good weld. You know you're getting it when your muscles remember what to do without help from the conscious part of your brain.

Groelz adds a tab to the tailpost of his Christavia fuselage.

The fuselage was gas-welded from plans.

Keepin' At It

At this point, many people bring up the old bromide about practice making perfect. Maybe, but it's important to define the terms. Practice and repetition are two very different things. *Practice* involves constant mental involvement and altering each repetition to improve and gain the desired result. *Repetition* makes for consistency, but it also can reinforce consistently wrong habits that are hard to overcome.

In my hangar, you can literally hear the difference. My wife is a professional violinist whose teaching studio is directly above my airplane building (currently welding experiment) workshop. When young students are practicing, they'll hit a difficult bit, stumble and then start over at some easier part. You can hear them getting tenser and more tentative as they approach the hard measures.

That's not what you would hear when The Violinist is practicing. She'll hit a hard part, stumble, then play *only* the hard part over again, slowly and deliberately, teaching her hands and ear the right movements and sound. This will happen several times, usually speeding up slightly, but always with the correct rhythm and pitch. She never goes back and starts at the easy part. She knows how to play that, so time spent there doesn't accomplish anything useful. Repetition is just a tool used during practice—it's the constant self-monitoring and correction with each iteration that achieve the result.

Old But Perfected

Although many think of gas welding as old-fashioned, it has several positive aspects. One is that you can gas weld anywhere you can drag a set of tanks and a torch. Of course, that dragging requires a bit of muscle as the standard tanks can be pretty heavy, but tanks are available in sizes comparable to a propane canister. That makes it pretty easy

That bead doesn't happen right away; there will be quite a scrap pile in the corner of your workshop before it does.

Eventually, the eye and the hand will cooperate, and something resembling a bead will appear.

to bring welding power to a job where electric power isn't available.

Another thing I appreciate about gas welding is the better visibility. Without the need for a really dark helmet, you can better see what's going on, though I suspect that once you become completely comfortable with whatever welding method you're using, this wouldn't be a big factor.

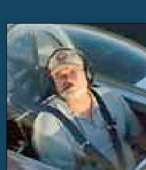
My favorite thing about gas, strangely enough, is aesthetic. There is something satisfying about the whisper of the torch and the soft splash of flame, as opposed to the hard crackle of wire-feed and TIG welders, that just made gas welding more fun.

So, after several months of on/off instruction, practice, and trial and error (lots of error) with three different methods of welding, I've managed to remove the welding monkey from my back. I'm not a real welder (every professionally welded piece I see reminds me of this), but I've found that, though welding is a real skill, it's a skill that the average person in a home shop can eventually acquire. It will take a modest investment in money and a more significant investment in time, but if you make it, you will have acquired a useful and enjoyable technique.

I'm shopping for an affordable TIG outfit for my home shop, and with some more practice, that Bearhawk might prove doable yet! ✢

KEN SCOTT

A longtime employee of Van's Aircraft, Ken Scott is also a multi-airframe builder (RV-6, KK-1, RV-12) whose quest for new skills remains unabated. He lives with his wife, Camilla, on a residential airpark near Canby, Oregon.



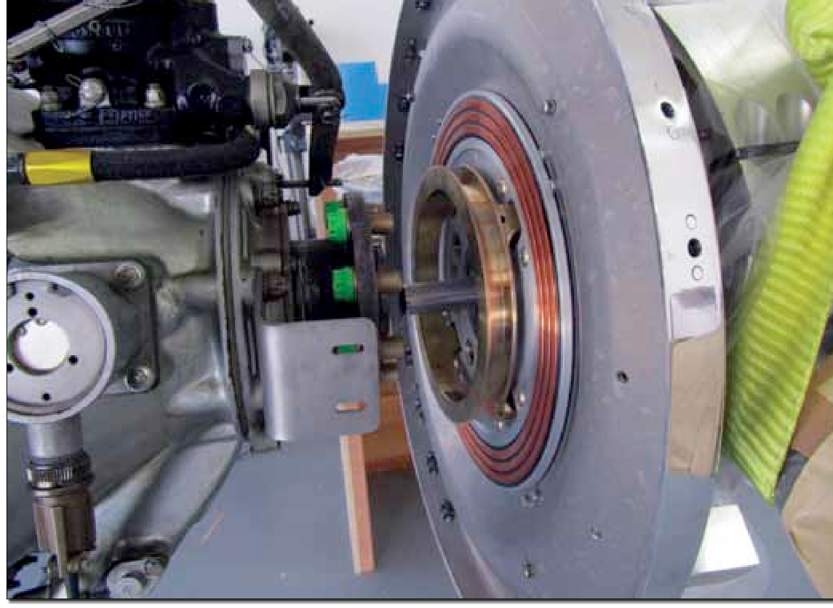
The Ultimate Upgrade

Wendell and Martha Solesbee begin installing systems in their Lancair Evolution.

BY DAVE PRIZIO

As we know from the first two installments in this series, Wendell and Martha Solesbee are building a Lancair Evolution, an honest-to-goodness 300-knot luxury kit aircraft that will someday whisk them across the country in a veritable eye blink. (These appeared in September and October, in case you want to get caught up.)

But for now there is still some assembly required, as they say. While the Solesbees' project began life in the factory-authorized build center, better known as Brian Harris's shop, they are now home on their own. The big structural parts were all done before transport from Oregon to California, but there are numerous systems to install, an engine to hang, interior and exterior finishes to worry about and, well, a lot of work to do between here and flying.



The contactor ring on the back of the prop allows for electrical power to be transferred to the propeller heating (deicing) elements. Access to the prop bolts becomes limited where the prop and engine come together. Wendell had to fabricate a special tool to tighten these bolts.

A Systematic Approach

So there are some systems to install. How bad can that be? The builders have instructions, right? Well, sort of.

The Solesbees were early kit buyers. When they first arrived back home in Chino with their new project, the instructions were what you might call a work in progress. When they unloaded the fuselage and wings at their hangar the instructions consisted of a few dozen sheets of notebook paper with sketches, notes and some dimensions. Because the Solesbees have previously built two other airplanes including a Lancair IV-P, they were undaunted by this considerable challenge and simply got to work.

In fairness to Lancair, the instruction manual is now well-developed and available for anyone to see on the company's web site. It is updated frequently and is apparently up to the considerable task of guiding a builder through the complex process of assembling a high-performance airplane, but it didn't start that way. Few new kit manufacturers get the instructions right from the start.

We will look at each system, in no particular order, to see what the Solesbees had to do. Remember they are not dropping into a professional builder-assist center from time to time where every tool and part is laid out perfectly to make assembly as easy as possible. They are working the old-fashioned way, which is why we are so interested in following along as they learn. Which skills are to be tested? Builder-installed systems in the Lancair Evolution include powerplant, electrical, avionics, fuel storage and delivery, hydraulics, flight controls and rigging, cabin pressurization and air conditioning. Yes, just about all of them. (Interior and exterior finishes will be covered in a future installment, as will the first flight.)

Put Your Pratt Here

Let's start with firewall-forward. Lancair helped the Solesbees secure a mid-time Pratt & Whitney PT6A, which saved them about $200,000 as compared to buying a new engine for about $450,000. The factory also provided the parts and fabrication necessary to set the engine up to install. This prep work and fabrication currently costs about $85,000 and is necessary to ensure that the engine will work well in this plane. If these numbers are leaving you a bit short of breath, you're not the only one. It takes time to get used to turbine prices. As early builders, the Solesbees saved some money compared to current costs, but they also paid a price by being guinea pigs for a developing product. Still, the fact remains that if you're going to fly on kerosene, you

Builder Wendell Solesbee connects a fuel line to the gascolator on the firewall. The firewall blanket protects the composite structure from the heat of a potential engine fire. On Wendell's right is the electrical control unit. In front of him and slightly to his left is the flow pack, which controls turbine bleed air used for cabin pressurization. Other items seen include the brake fluid reservoir, a ground bus bar, and two ammeter shunts.

Photos: Courtesy Wendell Solesbee, Dave Prizio, Marc Cook, Pratt & Whitney

With the engine and propeller now in place, Wendell can bring his considerable expertise with composites to bear on fitting the cowl. This was the most difficult composite work to be performed on the Evolution. It is also one area where an inexperienced builder would need some serious help.

The space between the engine and the firewall is a busy place in the Evolution engine compartment. In this photo the flow pack and gascolator stand out. Beyond that it looks like a big bowl of spaghetti, but the Solesbees know where everything goes, or so we hope.

The engine air intake mates to the scoop on the cowl. Inside the cowl the air is split so that some of it goes to the oil cooler, seen below the engine air intake, with the rest going into the engine. The plastic is there to keep dust out of the engine while the Solesbees sand the fuselage.

must be prepared for the overall economics of it.

The firewall-forward process begins with installing a protective blanket over the composite firewall structure, a step common to Lancairs and other all-composite aircraft. The blanket is there to ensure that the heat that could be present in the case of an engine fire will not ignite the composite structure, which will start burning on its own once it reaches about 700° to 800°. The test is to be sure that a 2000° engine fire can be contained for 15 minutes before it becomes a whole-plane fire. Lancair makes this protective blanket for the builder, and all the builder has to do is secure it in place. Once the blanket is installed, items like the flow pack (pressurization), the gascolator, the auxiliary fuel pump and the electrical control unit attach to the firewall. Lancair provides a layout for these items, so it is fairly easy to place them before the engine goes in, which makes things much simpler.

With the preparation now complete, the engine and mount slide into place. Lancair, as part of the firewall-forward package, has pre-installed the intake plenum, the oil cooler, the starter/generator and a host of other minor accessories, greatly reducing the need to work in the tight space between the engine and firewall. A massive Hartzell four-blade prop caps the engine installation, but the contactor ring to transfer power to the prop's heating elements produced some tight working spaces for securing the prop bolts, forcing Wendell to make a special wrench just for the task.

Volts and Amps

The electrical system of the Evolution goes a step or two beyond what most amateur builders will ever tackle, but it encompasses items that individually are familiar. They are just bigger and more complex than what most of us are used to seeing. The system begins with a pair of Concorde RG24-20 batteries. They are only rated at 19 amp-hours each, but remember that at 24 volts a 19 amp-hour battery puts out power (watts) like a 38 amp-hour, 12-volt battery. They weigh 42 pounds each and together put out power equivalent to 900 cold-cranking amps at 12 volts. The Evolution power control system connects these in parallel for starting.

We ordinary builders would expect to see things like master/starter relays and voltage regulators on the firewall, but in the Evolution all of these functions fall to the power control unit. This box manages the battery charging and electrical distribution chores, making sure power is always available when and where it is needed. To connect it, the Solesbees got good use out of their king-sized wire crimpers, where #2 and #1 AWG wires are common.

From the power control unit the big wires head to the starter/generator. This engine-mounted unit combines both starting and charging tasks into one device. This is standard for turbine engines, but unseen with piston engines, at least the kinds of piston engines homebuilders are used to working with. It makes perfect sense to get double duty out of such a heavy piece of equipment, but managing it does add complexity to the electrical system. Luckily, Lancair provides its customers with a detailed wiring diagram and installation instructions for all of these items. It also provides builders with pre-wired harnesses for most major systems. Some ends need to be attached to connect to certain components, but the wiring harnesses greatly simplify electrical tasks.

The control of the electrical system, the engine sensors and the avionics all come together on the instrument panel, so it makes sense to talk about them at the same time. The instrument panel is another area where Lancair has gone a long way toward making Evolutions look like factory-manufactured airplanes. As we read before, the basic structure of every Evolution is assembled in the factory jigs to ensure a great deal of uniformity across the fleet. The instrument panel is similarly factory pre-wired with little offered to builders in the way of choices. The philosophy is that if they all fly the same and have the same systems, then training can be standardized for the fleet and pilot checkouts can be greatly simplified. This also makes the insurance companies happy.

Big-Screen Glass

The instrument panel houses the Garmin G900X system with added controls to specifically address the needs of the Evolution. The Garmin 900X is the Experimental version of the widely used G1000 system found in so many new certificated airplanes. Autopilot choices are limited to the TruTrak Sorcerer or the Garmin system, which is quite a bit more expensive. The Solesbees chose to go with the TruTrak because of their

Pre-wired electrical harnesses make wiring easy for the Evolution builder. The clear labeling on these harnesses speeds up the work and ensures that wires go where they are supposed to.

There is a lot happening under the cabin floor of the Evolution. Several access panels cover up the systems underneath. The hydraulic pump for the landing gear can be seen on the lower left.

Big power needs big wires. Those king-sized wire crimpers come in handy when putting ends on the #1 and #2 AWG wires that run from the batteries and the starter/generator. The power control unit handles all the power switching, routing and regulating duties for the Evolution. In most homebuilt airplanes, each of these chores is handled by separate components.

past success with it in their Lancair IV-P. This is a two-axis unit with vertical and horizontal control including ILS approach capability. For about $8000 it is an impressive autopilot. The yaw damper adds another $2500 or so. The Solesbees also added an Avidyne TCAD traffic system to the basic G900X panel. This is a sophisticated traffic avoidance system that will give them near airline-quality traffic information. A keypad data entry system complements the G900X installation.

Mercifully, all of this fancy stuff comes in a completely pre-wired instrument panel that simply bolts into place. Several cannon plugs connect the panel to wiring harnesses that make everything work. Wire sizes and routings have already been selected, and wire ends and cannon plugs are already installed in most cases. It is almost a matter of just dropping everything into place. With all that Lancair has provided you really don't have to know too much about electronics to produce a truly impressive electrical/avionics system.

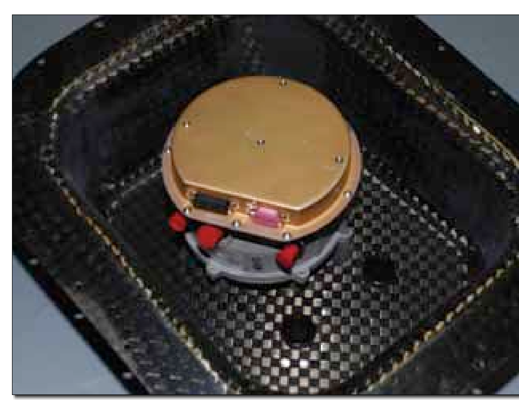
Antennas are almost an afterthought when avionics come up, but they need some special attention in the Evolution. Most "fast glass" builders are used to concealing antennas inside the fuselage, but with an electrically conductive carbon-fiber structure this is not an option. At 300 knots another thing that is not an option is inexpensive antennas. Nice, sturdy, high quality (expensive) antennas attached to the outside are the order of the day. Again, all of this is included in the kit price, so you hardly notice it.

The engine controls look familiar, but on closer examination they are a bit different than what piston drivers are used to. The Power lever controls turbine rpm and thus engine power. It also provides for reverse thrust or beta, in which the pitch of the propeller is changed so that it produces drag or negative thrust to help slow the airplane after landing. The Propeller lever controls propeller rpm, plus feathering. The Condition lever controls fuel to the engine, but does not adjust mixture as it would in a piston airplane.

Getting in Gear

The Evolution's hydraulic gear system is typical of larger airplanes from the certified world. The gear switch activates a hydraulic pump that raises or lowers the substantial landing-gear legs. These legs were originally machined aluminum, but early ground testing proved them to be rather fragile, so they were replaced

A small hand crank makes adjusting the position of the rudder pedals easy. In a matter of seconds, a taller or shorter pilot can be made comfortable with a few simple adjustments.



This valve, located in the aft cabin bulkhead, regulates the air pressure in the cabin by venting excess air overboard through the vents in the aft portion of the fuselage. If the pressure was allowed to get too high, it could blow out the windows and door seals; too low and occupants would not get the oxygen they need for high-altitude flight.

with heavy-duty welded steel legs that look like they could withstand just about any sort of landing short of a full-on crash. A hydraulic pump and accumulator sit beneath the floor of the baggage compartment where they can easily be accessed for servicing. If the hydraulic pump fails to respond when called, the accumulator may have enough pressure for one gear extension. Otherwise, gravity is the source of power for dropping the landing gear into place for the mains, and a gas pressure cylinder will extend the nose wheel. A little shake of the plane may be needed to lock the maingear into place when the gravity method is employed. There is no hand crank or manual hydraulic pump.

Flight controls look conventional, and they are. Good old cables run from the stick and rudder pedals to the various surfaces. The autopilot removes the need for rudder and aileron trim, but otherwise everything is as you would expect. The sticks are similar to the side sticks found in other Lancairs and various Cirrus models. They are attached to each side of the fuselage with one for the pilot and one for the copilot. Some Cub drivers may object to the reversal of the throttle and stick hands, but it is really pretty easy to get used to left-hand stick and right-hand throttle. If not, you can just sit in the right seat.

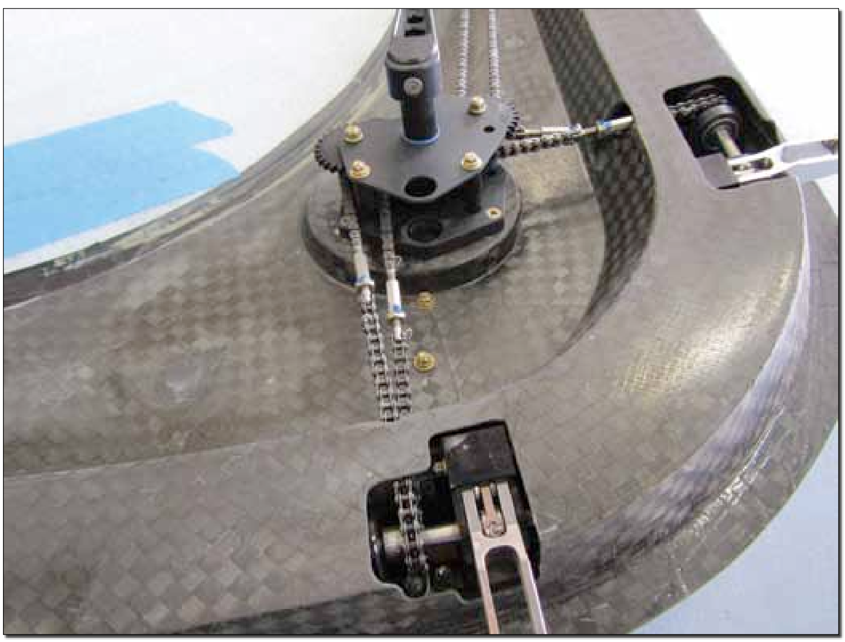
Wendell installs the new, beefed-up steel landing gear provided by Lancair after the original aluminum gear legs proved to be a bit too fragile. Lancair has been very good about providing these upgrades free to early kit builders.

The rudder pedals are fully adjustable, which brings a smile to Martha Solesbee's face. Being a bit shorter than Wendell, she really appreciates how easy it is to set the pedals in a comfortable position for someone of her height. A convenient hand crank makes pedal adjustment a snap. It is features like this that set the Evolution apart as a first-class airplane.

Gas and Go

The fuel system is simple except for the added complexity of a return system,

Martha Solesbee glasses in partitions in the cabin floor. These compartments will house various items such as the landing gear hydraulic system, the emergency oxygen system, and a number of electrical components. The complex latch hardware can be seen on the baggage door.



The complexity of the door latch mechanism is a thing to behold. In a pressurized airplane it is vital that each door latches positively and securely. At altitude there is an amazing amount of pressure on each door. Once the upholstery is in place no one will ever see all of this except at annual inspection time.

CONTROLS

Cockpit Powerplant Controls

PT6A engine applications use the engine power management system and propeller beta control capability to obtain optimum airplane flight and ground handling capability. The powerplant functions are typically commanded from the cockpit by means of three control levers and push-pull cables.

In some applications where certain powerplant functions are not required, simplified systems using two or even one cockpit control lever may be used.

Control	Location	Control Function
Condition	Fuel control unit (or start control)	Fuel cut-off and idle speed(s)
Power	Fuel control unit	Gas Generator speed
Propeller	Propeller governor	Prop speed and feathering

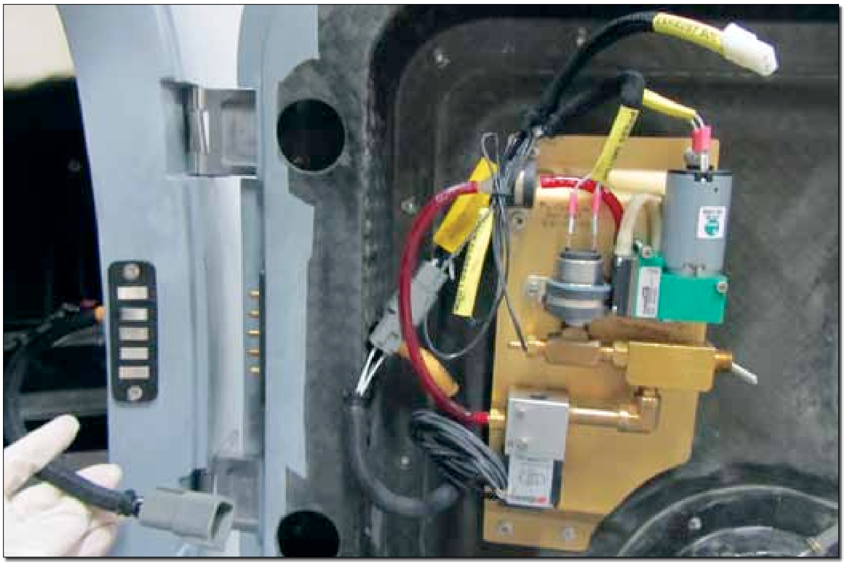
21

A page out of Pratt & Whitney's turbine manual. Lancair helped the Solesbees secure a mid-time P&W PT6A engine for their Evolution.

which is also found in some piston-engine planes. The tanks are provided by wet wing sections on each side and provide a total of 168 gallons of Jet A to feed the thirsty Pratt. There are no auxiliary wing tanks or center tank to add complexity, so things are pretty straightforward—this is a massive improvement over the turbine-powered Lancair IVs. A duplex Andair fuel valve switches feed lines and return lines simultaneously, so the return line system is transparent to the pilot once the plane has been assembled.

The engine controls are at once familiar and not quite so for piston pilots. There is a power lever that looks a lot like a throttle, and in fact acts much like a throttle. It controls engine turbine rpm and thus engine power. The power lever can also reverse the pitch of the propeller to help slow the plane after landing. Next is the propeller control, which also looks familiar, but has the added feature of feathering, something we see in twins but not in piston singles. The propeller control works through a governor on the engine to control propeller speed within a fairly narrow range of 1500 to 1900 rpm. Lastly, we see a lever marked "Condition." It looks like a mixture control, but it isn't. The condition lever is more of an on/off switch for the engine fuel, with added settings for high idle and low idle for ground operations. The actual fuel metering is handled by an automatic fuel control that is not directly linked to the pilot. These control levers connect to the engine through cables that could come right out of any homebuilt airplane.

A major system that is well-known to Lancair IV-P builders is the cabin comfort and pressurization system. Most of us consider this unfamiliar territory, but to the Solesbees this is ground they have covered before, at least in general terms. The Evolution pressurization system starts at the flow pack, where turbine bleed air is metered and sent to an intercooler to lower its temperature enough so that it won't melt the parts inside the air conditioning system. This is another component that Lancair found



To properly seal each door to an airtight condition, a small pump provides pressurized air to inflate the seal around the door. Electrical contacts in the door jamb allow power to be connected to the pump and controlled from the instrument panel.

wanting in its original form, so they sent the Solesbees a redesigned unit that works much better. Even though this caused a delay in the construction process, the free upgrade was most welcome, because it is such a critical component. Did I say free? Yes, Lancair has been good about making needed improvements during the building process at no cost to builders. The redesigned intercooler, just like the gear legs, were provided to kit builders at no extra cost. The company is to be commended.

Once past the intercooler, cabin air is cooled by an automotive-style air conditioner with an engine-driven compressor. The condenser is located in the back behind the aft pressure bulkhead and vented outside through two ports in the fuselage. With the bleed air already warm, added heat is unnecessary. Some electrically heated seats round out the cabin comfort package. One thing that goes automatically with pressurization is emergency oxygen. A small bottle provides about 20 minutes of oxygen to four people through masks in case of emergency.

The Builders' Perspective

While each system is fairly straightforward and furnished with clear instructions, an airplane with this level of performance has lots of items that need to be attended to, and the major differences between the Evolution and the IV-P have to do with support systems for the turbine engine. The Solesbees started out with little more than their previous experience and a handful of notes to go on—and let's not mince words: Their experience and craftsmanship on previous homebuilts count for a lot. But by the end Lancair had come through with a large volume of detailed instructions and some important upgrades. There is little doubt that an inexperienced builder would have been lost in the Solesbees' place, but now they would at least have a fighting chance of making it through to completion.

In all honesty, a fighting chance is not exactly what Lancair promises. Wendell and Martha brought a lot of building experience to this project, which made it possible for them to proceed where a novice builder surely would have been stuck without some serious professional help. What seems to be the case is that a large dose of professional help is needed to fulfill Lancair's promise to first-time builders, particularly those with a low-serial-number aircraft. We'll give Lancair its due and say that the manuals and guidance will continue to improve as more builders gain experience and the factory receives feedback from the field.

In the next installment, we will look at finishing the interior and exterior, a topic near and dear to the Solesbees' hearts owing to their longtime involvement in repairing, painting and customizing cars. In addition, we will look at the little details that are involved in getting from 90% done and 90% to go, which is about where the Solesbees are now, to really ready to fly. ✈

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

The beautiful Evolution instrument panel doesn't look as nice stripped of its major components, but the weight savings makes handling much easier and prevents possible damage to the expensive Garmin boxes that will go in later. Cannon plugs that connect to pre-made wiring harnesses make panel installation easier than you might think.

Some tips for stripping and crimping your way through any wiring project.

BY STEIN BRUCH

Many of you call and write asking for a simple overview of basic "wiremanship," so I thought I'd start out with a beginner's guide to wire stripping and crimping. Perhaps later we will have an opportunity to review other topics, but for this exercise I wanted to focus particularly on stripping a wire and crimping a terminal on the end of a wire.

So, yes, this process may not be as exciting as looking at fancy EFISes and GPSes, but being able to properly crimp wires is vital to your finished airplane. Even the most basic homebuilt aircraft will likely have a few wires that have been done improperly, resulting in bad repercussions. Indeed, there are a number of cases of airplanes—from large jetliners to small sport aircraft—that have crashed as a result of a simple wire terminal failure. For the purpose of this article I'll presuppose that you are using aircraft quality wire and aircraft quality terminals—*no automotive or hardware store brand components!*

Stripping

Most of your tools should be in the mid-level price range. Some import quality tools are acceptable as is, others must be modified to be acceptable. If you purchase your tools from a company that focuses on high quality tools or electrical components, you should be safe. Some of the tools from "big box stores" will be of good quality, but others not so much.

For stripping wire the best tool is a high quality stripper as shown in Figure 1. Most good strippers are made by Ideal, but other high end manufacturers make them as well. A good stripper will have a range of capability in its dies as shown in Figure 2. To strip the wire, simply insert the wire into the correctly sized cavity. In Figure 3 we see that when you first squeeze, the rear part of the stripper will grab the wire while simultaneously closing the stripping dies around it. To strip a wire, simply squeeze more, and the stripper will remove the outer

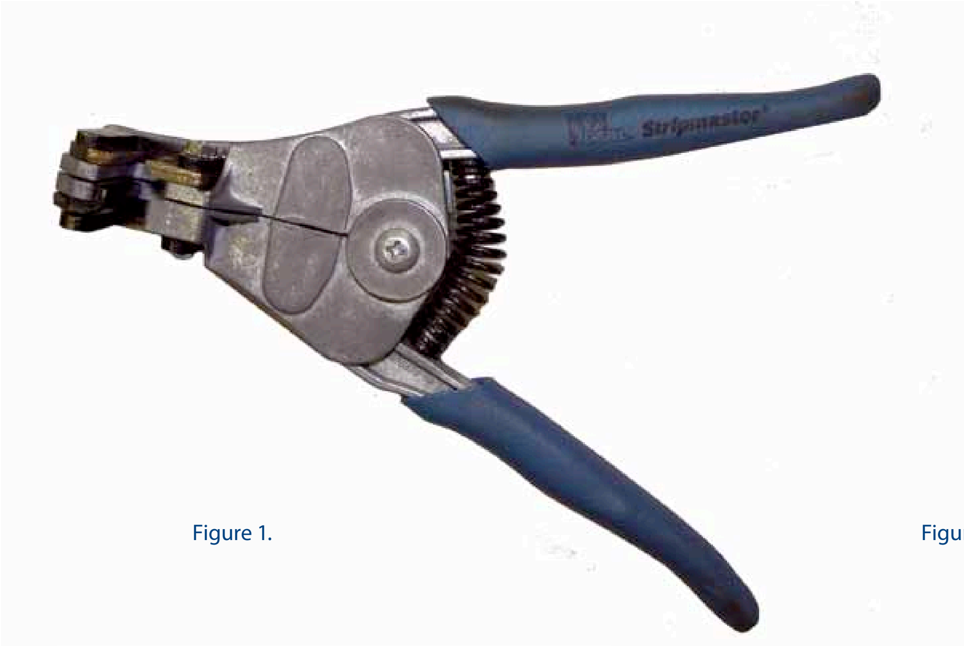


Figure 1.

Figure 3.

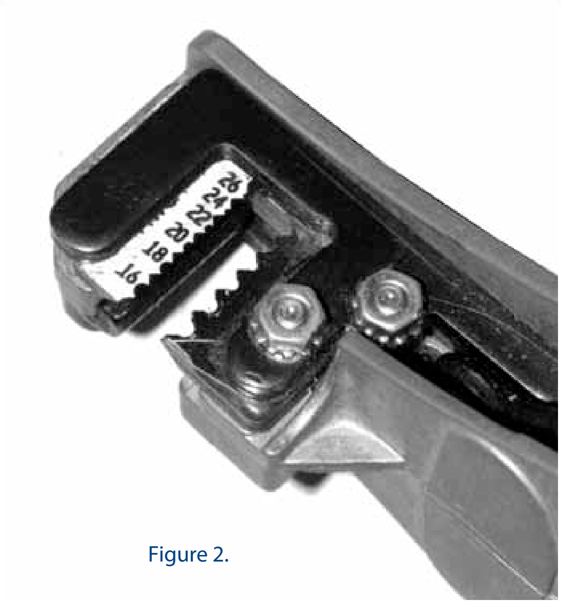


Figure 2.

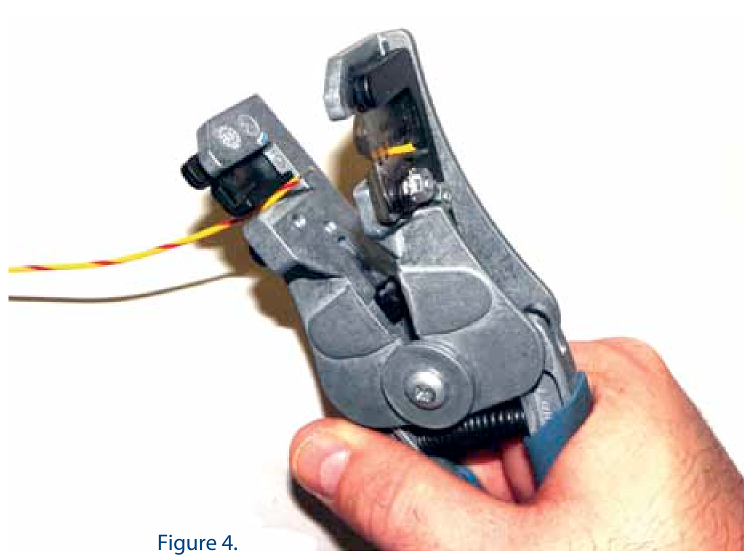


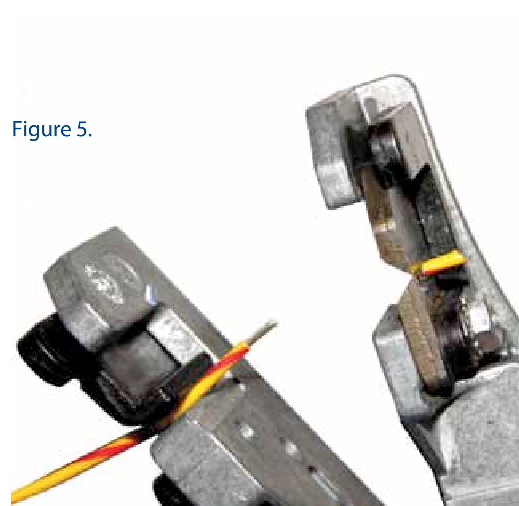
Figure 4.

length of insulation, leaving the conductor exposed as depicted in Figures 4 and 5. To fully cycle the stripper, you should squeeze it until the handles almost touch. If you have squeezed them far enough, the mechanism in the tool will release the wire first, then close the head of the stripper without damaging the exposed conductor.

Crimping

Once the wire is stripped, you can crimp on whichever type of pin or terminal you need. The first device we'll crimp here is a simple D-Sub machined pin, which is used throughout an airplane, from avionics to trim, wire, sensors and more. For crimping on these pins, most avionics shops will use a Mil-Spec certified crimper, but most homebuilders will be using a lower cost version as shown in Figure 6. (As far as I know, only B&C and SteinAir make the necessary modifications to imported tools for proper crimping.) To use this tool first place a pin onto the wire you just stripped. You'll notice on the small D-Sub pins that there is a little window (sometimes called a "witness hole") that allows you to see when the conductor is inserted the correct distance into the pin as in Figure 7. With the pin placed on the wire, you then insert it into the open cavity in the crimper face

Figure 5.



Photos: Richard VanderMeulen, Stein Bruch, Courtesy the Manufacturers

Figures 6 (right) and 7.

Figure 8.

(see Figure 8). You may also place the pin into the crimper and then insert the wire if you are sure the length of the stripped conductor is correct. If you are using a properly configured tool, the crimper will ensure proper depth placement of the pin as depicted in Figure 9. The indent crimper is easy to use: You simply squeeze it together until it releases. This is true for both certified and imported tools. A properly crimped pin will have four or eight indentations around the circumference of the pin as seen in Figure 10. Note that these pins may be soldered in place rather than crimped, and if done properly will be just as acceptable.

Figure 11.

Figure 9.

Figure 12.

Figure 13.

Figure 10.

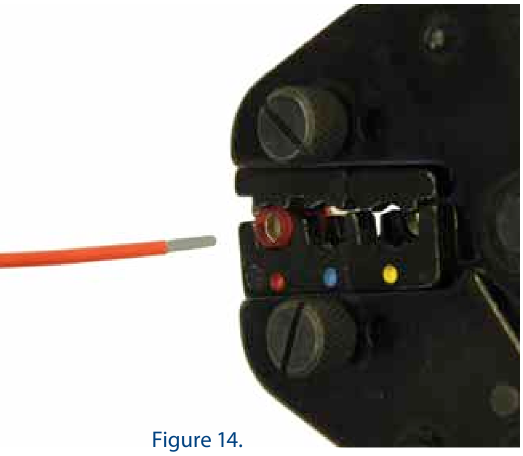
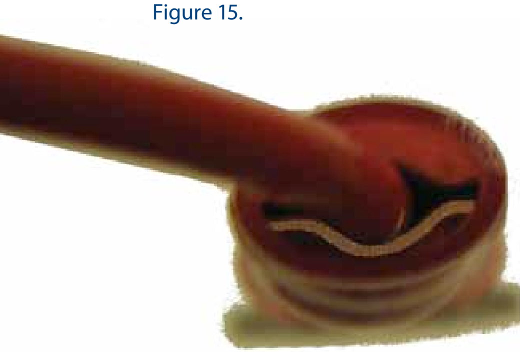


Figure 14.

Another type of crimper is the standard ratcheting terminal crimper shown in Figure 11. There are many variations of this crimper. Most will suffice if they have been reviewed or are being offered by a reputable company. These types of crimpers are somewhat adjustable and often will have interchangeable dies that allow you to crimp different styles of terminals and coax connectors. In this case we are specifically looking at the standard "red, blue, yellow" terminal crimper used for crimping ring terminals, spade terminals, butt splices and other similar components. The colored dots represent the color of the terminal to be crimped, and are sized properly for the wires you will be crimping.

You'll notice there are basically two rows of teeth to the crimper. If you look at Figure 12, you see that this is the front of the die with the colored dots and the cavity is shaped somewhat like a bowtie. This is the side of the crimper that will be used to crimp the insulation. The other side of the die as shown in Figure 13 has half-moon-shaped cavities and is used to crimp the conductor. Again,

Figure 15.



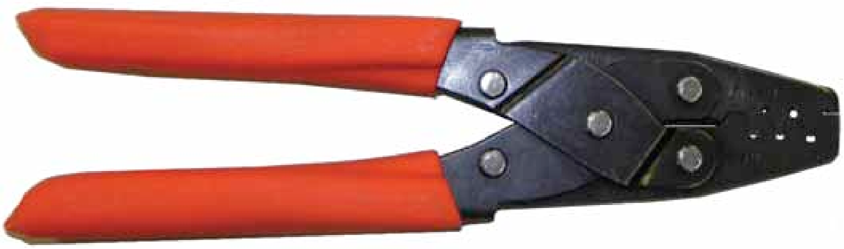


Figure 16.

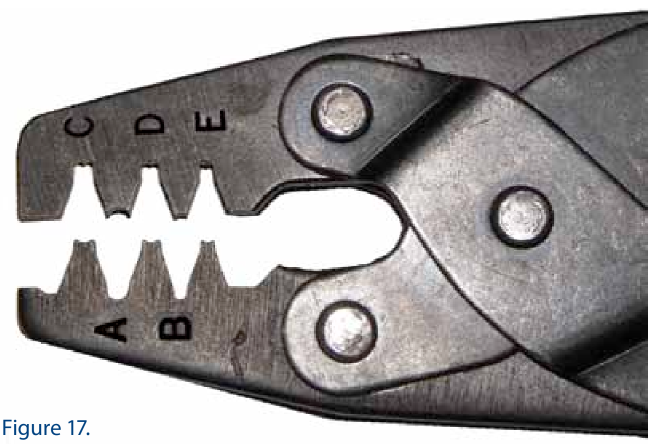


Figure 17.

Figure 18.

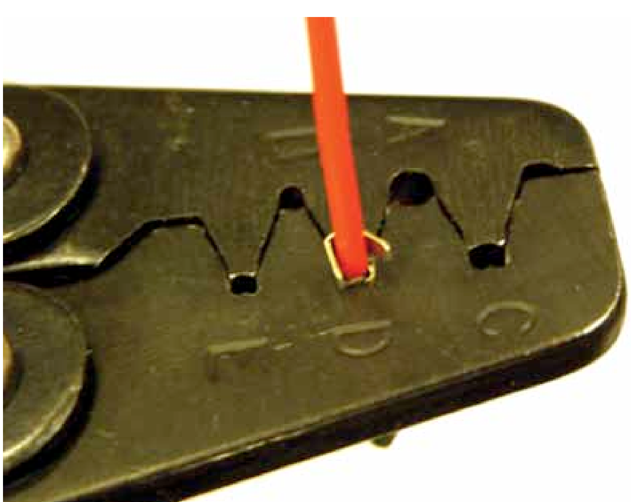


Figure 19.

you may insert the wire onto the terminal and then place it into the crimper, or you may position the terminal into the crimper first as shown in Figure 14. As with the other crimper, you simply squeeze these crimpers until they release. After you complete the crimp you can see that the rear of the terminal has a nice bowtie shape around the insulation (Figure 15). Helpful hint on these crimpers: Most of them have a "release trigger" in between the two handles. By moving this trigger you can release the crimper before its cycle is completed (useful if you have positioned the terminal improperly).

A common crimp used in homebuilts is the Molex type, which is used to crimp open barrel type pins for devices such as strobe lights, Mate-n-Lock connectors, strobe connectors and some avionics. A certified tool will cost hundreds of dollars but you can use a lower cost tool as shown in Figure 16. This crimper has multiple-size cavities in two different shapes. If you notice in Figure 17, the A/B cavities are circular in shape, while the C/D/E cavities are heart shaped. There's a reason for this. When placing the wire into this type of pin, there will be two sets of tabs on the pin (Figure 18). One set is for the conductor, and

Figure 20.

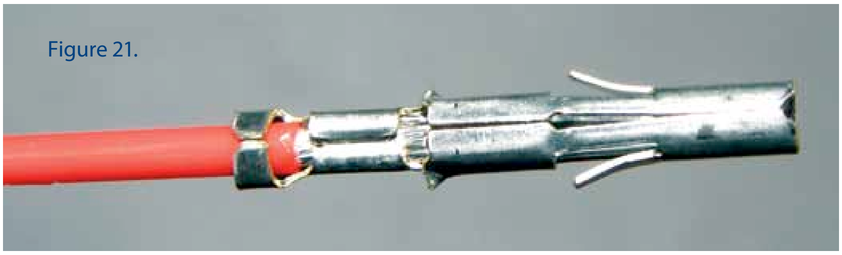


Figure 21.

the other for the insulator. To crimp these pins, the insulation gets crimped with the heart shaped cavities (C/D/E) first as shown in Figure 19. Next you move the pin and crimp the insulation in circular cavities (A/B) as depicted in Figure 20. The completed crimp that we show in Figure 21 highlights the circular bear-hug-type crimp and the heart-shaped crimp on the insulation. Note that these types of pins may also be soldered in addition to crimping.

Coax Connectors

Last but not least we'll look at the ubiquitous coax connector, specifically a BNC. While you will not use as many of these in your plane as most other types of crimped connectors, they are every bit as important, if not more so. Most audio, transponder and navigation problems on a newly built airplane can be traced to poor coaxial connections. For most BNC and TNC connectors we'll often use the same ratcheting type crimper as noted before, except with a new set of dies in it made expressly for coax crimps as seen in Figure 22. Figure 23 shows a piece of RG-400 coaxial cable as well as the typical components for a crimped-on connector. They consist of a center pin, a compression sleeve (ferrule) and the body of the BNC itself.

Figure 22.

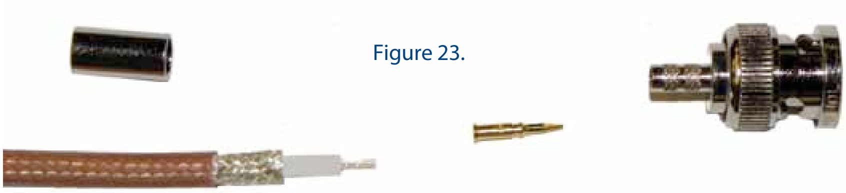


Figure 23.

Figure 24.

Figure 25.

Figure 26.

Figure 27.

Figure 28.

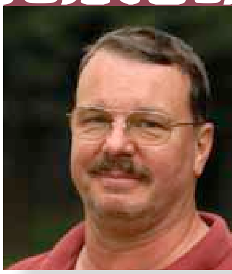
Figure 29.

You can strip the coaxial cable with a simple razor blade or purpose-made strippers. After you've stripped the wire, place the center pin onto the center conductor of the coax cable. You'll notice in Figure 24 that the center pin also has a witness hole to ensure proper insertion of the conductor. Next, simply crimp the center pin onto the coax (Figure 25).

After the center pin is crimped, place the sleeve/ferrule onto the coax cable (Note: If you don't do it now, you likely won't be able to put it on later). In Figure 26, we see how the body of the BNC relates to the outer shield. When inserting the pin, you'll feel a distinctive "click" when it is correctly seated. Then slide the compression sleeve that you previously placed on the cable up and over the shielding as shown in Figure 27.

Next, place the entire assembly into the appropriate crimper cavity and cycle the crimper as illustrated in Figure 28. Figure 29 shows the completed crimped BNC connector. We typically place a piece of heat shrink over the ferrule that both protects the connection and allows the connector to be labeled. Here's a helpful hint on BNCs and other coaxial cable connectors: They are gendered by the center pin, not by the body, so the connector pictured in these examples is a male, even though it appears to go over the outside of the mating connector as typical for a female connector.

The above noted examples certainly do not cover each and every type of possible crimp connector in the aircraft, but most are included. If you take your time and use proper tooling along with good quality components, your airplane will be quiet, safe and reliable. ✢



Dyna-Cam dreams.

"If this engine is so great, why can't I buy one?" mimicked engine entrepreneur Pat Wilks. "You just can't believe how many times I've answered that question." Wilks has devoted a good portion of her adult life to bringing this engine design to market, only to be thwarted when success seemed to be just within her grasp. Wilks and her brother Dennis Palmer have long been devotees of the axial engine design commonly referred to as the Dyna-Cam, and even after several decades of effort and personal investment, their passion for the project still runs deep.

You might think that 25 years would be long enough for any mere mortal to devote to such a project before throwing in the towel. But Wilks and Palmer have achieved many developmental milestones along the way, including maintaining the actual FAA certification of the engine for use in helicopters achieved in 1957. They also completed a successful installation and subsequent test flights in a Piper Arrow.

So, why isn't this engine powering airplanes?

A closer look at the main engine components. Twelve cylinders and six double-ended pistons turn the center shaft via roller bearings, with substantial thrust bearings on both sides of the center cam.

Nothing New Under the Sun

Also known as a swashplate, wobbleplate, cam or barrel engine, similar designs have seen service in airplanes since 1911. They're all called axial engines for good reason—the pistons are parallel to and surround the center output shaft, which is driven directly from the pistons firing in a sequential rotation, usually transmitting combustion stroke power via a tilting plate or sinusoidal cam. Intake and exhaust valve functions are as varied as the many versions of axial engines, from traditional rocker operated "poppet" and sleeve valves to simple intake and exhaust ports. Several of these versions were rotary in nature, where the cylinder barrel rotated around a fixed center shaft, like the Gnome rotary engine that powered WW-I fighter aircraft.

All of these early engine designs shared several attractive features: They all had a reduced frontal area, a low total parts count resulting in a higher power-to-weight ratio, and they all developed a relatively higher amount of torque at lower rpm than traditional piston engines. Their elongated, cylindrical exterior shapes made them perfect for applications where this particular form factor was ideal, such as powering torpedoes, and they even racked up an intermittent but proven role as aircraft powerplants.

Aerial Aspirations

Several features of the engine design are hard for airplane builders to forget. Besides a form factor that lends itself to a low-drag cowling, the latest iteration of the Dyna-Cam design produced 650 foot-pounds of torque at 200 horsepower, turning at 2000 rpm. Six double-ended pistons in 12 combustion chambers, all firing parallel to the center shaft, guaranteed that the engine would have low vibration and greatly reduced power-pulse transmission compared to traditional piston engines. Several propeller designers looked forward to the prospect of having a high-torque engine that would allow them to design more efficient props.

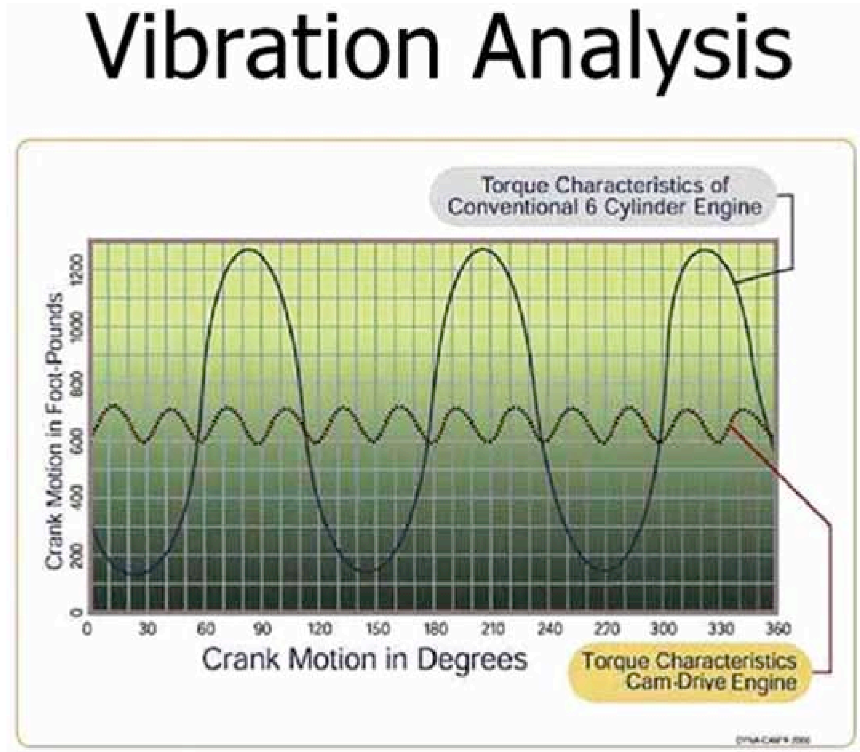
Rick Lindstrom *has been fascinated with motorized devices since the disassembly of his mom's Kirby vacuum when he was 3, predictably followed by record player motors and lawnmower engines. After he learned to fly, it was only natural that he gravitated to the world of alternative aircraft engines. He currently pilots a Corvair-powered Zenith and is undecided about what will power his GlaStar.*

The number of engine components was greatly reduced, as was the weight, typically coming in at right around 300 pounds with accessories. Dimensionally, including both intake and exhaust manifolds, this 200-hp aero engine had a diameter of only 16 inches and a length of 40 inches. It used a pair of garden-variety Bendix magnetos and a Bendix fuel-injection system, and many other minor components were stock aviation parts. The double-ended pistons driving the sinusoidal cam attached to the center shaft were atypical, but their elegant simplicity suggested increased longevity and low overhaul costs.

Ancestry

It was in 1916, just a stone's throw from the dawn of powered flight, when two brothers named Blazer developed what would become the Dyna-Cam. They sold the rights to Studebaker's head of engineering, Karl Herrmann, who improved the roller bearing operation and then patented the design in the late 1950s. During WW-II, Herrmann had been a civilian employee of the U.S. Navy, and a smaller version of his design that was only 6 inches in diameter ended up powering the Mark 46 torpedo.

In 1961, Herrmann was 80, and sold the rights to his engine to Edward Palmer, who created manufacturing and marketing plans for the design into the 1980s. His son Dennis and daughter Pat joined the effort and founded the Dyna-Cam Engine Corporation. After installation in the Piper Arrow test bed, the engine logged 700 flight-hours between 1987 and 1991. Another of their engines ran for nearly 4000 hours before requiring an overhaul. New patents were acquired between 1985 and 2000, and the commercial success of this design seemed almost assured—assuming that the right financial backing could be secured to propel the Dyna-Cam into full-scale commercial production.



Having 12 small cylinders instead of four large ones means three times the power pulses closer together, resulting in much lower total vibration, and less stress on the engine installation and prop.

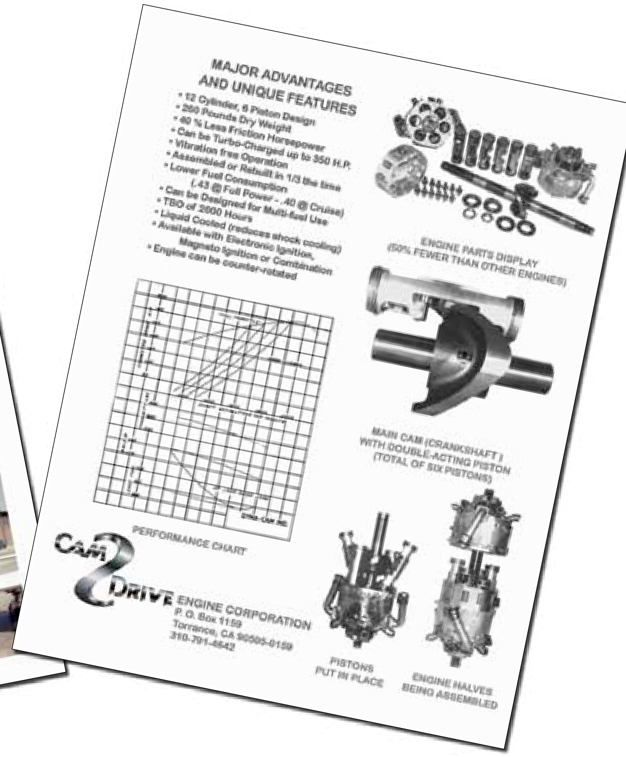
Cloudy with Chance of Rain

The plan was to go public in 2001, and with the help of a consulting management team, the company's initial public offering (IPO) awaited the approval of the Securities and Exchange Commission. The IPO was finally approved, but not until September 13, 2001. The attack on the World Trade Center two days earlier had changed the investment landscape instantly. "9/11 changed everything," Wilks said. "Investors just dried up. And there was growing sentiment in the investment community not to invest in industrial technology based on old designs."

"We were ready to throw in the towel," Wilks said, "but we found some new investors in 2003." Engines, components and manufacturing equipment

The aircraft version circa 2001, showing most of the major accessories installed except for the exhaust system, spark plugs and fuel-injector lines. It was FAA certified in 1957 with only one spark plug per cylinder.

Photos: Rick Lindstrom



This marketing page shows some of the planned uses for the engine, including marine. One of the prototypes powered this 20-foot boat over four years. Another version racked up 700 hours in the Piper Arrow test bed.

The company brochure from the early 1990s shows just how unconventional the design is when compared to a traditional piston aircraft engine. Features include low parts count, lighter weight, smaller size and high torque.

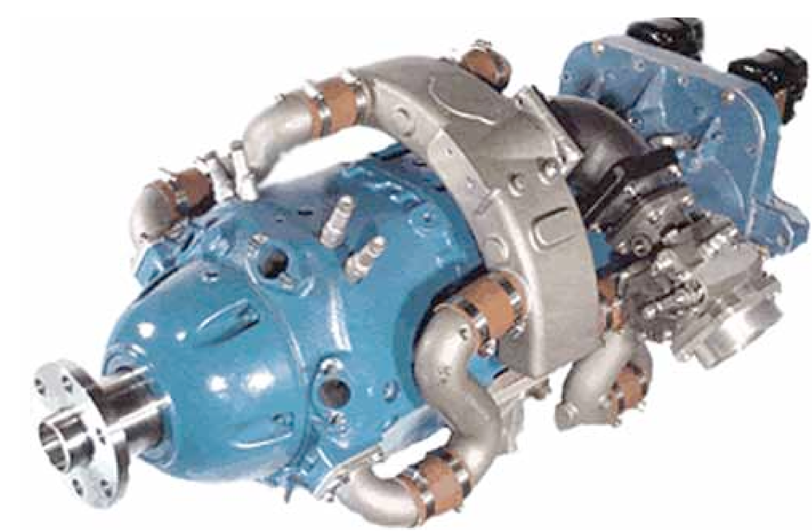
were shipped to the new company's headquarters in New York. Some of it was lost or destroyed in the process, however, and the new management seemed unconcerned, according to Wilks. The new relationship began to slowly but steadily drift off course. A lawsuit ensued.

Still Dreamin'

After the dust settled, where did that leave the engine design? The investors ended up with only the web site and the Dyna-Cam name, Wilks said.

Not surprisingly, there is still interest in the engine within the aviation community. A bit of time on YouTube with a search of "dynacam" serves up the original 12-minute marketing video. Although somewhat dated, it underscores the design's promise.

Wilks and Palmer have a good deal of the original assets needed to put the engine back into production, but it would take a bona fide investor who was willing to see the project through. Until the working capital can be secured, it appears this engine design will remain just out of reach. ✈



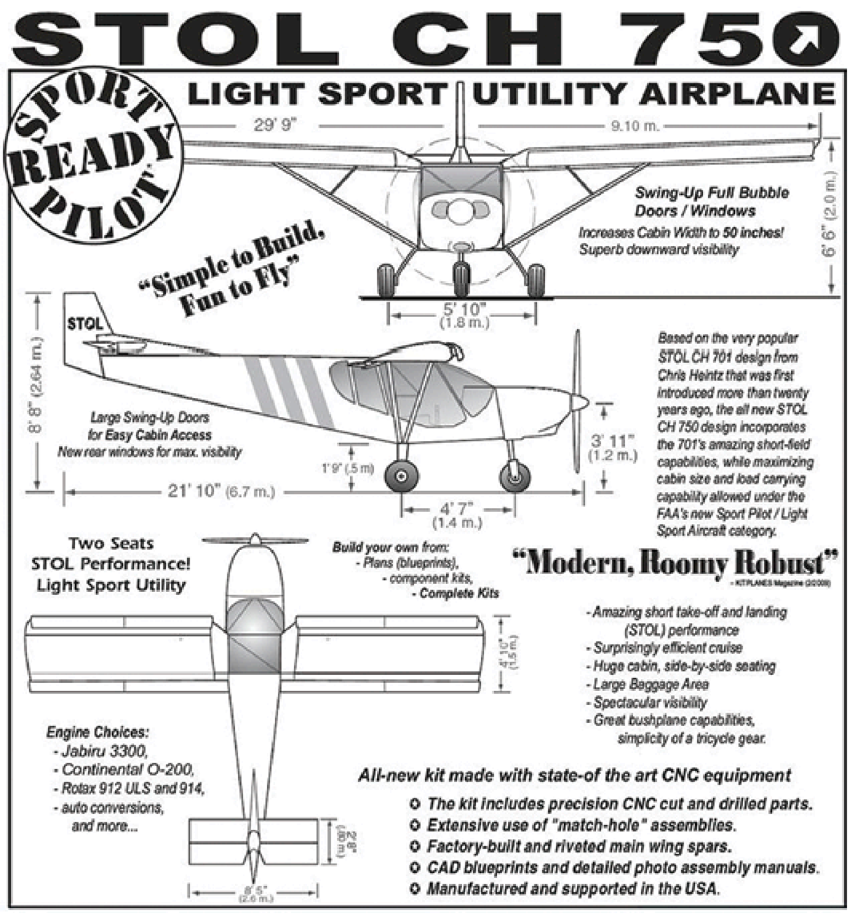
This view of the engine shows the conventional propeller hub, intake manifold arrangement, conventional carburetor and Bendix magnetos mounted on the rear accessory case.

SIM WORLD
SIM WORLD

SIM WORLD

With X-Plane, you can have the pleasure of "flying" your kitbuilt even while it is under construction.

BY CHUCK BODEEN



One of the first things you need to make a model is drawings of the airplane. These were found on Zenith's web site (*www.zenithair.com*) along with the dimensions and performance specs.

How much of a motivational tool would it be to be able to simulate flying your homebuilt long before it was actually completed? Using the X-Plane flight simulator, you can do exactly that: build and fly a computer model of any airplane.

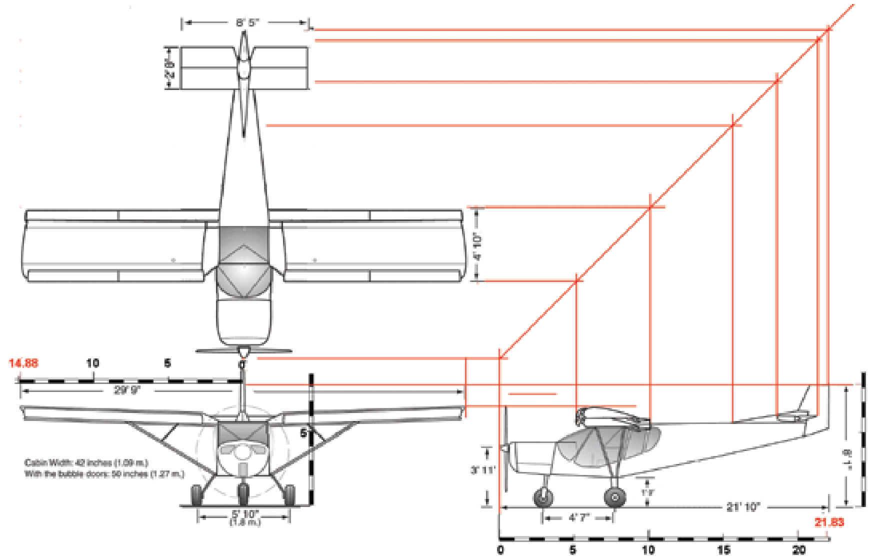
Laminar Research's software is actually a package of four programs: Plane-Maker is used to build models; Airfoil-Maker is used to specify the lift and drag characteristics of airfoils; X-Plane is the program used to fly the planes; Briefer gives a weather briefing using real data from the Internet and flight time for any plane among more than 25,000 airports.

The system works by dividing the model into hundreds of small areas, calculating the aerodynamic forces on these, adding them up and then using fundamental physics to determine the behavior of the plane. With good input, this usually results in accurate predictions of how an actual ship will fly. This article will show you the results, but not the details of how to use the programs included in the X-Plane manual. Let's try it out using the STOL CH 750 from Zenith Aircraft.

Photos: Chuck Bodeen

Plane-Maker

Plane-Maker is a computer-aided design program specialized for X-Plane modeling and is included with the $29 package from *www.x-plane.com*. The program understands the fuselage, wings, engines, landing gear, etc., and most of the more important information required can be found on the kit manufacturer's web site. Many other details can be filled in by contacting the company directly, but an educated guess may be necessary to fill in any data that you may be missing.



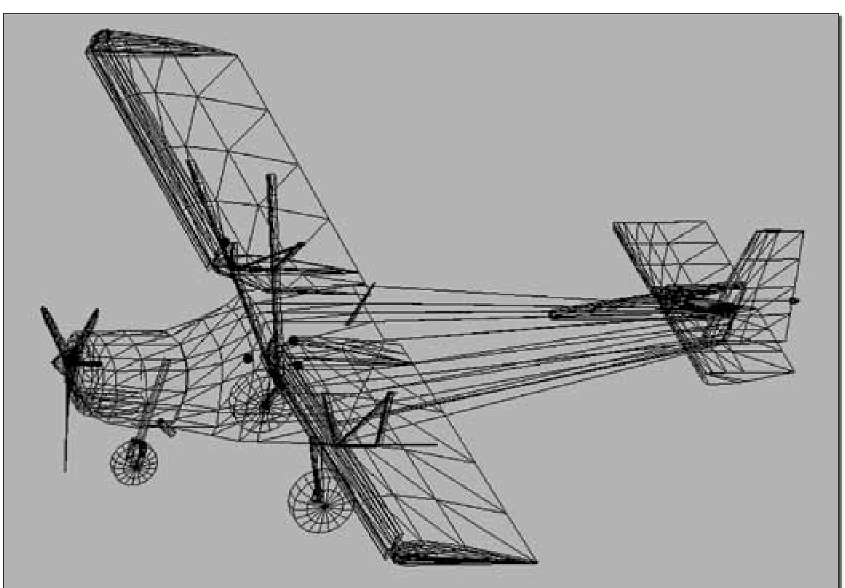
The drawings can be used as "backgrounds" in Plane-Maker, but should be checked against each other for consistency of scaling.

Length	21 ft. 10 in.
Height	8 ft. 8 in.
Wingspan	29 ft. 9 in.
Wing Chord	4 ft. 10 in.
Horizontal Tail Span	8 ft. 5 in.
Horizontal Tail Chord	2 ft. 8 in.
Empty Weight	775 lb.
Gross Weight	1320 lb.
Fuel	2 x 12 gal.
Engine Power	100 hp

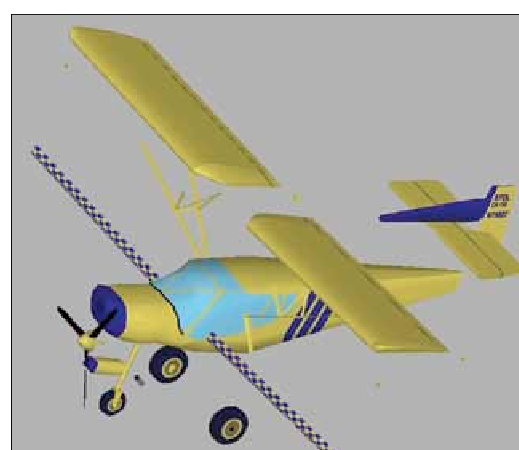
Table A: Critical data for the Zenith CH 750.

The plan view and the dihedral of the wing and tail are drawn in Plane-Maker, as are the extent and movements of the control surfaces. The CH 750 has flaperons, where one control surface does the work of both flaps and ailerons. In Plane-Maker, flaperons are specified by "ailerons with flaps" on the Special Controls screen. The flaperons are in two sections along the wingspan. The inboard part is a little lower than the outboard. The result is to provide the effect of wing twist without twisting the wing; the inboard wing stalls before the outboard part so that aileron control can be maintained. While Plane-Maker cannot lower part of the flaps, it does allow for two sets of flaps, each with different characteristics. I simulated this by giving the inboard flaperons a bit more lift coefficient (C_L) and drag coefficient (C_D) when extended.

If flaps are down to 15° and the pilot then commands ailerons to roll to max 13° deflection, one of the flaperons is then lowered to 15 + 13 = 28, and the other is at 15 - 13 = 2. The lift and drag characteristics of the airfoils are set by Airfoil-Maker.



Using Plane-Maker, a "wireframe" is constructed. Although there are many parts when the wingstruts are included, this is relatively easy because of the simple lines of the CH 750.



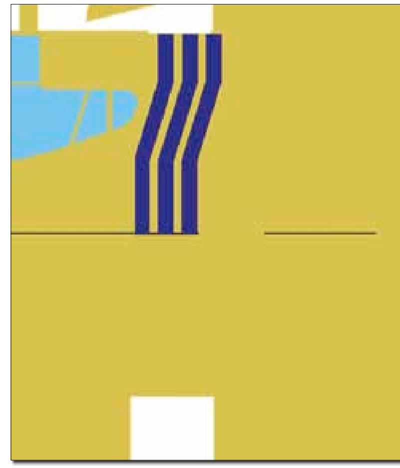
This picture shows the various parts after they were painted.

	Airfoil	Thickness	Dihedral	Incidence
Wing	NACA 650-18 (modified)	16.67%	1.25°	+3°
All-Flying Rudder (root)	NACA 0012	15.55%	90°	0°
All-Flying Rudder (tip)	NACA 0012	10.55%	90°	0°
Horizontal Stabilizer	NACA 4412 inverted	14.65%	0°	-1°

Table B: Zenith provided data on the airfoils.

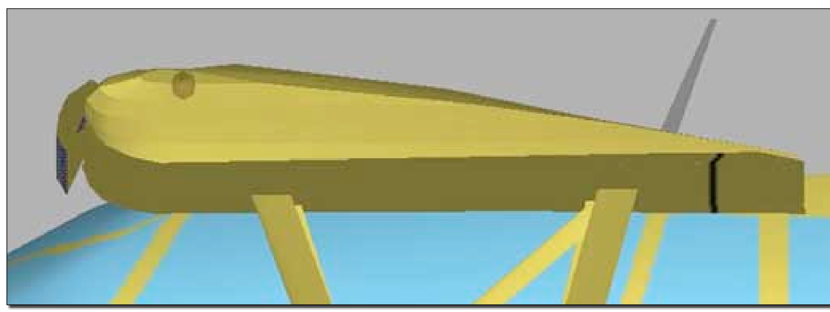
	Spanwise Extent	Chordwise Extent	Deflection
Ailerons	100%	14%	+/-13°
Flaps	100%	14%	0 to 15°
All-Flying Rudder	100%	100%	+/-23°
Elevator	100%	50%	+28°/-30°

Table C: Direct communication with Zenith Aircraft provided the control-surface deflections. Flaps are electrically controlled over the whole 15° and have no detents.



A file named "CH-750_paint" is used to apply texture to the wireframe. Each part can be assigned to any area of the file.

Plane-Maker has the ability to use more than 300 stock instruments, buttons and handles to design panels. You can modify the appearance of any of those and create custom ones as well. You may not find exact matches in the way they look and operate, but the fit will usually be close enough.



The slat on the leading edge of the wing is an X-Plane "misc body." It is specified to have zero drag and does not participate in the aerodynamics of the wing itself.

Airfoil-Maker

X-Plane represents airfoils that can be created or modified with Airfoil-Maker, which also comes with the package. There is a library of airfoil lift and drag coefficients as functions of angle of attack, and the NACA 0012 is included. Airfoil data is stored as text files with names like "NACA 0012.afl." These files contain the shape of the foil and long tables of C_L, C_D and moment coefficient (C_M) for angles of attack ranging from -180° to +180°. By entering parameters in Airfoil-Maker, you can change the shape of these three tables over AOA from -20° to +20°. When you save the file, the program makes a reasonable estimate for the data from -180° to -20° and from +20° to +180°.

The horizontal stabilizer has an inverted airfoil because of the need to keep the tail down at high angles of attack. The NACA 4412 data is available from sources such as *Theory of Wing Sections* by Abbott and von Doenhoff.

The model bears a good resemblance to the real airplane.

A working replica of the panel can be created in Plane-Maker.

In creating a new airfoil file, AirfoilMaker accepts data only for angles of attack between -20° and +20°. The program fills in the rest of the full range. This process is reasonable for airfoils that stall at angles of attack less than 20° and may be acceptable for the stabilizers. The real challenge is to model the airfoil for the wing.

Zenith modified the NACA 650-18 foil by adding fixed open slats on the leading edge and by stretching aft of the quarter chord point. This is probably why the thickness is less than 17% instead of 18%. Here is a summary of the information from Zenith about the characteristics of the wing:

For the linear portion of the C_L (coefficient of lift) versus AOA (angle of attack) curve:

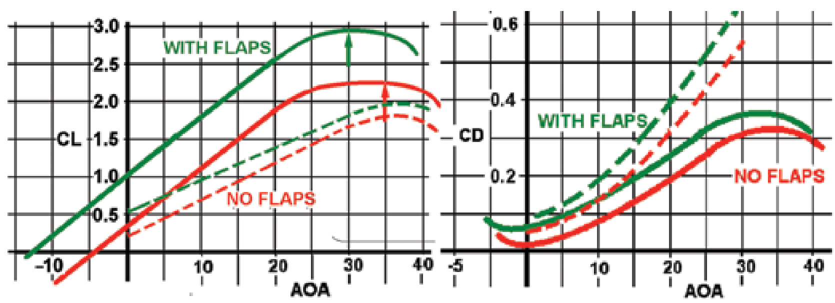
$C_L = 0.075 \times (AOA - 4.2)$ with no flaps

$C_L = 0.075 \times (AOA - 13.5)$ with full flaps

$C_{LMAX} = 2.25$ with no flaps

$C_{LMAX} = 2.95$ with full flaps

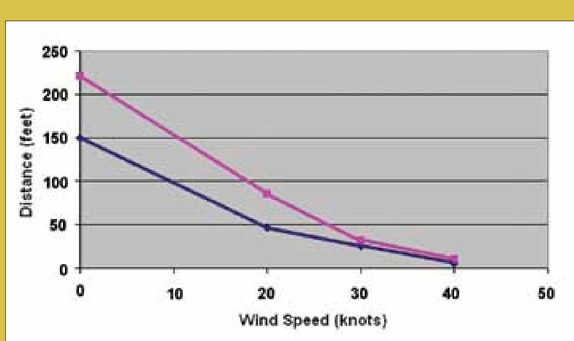
The drag coefficient is made up of two parts: skin friction and form, and



On these charts, data for the wing airfoil is shown with solid lines. The dashed lines represent C_L and C_D for the whole airplane whose values were obtained by flying the model. As angle of attack increases, whole-body lift decreases and drag increases relative to that of the wing itself.

Flying Conditions

The Wright brothers took their first plane to Kitty Hawk because they knew they could have a reliable headwind for takeoff. The wind on their first flight was reported to gust to 27 mph, and the groundspeed was less than 7 mph. That meant the airspeed was about 20 mph. With a headwind of less than 20 mph, they would not have been able to take off. In my simulation of the Wright flight, I found that if the wind exceeded much more than 32 mph, they would have taken off and flown backward like a kite.

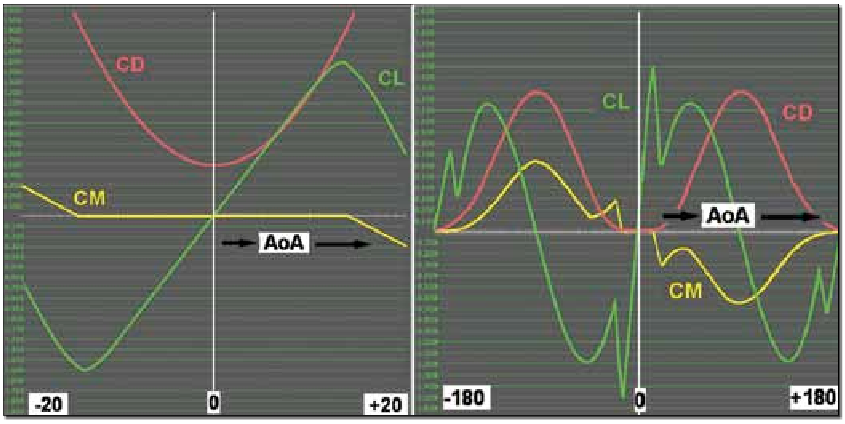


At different wind speeds, the model takes off at anywhere between the two lines. With a 10-knot wind the Zenith specification of 100 feet is matched.

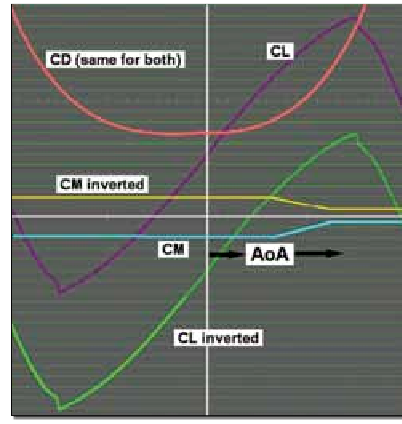
Sometimes reports of actual flying can also be useful. In the February 2009 issue of KITPLANES®, LeRoy Cook reported that when he flew the CH 750, it lifted off in "a scant few hundred feet" with "45 mph at liftoff and increasing to 65 mph in the climb."

The information about the takeoff distances reported by Zenith and by LeRoy Cook's flight review leave out one important aspect: the headwind. A recent web release and video showed that the CH 750 could take off in just 25 feet if there was a 20-knot (23 mph) wind. You can watch it at *www.zenith.aero/video/impressive-short-take-off-and*. I'm not an experienced STOL pilot, but as in the video, in my simulation I pushed the throttle all the way in and raised the nose before releasing the brakes. The original model made it up in an average of 85 feet. I then reduced the fuselage drag and the landing gear coefficient of friction and was able to reduce that even farther to 47 feet.

—C.B.



Airfoil-Maker allows you to work within 20° on either side of zero angle of attack and then fills in the rest of the full range for you. This is data for the NACA 0012.



Inverting an airfoil requires that the lift coefficient be reduced by an amount equal to twice the value at AOA = 0. The moment coefficient must simply have the algebraic sign changed at each value of angle of attack. The drag coefficient is not modified.

that which is induced by the lift (C_{DO} is drag coefficient at zero lift, and C_{DI} is induced drag coefficient).

$C_D = C_{DO} + C_{DI}$

$C_{DI} = C_L^2 / (\pi \, AR \, e)$

Where AR is the wing area ratio and e is the Oswald's efficiency number (Oswald's efficiency, similar to the span efficiency, is a correction factor that represents the change in drag with lift of a three-dimensional airplane wing, as compared with an ideal wing having the same aspect ratio and an elliptical lift distribution.) For the Zenith CH 750, span = 29.75 feet, and chord = 4.83 feet. So AR = 29.75 / 4.83 = 6.159. Then $C_{DI} = C_L^2 / (19.34 \times e)$ x Oswald's efficiency is equal to 1.0 only for elliptical wings, so let's use e = 0.9. Then $C_{DI} = C_L^2 / 17.41$. There is actually little information available about C_{DO}, but I settled on 0.032 with no flaps and 0.075 with flaps. The lift moment coefficient (C_M) was assumed to be constant -0.046 over the entire AOA range of interest.

Airfoil-Maker will not allow you to specify data outside the +/-20° range in angle of attack, so some other method must be used:

Use Airfoil-Maker for the +/-20° range.

Save the results as wing20.afl, which is a text file.

Import wing20.afl into a spreadsheet program such as Excel.

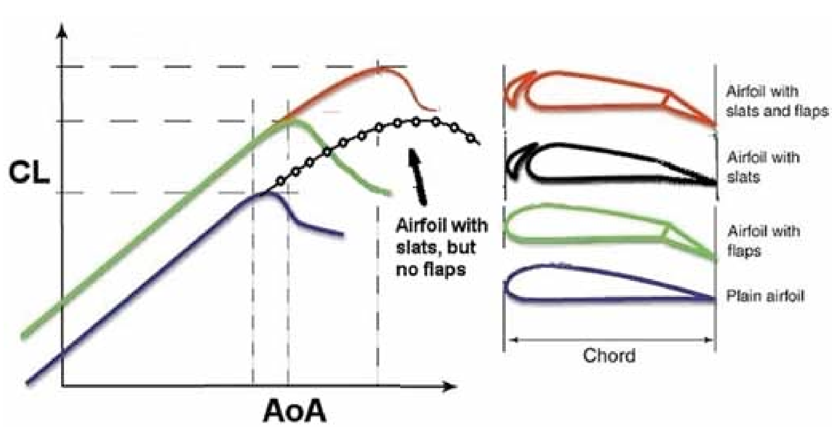
Carefully manipulate the data between 20° and 40° AOA. (This can be done by trial-and-error curve fitting.)

Save the data as NACA 650-18.aft, again as a text file.

The data that Airfoil-Maker supplies outside -20° to +40° AOA will not be realistic, but the plane is not likely to fly under those conditions anyway.

X-Plane uses airfoil data for "no flaps" and then adds the difference between "flaps" and "no flaps" as the flaps are lowered. In this case, C_L increases by 2.95 – 2.25 or 0.70, and C_D increases by 0.075 – 0.032 or 0.043 as flaps are lowered to their full down position. There is another change as flaps are lowered: The angle of attack for maximum C_L moves to a lower number, but X-Plane does this automatically.

Zenith designer Chris Heintz has written an informative article about high-lift airplanes. You can read the full text at *www.zenithair.com/stolch801/design/design.html*. Find a direct link at *www.kitplanes.com*. ✈



The case of "Airfoil with slats, but no flaps" was added to this figure from Chris Heintz's article about high-lift airplanes.

Flight Testing	
Takeoff Roll	100 ft.
Landing Roll	125 ft.
Max Level Speed	105 mph
Cruise Speed (75%)	100 mph
Stall Speed (flaps down)	30 mph
Rate of Climb	1000 fpm
Service Ceiling	14,000 ft.
Range (no reserve)	440 miles

Table D: These performance specs from the Zenith web site were used to check the viability of the model.

Some background, and then some basics.

In my role as a columnist for this magazine, I'll now be writing "Maintenance Matters," a new every-other-month feature designed to educate readers about the basics of, well, aircraft maintenance. I'll include tips and recommend tools I've learned about over the last 40 years.

My aviation maintenance education began in the U.S. Navy. After getting out I attended airframe and powerplant (A&P) school in May 1970 at the Northrop Institute of Technology (NIT) in Inglewood, California. We spent four hours each day in shop and four hours in class, got two weeks off at Christmas and two weeks off during the summer, and completed the training in 14 months.

The school required students to purchase texts such as *Basic Science for Aerospace Vehicles*, *Maintenance and Repair of Aerospace Vehicles*, and *Powerplants for Aerospace Vehicles*, which were written for NIT by James L. McKinley and Ralph D. Bent.

The NIT textbooks were the leading texts for A&P schools in that era. Today aviation companies such as Aviation Supplies and Academics (ASA), Jeppesen, and King Schools offer A&P course books, tests and DVDs. All are well done and can be helpful.

Lessons Learned from School

I spent the first month at NIT in basic shop where we built a specialized tool using nothing but files, a drill press, hacksaws and thread-cutting tools. Those basic hand-tool skills have stood me in good stead for decades. Aircraft owners and builders need basic hand-tool skills.

The second skill I learned that has always kept me out of trouble is to get instruction on tasks I haven't done before, or to at least get someone to talk me through a new task. I also learned to go to the book, and by that I mean all of the manufacturer's publications including the latest service information updates in the form of bulletins, letters and notices to augment what is in the basic manuals. For instance, the Lycoming overhaul manual for all direct-drive engines is ⅜ of an inch thick. A service table of limits and torque value recommendations book is also ⅜ of an inch thick. Lycoming service bulletins, service letters and service instructions fill 7¾ inches of bookshelf space.

The author on the job, circa 1988.

After A&P school I moved to Seattle where I worked in the mockup shop at Boeing Aircraft for about six months, installed Fowler flaps systems on 400 series Cessna twins for Robertson Aircraft and helped out at the Aero Sport Flying club on Boeing Field. These jobs helped me develop my skills in sheet-metal fabrication, reading installation drawings, drilling out rivets, fitting and installing modification kits, and techniques for bucking rivets in restricted spaces. Nothing takes the place of hands-on practice to develop skills. More on this later.

Why We Need to Think About Maintenance

The amateur-built side of aviation is growing due to three factors. First, as shown in the December 2010 kit aircraft buyer's guide in this magazine, which listed 320 designs, builders are free to pick from a wide variety of airplanes. If the goal is to build an inexpensive, low, slow, sightseeing airplane that sips auto gas, there are plenty to choose from. Or if you want to build a pressurized cross-country speedster, that is also on the menu. There are even kits for modern versions of historic airplanes such as the Mignet Flying Flea or the Fokker D-VII WW-I fighter.

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

Basic hand-tool skills will stand you in good stead during maintenance tasks.

Audrey Knight's experience included being a mechanic's helper on a B-25. Married to the author, she sometimes assists in the maintenance of their airplane.

The second reason, which goes hand in hand with the diversity of airplanes, is the freedom to install equipment such as an avionics suite that meets your needs at prices that are much more affordable than similar—and in some cases less capable—FAA-certified equipment.

Lastly, the regulations allow amateur-built airplane builders freedoms with respect to maintaining their airplanes. But with all of these freedoms come responsibilities.

Maintenance and Mods

Almost anyone can perform maintenance on an amateur-built airplane. But there are a couple of catches.

The defining document for Experimental/Amateur-Built aircraft is the operating specifications (ops specs), and most often it includes a sentence that reads something like this: "This aircraft may not be flown after incorporating a major change as defined by Code of Federal Regulations (CFR) Part 21.93 unless the owner has notified the FAA and their response is received in writing." What does that mean? Here's the FAA's definition. A "minor change" is one that has no appreciable effect on the weight, balance, structural strength, reliability, operational characteristics or other characteristics affecting the airworthiness of the product. All other changes are "major changes."

Suppose a builder decides to install a new propeller—the vendor promises a vast improvement in performance. Yet there's no data from either the propeller manufacturer or the FAA certifying that the builder's prop/engine combination has passed reliability testing. Does installation of the prop constitute a major change? You bet.

By contrast, all maintenance on certified aircraft with the exception of preventive maintenance tasks as defined in Code of Federal Regulations (CFR) Part 43 Appendix A must be performed by an FAA-certified mechanic or be supervised by a certified mechanic. (An owner is permitted to do all of the maintenance if supervised.) The definition of supervised means the mechanic must be readily available, in person, for consultation and must ensure the work is done properly.

Is the owner of a certified airplane free to install a modification or upgrade? Not unless the modification or upgrade has been approved by the FAA. It can be approved by Supplemental Type Certificate (STC), or through a one-time approval process by an individual FAA maintenance inspector. The one-time process is called a field approval.

Kit aircraft builders don't need these approvals—the responsibility for determining whether the product is suitable for installation rests with the owner.

Inspections

Experimental/Amateur-Built airplanes must be given a "condition inspection" every 12 months that follows the general checklist of items in CFR Part 43 Appendix D. Lo and behold, that's the

Placing a flag on the part you were working on will allow you to readily pick up where you left off when you return.

Photos: Steve Ells

same checklist that the FAA provides for annual and 100-hour inspections on certified aircraft. The 100-hour inspections are identical in breadth and scope to annual inspections and are required on aircraft used for hire such as flight school or charter work. The 100-hour can be signed off by a certified mechanic; the annual must take place by the last day of the twelfth month after the last annual and must be signed off by an A&P mechanic who holds an FAA Inspection Authorization (IA).

Condition inspections must be signed off by an FAA-certified mechanic holding airframe and powerplant (A&P) certificates, or the owner if he holds a repairman certificate for his airplane. A repairman certificate for an amateur-built airplane applies only to the builder's own airplane—he can't use it to sign off a condition inspection on his neighbor's airplane even if it's exactly the same type.

Work Logs

Every kit aircraft builder must develop the practice of keeping a detailed work log. In order to issue a repairman's certificate to the owner, the FAA requires that the owners prove they have done the majority (usually referred to as 51%) of the work on the airplane. The work log is the builder's proof.

The work log will also help track maintenance, and reviewing the work log will reveal maintenance trends.

To ensure safety and airworthiness of an airplane, both the airframe and the engine must be maintained. Reviewing the work log will show if maintenance is balanced. If you're not spending enough time noodling on the engine or lubing and maintaining airframe items, the log will point that out.

Inexpensive digital cameras and personal computers have made it easy to create and maintain a work log. Use Microsoft Word or a similar program to set up an aircraft maintenance log (file) and add documents identified by date and subject to create a log. Insert photos to illustrate hard-to-describe procedures. I keep a digital camera in my toolbox just for this purpose.

A well-kept log will help you grow as a mechanic and will provide guidance in formulating and maintaining a comprehensive and well-rounded maintenance schedule.

Developing a Maintenance Schedule

At the very least a maintenance schedule must include engine preventive maintenance tasks such as oil and oil filter changes at 50 operational hours or four-month intervals (whichever comes first), induction air filter cleaning or changes every 100 hours or annual unless operating in dusty conditions, carburetor or fuel-injection inlet screen inspection

Some Reassembly Required? Tips for How to Keep It Together

Develop a foolproof method of orienting parts and tracking progress when working through maintenance tasks. I'm a visual person, so I take a lot of digital pictures before I start disassembling anything.

Setting parts down in the order that I remove them provides me with guidance when I start reassembly. I use shallow baking pans I pick up at secondhand stores to contain the parts.

The pans are labeled with a Sharpie permanent marker (front, up, left, etc.), and I use these labels to orient the parts as I remove them.

It's helpful to always recruit a second person (set of eyes) to inspect your work, especially at major steps in construction and maintenance.

Before you start on any project, make sure you have all of the necessary parts on hand. Nothing drags maintenance to a halt faster than discovering that a part—usually it's a small but essential part such as a gasket you forgot to order—will have to be ordered or be found locally to finish the job.

Use flags to remind yourself that a task needs to be completed. If I'm called away or stop before completing a job, I tear off a piece of surveyor's tape and tie it onto the part that will need attention when I return. Surveyor's tape is plastic non-sticky tape that can be purchased at any hardware store. It comes in blaze orange and lime green, and it's inexpensive.

—S.E.

Trays are good for keeping all of the parts together during disassembly and reassembly. They can be marked to indicate the proper orientation of parts.

Manuals and CDs are helpful in the shop. This is one of the author's favorites.

and cleaning every annual, magneto-to-engine timing checks and adjustments every annual, and spark plug inspection, cleaning and rotation every annual inspection. Of course, specific guidance from the engine manufacturer or airframe designer will supersede these general recommendations.

Airframe maintenance must include main fuel strainer screen inspection and cleaning every annual, lubrication of hinges, joints, linkages and wheel bearings every annual, inspection of brake pads, hoses and disks for condition and wear every annual, and a thorough visual inspection of the fuel system components such as selector valves and filler caps for operation.

This list is just a beginning. Download the inspection checklist in CFR Part 43 Appendix D from the Internet. Use it as a baseline to create your own airplane-specific maintenance inspection schedule. Builder's forums are also an excellent place to ask for and get guidance on maintenance issues.

Supplemental Materials

When I bought a VW bug my uncle Bob handed me a copy of Henry Elferink's *VW Technical Manual*. This book stressed the three keys for maintaining air-cooled engines: Set the correct valve lash; set the correct ignition timing; and set the correct idle mixture and idle speed. I've used these three rules to maintain aircraft engines up through Pratt & Whitney radial R1830-94 engines and believe they are the cornerstone of air-cooled engine maintenance.

All builders and owners who do their own maintenance need access to FAA Advisory Circular AC 43.13-1B and AC 43.13-2B. This AC is titled *Aircraft Inspection, Repair, and Alterations: Acceptable Methods, Techniques and Practices*. This is the bible for light airplane maintenance. This weighty circular can be accessed free of charge at the FAA's web site.

I keep a paper copy, but there's also a version on CD that everyone working on airplanes should own. John Schwaner of the Sacramento Sky Ranch is the author of the *Sky Ranch Engineering Manual* and the interactive CD titled *Mechanic's Toolbox and Engineering Manual Companion*. If I could afford only one publication to guide me in aircraft maintenance, I'd buy a copy of Schwaner's *Mechanic's Toolbox*. This CD is chock-full of ready reference material. Need to find the right firewall sealer? No problem. Need to get a part number for an O-ring? No problem. Schwaner's CD is invaluable, and at less than $40 it's a steal.

Another handy toolbox-sized reference book is the *Aviation Mechanic Handbook* by Dale Crane for ASA.

Adventures in Mechanic-Land Continue

After working as a mechanic for Aero Dyne, a non-scheduled contract freight company that operated six DC-3s, for four years I went back to school to strengthen my understanding of electrical circuits and avionics.

During the summer break from school I was hired by an Alaskan freight hauler operating out of Soldotna, Alaska, to swing wrenches and hold down the right seat of the DC-3 for a flight or two whenever one of the real pilots fell ill. The company leased an Aero Dyne DC-3, a DC-6 and a Lockheed Electra to haul salmon from the western fishing grounds to processors in Anchorage.

After I finished school I toted my toolboxes from the shores of Lake Washington near Seattle, to Laredo on the Texas/Mexico border to work as the Director of Maintenance on a two-DC-3 freight operation. That job ended, but not before I bought a 1947 Piper PA-12, which I commenced to fly from Corpus Christi, Texas, to Alaska. All day VFR and all "I Follow Roads" (IFR). It took 50 flight hours.

I opened a small aircraft maintenance shop in Soldotna, Alaska, and soon found that I wasn't much of a business man. In 1992 I called my brother, who flew up from Seattle and helped me drive back down to Washington state. My more recent professional history includes work as an editor for the Cessna Pilots Association magazine and for the Aircraft Owners and Pilots Association (AOPA).

Next time we'll look at setting up a shop space where you can conduct your aircraft maintenance tasks.

If you have questions or want an explanation on a particular maintenance subject, email editorial@kitplanes.com and put Maintenance Matters in the subject line.

RESOURCES

Aviation Supplies and Academics (ASA)
www.asa2fly.com

Aviation Tool Supply
www.aircraft-tool.com

Brown Aviation Tools
www.browntool.com

Jeppesen
http://jeppdirect.jeppesen.com/index.jsp

King Aviation Schools
www.kingschools.com

Sacramento Sky Ranch
www.sacskyranch.com

Liberté! Egalité! Electricité!

It's nice to know that Boeing and Airbus are working on future electric airliners, and that biofuels may power the big aircraft in the interim. But seeing a bunch of homebuilt electric aircraft capturing records and making history renders this writer ecstatic. The fact that three of these organizations are in France makes visiting the Eiffel Tower an imperative.

Lavrand, APAME and Electravia

Overseeing a growing legion of electric vehicle enthusiasts, and maintaining an aircraft design and construction firm; an electric motor, controller and battery development and sales operation; and a propeller company, Anne Lavrand is *très* busy, even reporting on her many activities in a near-daily blog. The Organization to Promote Electrical Aircraft (APAME), endeavors to educate and inform its members on happenings in electric flight. With over 400 members worldwide, its environmental concerns are a growing factor in the interest being generated by electric flight.

Corporate concerns center on creating an array of small aircraft powered mostly by Lynch-type motors, a simple brushed unit that requires a fairly simple speed controller. She oversees the parent organization, Electravia, which comprises several related enterprises: E-Motors, E-Props and the online E-Props Shop.

With a diploma in business and certificates in aerospace education and "judicial expertise," she works with Christian Vandamme, her chief technical lead, Jérémie Buiatti, lead in propulsion and propellers, and Sammy Dupland, head of E-Props and flight testing.

E-Motors configures and sells motors, controllers and batteries—often complete plug-and-play systems—to clients in Europe, China and North America.

Lavrand claims many firsts and records, including the ultralight Electra flying 50 kilometers (27 nautical miles) in 48 minutes in December 2007, followed by her Electron Libré (Free Electron) trike in June 2008 and more than hour-long flights by an Alatus ME sailplane in January 2009.

Her drive keeps things moving, with a recent world speed record of 262 kilometers per hour for the two-motor Cri-Cri, and topping that very publicly with a 283 km/hr romp down the main runway at Le Bourget for the Paris Air Show.

Pouchellec—A Pou de Ciel (Flying Flea) made with a ladder-like fuselage and powered by a Lynch electric motor.

E-Fenix shows a four-blade E-Prop with offset blades. These cause "dephasing of sound waves and lower noise."

At a much slower pace, E-Fenix, the first electric two-seater paratrike in the world (there was one in eastern Europe, but never shown with two people on board) has flown with a 35-hp GMPE 104 motor, an E-Props four-blade thruster and a 6 kWh Kokam li-poly battery pack. The wing is a 38-square-meter Bulldog.

Developed with Planète Sports & Loisirs, a leisure activity firm based on Re Island, E-Fenix will carry the pilot and a sightseeing passenger over the scenic region for up to 35 minutes. The E-Prop that propels it lowers the noise level for passengers and those below, making the tour a peaceful one.

Take one of the stalks on the nose of Cri-Cri, attach a 26-hp 104 and controller and top a vintage Fauconnet with it. Couple this with an E-Props propeller, instruments and a 3-kilowatt-hours,

Dean Sigler

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

24-kilogram (52.8-pound) Kokam lithium-polymer battery pack, and you have a "poor man's" Antares. While the more sophisticated Antares will set you back €200,000 (about $285,000), Lavrand says her ElectroPod package will sell for about €15,000 ($21,300). Considering the cheap launches and the low cost of recharges, the economy of the system becomes apparent. "It's a solution to have an electric motorglider for a reasonable price," Lavrand said, with it providing an hour and 20 minute cruise or a total climb of 3000 meters (about 9600 feet).

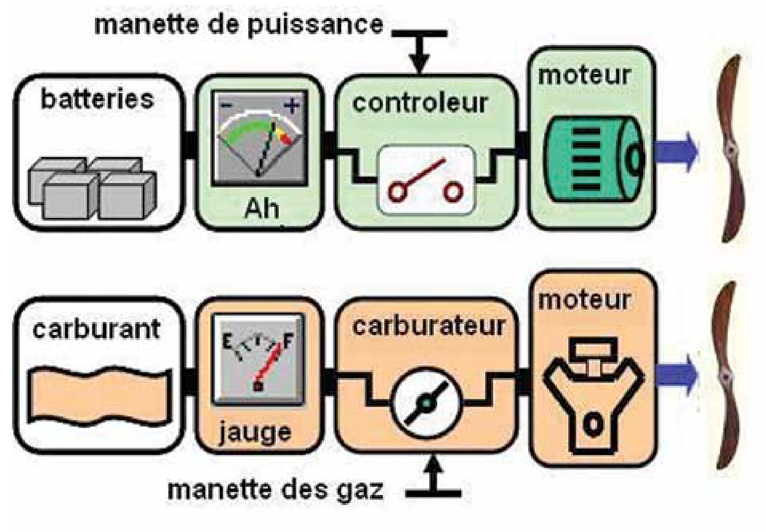
The E-Props part of the enterprise makes both two-blade and four-blade propellers, with individual blade segments having optimized airfoil sections for best performance. The four-blade units have a unique characteristic in that the blades are not set at 90° separation, but at an acute/obtuse arrangement.

According to Electravia, on a trike with a Rotax 582, the E2QD prop gave 6% better climb rate, 3 kilometers per hour higher top speed, 8.8-dB noise reduction, and 1.15 liters lower fuel use per hour than the original stock prop. Future plans include a hybrid power system, a two-seat flying wing and an ultralight.

Flying Ladders

The Association for the Promotion of Flying Ladders (APEV) web page is graced by an Elizabeth Montgomery-like witch scooting skyward on a ladder, rather than a broom. Its designers originally used a commercial aluminum ladder as a fuselage to which wings, pilot's seat, engine and tail feathers were affixed. The company had to turn to bolting and riveting standard aluminum extrusions together when the ladder manufacturer was spooked by visions of lawsuits from ladders falling greater than usual distances.

Early designs were based on Henri Mignet's Flying Flea formula, a tandem-wing, pitch-and-rudder-controlled configuration that compensated for Mignet's inability to manage a full-three-axis flying machine. Initially powered by Rotax two-strokes, the little airplanes climbed rapidly, cruised at ultralight speeds and demonstrated acceptable handling characteristics. Moving to electric power,



Electravia's proposed serial/parallel hybrid approach.

The bewitching logo for the Association Pour La Promotion des E'chelles Volantes (Association for the Promotion of Flying Ladders).

they used a Lynch motor, Kelly controller, and Kokam batteries and propellers from Helix, a German firm.

The APEV has designed and built an aluminum look-alike for the Santos Dumont Demoiselle called the Demoichelle, a pun on the ladder-like frame. Replacing the Rotax with an Agni 112R motor changes its appellation to Demoichellec, a further play on words indicating a ladder-like, electrically powered Demoiselle. A vintage-looking wood box encloses the batteries, and is about the only non-metallic bit on the machine.

Its pair of pivoting wings, eschewing ailerons, roll the airplane to provide lateral control. This makes for simplified wing construction and a lively turn, simplified enough to enable the APEV team

Cedric Lynch and his Pancake Motor

Cedric Lynch is an English inventor who won a competition in 1979 with a homemade motor with "armature and field lamination cut out from flattened soup cans," according to his biography on the Agni Motors web site. With his making improvements and using better materials, his axial flux motor was a breakthrough that allowed greater power and higher torque than existing radial flux motors.

In 2002, his company in England was involved in some complicated lawsuits, and Lynch was dismissed by his Danish backers. An "industrial tribunal" found that Lynch had been dismissed unfairly and ordered a large settlement from the Danes. The UK-based firm reopened under the LMC name, while Lynch moved his work to India, where friends there helped him start Agni Motors.

Thus, we can purchase Lynch motors from England and India, all with the same basic technology, but competing with one another. Lynch has been active, racing an electric bike with two 43-hp Agni motors on a competition motorcycle frame to win the 2009 Isle of Man TTGPX, an all-electric motorcycle race around the famous 37-mile course.

—D.S.

Photos: Courtesy Dean Sigler, Xavier Genoud and the Manufacturers to assemble and fly Demoichellec at the 2010 Paris Green Air Show.

The wings show up on APEV's latest offering, the Scoutchel, a more modern trigear aircraft but with all of the simplicity of the organization's other creations.

Plans and kits are available for APEV's creations, with most airframes costing less than $10,000.

Aiming for the Record Books

Luxembourg Special Aerotechnics (LSA), chartered in its namesake country but flying for Monaco, has a great set of ambitions according to its founder, Jean-Luc Soullier. Its Colomban MC-30 set two world's records at this year's Friedrichshafen Aero Expo, its triumphs witnessed by His Serene Highness of Monaco, Prince Albert II, a "godfather" for the team. In another principality-related event, Soullier intended to fly the first international electric air mail between Monaco and France last September, though conditions did not permit.

As announced on LSA's web site, "The FAI (Fédération Aéronautique Internationale) has released our first record: 13 April 2011 Microlights: speed over a straight 15/25 km course: 135 km/h Jean-Luc Soullier." The maximum altitude part (would be any altitude at which the aircraft flew, because no one else has filed for such a record. Things should heat up in this category of record-setting, however, as the airplanes involved are small, light and, best of all, inexpensive, allowing other motivated amateurs to compete and bring electric aviation to a broader audience.

The team has grand ambitions, seeking to win all world records for an electric airplane in its class and to cross the Mediterranean Sea in homage to Roland Garros, the WW-I aviator who flew from southern France to Tunisia in northern Africa in 1913.

The forum moderated by LSA provided a great many insights into the problems faced by those attempting to design electric power systems for aircraft. Soullier and his partners, Marschner von Helmreich and Fabrice Tummers, are forthcoming and open in their assessments of the issues that confront them. They had written about the overheating problems with their past technical

Demoichellec, showing off its Agni 112R motor and wood battery box.

MC-30 in LSA's workshop, showing simple construction, motor and battery installation. This was designed by a Concorde designer.

LSA's MC-30 with Jean-Luc Soullier in the cockpit. In the background is the zeppelin with which it shared a hangar at Friedrichshafen.

partner's equipment, for instance, and considered various options. Now, according to Anne Lavrand, they have turned to her to install an Electravia replacement, a larger and heavier, but more powerful Lynch motor.

They started even smaller, flying a Colomban MC15, which with its two Plettenberg Predator model airplane motors, "climbed for the trees," if I'm translating the pilot's remarks correctly. No more testing has been done on this airframe, but if it were to use two Lynches like Electravia's successful effort, we could look forward to electric Cri-Cri races (a hopeful fantasy on your author's part).

How Much Does It Cost?

All of the systems shown use the Lynch or Agni motor package, so we can at least give a reasonable cost estimate for the motor, controller and battery system. We'll omit instrumentation and other options to reflect a basic package, with the caveat that your budget may vary.

Electravia's motors come in three flavors, the 26-horsepower GMPE 102, the 35-hp GMPE 104 (as used on the record-setting Cri-Cri) and the 50-hp GMPE 205, the latest offering. All motor prices include the company's specific Electravia controller. Prices shown are without French taxes included.

GMPE 102: 19 kW, 26 hp	GMPE 104: 26 kW, 35 hp	GMPE 205: 37 kW, 50 hp
€2700 ($3834)	€3000 ($4260)	€4640 ($6588)

Because the GMPE 104 and 205 kick over at 6000 maximum rpm, they require a propeller speed reduction unit (*reducteur*) to bring the propeller into a more tolerable range. The 104 reducteur costs €1400 ($1988), and the 205 unit €1590 ($2258).

Hooking up the batteries reveals the economic Achilles heel in this approach to budget flying. Batteries are the most expensive part of the equation and the one hardest to come to grips with for most would-be builders. All Electravia battery packs come with PCMs (protection circuit modules, which keep everything within preset temperature and charge parameters) and BMS (battery management systems, which control charging and discharging to individual cells to ensure optimum operation and run times). Weights and pricing are from the Electravia web site.

Pack of 3 kWh = 2 x 10 cells 74 V, 40 Ah 350mm x 250mm x 220mm (13.8 x 9.8 x 8.7 inches) Mass = 23.5 kg pack (51.7 pounds)	€5290 ($7520)
Pack 4.5 kWh = 3 x 10 cells 111 V, 40 Ah 350mm x 250mm x 330mm (13.8 x 9.8 x 13 inches) Mass = 35 kg pack (77 pounds)	€8630 ($12,255)
Pack 6 kWh = 2 x 20 cells 74 V 80 Ah 2 x (350mm x 250mm x 220mm) Mass = 47 kg pack (103.4 pounds)	€10,100 ($14,342)
Pack 9 kWh = 3 x 20 cells 111 V 80 Ah 3 x (H x L 350mm x 250mm E 220 mm) Mass = 70.5 kg pack (155.1 pounds)	€14,900 ($21,158)

Component prices allow us to add up a grand total for our electric flier. Taking the middle ground, with a GMPE 104 motor and controller, two-blade prop, reduction drive and a 4.5 kWh battery pack gives a total of slightly over $19,000, with energy storage accounting for more than half of that. Many of these aircraft can be built for less than $15,000, and a few for less than $10,000. Flying for the cost of a recharge should make these airplanes highly desirable.

We can also total weights. Electravia motors and controllers don't vary much, regardless of kW/hp ratings. The 104 with controller, reduction drive and prop flange weighs 15 kg (33.3 pounds). A 4.5 kW pack adds 35 kilograms (77 pounds), giving a total of 110.3 pounds. Add instruments, motor mounts and possible cowlings, and the total is a bit more than a full-dress equivalent two-stroke. Note that batteries account for twice the weight and twice the cost of the motor/controller/propeller drive combination.

With these innovators bringing electric flight to the masses (nothing they produce comes close to the cost of an LSA), we can expect to see increasing interest in these simple fliers. As batteries become lighter and cheaper, this segment of aviation will become even more significant. ✈

Students at Chartres' IUT (the university's technological institute) building a Demoichellec.

RESOURCES

APAME and Electravia
www.apame.eu/AA%20welcome.html
http://www.electravia.fr

APEV
www.pouchel.com/english/index_eng.php

Kelly Controllers
http://kellycontroller.com/index.php

Kokam Batteries
www.dowkokam.com/index.php

Luxembourg Special Aerotechnics
www.lsa-aerotechnics.com
http://forum.pegase.tv/viewtopic.php?f=3&t=4978&sid=2161236282b974578779984adb8db7ca

Lynch or Agni Motors
www.lemcoltd.com/
www.agnimotors.com/home/index.php?option=com_frontpage&Itemid=47

Find direct links at *www.kitplanes.com.*

Superior judgment versus superior skill.

The old saying that, "A superior pilot uses his superior judgment to avoid having to demonstrate his superior skill," is actually a tongue-in-cheek allusion to the fact that most pilots will never reach the point where they have the superior skill that they think they have. If you do have that much skill, and are sure of it, that's great. But the truth is, those who have determined that their skill is enough to keep them alive frequently meet their end in an aviation accident. You don't have to believe me; you can look it up. Many a fatal accident has taken the lives of pilots with thousands of hours in their logbooks.

If all you ever do is perform aerobatics over your home field, superior skill might be all you ever need—or it might not. But once you venture out into the wide world of aviation, decision-making skills will be of vital importance. Determining if the weather ahead is flyable or worth the risk, deciding if the headwinds are going to decrease or if you should stop for fuel or, frankly, deciding whether you are up to a particular task on a particular day with a given airplane are all examples of judgment.

Good judgment in design can be shown when planning backup instruments to cover potential failures.

Judgment Day

The problem with most discussions on the topic of judgment is that they pick up at the point where a pilot is trying to make an inflight decision. I think that some folks fail to recognize the broad nature of the word "judgment." Judgment is, in fact, interrelated with all aspects of aviation, including stick and rudder skills, honest self-evaluation of those skills, and (just as important) decisions made by the designer of the aircraft's systems and the building of the airplane. Failures of judgment come in many forms:

1) Deciding to fly into the busy Oshkosh environment as a low-time pilot with only 20 hours logged in the past year, and then getting overwhelmed and losing the airplane on the base-to-final turn. Good judgment wouldn't put such a pilot here; he would ride with an experienced friend.

2) Letting the airplane surprise you because you *chose* to be so far out on the edge that you fell over it.

3) Failing to use good self-evaluation skills to recognize when you are about to tackle something beyond your capabilities (or the capabilities of the aircraft and its systems).

4) Designing an aircraft's systems without sufficient redundancy.

You can add countless examples to the list, of course—the point being that judgment is not just about deciding

Paul Dye *is an aeronautical engineer, commercial pilot and avid homebuilder with 30 years of leadership experience in aerospace operations and flight testing. He is also an EAA tech counselor and flight advisor who currently flies an RV-8, which he built, and is working on an RV-3.*

Photos: Paul Dye

whether to continue a flight into doubtful weather. It is about making the decision to fly in the first place.

Decisions, Decisions

The bottom line is that every accident begins with the pilot's decision to do something with an airplane. The Proximate Cause may read: "Pilot failed to maintain flying speed during the base to final turn, stalled and spun in." And we can all say, "Well, he didn't have the skills he needed." But that doesn't really solve anything or answer the real question. Why the heck did this happen? Why did the pilot get low, slow and out of control? Was his training incomplete? What were the distractions? Why did he decide to be there if his skills weren't up to par? Ego? Hubris? Peer pressure?

Only when you pursue accident reports beyond the obvious do you learn the real secrets of why accidents happen. You need to look for root cause. Ask why, and keep on asking that question until you reach the true beginnings of the incident, and only then can you try to prevent it in the future. In most cases, it goes back to a pilot deciding to do something for which he is not (yet) qualified. It takes time to truly learn to fly, beyond stick-and-rudder skills. A pilot needs to make the decision to limit his own personal flying envelope until his skills improve.

That being said, I will always maintain that I would rather fly with a pilot of moderate skill and good judgment than a pilot who knows how to fly inverted 100 feet off the deck and chooses to do so at an inappropriate time. Stick-and-rudder skills alone are not the solution—there are many, many dead airshow performers and aerobatic champions who had far more command over their aircraft than most of us ever will. They *chose* to put themselves in a position where an instant's distraction, an unexpected wind gust or a mechanical glitch left them no options. That is decision-making, right or wrong.

How we choose to build our airplanes and design their systems influences their ability to be operated safely. A pilot is often forced to make a Go/No-Go decision for an airplane or equipment that isn't suited for the mission being contemplated. How many times have you had to compromise your standards (You *do* have standards, right?) for safe operations because your airplane didn't have the redundancy to handle the flight requirements and still have sufficient backup for unexpected events? It happens every single day to pilots everywhere. You plan a flight where the weather might deteriorate, but the IFR certification is out of date. What we frequently forget is the simple phrase: "We can't fly today." Remember that until you have left the ground, you are not committed to flying—and never should be.

Doing enough preflight planning to evaluate the risk is also a sign of good judgment.

Stop and Think

Our understanding of risk management has changed a great deal in the almost four decades I have been involved in aviation. It seems there are now more feel-good courses and classes that tend to turn off the real aviators among us. But if the only answer to flight safety is being the world's best airplane handler, then the accident rate will only increase. If you study accident reports for airline and general aviation over the past several decades, you will find that only one has improved. The airlines have gotten safer through a greater understanding of the risks involved in poor decision-making. If airlines had the record of GA flying, they would have gone out of business long ago. They *must* keep accidents essentially at zero.

As long as GA pilots deny the root causes of accidents, they will continue to happen, and we will never see an improvement. Root cause, and not proximate cause, has to be addressed if we are to save more people and more airplanes. Study accidents and incidents in all areas of aviation—commercial, military, civilian—and find the common threads where different decisions could have been made to avoid the end result. Vow not to go there. And, yes, sometimes the answer is as simple as choosing not to fly this time. ✈

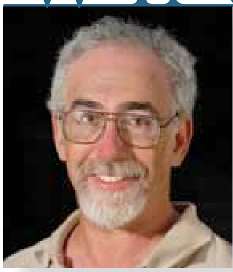
SPORTPLANES™ MARKETPLACE

This section is dedicated to aircraft and accessories for the new Sport Pilot and Light-Sport Aircraft category.

For details on this new rule, go to: http://www.kitplanes.com/sportplanes

Aircraft manufacturers state that these designs meet the required light-sport aircraft specifications and can be operated within the performance limitations of the rule:

E-LSA and S-LSA manufacturers state that they meet the ASTM consensus standards. Aircraft may be available to register as Experimental/Amateur-Built, Experimental Light-Sport (E-LSA) or Special (ready to fly) Light Sport (S-LSA)



Understanding and avoiding spins.

In the early days of powered flight, many plane crashes were preceded by what witnesses described as a "spiral dive." The airplane would quite abruptly put its nose down and follow a corkscrewing path to the ground. Today, of course we understand that the so-called "spiral dive" is really a stall/spin sequence. Pilots feared the spiral dive because they didn't know what caused it, much less how to correct it, and so it was often fatal.

The first successful recovery from an inadvertent spin is widely attributed to English Lieutenant Wilfred Parke, who got into one in an Avro cabin biplane (one of the first airplanes with a fully enclosed cockpit) in 1912. For several years the British aviation community referred to a spin as a "Parke's Dive." Parke reported that he recovered by opposing the rotation of the airplane with the rudder. But what saved him is that, through luck or insight, he chose to concern himself primarily with the rotation of the airplane rather than the nose-down diving attitude.

By the early 1920s, the cause of spins was well understood, and several standard spin recovery techniques had been published. In 1936 NACA published Technical Note 555, which described the "basic spin-recovery procedure" that is still taught today and can be found in the pilot's manuals of many light airplanes. The classical spin recovery technique for single piston-engine, tractor airplanes from NACA TN 555 (1936) is:

1. Briskly move the rudder to a position full against the spin.

2. After the lapse of an appreciable time, say after at least one-half additional turn has been made, briskly move the elevator to approximately the full-down position.

3. Hold these positions of the controls until recovery is effected.

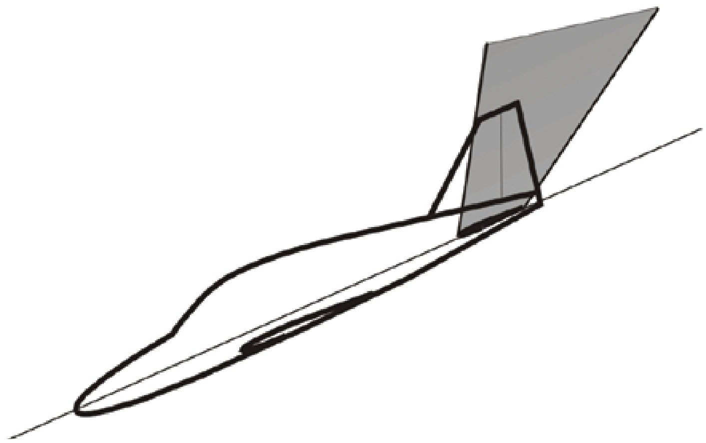


Figure 1. The configuration shown here—low tail, swept-back fin, rudder on top of fuselage—is likely to have spin recovery problems. The wake of the tail in a spin can be approximated by drawing a line from the leading edge of the horizontal tail at 60° from the centerline, and a similar line from the trailing edge of the horizontal tail at 30°. The area between the lines is likely to have separated flow, and the fin and rudder area inside the wake will be ineffective for spin recovery.

Basically, for typical light airplanes, the single most important control input is full rudder against the direction of rotation.

The majority of airplanes are never spun on purpose. At first look it would seem that for these airplanes spin recovery characteristics would be unimportant. But an airplane can go into a spin when it is inadvertently stalled during a maneuver—for example, the turn from the base leg of the pattern to final approach. For the airplane to be flown safely, the pilot must have sufficient control power available to stop the spin and recover to level flight.

Until the mid-1970s, the majority of spin research done by NACA and other groups was aimed toward understanding what facets of the configuration affected the ability of the airplane to recover from a developed spin.

In a spin, the airplane is subjected to both aerodynamic and inertial forces. A developed spin is a dynamically stable situation; the aerodynamic forces developed on the wings drive the spin. The rotation is opposed by the yaw damping of the tail and fuselage, leading to a dynamic equilibrium where the rotation rate is close to constant. The inertial and aerodynamic forces are in balance, off-

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.*

setting each other. If nothing is changed, the spin will continue indefinitely (or until ground impact). To recover from the spin, the stable balance of forces must be broken.

Angle of attack during the spin is well above the initial stall angle of attack. For most light airplane configurations it is somewhere between 30° and 60°. At least one wing of the airplane is stalled or partially stalled. The asymmetry of forces between the more-stalled wing and the less-stalled wing provides the pro-spin moments that drive the autorotation of the airplane. The airplane descends nearly vertically, while rotating in a coupled rolling and yawing motion about the flight path. To break the spin, the pilot must re-establish symmetric lift and drag on the wings. The goal is to unstall both wings and stop the rotation on the airplane.

For the single-engine tractor configuration typical of most light planes, the key to successful spin recovery is stopping the rotation of the spin with anti-spin rudder. After the rotation has been slowed or stopped, down elevator is used to reduce angle of attack and establish unstalled flight. Because the ability of the rudder to generate anti-spin yawing moment is so critical to spin recovery, much attention has been given over the years to the proper design of tail surfaces for spin recovery.

Rudder Power and Tail Design

When the rudder is deflected against the direction of the spin, it produces a yawing moment that opposes the rotation of the airplane. In order to break the spin, this yawing moment must overpower the pro-spin moment being generated by the wing. This means that the airplane's rudder must be large enough to generate the required moment. The rudder must also have enough clean airflow over it to be effective.

The angle of attack in a spin is much higher than it is in normal flight. The high angle of attack, combined with the presence of large amounts of separated flow can dramatically change the airflow over the tail of the airplane. The flow over the top of the horizontal tail is separated, and there is a separated wake that trails back and up from the tail. Unfortunately, a large portion of the fin and rudder is often immersed in this low-energy separated flow from the horizontal tail. The area in the separated wake is ineffective, and does not contribute much yaw damping or rudder power to aid in spin recovery. The same is true for the fuselage side area above the horizontal tail.

Figure 2. The original tail configuration of the Skycatcher had no fin area below the horizontal tail, and the highly swept-back fin was almost entirely in the "dead zone" above the horizontal tail in a spin.

Figure 3. The tail configuration of the definitive production Skycatcher. The rudder now extends below the horizontal tail, and some ventral fin area has been added.

If too much of the rudder is buried in low-energy separated flow, it will not be able to generate enough yawing moment to stop the rotation of a spin. A method of estimating how much of the fin and rudder is blanked by the tailplane wake is shown in Figure 1. On a side view of the airplane, draw a line from the leading edge of the tailplane upward at an angle of 60° above horizontal. From the trailing edge of the tailplane, draw another line upwards at an angle of 30°. The airflow in the area between these two lines is likely to be separated in a developed spin. Any fin or rudder area between the two lines will be blanked by the tailplane and will be ineffective.

For acceptable spin recovery characteristics at least a third of the rudder should be outside the separated wake. This is not a guarantee of good spin recovery, but if less than a third of the rudder is clear of the wake, then problems are likely. Because of this, the relative position of the tailplane, fin and rudder are important.

If the rudder ends on top of the fuselage, then the leading edge of the horizontal tail should be aft of the leading edge of the fin. The upper portion of the fin and rudder will then be out of the wake of the horizontal tail. Sweeping the vertical fin aft in such a situation can be highly detrimental, as it moves the upper portion of the fin and rudder aft into the tailplane wake. If the horizontal tail is mounted low and too far forward, it is possible to end up with the entire fin and rudder immersed in the tailplane wake if the tail is aft-swept. An airplane with such a tail design is likely to have spin recovery problems.

A configuration with a rudder that ends on top of the fuselage is less favorable for spin recovery than one with a rudder that extends all the way to the fuselage bottom. Even if the rudder is clear of the tailplane wake, the fuselage may still have a detrimental effect on the airflow over the fin and rudder at high angles of attack. Despite this, there are quite a few airplanes with rudders that end on top of the fuselage, and have good spin recovery characteristics.

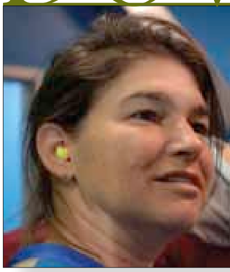
A T-tail has good yaw damping and rudder power in an upright spin because the tailplane wake does not impinge on the fin and rudder. In an inverted spin, the opposite is true. Unfortunately, the non-linear pitch behavior that some T-tail airplanes exhibit makes them more prone to enter a spin in the first place. The pitch forces lighten up as angle of attack is increased, and it is relatively easy to get into an inadvertent stall.

If the rudder is carried down to the bottom of the fuselage, then the tailplane should be well forward and/or relatively high on the fuselage. This allows the bottom portion of the rudder to operate in clean air. It has the additional advantage of allowing the lower aft fuselage to produce yaw damping that slows the spin rate.

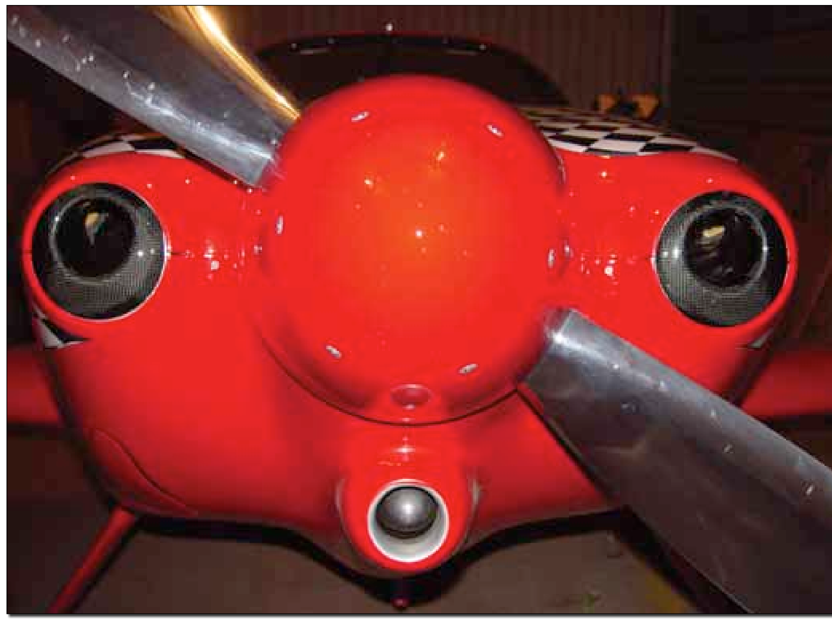
An example of how much small changes in tail configuration can affect spin recovery is the evolution of the tail of the Cessna Skycatcher. The original tail configuration, shown in Figure 2, had no fin area below the horizontal tail, and the highly swept-back fin was almost entirely in the "dead zone" above the horizontal tail in a spin. Cessna engineers, to their credit, chose to test the airplane to much higher spin recovery standards than the LSA rules require, including recovery from fully developed spins. An early prototype with the same tail configuration as the POC airplane shown in the photo was lost when it failed to recover from a developed spin. The pilot bailed out successfully and was uninjured.

Figure 3 shows the tail configuration of the definitive production Skycatcher. The rudder now extends below the horizontal tail, and some ventral fin area has been added. The additional high angle of attack yaw damping and rudder control power provided by these changes give the airplane satisfactory spin recovery capability.

For a detailed summary of NACA research on tail design and spin recovery see NACA-TN-1045: "Tail Design Requirements for Satisfactory Spin Recovery" by Jacob H. Neihouse, Jacob H. Lichtenstein and Philip W. Pepoon. You can find it at *www.archive.org/details/nasa_techdoc_19930081653*. ±



Cooling it: The ongoing saga of the RV-10's engine.



An RV with adjustable inlets. Well, ground-adjustable, anyhow. The inserts can be removed with a little trouble for hot-temperature environments, and replaced to narrow the air inlet openings in cooler temps. The cowl is a Sam James Holy Cowl, and the inlet innovation is homegrown.

The bottom line is: Yes. OK, if you haven't been following the saga of engine cooling for the big-bore Lycomings (namely the Lycoming IO-540s) under the hood of most Van's Aircraft RV-10s, then I'll give you the quick synopsis. Just about everyone has some sort of issue to tweak. Yes, even those RV-10 builders who have stuck with the stock Van's cowling and baffling have been, frankly, baffled by the seemingly gargantuan task of correctly ducting air over the engine, through the intricate fins of six cylinders, down, and out the bottom of the cowling.

Some builders have had success using louvers, such as the ones you'll find on a Cessna 182, which increase the suction on the bottom of the cowling to pull air through. Others have created an adjustable cowl flap (an old-school fix found on numerous aircraft).

Some just deny that it's an issue. A recent perusing of the RV-10 builders' forums noted several owner/operators who are managing to keep cylinder-head temperatures under 400° by simply throttling back to 55% power (23 inches of manifold pressure, 2300 rpm) and flying at 150 knots. Another says, "Oh, I just reduce power in the climb and push the nose over, giving up climb performance [and potentially, safety] to keep the engine cool." Well, we didn't build our airplane to fly at 150 knots or climb at 500 feet per minute. We built it to fly 170 knots and climb away from hazards at a brisk 1200 fpm. And we are sure it can—all day, if we balance the airflow inside the cowling.

An example of louvers appended to the bottom of an RV-10 cowling to help draw out the hot air from the lower cowl.

Plenum Redux

Again, pardon the review if you have already read this, but we opted to go with non-stock equipment on our cowling; a fiberglass plenum bolts to the top of the engine instead of silicon baffling. The plenum receives air through two circular air intake ducts behind the propeller and squeezes it, Bernoulli-style, so that the air accelerates across the cylinders and between their fins, carrying the heat back, down and out an outflow "gate" at the back and bottom of the engine area, forward of the firewall.

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

Photos: Amy Laboda

Here is the original configuration with 4-inch intakes.

Round air intakes come in many sizes.

Our plenum has not been a perfect solution, until now. With the help of the manufacturer, Sam James, we've refined our installation until, finally, it works. It wasn't easy.

In the spring we heard from James about our issues. He suggested we first try a new plenum, which he'd refined, specifically enlarging the outflow "gate." We agreed. He also came to our shop, as he has done for other clients, and assisted in the installation. He asked us to enlarge the forward air intake ducts to 4 ⅞ inches (inside diameter). We did. He wanted us to move our oil cooler from the engine firewall to a spot on the rear baffle of the engine itself. We opted not to do that, wanting to see first how the engine cooling changed with the new, more precisely fit plenum under the cowl.

The initial flights were good, with cylinder-head temperatures trending cooler and oil temperatures near 200°. Then it got hot, which it is wont to do in South Florida in the summer. *Really* hot. Melt-me-now hot. And the engine temperatures began to be a bothersome issue again.

We called James, and he said, "Make the intakes bigger. A full inch bigger. I'll give you the rings." We groaned. We'd just ground down the cowling a couple of months before, and managed to enlarge the intake area by about an inch without ruining the paint job. Now it was time to do it again? Well, yeah, it was. That's Experimental aviation. We'd experimented with the 4⅞ inch intakes and they weren't enough. Even with two sets of louvers on the bottom cowl to help create suction to "pull" the air out of the bottom of the cowling, it simply wasn't enough. We sucked it up and went back to work.

The new 6-inch rings are visibly larger. Now the airplane, from the front, looks more like a Cessna Corvalis than ever. (It's not, of course. Those speed demons, whose legacy is the Experimental homebuilt Lancair lineage, carry

The raw materials: a top and bottom cowling, air scoop (white) and a plenum (orange), ready for the builder to trim and fit, and then trim and fit again. Eventually all will fit this custom installation. Then let the riveting, bonding and bolting begin!

This is the best time to decide how large you want your air intake openings. It's easy to trim the openings to an exact size and fit the rings before the final sanding and filling.

The 4-inch rings on the James cowl.

A face only a mother could love? There was a fear that larger air intakes would slow the airplane, but that does not appear to be the case. True airspeeds remain the same, as tested at altitudes between 5000 and 10,000 MSL, on several long cross-country legs. All they've slowed is the deterioration of the engine from issues related to heat damage. Good news.

significantly more horsepower, both turbocharged and intercooled.) No matter. We can handle being mistaken for a Corvalis. All we cared about was whether it worked.

So…Does It?

No time like a June afternoon, with surface temperatures of 95° and 90% humidity, to check out an engine's performance. The airplane climbed out at 120 knots and 380° for the hottest cylinder. The oil temperature crept up to and held at 200°. Air cooling at its best. We climbed out from sea level to 10,500 MSL. Again, the temperatures held, then began to drop through 360°, allowing us to lean the mixture for performance in the last half of the climb. We were still climbing at 1000 fpm and 120 knots at the top. We flew the airplane to Virginia nonstop, burning 11 gph at 8500 feet, 70% power at 170 knots true airspeed with temperatures in the 380° range. Then we did a quick turn, the real test.

When an engine has been running with air flowing over it for hours to cool it, and then you stop the engine and the air cooling at once, the engine will continue to heat up for about 15 minutes before the temperatures of the metals and oil finally begin to drop. If you try to restart a big fuel-injected engine such as a Lycoming during these 15 minutes or so, say, after you've topped off with fuel, you might find yourself with vapor lock as hot fuel vaporizes in the lines. The engine won't start. (We counter that with a priming system that allows us to pump cool fuel from the right tank through the lines and into the left tank, cooling things down. It helps.)

Once you start up from a quick turn, you'll notice engine and oil temperatures warm right back up to cruise conditions, and often even warmer, before you can complete your taxi and runup checks. Getting air flowing through the cowling is paramount at this point, and it is best to get the plane in the air to do that. This was the real test of the new intakes—and they passed. Initial climbout CHTs closed in on but did not bust the 400° mark (and as we cleared the hot air at around 4000 MSL, they dropped below 380°). The oil temperature held at 205°. Success!

One interesting side note: Where before the No. 6 cylinder was almost always the hottest, now, after our plenum and intake changes, the hottest cylinder is No. 5. So what's our next fix? We are contemplating rebalancing the fuel distribution across the cylinders. We would do that by swapping out the sleeves in our Airflow Performance injection nozzles, again, giving the No. 5 cylinder a little more avgas, perhaps. But that's another column entirely. ✈

A plenum is not, by far, the standard for cooling baffling. Here is a baffle box made of silicon and aluminum baffling that sits flush with the top of the aircraft's cowling. It is an inexpensive solution, tried-and-true. It does require that your top cowl be of a heavier material, though, as it will have to withstand the force of the air running under it.

The new air intakes are 6 inches wide, tapering only slightly as they duct air into the plenum.

Ask the DAR

Know your limitations: required inspections.

BY MEL ASBERRY

We're pretty deep into the operating limitations for our Experimental aircraft. So what about required inspections? (22) No person may operate this aircraft unless within the preceding 12 calendar months it has had a condition inspection performed in accordance with the scope and detail of appendix D to part 43, or other FAA-approved programs, and was found to be in a condition for safe operation. As part of the condition inspection, cockpit instruments must be appropriately marked and needed placards installed in accordance with 91.9. In addition, system-essential controls must be in good condition, securely mounted, clearly marked, and provide for ease of operation. This inspection will be recorded in the aircraft logbook and maintenance records.

Sounds a lot like an "annual inspection" doesn't it? So why isn't it called an annual?

Well, for one thing the sign off for an annual states that "the aircraft was found to be in an airworthy condition." Can our Experimental aircraft be "in an airworthy condition?" To do so, an aircraft must meet its Type Certificate. Do we have a Type Certificate for our aircraft? I don't think so. If we did, it wouldn't be Experimental. We can only find our aircraft "to be in a condition for safe operation."

Notice also that any of those placards that you installed to pass your initial airworthiness inspection must be replaced if they have fallen off.

(23) Condition inspections must be recorded in the aircraft logbook and maintenance records showing the following, or a similarly worded statement. "I certify that this aircraft has been inspected on [insert date] in accordance with the scope and detail of appendix D to part 43, and was found to be in a condition for safe operation." The entry will include the aircraft's total time-in-service (cycles if appropriate), and the name, signature, certificate number, and type of certificate held by the person performing the inspection.

Paragraph 23 tells us how to sign off the condition inspection and also what information about the inspector must be included.

The next two paragraphs, limitations 24 and 25 will be issued in lieu of limitations 22 and 23 for turbine-powered amateur-built aircraft.

(24) This aircraft must not be operated unless it is inspected and maintained in accordance with an inspection program selected, established, identified and used as set forth in 91.409(e) through (h). This inspection must be recorded in the aircraft logbook and maintenance records.

We see that turbine aircraft are treated a little differently and require a specific inspection program, which is typically provided by the engine manufacturer or an airframe manufacturer who uses the engine. This inspection program must be approved by the local FSDO.

(25) Inspections must be recorded in the aircraft logbook and maintenance records showing the following, or a similarly worded statement. "I certify that this aircraft has been inspected on [insert date] in accordance with the scope and detail of the [program title] FSDO-approved program dated [insert date], and found to be in a condition for safe operation." The entry will include the aircraft's total time-in-service (cycles if apt) and the name, signature, certificate number and type of certificate held by the person performing the inspection.

Paragraph 25 contains the same basic information as 23, except it changes the wording to fit the specific inspection.

Next time we'll finish up with who can perform and revise these inspections, and when you must advise ATC of your Experimental status. ✈

Photo: Mel Asberry

COMPLETIONS

Ron Smith's RANS S-19

After two years and six months of build time, N619RS was signed off and flown a few days later. With a Rotax 912S engine and a Sensenich 68-inch ground-adjustable prop, it cruises at 128 mph at 5500 rpm burning 5.0 gph. With a VFR panel, analog flight instruments and a Dynon D120 EMS, Garmin 296 GPS, Becker transponder and Flightline com radio, it weighs 838 pounds. It was fun to build and is a blast to fly. Thanks to all my friends who helped with the project.

GOODYEAR, ARIZONA
RONRVFLYER@COX.NET

Andrew Butler's RV-7

After a seven-year build in a cold, wet shed at Galway in the west of Ireland, RV-7 EI-EEO took to the air on the February 19, 2011, with Gerry Humphreys (RV-7 EI-HUM) at the controls. Fitted with an IO-360 attached to a three-blade constant-speed MT prop, it flies like a dream and exceeded my expectations by flying straight and level, hands-off. That something I built flies so great from the get-go is more a credit to Van's than to my skills (or lack thereof) as a builder. Thanks to Van's for such a great kit and the all-important great instructions!

Thank you to all of those who helped, particularly my wife, Fabulous Fiona, and a special thank you to Gerry for his assistance in getting me over the line and taking the controls on the first flight. Video and photos can be found at *www.youtube.com/watch?v=hBIdAxH1ycI,* and at *https://picasaweb.google.com/fzvs2f/2011_02_19FirstFlight#*. (We'll provide direct links at *www.kitplanes.com*.)

GALWAY, IRELAND

Gary Meuer's Starduster SA900 V-Star

Here is a picture of my recently completed Starduster SA900 V-Star, a great sport plane. It has a Lycoming O-290 with a Sterba prop. It stalls at 45 mph, cruises at more than 100 mph and is easy to fly, take off and land. The project started life in 1974; the only parts that were store-bought are the fiberglass turtleback, wheelpants and the bubble windshield. I made a low-profile fiberglass cowling, so I can actually see over the nose during taxi and takeoff. The bubble canopy is larger than most, so I can wear a baseball cap when flying without it blowing off.

I have a door on the left side for easy entry and a large baggage compartment to store a portable chair, which is useful at fly-ins. My brother has a twin to my Starduster, and we have the same cowling and mostly the same hardware. They fly well together. The plane comes off the ground a bit over 44 mph and climbs at 60 mph to 80 indicated. I cruise at around 100 mph, and max speed seems to be around 130 indicated. This is a nice, light sport biplane that has a light wing loading (7.8 pounds per square foot of wing area), so it bounces around about like my Luscombe. It's very fun to fly.

TULLAHOMA, TENNESSEE

BUILDERS SHARE THEIR SUCCESSES

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

Tim Delf's Sky Jeep

After 10 enjoyable years of on-and-off building, my plans-built Zenith CH 701 aircraft received its airworthiness certificate on March 10, 2011, and took to the air on March 11. It flies great! With a good, used Continental O-200-A engine and a simple panel, it is an inexpensive airplane that is really fun to fly. I would like to thank Chris Heintz for the design. With his designs, anyone with a pair of tin snips, a 4-foot bending brake and the discipline to build can have an airplane. I received much help from Carl Ritter, my friend and technical advisor from EAA Chapter 111, and from my brother Steve, who helped me paint the airplane and provided an extra set of capable hands whenever needed. And, of course, thanks to my wife, Barb, for her love and support.

BLUE GRASS, IOWA
DELFTR@AOL.COM

Scott Ehni's Zenith CH 701

This is our scratch-built turbine Zenith CH 701. It first flew on November 27, 2010, and just completed its 40-hour test phase. Some people think it's not practical at 12 gph average, but who else is logging turbine time for less than $50 per hour? This plane is made for the mountains and climbs at 500 fpm at 10,000 feet. The Zenith 701 is more capable than I ever imagined it could be. Special thanks to my wife, Dallas, Kary McCord and Steve Trentman for helping to make the dream come true. Next it's off to the paint booth. You can see it fly on YouTube at *www.youtube/ehprocustom fab*. (We'll provide a direct link at *www.kitplanes.com*.)

TRINITY, TEXAS

Phil Bolenbaugh's RANS Coyote II (S-6ES)

My RANS Coyote II received its airworthiness certificate in April 2010 after 14 months and 1500 hours of build time. Powered by a Rotax 912 UL engine, this 748-pound aircraft cruises at 95 mph at 5000 rpm. At 5200 rpm, cruise increases to 102/105 mph with a 4-gph burn rate. After some minor adjustments to the rigging configuration, it now flies hands-off and is very predictable throughout all flight maneuvers.

Instrumentation and special features include a Dynon EFIS, EMS, AP 74 (two-axis auto pilot), traffic watch system, nosewheel disconnect with shimmy damper, insulated cabin, two heaters, two baggage compartments, dual hydraulic toe brakes, electronic fuel monitoring system, Lowrance GPS, XCOM radio and a Becker transponder. If the glass panels fail, there are regular "steam" gauges that provide airspeed, altitude, VSI, slip/skid, wing level to horizon, engine rpm and engine oil pressure information.

This was a fun project that produced a great flying machine. The added bonus was the Grand Champion Award (Gold Lindy) at AirVenture Oshkosh 2010 in the Light Plane category. It just doesn't get any better!

SUGAR GROVE, ILLINOIS
PWBOLENBAUGH@SBCGLOBAL.NET

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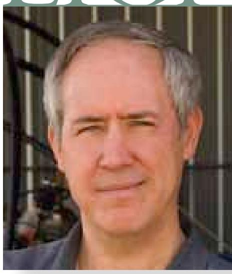


Safety by the numbers.

As someone who sells powered parachutes and trains people to fly them, I get a lot of calls from non-pilots who are attracted to this unique form of flight. A common theme that I've heard from non-aviators goes something like this: "One of the reasons I like powered parachutes is that if the engine goes out, I'll be under a parachute and be able to land safely." Ouch.

The dilemma then is to either agree with the customer and go for the sale, or to point out that nearly anything with a wing will continue to fly without an engine. There are a lot of great reasons to fly powered parachutes, and one of them is safety. But continuing a myth about imminent danger if the propeller stops turning on an airplane isn't the way I want to introduce someone to aviation.

Now that we have all taken a moment to enjoy our superior knowledge and judgment over the non-aviator, I would like to talk about common misconceptions on the "real" aviator side. As often as I have heard the comment about being under a parachute when the engine goes out, I have heard conventional pilots remark that they don't want to risk their lives in something as light and unsubstantial as an ultralight. Believe it or not, that statement is nearly as unmoored from scientific reality as are non-pilot worries about engine failures.

The ultimate example of low kinetic energy is a powered paraglider with landing speeds of a few miles per hour and incredibly low mass.

Feel the Energy

If you are in an aircraft accident (or automobile accident, or even a bicycle accident) your immediate problems have to do with kinetic energy. First is the amount of kinetic energy you've accumulated before your contact with the ground or an obstacle, and second is what you and the aircraft are going to do to dissipate that energy immediately before or during impact.

The formula for kinetic energy is simple: $E_k = ½ mv^2$ where E_k is kinetic energy, m is equal to mass, and v represents velocity. The larger the amount of kinetic energy you must deal with, the bigger your problem. The formula shows that, as your mass increases, so does your kinetic energy. In other words, flying in a lighter aircraft, if nothing else is considered, is safer than flying in one that is heavier. But even more important than mass is velocity.

The increase in mass increases energy linearly. That means there is a straight-line correlation between mass and kinetic energy. However, kinetic energy gets a double dose of velocity because the velocity value is squared.

Roy Beisswenger *is the technical editor for Powered Sport Flying magazine (www.psfmagazine.com) and host of the Powered Sport Flying Radio Show (www.psfradio.com). He is also a Light Sport repairman and gold seal flight instructor for Light Sport Aircraft as well as the United States delegate to CIMA, the committee of the Fédération Aéronautique Internationale (FAI) pertaining to microlight activity around the world.*

True ultralights and many Light Sport Aircraft have low top speeds compared to their general aviation brethren. Just as importantly, they both have low stall speeds. For the sake of illustration we will compare an ultralight with an aircraft that qualifies as both a GA and a Light Sport Aircraft. We'll do the math for an ultralight at the high end of the legal weight and speed limitations with something relatively benign from the GA world: a Piper Cub. I like using the J-3 Cub as an example because of a famous quote from Max Stanley, a Northrop test pilot. Stanley said, "The J-3 Cub is the safest airplane in the world; it can just barely kill you." I suspect he was also thinking of speed and kinetic energy.

Figure 1 shows a loaded, full-weight ultralight compared to a fully loaded J-3 Cub. The numbers are broken down differently because the maximum weight of an ultralight is not defined by gross weight, but empty weight. However, for comparison, we'll load the ultralight up with the maximum fuel it can have on board as well as a 200-pound pilot.

Based on the weights and speeds shown, the J-3 Cub ends up having almost five times the kinetic energy of an ultralight (4.76 times the amount of energy that would have to be dissipated on impact).

Now keep in mind that this is comparing the heaviest of legal ultralights with the slowest and lightest of general aviation aircraft. If we work the numbers with something like a late model Cessna 172 at gross, we will find that it has nearly 20 times the kinetic energy of an ultralight. That is all energy the pilot and aircraft would need to dissipate in the event of an off-airport landing.

Really Feeling the Energy

The first part of this issue involves determining the amount of kinetic energy that needs to be dissipated, and the second part of the problem is actually doing the dissipating.

Pilots normally have a lot of control over the aircraft all the way to the end of an off-airport landing. The first big decision is where to land in the first place.

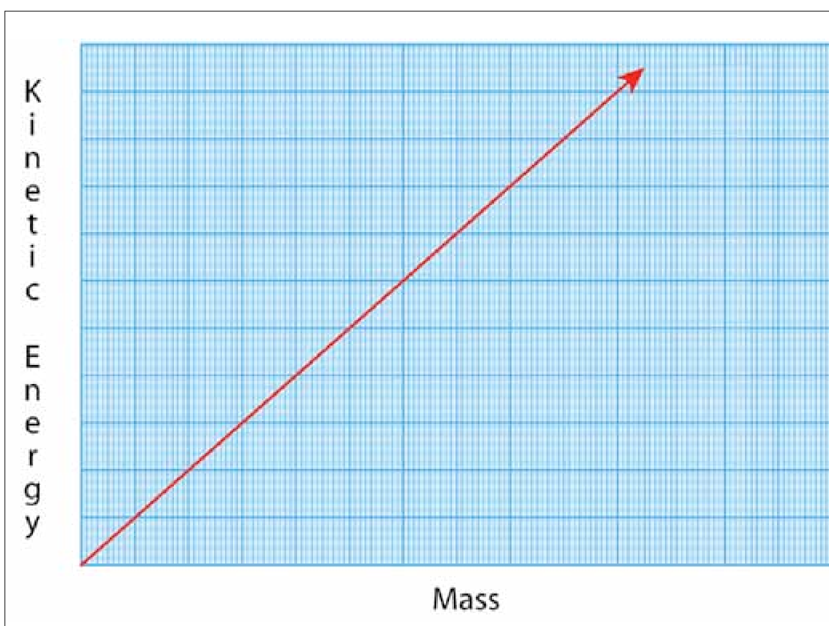
	Ultralight	**J-3 Cub**
Gross Weight	N/A	1220
Empty Weight (lb.)	254	N/A
Weight of 5 Gallons Fuel (lb.)	30	N/A
Pilot Weight (lb.)	200	N/A
Total Weight (lb.)	484	1220
Stall Speed	24 knots	33 knots

Figure 1

The heavier the aircraft, the more important it is to try to land in a spot where the landing gear will work. Allowing forward kinetic energy to just roll out is a good thing. But even without a smooth landing area there are engine-out landing techniques that are similar to all aircraft but are certainly not the same. Aggressive flaring is common—it converts kinetic energy to lift, which is downright handy. Less speed and more "up-ness" on a landing is just what the pilot ordered.

But if you can't do everything right, or if you don't have a chance to do anything right, you're going to be relying on the aircraft to take care of your energy issues for you. And how does an aircraft do that? Basically the same way modern cars do. Kinetic energy is absorbed by breaking and bending structural parts. The key is that you don't want any of the breaking and bending parts to be yours.

Most ultralight aircraft are extremely good at bending. (Yes, you can quote me on that.) I have observed some fearful looking accidents and seen some images from even more incidents where you just know someone must have perished based on the condition of the aircraft. Fortunately, like a tornado through a trailer park, ultralight accidents don't kill as much as they destroy property. That is

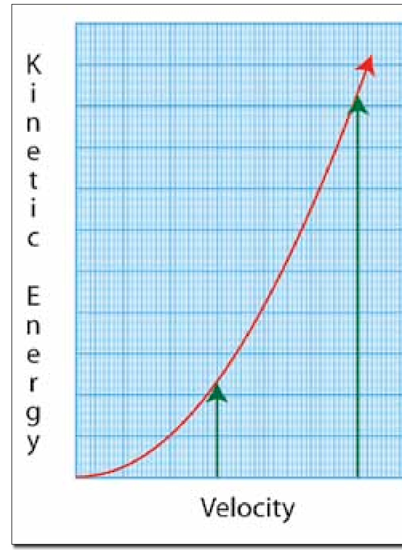


In this example of linear progression, as the mass is doubled, the kinetic energy doubles.

partly because of the low kinetic energy involved in these accidents, but it is also because non-critical parts are being bent.

Where the automobile industry spends a lot of money ensuring that cars pass crash tests, the ultralight world does well without trying because the spread-out masses in the wings and the rest of the structure naturally give way. That doesn't mean there isn't room for designers to make aircraft more crash-worthy, and some designers have put effort into this. Shock absorbers for hard landings as well as crumple areas and protective bracing for other areas have been incorporated into some designs. That is all good and makes a safe kind of flying even safer.

The weakest link in the performance of ultralight aircraft is the same as that of general aviation aircraft: the occupant in the pilot's seat.



As velocity is doubled in this example, the kinetic energy increases by a factor of four.

Finally

So, you may be wondering what I actually tell the wannabe pilot on that first call. I point out that there are a lot of different reasons that people take to the sky. These reasons include transportation, sightseeing, photography, adventure and more. Ultralights, powered parachutes, trikes, gyroplanes and Light Sport Aircraft all offer advantages and disadvantages. The key is to discover what kind of flying you want to do, who is available to provide training and to support your aircraft purchase, and of course, how much money you're able to spend. Then, if you get the right training and make a sound equipment choice, you can safely fly any category of aircraft you choose. (But powered parachutes are still the best!) ✢

Rotorcraft store kinetic energy in their rotors. In an engine out, the key is to first transfer potential energy of altitude to the rotor by speeding toward the ground and then flaring before touching down. The lighter the rotorcraft, the less energy there is to worry about.

What hath Babbage wrought?

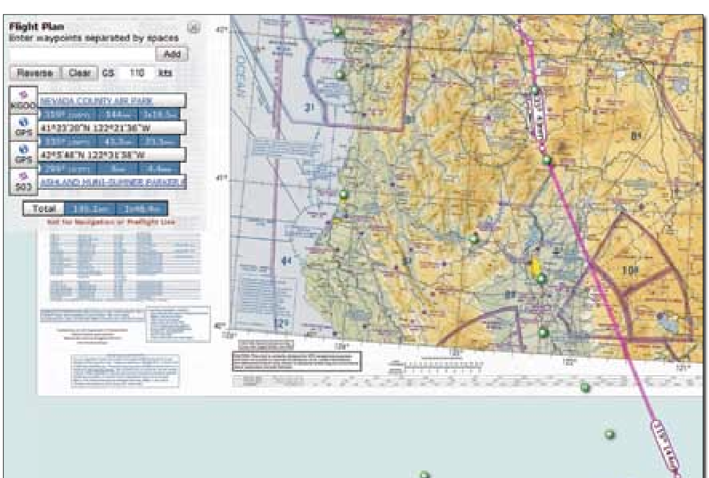
Charles Babbage had the right idea in the 1800s with his mechanical "difference engine" computer, but the poor machining of the day kept it from working until his original plans and the CNC-controlled milling/lathe machinery of the 20th century actually let us construct one of his devices in 1991. It had 32-decimal-place accuracy, which is a trick that most modern calculators can't achieve. But his idea for a computer took fire in a monster called ENIAC (Electronic Numerical Integrator And Computer). It was originally designed in 1943 and by the time it was completed, weighed more than 30 tons, used more than 17,000 vacuum tubes, 1500 relays, and 80,000 resistors and capacitors. It consumed 150 kW of power. It was designed to be used to calculate artillery firing tables (the battleship Missouri is often mentioned), but the first real computing it did was calculations for the first hydrogen bomb.

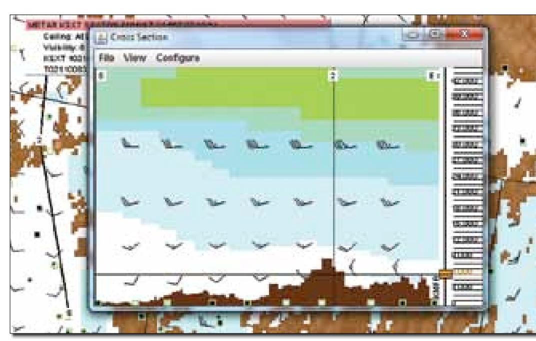
A few short decades later we are armed with both Windows and Apple (which I will abbreviate as PC and Mac). Both do a splendid job of number crunching, and both are working their way into the general aviation mainstream. Here are a few programs we found that are exceptionally useful in the GA environment.

Choose Your Path

The first tool I ever used on the "aviation Internet" was NOAA's Aviation Weather Center. For some years they had what they called a Flight Path Tool, to which they recently made improvements. The screen shown indicates a 2-hour flight from my home airport (KGOO) in Grass Valley, California, and the editorial office in Ashland, Oregon (SO3). I chose a particularly poor altitude of 6000 MSL, which runs right into Mt. Shasta (the brown cross section). I have two choices: I can either take my plane up to 10,000 feet, or dogleg around Mt. Shasta, which the tool lets me do quite easily. Note that going up to Oregon will be quicker than coming back to California, because I'll have a 5-knot tailwind going up and a 5-knot headwind coming home. (PC only; free.)

For you iPad/iPhone folks, the clear winner in this game is Foreflight. Given the space available here, anything I say will have to be a light gloss off the top. You really need to go to the web site to see all the goodies that this gem will give you for a relatively expensive $75 per year. That $75 buys you complete charts (IFR/VFR) for the entire United States, online weather, flight planning and a whole bunch more. Why no screenshot for this one? There is way too much information to pack onto a single image. If I had to pick fault, I'd say that the ability to get charts (for example) for Maine when I live in California is just a waste of bandwidth. I'd like a little less coverage and a





The chart from Skyvector.com (left) displays a dogleg around the tall, hard stuff. The same information in DUATS enhanced format (above).

Jim Weir *began acquiring Aero'Lectrics expertise in 1959, fixing Narco Superhomers in exchange for flight hours. A commercial pilot, CFI and A&P/IA, he has owned and restored four single-engine Cessnas. He is chief avioniker at RST Engineering and teaches electronics at Sierra College. He'll answer questions at www.pilotsofamerica.com - maintenance. Check out www.rst-engr.com/kitplanes for previous articles and supplments. Gail Allinson is technical advisor.*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Other hotels near Ashland Municipal Airport-Sumner Parker Field

	Miles	Price ($)
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HOLIDAY INN EXPRESS & SUITES ASHLAND	0.4	139-149
SUPER 8 ASHLAND OR	0.5	85-111
TIMBERS MOTEL	1.6	89-99
ASHLAND MOTEL	1.8	
STRATFORD INN	2.4	243-244
ASHLAND SPRINGS	2.7	159-229
BEST WESTERN BARDS INN	3.0	77-152
LA QUINTA INN & SUITES ASHLAND	4.8	94-162

Distances are approximate, and may vary depending on the actual route traveled and the location of the travel start on the airport.

AirNav.com's listing of hotels and motels in and around Ashland Airport, some with reviews.

little less money for a subscription. (Mac only; $75 annual fee.)

Coming in a close second is a parlay of two programs that add a little more versatility to the inflight environment. The first one is an app called WingX Pro, which does a credible job doing all the things that Foreflight does in a slightly different manner. Again, the kicker is the $75 annual fee for the charts and updates. The second program (which dovetails with WingX) is an inexpensive weight and balance program called FlightScale ($6.99 at iTunes). It features lots of goodies like full and empty fuel tanks on the loading graph, premade templates for simple and complex aircraft, and color-coded "out of limits" data. (Mac only; $75 annual fee.)

Check Your Charts

For those of you interested in charts without all of the frills, check out Skycharts Pro which goes for the modest sum of $19.99 at iTunes. It's nothing fancy, but has all the charts that you could possibly want for your iPad. (Mac only; $19.99.)

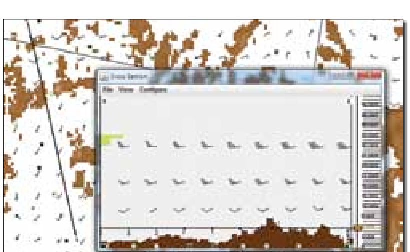
You may already be familiar with DUAT and DUATS, which have been with us for more than 20 years now and seem a little long in the tooth when compared to current programs and apps. I prefer DUATS because it features a Graphical User Interface (GUI) for Windows that lets me access all the same data but in graphical format. However, the current GUI, Golden Eagle, seems to be somewhat limited and is more of a shell to sell "value-added services." I found it less than easy to navigate and not at all intuitive. Rumor has it that DUAT has an iPhone app, but I could not find it. (PC only; free.)

Sky Vector offers a nice chart planner, which uses either Sectional or WAC charts for flight planning. Again, you can drag your proposed route away from the large cumulogranite obstacles and stay down where the air is breathable. (PC only; free)

NavMonster is a kind of nifty all-in-one site, though it doesn't allow you to move your proposed route. The workaround is to crow-hop from airport to airport—a clunky approach. (Mac and PC; free.)

Plan Your Trip

The granddaddy of them all is AirNav.com—the best airport facility directory on the Internet, complete with pilot reports on the nearby businesses. Want to find a hotel or motel close to the airport? Not a problem. I found no fewer than 12 places to stay in Ashland, and the last time I went up for the annual Shakespeare Festival I found the prices to be right on the money. However, one beef I've had with AirNav.com is that there are practically no budget motels listed (for example, a Motel 6). However, there is more than enough good information on the site that I highly recommend it. (Mac and PC; free.)



DUAT indicates a flight between Grass Valley and Ashland at 6000 MSL impacting Mt. Shasta about 1000 feet below the peak.

When all you want to do is find the best fuel prices in a particular area, take a look at 100LL. When I looked up my destination airport of SO3, I found the cheapest fuel at Tulelake, California (KO81), for $5.25 per gallon. For something a little closer, Medford, Oregon (KMFR), had fuel for $5.81, or I could refuel right at Ashland for $5.85 per gallon. If you're in the market for Jet A, 100LL will point you in the right direction (these days Jet A looks to be more than a buck a gallon *less* than 100LL). (Mac and PC; free.)

In coming months, I'll wrap up this series with a prowl of the various regulatory sites (FAA and state). Until then, stay tuned. +

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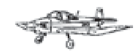

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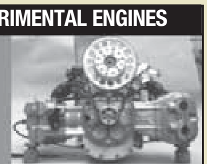

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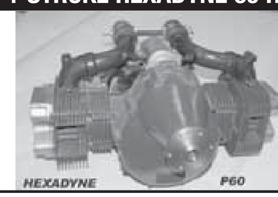

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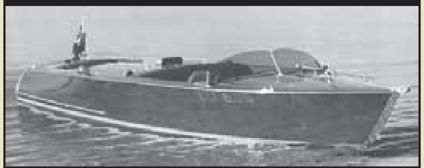

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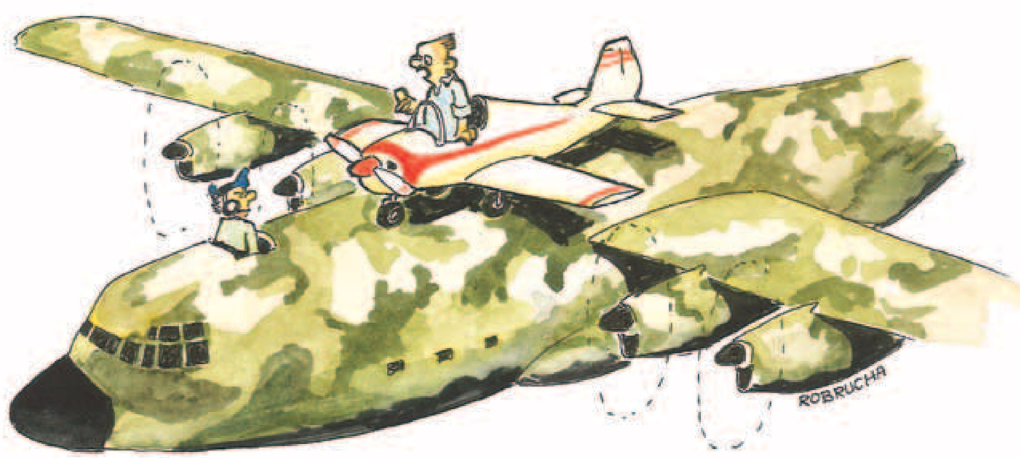

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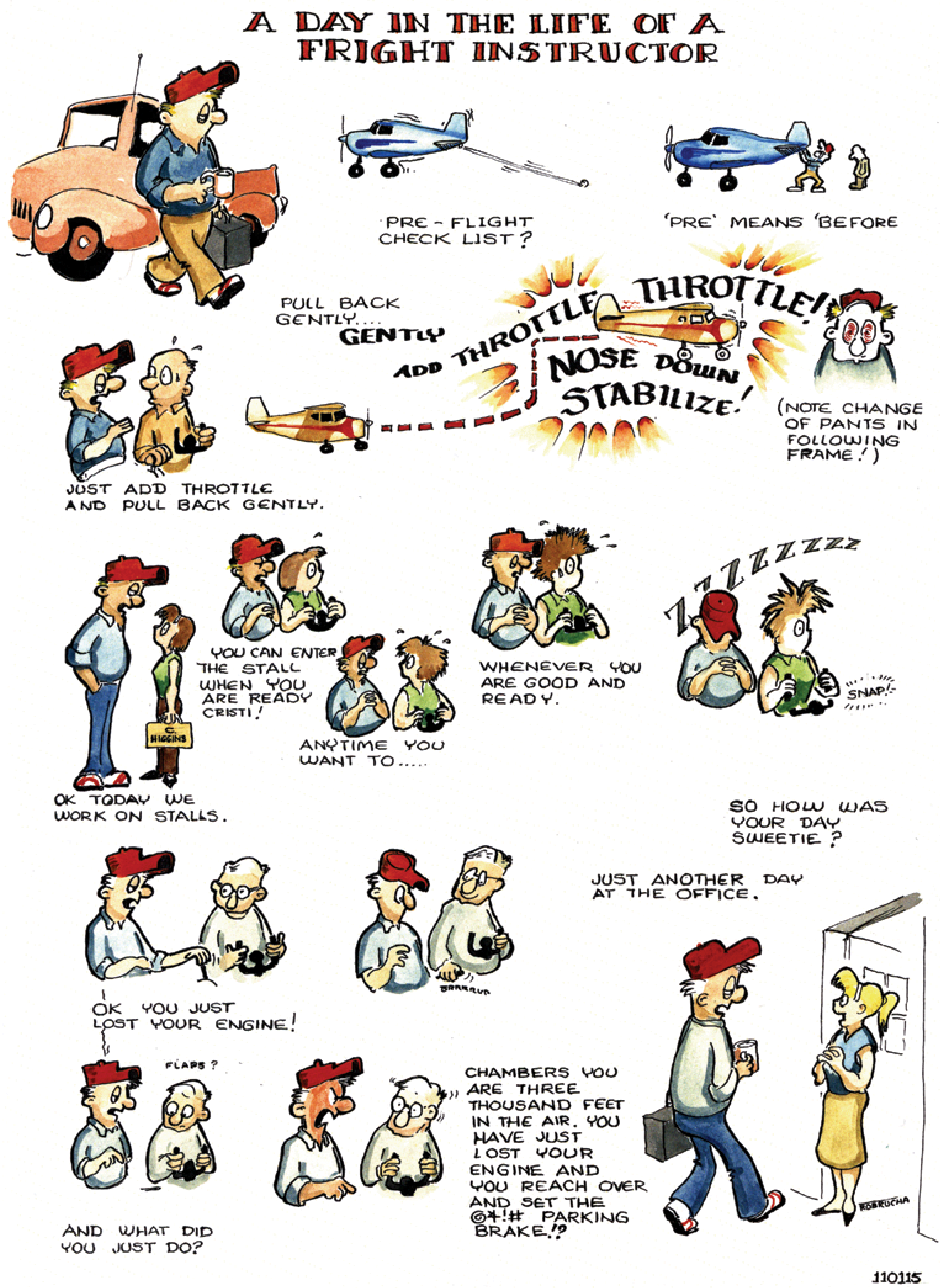
A DAY IN THE LIFE OF A FRIGHT INSTRUCTOR
PRE - FLIGHT CHECK LIST ?
'PRE' MEANS 'BEFORE
JUST ADD THROTTLE AND PULL BACK GENTLY.
PULL BACK GENTLY.... GENTLY
ADD THROTTLE
THROTTLE!
NOSE DOWN
STABILIZE!
(NOTE CHANGE OF PANTS IN FOLLOWING FRAME!)
OK TODAY WE WORK ON STALLS.
C. HIGGINS
YOU CAN ENTER THE STALL WHEN YOU ARE READY CRISTI!
ANYTIME YOU WANT TO.....
WHENEVER YOU ARE GOOD AND READY.
ZZZZZZZZ
SNAP!
OK YOU JUST LOST YOUR ENGINE!
FLAPS ?
AND WHAT DID YOU JUST DO?
CHAMBERS YOU ARE THREE THOUSAND FEET IN THE AIR. YOU HAVE JUST LOST YOUR ENGINE AND YOU REACH OVER AND SET THE @*!# PARKING BRAKE!?
SO HOW WAS YOUR DAY SWEETIE ?
JUST ANOTHER DAY AT THE OFFICE.
ROBRUCHA
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