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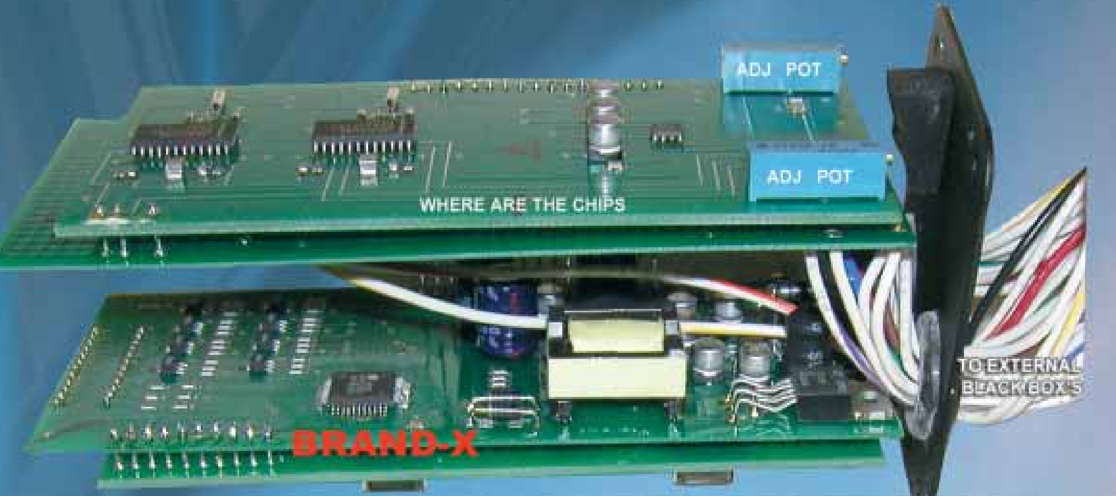

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KITPLANES
THE INDEPENDENT VOICE FOR HOMEBUILT AVIATION


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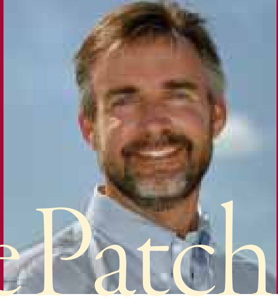
On the cover: Kevin Wing caught this final-approach shot while shooting from the front cockpit of Budd Davisson's Pitts S-2A.



BY MARC COOK

Welcome to the world, N30KP.

Some months, it has to be said, are more interesting than others. My January was nothing short of breathtaking. And the reason is the airplane pictured below, the newest member of the KITPLANES® family. It's a GlaStar Sportsman 2+2, that much is obvious, but it also represents a change in the way we should think about quickbuild kits and outside assistance.

You see, with the help of Glasair Aviation's Customer Assembly Center, located off the airport at the firm's base in Arlington, Washington, this airplane was started and flown in 18 working days. On January 9, I rolled into the CAC at 7:30 a.m., still bleary from the 1200-statute-mile drive up from California but fortified by a huge cafe latte, to begin the program. On January 31, I took N30KP into the air for the first time. (The first flight was, incidentally, just about trouble free.)

In between, it was, as others who have "survived" the traditional three-week CAC program have described it, action packed and massively educational. You'll notice the lack of the term "I built this airplane" in the context of the CAC, because that would imply a solo effort. Nor was it true that I came to Arlington, hung out in the breakroom watching MythBusters, and spent my afternoons touring the Space Needle in between writing checks and conducting business calls on the cell phone. Nope. This version of the CAC is a full-immersion process, completely hands on and utterly involved. I know every system in the airplane, can show you scars from the dozens of cotter pins I set and the "smilies" on a few of the rivets I pounded in the wing before I grasped the techniques. I can tell you precisely why a few of the approximately 10,000 nutplates in the Sportsman—possibly that's an exaggeration—aren't quite where they should be. Go ahead and ask, but bring a pot of coffee and maybe a folding chair; it'll be a long explanation.

It's the rare sunny day in northern Washington state...particularly for early February. Our Sportsman 2+2, N30KP, is ready to head home to California.

I have no doubt that some of you will believe this was a publicity stunt, a special one-off deal. As you weren't there, you'll have to take my word that it was a full-on development program, a concoction of various prototype concepts aimed at not just getting N30KP into the air but also to make it feasible for the company to offer a program much like this one to the general public. It was to have been announced by the time you read this, but Glasair Aviation is intending to offer a "two weeks to taxi" CAC program that will take the almost month of calendar time I spent in Arlington and compress it into 10 long days jammed into a two-week span, just right for those of us who can't quite manage a month out of the office. Ultimately, the company hopes to have the Sportsman 2+2—it will not be offering the program for the two-seat GlaStar—ready to fire up and taxi around at the end of the two weeks, and be ready for flight after a modest number of hours' work when the builder gets home. This is in contrast to the current three-week CAC, where there is no electrical-system work done and the airplane is at least a couple hundred man-hours from being ready to fly.

This was, to put it mildly, an intense experience. During my time there, the CAC was ably manned by Brandon Rodstol and Seth Town, who worked with me the entire time, as well as Ted Setzer, who has been with the company since the Stoddard-Hamilton days and is a superb prototyper, as is often the case when your day job is to build factory demonstrator aircraft. When we begin our coverage of the build process in the August issue, I'll get into more details of the CAC program, the decision-making process surrounding N30KP, and the gory particulars of flight test.

At press time, the airplane was in the final segment of Phase I flight test, which was pegged at 40 hours because of the Experimental nature of the Barrett IO-390 and the special 74-inch Hartzell blended-airfoil prop. Moreover, as this is the first IO-390 to fly in a Sportsman 2+2, there have been many integration issues to work through. Lots of little things—just like every other homebuilt. That's because, as we know, building and first flight combine to make just the first part of the journey. Check our web site—www.kitplanes.com—for regular updates on N30KP's progress. ✢

Marc Cook has been in aviation journalism for 19 years and in magazine work for 25. He is a 3800-hour instrument-rated, multi-engine pilot with experience in nearly 150 types. What's more, he's mad about homebuilts.

Photo: Courtesy Glasair Aviation

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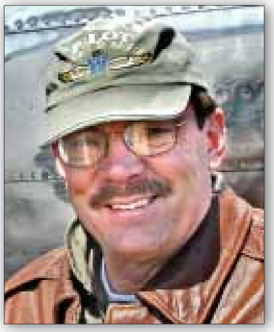
CONTRIBUTORS

LEN BUCKWALTER

Though a newcomer to the pages of KITPLANES®, Len Buckwalter is no stranger to writing about avionics-related topics. He founded Avionics Magazine and served as publisher and editor for 17 years. To date, Len has written 25 books and more than 2000 articles; he currently works as director of training for Avionics Systems, a custom panel builder, and publisher of www.avionics.com. This month, we asked him to tackle the prickly subject of TSO requirements for instruments and avionics in homebuilt aircraft.

PAUL MILLNER

An engineering manager for a major oil company where he's worked for 30 years—sorry, we can't tell you which one, but trust us that it is a major player—Paul Millner is not only intimately familiar with the day-to-day production of avgas, but he also has some cogent insights into its future. Paul is also a 3500-hour private pilot and a founder of Cardinal Flyers Online (www.cardinalflyers.com), a type club for Cardinal owners, operators and aficionados.



DOUG ROZENDAAL

Doug Rozendaal will tell you he learned to fly "in a Cessna 150, one dollar at a time, with money I did not have." And yet, he says he's the "luckiest guy you ever knew." That's because he spends weekends flying various warbirds for the Commemorative Air Force, as well as other museums and private collectors. In his spare time, Doug owns and operates a lubricant manufacturing and contract packaging business. In his hanger, you will find an F-1 Rocket, a Beech Debonair and his own warbird, a Taylorcraft L-2M.

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LETTERS

EDITORIAL@KITPLANES.COM

Is Nighttime the Right Time?

I would like to point out an inaccuracy in the March issue of your magazine. In Dan Johnson's Light Stuff article on Page 73, he states that SLSAs powered by Jabiru engines are restricted to day/VFR operations because of our JAR-22H certification. That is not correct. JAR-22H is not the basis for any of the SLSA certifications using Jabiru engines. Jabiru Aircraft Pty, Ltd has issued a compliance document indicating that the Jabiru engines comply with ASTM F2339-04, the engine standard for Light Sport Aircraft. That is the basis for certification in LSAs powered by our engines.

The only application of Jabiru engines that I know of in the U.S. that would prohibit night operations because of a JAR-22H engine certification is use of the engine in primary category aircraft where the aircraft could be certified with a gross weight under 750 kilograms for day/VFR only. Light Sport or Experimental/Amateur-Built aircraft powered by Jabiru engines obviously do not fall under the primary category .

PETE KROTJE
JABIRU USA SPORT AIRCRAFT, LLC

Pete is correct. We mistakenly added Jabiru to the list during editing of Johnson's story. We regret the error. —Ed.

Thanks for the great article by Dan Johnson about IFR flying and LSAs ("Light Stuff") in the March 2006 issue. Dan's mention of engine-specific restrictions as to night flying got me to wondering...does this apply to LSAs only? I'm currently building a Zodiac XL from Zenith Aircraft and had planned to install a Jabiru 3300 engine.

I hold a private pilot certificate and plan to get instrument rated when my Zodiac is completed. Although I could fly the completed Zodiac XL as an LSA, I plan to fly it as an Experimental using my private pilot privileges.

The Johnson article indicated that Jabiru engines are not approved for night flight by the manufacturer. Does this mean that I won't be able to fly my Experimental at night if I install the Jabiru rather than a Continental or Lycoming?

Thanks again for a wonderful magazine. It is always a cover-to-cover read.

PHIL SCHMIDT

Phil: Worry not. First of all, read the letter above this one—our statement about the Jabiru was inaccurate. Second, as the builder of an Experimental/Amateur-Built aircraft, it's up to you to set the operating limitations of the airplane, and so the primary consideration is that you meet the equipment requirements for the phase of flight. —Ed.

Panel Discussion

Ed Wischmeyer really missed the mark with his building panels story. The whole idea in Experimentals is *not* to do the standard stuff but to customize to a better concept. I have a mixture of glass and steam backup all placed where I think the pilot should be looking if the glass fails and he needs steam backup.

I'm more interested in looking forward.

JERRY SANTA

As someone who's written four articles on ergonomic circuits and gadgets for KITPLANES®, and as author of the booklet "Ergonomic Instrument Panel Design," I wish to opine on the recommended panel design in February's magazine.

On Page 43, a "good panel" is shown. While it is better than the bad panel, the Manifold Pressure (MP) gauge should be located where the VOR head is, and the VOR head moved down where the autopilot is. Why? Because the MP gauge is a "primary" flight instrument. If you're flying "by the numbers," as all good pilots do, you should be able to set a climb, cruise or descent by setting power and pitch. This is especially important in instrument flying, where looking over to the right to find that information is troubling.

Why does the MP have to be in the top row? Because on takeoff, you want to be able to scan easily for full power indication while your eyes are out the window. Putting the gauge on the top row will make this easier. Also, when you're navigating using the VOR, you will be flying using the directional gyro (DG) for intercepts, and keeping the VOR and DG in the same row will make it easier to scan this pair.

If this were a fixed-pitch propeller plane, then the tachometer would be the primary flight instrument. Our S-TEC autopilot head is on the right of our Glasair panel, and is fine there. All we ever do is punch one button on it. It can be turned off with the disconnect button on the stick, so it need not take up prime real estate.

MIKE PALMER

Wischmeyer's point about standardization should be fully considered. Pilots often come from another airplane—probably a production model—and should be aware that flight testing a brand-new homebuilt is stressful enough without having to also learn an entirely new (and unconventional) panel layout. Also, we're not sure about the MP/VOR swap. On approach, you set MP every so often and it's not critical to get it to within a tenth of an inch. Following the nav indications is another matter; you're constantly referencing the needles to adjust your flight path. We'd rather have it in the "prime" neighborhood. —Ed.

WHAT'S NEW

The HeloWerks WASP: The Industry's First Turbine-Powered Two-Place Kit Helicopter

A year after its splashy public debut at Sun 'n Fun's Choppertown in 2005, HeloWerks has announced receipt of an Experimental airworthiness certificate for its turbine-powered WASP helicopter prototype. According to company president Tony Peña, the WASP is the first kit-built, turbine-powered, two-place helicopter to receive an airworthiness certificate.

The WASP is a small helicopter powered by a JFS-100-13A turboshaft engine. WASP designer Peña says he's a composite specialist who's worked in the aerospace industry for 26 years. That includes time at Advanced Technologies, the company that developed the UltraSport line of kit helicopters offered by American Sportscopter. According to Peña, the WASP design shares some similarities with the UltraSport line: "I took all of the good stuff from the UltraSport and kept it, and I threw out the rest."

After three or four years of design and development, Peña started building the prototype WASP in 2001 and completed it in time for hover demonstrations at Sun 'n Fun 2005. The turbine benefit, according to Peña? Reliability. And initial tests have proven that the engine produces enough power to easily hover the 1200-pound WASP. "The JSF-100 turboshaft engine installation is simple, the airframe is simple, the composite fuselage is simple, and even the tail rotor has a simple composite fenestron-type tail rotor shroud."

With the airworthiness certificate in hand, the next step for the WASP is flight testing. HeloWerks is also developing kits for the aircraft, which will be offered as an Amateur-Built helicopter. The kit will be sold in three stages—powerplant, fuselage and dynamic components—and Peña mentioned the possibility of a factory quickbuild program for interested builders.

Pricing will be set as kits get closer to production. For more information, call 757/342-6982. A direct link to the company's web site can be found at www.kitplanes.com.

Approach Systems and Park Rapids Join to Produce Modular Wiring Systems

Approach Systems, manufacturer of modular plug-and-play wirings systems for homebuilt airplanes, announced that it has formed a joint venture with Park Rapids Avionics. The new company will be called Approach Fast Stack Systems, and it will develop and sell a line of avionics products for the industry.

Approach's modular wiring system interconnects avionics components with a central hub and ready-built cables for the majority of avionics available to homebuilders. It's designed to eliminate time and error from the hand wiring methods many at-home builders still use.

With your avionics mounted in the instrument panel, installing wiring in your new airplane or retrofitting your existing ship with the system is said to be this simple: (1) Select the Approach hub for your panel (basic, IFR or VFR). (2) Choose the ready-built cables for your particular avionics units. (3) Install the hub. (4) Plug in the cables between the hub and avionics. All cables are double-shielded and grounded at the hub to eliminate the possibility of ground loops.

According to Tim Haas, general manager for the new company, "An average wiring system ranges from $1200 to $1500 depending on equipment, and the hubs range from $300 to $600. Each harness ranges from $79 to $289 depending on complexity and length."

Approach Fast Stack Systems will also serve as a dealer for all of the major avionics units on the market as well as for many of the smaller Experimental-only avionics companies. For more information on the company's systems, call 218/237-STAK. A direct link to the company's web site can be found at www.kitplanes.com.

Aircraft Spruce East Super Sale Scheduled for May 20

Aircraft Spruce and Specialty's Eastern Outlet has announced plans to hold an open house and super sale on May 20 from 8:00 a.m. to 4:00 p.m. The facility, which serves as a distribution center for Aircraft Spruce's complete line of building and restoration products, will be offering substantial savings on many of its products for the one-day event at Peachtree City's (Georgia) Falcon Field.

Representatives for a number of manufacturers of aviation-related products will be on hand to explain how the items are used. Tickets will be sold for raffle prizes, and free food and drink will be distributed by EAA Chapter 468 from Stockbridge. Anyone flying in can show a purchase invoice at the fuel pumps on May 20 and receive a 10-cent/gallon discount on avgas.

"Response to these annual super sale events has been very positive and enthusiastic" said Aircraft Spruce President Jim Irwin. "Most people who fly or drive in invariably run into friends and spend a number of hours socializing before they head home. It's a very laid back affair that's developed into a fly-in atmosphere." Interested? Call 770/487-2310 for more details. A direct link to the company's web site is available at www.kitplanes.com.

Garmin Unveils Bigger, Better Multi-Function Display

GPS goliath Garmin International announced the debut of its latest system—the GMX 200, a multi-function display (MFD) with a high-resolution display the company says is almost 20% larger than any other panel-mount MFD unit on the market. According to the company, an advanced backlighting scheme improves the color and contrast on the 640x480-pixel unit, resulting in chart depictions and images that are brighter and more vivid in all lighting conditions.

The GMX 200 builds on the company's MX20 MFD—at a glance, you se your aircraft's position relative to terrain, obstructions, weather, airways, navaids, restricted airspace and more. With a press of a soft key, the pilot can select between several charting options and add or remove details. A new rotary knob has been added to allow for quicker map scale changes and entry of data. In addition, a new front-loading SD card slot allows for expanded memory and makes loading updated charts uncomplicated. The GMX 200 fits in the same panel space as the MX20 and has more serial ports for added sensor capacity.

The unit includes high-res terrain data for the entire world. For advanced weather depictions, you can combine the GMX 200 with the Garmin GDL 69 for nationwide weather information via XM Satellite Radio.

And like the MX20, the GMX 200 is available in three versions: Standard, Traffic or Radar/Traffic. The Traffic version allows interface with Garmin's TIS-capable transponders and ADS-B transceivers as well as interface with select TCAS systems. The Radar/Traffic version increases capability with interface to Garmin's GWX 68, a new color digital weather radar system.

Prices start at $8995. For information, contact Garmin at 800/800-1020. A direct link to the company's web site can be found at www.kitplanes.com.

Direct-To Issues Recall on Crossbow AHRS Units for Chelton EFIS

Direct-To Avionics (D2A), exclusive distributor for Chelton's line of EFIS systems for Experimental aircraft, announced a full recall of the Crossbow 425EX AHRS. According to D2A, performance and reliability problems have plagued the Crossbow AHRS.

"Direct-To Avionics is committed to providing the best, most reliable and most accurate components for our Chelton EFIS systems," said Kirk Hammersmith, company president. "Our customers want to know that when they're flying with their families, they're flying with the highest quality, best performing equipment available. Therefore...D2A will now supply the Pinpoint Inertial GADAHRS with the experimental Chelton EFIS systems."

In side-by-side comparisons with certified systems by Rockwell Collins, Litef and others, and after exhaustive, real-world flight testing, the Pinpoint Inertial GADAHRS (GPS, Air Data, Attitude and Heading Reference System) has proven to exceed all performance and reliability parameters established by D2A. Based on technology currently used in certified commercial and military applications, the Pinpoint Inertial unit is the first and only GADAHRS optimized for reliability while working within the dynamics of high-performance Experimental aircraft.

D2A requests that all Crossbow units be removed or henceforth limited to day VFR flight conditions until a control group has logged 100 hours each without any performance problems. For details regarding replacement of Crossbow units, visit the Direct-To Avionics web site. A link can be found at www.kitplanes.com.

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THE MODERN MUSTANG

When the rare chance to fly a Titan T-51 kitbuilt alongside a *gen-u-ine* North American P-51 Mustang, who is to say no?

BY DOUG ROZENDAAL

During WW-II, American bombers were flying unescorted daylight missions deep into Germany. The losses were terrible. The lifespan of a bomber crew was measured in missions, and that number was small. Before the U.S. entered the war, the British had asked North American to build P-40s under license from Curtiss, but North American had a better idea. The engineers sketched out an airplane, and 120 days later it flew. The P-51A was a formidable airplane with the 1200-horsepower Allison engine, but the British thought their more powerful, supercharged Rolls-Royce Merlin would make the perfect match, offering high-altitude capability lacking in the P-51A.

The marriage of the P-51 with the Merlin engine made the P-51B and P-51C, but soon after the airplane was modified again to the P-51D with a bubble canopy, more firepower and a better fuel system. Before the war ended, more than 15,000 were built. With the speed and range to follow the bombers all the way to Berlin and back, many credit the arrival of P-51s escorting bombers over Berlin as the turning point in the European war.

End of an Era

The Mustangs finished the war in Europe and started the war in Korea, but the advent of the jet-propelled T-33 and F-86 quickly made the P-51 obsolete. Most met the smelter, but a few were sold surplus. Over the years Mustangs have been restored, rebuilt and some even built from scratch to better-than-new condition. The number of flying P-51s is climbing today because of the mystique this incredible airplane holds over pilots, airshow attendees and war veterans all around the world. It is a kind of desirability—no, indeed, fanaticism—propelled by a combination of the airplane's wartime prowess and its undeniable sex appeal.

The Mystique of a Mustang

The mystique of the Mustang captured a pilot living in Ohio named John Williams. Williams was an electrical engineer who had recently started a small company in the electrical heat control business. CGS Aviation was selling kits for its Hawk line nearby, and Williams teamed up with the company to manufacture its kits.

Photos: Heather Alexander and Howard Levy

But Williams had a bigger idea. He started dreaming of building "a Mustang for the average weekend flyer." In the late 1980s, there was a P-51 based at the Geauga County Ohio airport (7G8). Williams took photos and measurements. But his desire to design his own airplane was diverted into the Titan Tornado, and Williams started selling kits for the Tornado in '91. The Tornado was an immediate success, including sales to the Taiwanese Air Force as a primary trainer, but the Mustang dream remained.

For 10 years, the success of the Tornado kept the dream of a Mustang dormant, but September 11, 2001, provided a break in Tornado sales that Williams needed to launch the Mustang project. "I gathered the group together, and we committed to build the T-51." The first flight was the following May, and the first kit was delivered less than a year from the project's inception at Oshkosh '02.

The key to the P-51 was the Merlin engine, and the key to the T-51 was the 912/914 series of Rotax four-cylinder engines. Williams had lots of experience flying two-stroke Tornados with "lots of dead-stick landings. The Rotax 912 changed things—it was as reliable as a Lycoming with the power and size that I needed to build the T-51."

Williams' desire for a docile airplane sent him on a search for the right airfoil. He explored the evergreen NACA 23012 airfoil, "But I didn't like the stall characteristics." Williams settled on an airfoil he found in a book, the Riblet 35415. "The Riblet airfoils were designed as samples for wind-tunnel testing, but designers started using them because data points were available."

Williams called designer Harry Riblet, and he agreed that the 35415 airfoil had the high lift and low pitching moments that he wanted for the T-51. Copying the P-51 planform but trimming the wingspan gave the desired stall speed and ride in turbulence.

P-51, T-51: Compare and Contrast

The P-51 wing used laminar-flow technology. The max camber in the P-51 wing is at roughly 50% of the chord. This wing, coupled with the extraordinarily clean airframe, gave the Mustang commendable efficiency. But the performance of the Mustang wing comes at a cost. The P-51 has miserable stall characteristics: Acceptable for a fighter but not something Williams wanted in a plane for weekend flyers.

Side by side, the T-51 (foreground) and the P-51 share the critical styling themes and proportions. But the scale—full vs. $^3/_4$— can't be denied.

Capturing the feel of the P-51 without the bad habits was paramount in the design process. Williams and the folks at Titan Aircraft have gone to great lengths to accomplish that feel. Little details like the canopy crank, the gear-handle and the throttle quadrant are all patterned after the P-51's.

Both airplanes are water cooled, which adds an element of complexity. The cooling system held another secret of the P-51's success. It was called the Meredith effect. The radiator and oil cooler heated the air that entered the cooling scoop under the fuselage. That air was forced out the exit door, and the heat energy was recovered as thrust. The T-51 has the same system, but at the speeds it flies, the thrust recovery is probably negligible.

"The Real Thing, 12 o'clock!" Or is it? A pair of T-51s battle it out on a sunny Sunday morning. This is why you build an airplane like this!

The Merlin is a V-12 with 1650 cubic inches, a two-stage supercharger, and turns out 1490 hp. The 914 Rotax packs just 82 cubic inches, an exhaust-driven turbocharger, and 115 hp. Both airplanes have a gear reduction unit that slows their hydraulically controlled constant-speed propellers to reasonable speeds.

Both have sequence valves in their hydraulically actuated landing gear to open and close the clamshell doors that totally enclose the landing gear in flight. The P-51 hydraulic system is engine driven, the T-51 has an electric power-pack to generate hydraulic pressure. The emergency gear extension procedure in the P-51 is simple—put the handle down and the wheels fall out. The T-51 has a pair of valves to dump pressure in th door and gear systems that accomplish the same result.

The P-51 was a single-seat airplane with an 85-gallon fuel tank behind the pilot. Most modern Mustangs have the fuselage fuel tank removed and a jump-seat installed for a passenger. The wing on the P-51 keeps the center of gravity narrow. The T-51 was designed with a rear seat, but the light overall weight of the airplane has the same effect on the c.g. range. It carries 25 gallons total in two wing tanks located in the prefabricated center section. Care should be taken in both not to overload the rear seat.

To easily build the P-51 during WW-II, North American used simple extrusions and parts off the shelf from other airplanes it had available. In the T-51, Titan has employed simple construction techniques learned from the Tornado. The D-cell on the leading edge is carved in foam and wrapped in aluminum to make a very strong structure that is quick and easy to fabricate.

In the T-51, the kit comes with the center section, featuring the main spar, wing skins and fuel tanks, prefabricated. The landing gear bolts into this assembly and comes with the hydraulic actuators

You might be surprised to know that's not the P-51's laminar-flow airfoil, nor is there anything like the throbbing dozen cylinders of the Merlin under the cowling. Nope, this is a special Riblet airfoil pulled along by a Rotax 914.

already in place. The aforementioned foam-core leading edges are built at the factory in a jig and are mated to ribs, stringers, an aft spar and skins by the builder. In addition, the wing/fuselage fittings are installed and pre-drilled.

The fuselage structure, unlike the Mustang's aluminum monocoque, is made up of 1/2-inch square steel tubing sheathed in varying thicknesses of 2024 aluminum skin. Fabric covers the elevator and rudder skins.

The kit is surprisingly complete including the Rotax engine mount, seat belts, canopy, various fairings, the electrical system pertaining to the gear-retract mechanism, wheel/tires/brakes, seat cushions with upholstery, and so on. The builder is responsible for completing the rest of the electrical system, buying and installing avionics, purchasing and installing the radiator and cooling system, plus all external lighting.

An LSA-compliant version is available, too, with fixed conventional landing gear and a reduced maximum-gross weight, down to the limit of 1320 pounds from the normal 1450. The kit is $1500 less expensive than the retract model.

Flying Comparison

Just like the P-51, the T-51 cockpit is snug for a 6-foot-1, 200+ pounder. I flew the T-51 for the formation photos accompanying this article on the wing of a T-6, our photo ship. Robert Odegaard and his P-51, *Dazzling Donna*, were on the wing of the T-51.

Once situated in the cockpit of either airplane, the similarity in their systems make the before-start ritual almost identical. But starting the airplanes is a different matter entirely. The Rotax with electronic ignition starts like a car. There is a rough spot in the gear reduction at low rpm—at this low load, the gearbox chatters and clanks—but bumping the throttle above that range makes the little engine purr like a kitten.

Starting the Merlin is a bigger production. The Rolls-Royce starts with the mixture in idle cut-off and mags turned off. An ignition vibrator sends spark to a trailing finger in the magneto that retards the spark. Tickling an electric primer supplies fuel. When the engine fires, turn on the mags and make the mixture rich. If all these steps are done in the right order at the right time, with the right amount of tickle, the magnificent Merlin roars to life. Too much fuel, and fire will belch from the short exhaust stacks. Way too much fuel, and the fire will climb up the sides of the cowling and over the top to join the flames from the other side. This phenomenon is referred to in the business as a "wienie roast." Whether the fire is big or small, the solution is the same—mixture idle cut-off, crank till the fire goes out and pray that the battery holds up.

Under way, both engines have another thing in common—they both run incredibly smoothly. The Rotax lacks the staccato bark of the Merlin, but both run smoothly. The runup sequence on both airplanes is similar again for the same reasons as the before-start checklist. There is much commonality in the airplanes.

Launching a Mustang is an experience. The Mustang is not a difficult airplane to fly, but it is very unforgiving of inattention. As much power as it has, the airplane doesn't jump into the air. No matter what the crosswind, the takeoff roll in the P-51 is always started with the stick in the right rear corner. Slide the throttle up to 50 or 55 inches of manifold pressure, push hard on the right rudder, and hang on. As the airplane accelerates, allowing the tail to come up before the rudder is fully effective results in an immediate left turn off the runway. Holding the tail down too long will cause the airplane to crawl into the air barely above stall speed. Ease the stick forward at the right time, and it feels like the propeller is gracefully pulling the tail into the air, and the transition from tailwheel steering to rudder authority is seamless.

Now for the T-51

The T-51 takeoff is straightforward if a bit less dramatic. Put the aileron into the wind, slide the throttle up to 40 inches. The airplane leaps into the air and simply flies away. The company says the takeoff roll is 300 feet, and that's believable. Any weekend flyer with average tailwheel skills will feel at home after a few circuits. Capturing the feel of the P-51 launch was not a design objective for the T-51.

Once airborne with the gear retracted, the airplane climbs out on a cool day at nearly 1000 fpm, about the same rate as the P-51. (During wartime, when Uncle Sam paid for

The Titan's long oleo-strutted landing gear folds inboard thanks to a hydraulic cylinder and electric power pack. These pieces are prefitted in the kit.

Large slotted flaps help make the T-51 docile near the ground.

Any of the Rotax 912/914 family members will fit under the T-51's generously sized cowling. Clever use of the four-banger's exhaust helps create the something of a "poppa-poppa" short-stack sound.

Mass- and aerodynamically balanced controls mark the T-51's tail section. The rudder and elevator are skinned in fabric, which is, as always, light and strong. Adds a period touch, too.

The T-51's scaled-down cockpit—from the P-51's—isn't much smaller or less comfortable. In any event, this is a sporty fun tool, not primarily a long-distance traveler.

the engines and the fuel, the P-51s would use more than 50 or 55 inches and would climb better.)

Once in the air, the smoothness of the T-51's Rotax is even more apparent, almost turbine like. The airplane flies normally with good manners. Pitch and roll are well balanced. The rudder travel is longer than I would like, but it makes for nice ground handling. (Given the intended market for the T-51, trading some leg movement for more relaxed responses seems appropriate.) Flying propeller-driven fighters, every change in speed or power means a change in rudder trim. The T-51 follows suit, but less vigorously: It has no rudder trim, but changes in speed and power do affect the ball. Rudder trim might be a nice option and make the airplane fly and feel even more like its big brother.

Both airplanes fly easily in formation. To give the P-51 the speed it needed to be comfortable in formation, leaning on the little Rotax was required. Its temperatures were comfortably in the green at nearly full power for the time we were in formation.

My flying time in the T-51 was short and aside from the amazing smoothness of the engine there were no surprises at all. I did not sample the slow flight or stall characteristics of the airplane, but

Williams says it has very docile manners and, looking at the wing, I believe him.

Runway Manners, P-51-style

Landing the P-51 is busy but easy. The gear is wide, and the airplane wants to go straight down the runway. Some say, "All you have to know to fly a Mustang is three things—don't go below a hundred, don't go below a hundred, and don't go below a hundred." Knots, that is, and it is good advice. The safest way to land a P-51 is from an overhead 360 approach. Enter the initial (the same path as the final) at 1500 AGL and 200 knots minimum. Break over the numbers, and pull the power to 20 inches. The break is a 75° to 90° bank, and then a pull, reducing bank through the turn to end up wings level on downwind at 150 knots. Abeam the touchdown point, the drill is "Gear down, quarter flaps, landing check." Start a continuous 180° descending turn to a very short final. At the 90° point, 130 knots is the speed, check the green light and select flaps 30°. Don't move your hand because in moments the runway is made, the flaps go to 50°. Pitch the nose down even farther and roll wings level on a very short final, cross the numbers at no less than 100 knots. Wipe off the power and flare. Flaring brings the big nose up and the runway disappears. The trick now is to keep everything moving in the same direction on both sides of the panel. The main gear will squeak down with the tail still slightly in the air. With the small wing, huge flaps and massive amount of propeller drag, there is no tendency for the P-51 to float or bounce. It sits down and stays.

Like the P-51, the T-51 strikes a rakish, nose-high stance on the ground. Pilots unaccustomed to making S-turns on the ground will, well... become accustomed to them soon enough.

Design Goals, Achieved

Again, the design goal of the Titan was an airplane that landed at speeds safe and reasonable for a part-time pilot. The pattern in the Titan can be flown at speeds comfortable in a Cessna 150 or a Citabria. Just like the P-51, the nose is big and tail-low landings will hide the runway behind the long snout. With a little extra speed forward visibility is good during a wheel landing, but be ready for the centerline to disappear when the tail comes down. The T-51, like the P-51, has wide gear and excellent ground handling.

Taxiing back to the ramp, both airplanes require S-turning to clear the path. As a flight instructor, it is puzzling to me why students are so concerned about seeing the centerline on the runway during takeoff or landing, but seem to have no concern at all during taxiing. Many Mustangs have chewed the tails off other airplanes while taxiing, and T-51 drivers would do well to learn from their lessons.

The original P-51 was aerodynamically efficient. Part of which came from the clever pod-style cooling system, which is said to have near-zero-sum drag.

Why a Replica?

Arriving at the ramp the process is the same in both planes. Shut down the engine, crank back the canopy, climb off the wing, and marvel at the men and women who flew a magnificent airplane fighting for our freedom. John Williams and the folks at Titan Aircraft have not built an airplane that flies precisely like a P-51. That was never their intention. They built an airplane that looks like one and allows the pilots who fly them, and the people who watch them fly, to imagine what it was like fighting FW-190s while escorting bombers to Germany and back. There is no doubt—flying a P-51 is a great thrill. The problem is that most pilots lack the money and some lack the skill required to own and operate a P-51. As much fun as the Mustang is to fly, the real gratification comes from using the airplane as a tool to tell a story—a story that honors the legacy of the people and machines that fought for our freedom. It is rewarding work. ✈

For more information on the Titan T-51, call 440/275-3205. A direct link to the company's web site can be found at www.kitplanes.com.

TITAN T-51

Price (excluding quickbuild options)	$49,900
Estimated completed price	$70,000
Estimated build time	600 - 800 hours
Number flying (at press time)	4
Powerplant	Rotax 912S 100 hp @ 5800 rpm
Propeller	Whirl Wind four-blade constant-speed
Powerplant options	100 - 115 hp

AIRFRAME

Wingspan	24 ft
Wing loading	12.28 lb/sq. ft
Fuel capacity	25 gal
Maximum gross weight	1450 lb
Typical empty weight	850 lb
Typical useful load	600 lb
Full-fuel payload	450 lb
Seating capacity	2
Cabin width	24 in

PERFORMANCE

Cruise speed	150 mph (130 kt) 7500 ft @ 75% power, 5.5 gph
Maximum rate of climb	1200 fpm
Stall speed (landing configuration)	39 mph (34 kt)
Stall speed (clean)	51 mph (44 kt)
Takeoff distance	300 ft
Landing distance	300 ft

Specifications are manufacturer's estimates and are based on the configuration of the demonstrator aircraft. As they say, your mileage may vary.

Biplane Boot Camp

Want to *really* impress your flying buddies? Here's your chance to master the Pitts Special.

BY ED WISCHMEYER

Don't we all want to be able to fly like Bob Hoover? Or get to perform first flights in just about any type of homebuilt like test pilot Dave Morss? Well, a career change may not be near at hand for most of us, but for the average kit builder and homebuilt pilot, there are some more reachable goals out there. For us kit builders, the piloting gold standard has to be flying a Pitts.

Why? Perhaps it's the mystique of the Pitts or the superhuman skill required to handle one. Maybe it's the nothing-left-to-prove status it bestows on the pilot, or the panache. Whatever the appeal is, real or imaginary, there's no doubt the desire to fly a Pitts exists in the hearts of many pilots.

Is your name on that list? Well, you're in luck. There's an Arizona-based flight instructor who claims that in only 8-10 hours, he can turn any tailwheel pilot into a Pitts pilot. And if you're looking to transition to a similar tailwheel design—like an Eagle, Skybolt or even a Cassutt—chances are that the instructor, having flown numerous examples, will be able to give type-specific hints. And the Pitts training will transfer. I've been there, and I'm a believer.

The program is called the Pitts Experience, offered by Plus 5/SportAERO. The purveyor of this training is Budd Davisson. Yes, *that* Budd Davisson—same guy whose pilot reports on all kinds of airplanes have graced the pages of the aviation press for years (a handful of those in KITPLANES®, you may recall). Davisson has flown twice as many types of airplane as my 150 (and his counting system is stricter), has 10 times my 500 hours of tailwheel time, and has been a Pitts CFI since before I soloed 33 years ago. Staying at his Scottsdale B&B and flying twice a day under his supervision, I was destined to learn something.

Ground School

The program kicks off with 3 hours of ground school spent reviewing the fundamentals; you'll encounter nothing that wasn't familiar after your first 10 hours of flight instruction. Davisson points out that the fundamentals are universally applicable, but for many pilots they are more rusty than trusty.

Then it's time to talk about the airplane. Davisson considers the Pitts the ideal trainer for two reasons: First, the Pitts is almost a "caricature of an airplane," he says, making obvious any piloting technique that is less than perfect. Second, it has abundant control authority, so the instructor can recover from just about any maneuver. Subsequent flights in the Pitts show that those observations are right on.

The Pitts does exactly what you tell it to, neither more nor less, Davisson says, but it keeps doing that until you tell it to do something else. Sitting in his office, this sounds reasonable, but when you see it in the airplane, especially when it's because you've screwed up a little, "accountability" becomes a four-letter word. The cut-'em-no-slack handling characteristics of the airplane are part of why Davisson rates the Pitts so highly for training.

But for those willing to put enough work in, the Pitts rewards three things, Davisson says. First—rudder coordination. Second—precision and discipline in pattern flying. And the third payback comes from making love to the airplane with control pressures (instead of control movements) and a smooth flow to the flight. Numerous examples and anecdotes illustrate these points.

Ground school includes tons more, as you might expect from an experienced, articulate and perceptive instructor. Indeed, Davisson says that he'd actually rather instruct than fly. Most everybody does well in the program, but some experienced pilots place unrealistic expectations on themselves and suffer strong emotional reactions to not living up to those expectations at first. Think of Pitts school as the equivalent to getting a new rating with new sensations and stimuli to assimilate—that's what it's like. Davisson says that serious photographers and gun shooters make good Pitts students because they are skilled at visual discernment. If you already know it all, or if you merely want to have your opinions confirmed, you're already in trouble. Davisson gets relatively few high-ego pilots, he says, because they never ask for help to begin with.

The Secret Unveiled

One of the big secrets of flying a Pitts is learning what's under the cowling. To the average pilot or A&P, it looks like an IO-360 lightly modified for aerobatics. But that isn't so, no matter what sound the powerplant makes or what the specifications say. So what's really under the cowling? A Star Trek "cloaking device" that hides obstructions such as runway lights, taxiways, runways and under the right conditions, big chunks of large airports.

Coming in for landing—if only the view were this good for the pilot! An important hint for the Pitts: If you can see over the nose in the traffic pattern, you're doing something wrong.

One of Davisson's exercises is to do a "Cessna approach," flying final on the extended runway centerline. On short final, I could see only the last 3000 feet of the 8000-foot runway. The VASIs and all the normal aiming points and visual references were not visible, nor were the parallel taxiways on each side of the runway. There was no way to tell where we were going to touch down—on the numbers, at midfield or on top of any plane that might be on the runway beneath us. The cloaking device performed admirably, for sure. One important item to remember: If you can see straight ahead over the nose in the traffic pattern (or anywhere else, for that matter), you're probably doing something wrong.

The Line and the Slip

To negate the effects of the cloaking device, the standard Davisson approach focuses on "the line," an imaginary line that extends from the center of the numbers through the end of the hold short line and is offset maybe 15° from the runway centerline. If you fly down the line in a slip, you can see the numbers and judge your "turn" to final alignment.

But that turn is not a real turn; it is a slow, controlled easing off of the slip with the airplane gracefully ending up on centerline aligned with the runway in the acceptable height envelope. At this point, you know where you are, the speed is under control and you have each side of the runway for guidance. That's really all you need once you learn to read the cues, not just in a Pitts, but in any blind-landing airplane.

When you're in that left slip, if you use too much of the extremely powerful rudder, several things will happen. You'll drift right, changing your ground track, and in extreme cases, the fuselage will start to lift as in knife-edge flight. But don't blame the plane—the Pitts is simply doing what you told it to do. As Davisson says, the Pitts is the great equalizer of pilots, because it makes errors so patently clear.

Even if you do slips regularly, slips in a Pitts are different. The bank angle is probably 30°, though I never had time to peek at the horizon, and we may have gone past 60° on at least one slip, which Davisson said was still not as steep as the Pitts will go. This kind of slip is eye-opening, but hardly dangerous, as the Pitts has as much control authority as an RV plus two Cessnas.

Flare is not a big deal, surprisingly. If you come out of the slip at 85 or 90 mph and hold the three-point attitude, the

Photos: Kevin Wing and Ed Wischmeyer

Pitts will touch down nice as you please if you're straight with no drift.

The Approach

Upstream of that slip in the approach is a wild traffic pattern, even by power-off landing standards. Downwind is tighter than anything you've flown or even seen. Opposite the numbers at 1000 feet AGL, pull the power back all the way and roll briskly into a 45° bank, leveling off after a 90° turn for one last traffic check. Then briskly re-enter the turn, staying with it till the runway numbers are just visible to the left.

Keeping the numbers barely visible until you get close to the line, slip with left aileron, but don't use much, if any, rudder. Remember that old trick about watching to see if the numbers rise above or sink below the nose as a glide indicator? That works here too, except you control the numbers' position with the degree of slip. Davisson locks the numbers in place in his demonstrations.

Approaches require most of the training time. Davisson says that learning the runway handling takes only 2 hours or so and is not that big a deal once you glean the cues and learn to precede the rollout with a good approach and touchdown. Although I barely achieved that level of competence, I did note that Davisson was right on.

The Bottom Line

So what's the skinny on learning to fly the Pitts? The main challenge is observing, absorbing and reacting quickly to the torrent of cues coming at you. I needed 4 hours or so to start comprehending these. Because of the abundant authority and the sensuousness of the controls, control manipulation per se was not an issue.


According to Davisson, runway handling only takes a couple of hours to learn—preceded by a solid approach and touchdown, rollout isn't difficult to manage.

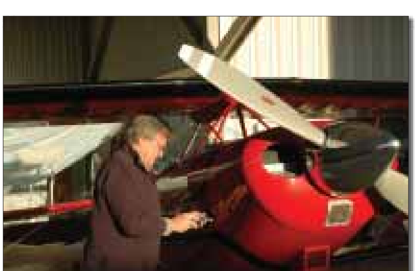
The second point is that flying the Pitts well requires a high level of concentration at all times. The rewards? Satisfaction, for sure. And, oh yeah—fatigue from the effort! It is satisfying to check the skid ball and see it centered, seemingly of its own accord, but it is extremely annoying to enter a turn and see it scoot off to the side and hear those oft repeated words: "Feel your butt, center the ball!"

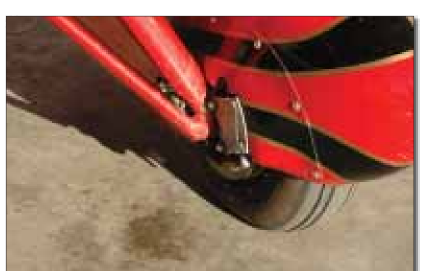
Lastly, flying at this level as a goal is like striving to stay in shape; you have to keep working at it. However, the longer you fly at this high level, the more tolerant you'll be of layoffs, just like when you were first learning to fly.

The Daily Log

So, you must be wondering how I did, right? My training consisted of six in-flight sessions over four days. Mixed in, of course, were some great meals at Davisson's B&B and a couple of well-deserved naps to replenish my energy. Allow me to give you the play by play.

Flight No. 1: Tuesday Afternoon. I start off in the front (open) cockpit, reassured by a slightly snug double lap belt. It's breezy and cool, especially on the back of my neck,


CFI Davisson preflights the S-2A—a quick check to make sure the cloaking device works is imperative.


Slightly flexed sidewalls make the Pitts easier to land; and fully inflated tires engender student humility.


The front office—without much clutter to distract, the front cockpit is perfect for a new student. (The piece of tape on the throttle quadrant beneath "THR" is power to fly level in the pattern.)

but the Pitts is really fun to fly with light, responsive, low-friction controls.

If you've flown floats or gliders, you'll remember those aircraft that don't want to fly with the yaw string or ball in any particular position. The Pitts will hold the ball in one position, but you have to tell it what position you want and remind it frequently. Adding and decreasing power moves the ball left and right, and turns always want at least some rudder.

Stalls show me something new. It's not hard to determine onset, but the cues are not blatant. More curious, though, is that airflow reattachment on stall recovery is annunciated with a nearly imperceptible thump. Davisson points out that aerobatic airplanes need to have good control authority in the stall, and the Pitts has this in abundance. I seem to be adapting quickly and feel good about my prospects.

We go through several approaches down the line, and the cues come fast and furious. It's been a long time since I've felt so far behind an airplane. A challenging afternoon altogether, and that evening, my monthly beer tastes better than ever! (And the B&B dinner is top notch!)

Flight No. 2: Wednesday Morning. I'm offered the rear cockpit but choose the front so as not to be distracted by all the controls and widgets. I'm still working hard on my sight patterns. We do a bunch of bounce-and-goes, landing the other direction on the runway. I'm starting to remember how good I used to be in tailwheels and want to be doing lots better than I am now. Skid ball transgressions lasting longer than nine-tenths of a second are rewarded with: "Feel your butt, center the ball." All right, already. I'm workin' on it!

When we get back to the B&B, the concentration has completely exhausted me. I nap for over an hour, go out to lunch, take a short 2-mile walk and need another nap.

Flight No. 3: Wednesday Afternoon. We start on full-stop landings with Davisson doing the taxi-backs, which extends my fatigue limit considerably. The sun is starting to set 30° off to the right, and although I'm looking out both sides of the airplane, Davisson observes that I'm looking mostly to the down-sun side. I do a terrible job of runway control. Maybe this is my premature 5-hours-of-training setback.

Leaving the airport, we wait for a covey of 40 or 50 quail to skitter across the road with no apparent ground handling problems. If only the Pitts were so easy! That night, I feel just like I did as a student pilot—lost, trying to learn to land the plane, trying to comprehend all the cues. At dinner, Davisson says that he could tell I was tired because my reaction times were noticeably slower.

Flight No. 4: Thursday Morning. I'm in the back seat under a canopy, which is more familiar than an open cockpit. My flying wardrobe somehow did not include a windbreaker, so Davisson loans me one given to him by Patty Wagstaff. The rear cockpit seems cozy and familiar and has a slight no-nonsense smell of sweaty canvas. I feel at home.

In flight, the sight pictures are easier, but the skid ball is smaller, and the airspeed indicator is below the altimeter, where it takes me an extra second to find it each time. The air is full of thermals even at 10 a.m. on a January day, and there is a quartering tailwind that tends to shorten our time on base leg. On the go-arounds I forget to leave the stick

alone, and my runway rudder technique results in curves and swoops—interesting, but not enough to make the tires squeal.

On the last crosswind landing, I get the rudders right and earn an "Excellent!" from the front seat. A nice reward, but I'm tired after only 0.9 hours on the Hobbs. Back at the B&B, it's another long nap, lunch and another nap. My enthusiasm is up and I resent the fatigue.

Flight No. 5: Thursday Afternoon. Things are starting to fall into place. Mindful of Davisson's admonitions not to get low, I overachieve. One time he takes over to show me again what things should look like (not that my approach was unrecoverable), and then he gives me the airplane back at 50 feet. Yikes! On two approaches, trying to be quick on my turns to base, I am instead abrupt and don't use enough rudder,

The key to landing the beast is in the approach, of course. Fly down "the line" in a slip, check the numbers, and judge your final turn—more like an easing off the slip—to final alignment.

prompting plaintive whines from the front cockpit as from a small mammal being tormented.

The setting sun is again 30° off the nose, but so what? Undistracted, I observe the bright tangerine sunset as the sun hides itself behind a peak, and the corresponding sunrise as we climb on the upwind. Scottsdale Airport attracts jets like flies to sugar, and sometimes it seems as if you can feel the pilots' contempt for our little biplane and our approaches emanating from the jet cockpits. If they only knew!

At dinner, Davisson points out that when he gives the airplane back to me on short final, it's where it needs to be. He's right, but it still gets your attention. He says that I'm 3-5 hours away from being ready to solo a two-seater, and another 2-3 more hours will be required for me to solo a single-seater. There are some things I need to see that I haven't seen, such as a real crosswind. He also says that he's conservative and that he's had students that came in with 5 hours in a Pitts and a dealer sign-off but without enough training to be safe or to enjoy their aircraft.

Flight No. 6: Friday Morning. Things are becoming much, much better. I'm not working nearly as hard, and I focus on good rollout handling rather than survival. I get back to holding attitude on takeoff and take to heart the notion that changing attitude in the flare is not a good idea. It's too easy to overcontrol and either balloon or land on the tailwheel.

At lunch, Davisson tells me that, yes, I've got it, but only by my fingernails. I need practice and experience to lock in the lessons, and if I come back later there's a good chance some experience will be lost and have to be relearned. I've not seen any serious crosswind either, but Davisson says that the light crosswind we encountered this morning was more challenging than a "real" crosswind because the cues are so subtle.

The Final Take. I'm not ready to solo, but that was not the objective. I have learned how to fly and land the Pitts. Hallelujah! Statistics: 5.5 hours, six flights.

Epilog

That afternoon, following my morning lesson and the 100-mile drive home (surprisingly, no nap needed!), I roll my

Cessna 175 out of the hangar to see what flying the Pitts has done to my spamcan skills. Taxiing out, the forward visibility is overwhelming, almost more than I can tolerate. Takeoff is on the closest runway with a 90° crosswind, 10G15. I track the runway centerline exactly, but on liftoff the crosswind correction is inadequate and the aircraft rotates to a crab angle immediately. I continue track the centerline precisely, seemingly with no effort.

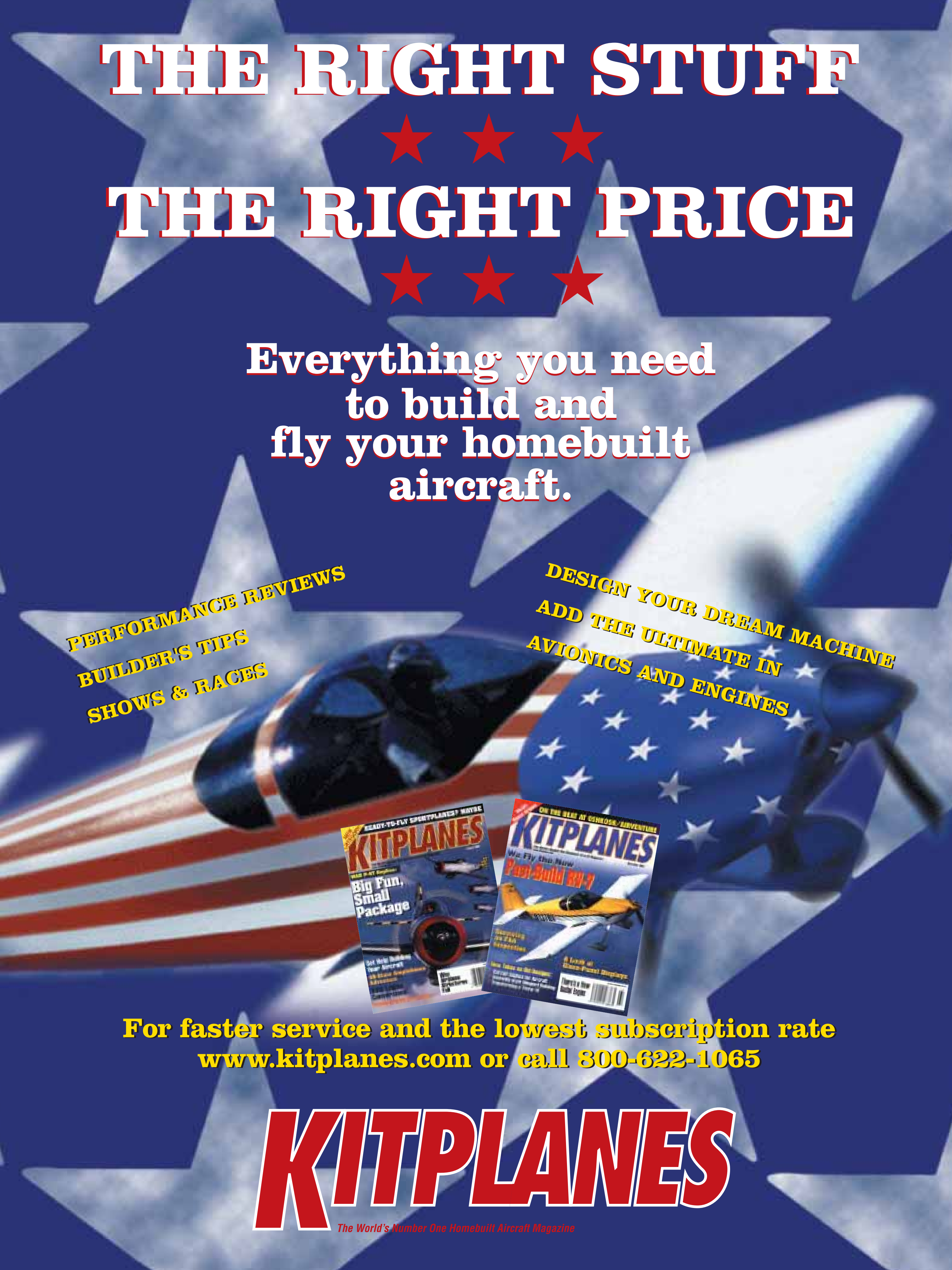
On climbout, I force the nose unnaturally low, and the airspeed is stable at 81 mph. Normally, I pull the nose up to hold 90. In the pattern, there is this strange need for large, frequent and annoying amounts of trim, never dreamed of in the Pitts patterns.

On the first landing, I turn final early but then capture the centerline. In the flare, I track the centerline perfectly and sit back to watch my feet tap-dance effortlessly. The rudder deadband—for those unfamiliar with the term, it's the portion of control displacement with little or no authority (think of the steering in a 1956 DeSoto)—is noticeable, and response to the numerous minor corrections is gradual. The flare goes slowly until I touch down on the mains, the stall warning horn announcing my arrival with a chirp.

On the second landing, the wind is now a 30° crosswind. As I reduce power on downwind, left rudder comes in automatically from who knows where, and the ball is glued in the center. Fooled by the changing wind gradient, I'm way high and use flaps 40. Touchdown is again exactly on centerline with another chirp from the stall warning.

Driving home, I realize that I have just flown with as much precision as I have ever experienced, but with absolutely no effort. Achieving this level by training in a Cessna seems as plausible as learning mountaineering in Florida. I'm ready to start looking for a good Pitts, one that hasn't been thrashed and trashed in hard acro, or maybe an Eagle or Skybolt. I'll give it a really good home. If this is what flying a Pitts with Davisson does for your skills, I'm all for it.

Think you can do it? For more information on the Pitts Experience, contact Plus 5/SportAERO at 602/971-3991. A direct link to Davisson's web site can be found at www.kitplanes.com.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HEADSET BUYER'S GUIDE

In Part 1 of this three-part guide, we'll review passive noise reduction headsets in the *$200-or-less* economy range.

BY CORY EMBERSON

A comfortable, easy to wear headset with a clean sound makes communications one less thing you need to deal with in flight. Can you hear me now? Good.

Can we all just agree that wearing a noise-canceling headset is as important to aviating safely as having gas and flyable weather? OK, then: Here's where we find ourselves in headset performance and design, circa 2006.

Market pressures as well as increasingly sophisticated electronic technologies have brought us to the point where hearing loss and noise-induced fatigue have been reduced to mere footnotes. While active noise reduction (ANR) headsets have become commonplace for the pilot and copilot positions, passive noise reduction (PNR) headsets are a good choice for budget-conscious pilots, infrequent passengers, student pilots, flight schools and FBOs with a rental fleet.

Part 1 of our headset buyer's guide, in which we've combined a few select actual in-flight product reviews alongside complete specifications and descriptions for headsets in the category, addresses economy PNR headsets priced at $200 or less. Our next installment will feature higher-end PNR headsets, and to close, we'll look at ANR headsets later in the year.

Some of the headsets featured are available directly from the manufacturer, while others can be found in catalogs and via web-based vendors. (If you're feeling adventurous, you can even find used headsets on eBay, but your mileage will definitely vary in terms of the condition of the headset and the seller's return policy, if any.) Because headset comfort and quality are subjective, it's strongly recommended that you consider the manufacturer or dealer's return and repair policy before you buy.

We flew eight sample headsets from four manufacturers: AvComm International, DRE Communications, Flightcom and LightSPEED Aviation. And, we researched the features on the rest of the options as well—those are listed in this story. Testing every headset in this category would be a monumental undertaking, and our goal here is to give you a useful evaluation of representative examples. Moreover, we welcome input on your experience with any of these headsets; e-mail us at editorial@kitplanes.com.

Flying the Headsets

This is the fun part—loading up a small plane with a bunch of headsets and trading them throughout the flight like baseball cards. With fellow Contributing Editor and audiophile Rick Lindstrom in the left seat of his Tiger and my son Chris in the back, each wrangling the headsets, we set off for a day's flying, talking, taking notes and swapping headsets. We were also armed with a sound pressure level (SPL) meter to measure the noise in the cockpit. In cruise, the dBA level was 92, and the dBC (low frequency) level was 101. (The A scale more accurately represents the spectral sensitivity of the human ear.) Yes, it was noisy—right there between a pneumatic jackhammer and Spinal Tap, according to published noise-level scales—and a good test of the sound-reduction abilities of these PNR headsets.

Oh, and before we get started, a tech note: Throughout this story, we'll refer to a given headset's noise reduction rating. NRR measures, in decibels, how well a hearing protector (such as a headset or earplugs) reduces noise as defined by the EPA. The higher the number, the greater the noise reduction. You'll also notice that one headset manufacturer recommends wearing noise-reducing ear plugs under the headset. The rule of thumb for total NRR is to add 5 dbA to the better of the two noise-blocking devices.

You will note references to stereo vs. mono when it comes to the headsets. Aviation radios still produce single-channel audio only, but the proliferation of in-flight entertainment (i.e., music) has made stereo headsets desirable for many pilots. Most allow you to switch from stereo (for use with newer intercoms and audio panels that have stereo music inputs along with normal mono radio communications) to mono only (for use with older intercoms that don't have independent left and right music channels). There are still some mono-only headsets, however, especially in this budget category.

AvComm AC-200 ($113).

AvComm AC-454 ($178).

DRE-4000 ($149).

AvComm International

AvComm offers two headsets in our price range. The AC-200 ($113) is a good choice for the new pilot who is already carrying significant expenses. The mic sounded pretty good through the intercom system, and the ear cup seal was snug but not uncomfortable with sunglasses; noise reduction is rated at 23 dB.

This headset weighs 13.4 ounces, and some of the weight was shaved by the use of Neodymium speakers. The plugs are gold-plated, a nice touch for corrosion resistance and good signal transfer. The headbands are set on a stainless steel base, with air waffle cushions on the wide headband. The stainless mic boom was articulated in two places, allowing easy placement of the mic. If I were to wear these for longer than an hour, I would get the aftermarket gel ear seals. And I did snag my hair in some of the metal attach points.

Surprisingly, the AC-454 ($178) did not provide the same audio quality as the AC-200. The mic sounded slightly overdriven, and the audio quality sounded filtered and thin. The headband profile was high, with just enough room between it and the plane's headliner when worn by my taller copilot. The articulated mic boom was easy to maneuver, and the microphone element can be twisted so it's in line with the lips. This headset is rated for noise reduction between 18-23 dB.

Once I adjusted the headband, it was snug but tolerable. The push-to-talk switch built into the ear dome is a nice feature, as are the stereo/mono switch and gold-plated plugs. The AC-454 weighs 14.1 ounces and offers cloth ear cup covers for comfort in hot or cold weather. AvComm offers a five-year warranty on its headsets.

DRE Communications

My first impression upon opening the box from this San Jose-based company was that the shiny, hard ear domes were inspired by David Clark's product line. (Come to think of it, so do most of the headsets in the world.) A shiny off-white, these products were the surprises of the pack. The DRE-4000 ($149) features a traditional construction of metal bands, a wide headband pad and hard-cup ear domes. Weighing 15 ounces, this set has a stereo/mono switch, a decent 24 dB NRR and a fully flexible mic boom that stays where you put it. The headband was comfortable and did not produce any pressure spots on the top of my head or my ears—and it did not give me a face full of sunglasses due to excessive pressure from the headband. The gold-plated contacts provide corrosion protection for that frequently-used component.

DRE-1000 ($89).

Flightcom 4DLX Classic ($139).

The low-cost DRE-1000 ($89) would have won the Best Bang for the Buck award, had we decided to institute one. At 14.5 ounces, this headset provided a good seal for our larger pilot, but the headband was a little tight on him out of the box. A slight adjustment cleared that up. Both the mic and the speakers provided clear and natural sound with reasonable sensitivity, a real plus for student pilots who don't want to start their aviation career missing calls from ATC. The DRE-1000 also provides a 24 dB NRR as well as dual volume controls.

The DRE-2000, the company's mid-range PNR headset, has been discontinued. DRE Communications offers a 30-day money-back guarantee and a three-year warranty.

Photos: Rick Lindstrom, Cory Emberson, Courtesy the Manufacturers

There's More!

Flying each of the headsets may be the fun part, but there are simply too many options to test every possibility from every company. Aside from the eight headsets we flew, there are quite a few others that fit into the under $200 PNR category. Here's an overview of some additional offerings for economy PNR headsets:

•**ASA.** The company's HS-1 model ($149) features ear cups filled with high-density foam, a stereo/mono switch and gold-plated mic and headphone connectors. The headband can be adjusted with thumbscrews and is supposed to eliminate hot spots on the head. The NRR is 23 dB, and it's slightly heftier than the others, at 17 ounces. The company guarantees the headset for the life of the original owner, and while it advertises a 30-day money-back guarantee, it will honor reasonable returns beyond that timeframe.

ASA HS-1 ($149).

•**Pilot Avionics.** The PA-1161T ($125) replaced the P-51 Trophy in fall 2005 to cover the economy PNR market. It is the sole entry in this category, excluding specialty products such as listen-only or youth headsets. The head pad features air-foam cushioning, and the ear cups use liquid ear seals. Designed for fleets and flight schools, the company includes a three-year unconditional warranty, a gutsy offer given the abuse headsets can suffer by renters and students. The headset weighs 15.5 ounces, and the NRR is 24 dB. This entry has added a cell phone/music interface, and a combination wire spring/flex boom replaced the straight wire spring of the P-51.

Pilot Avionics PA-1161T ($125).

•**Sigtronics.** The entry-level S-20 headset ($144) weighs a feathery 12.4 ounces, providing 24 dB of noise reduction and a single volume control. The metal articulating mic boom is reversible, and the ear seals are foam-filled. This model carries a three-year warranty. The S-40 ($160) has the same general characteristics (weight and noise reduction) as the S-20, but features more cushioning and a more substantial mic boom.

The S-45 ($195) weighs a little less than the previous two models (12.2 ounces) and seems to be built for comfort. The ear cups feature thicker gel and foam cushioning, and the headband has air pillow cushioning. The company touts it as suitable for noisy environments such as Experimentals and warbirds; the S-45 also provides 24 dB of noise reduction.

Sigtronics S-20 ($144).

•**SoftComm Products.** SoftComm offers a wide variety of PNR headsets in the economy category. On the mono side, the C-40 Pro-Am lists for $99, as does the C-45 Prince; the C-40 features plastic ear cups and folds after use, but it's not a contender for frequent use. It weighs 12.3 ounces and is rated at 23 dB noise reduction. These headsets carry a three-year warranty and feature gold-plated jacks. The C-45 is a little lighter, at 11.4 ounces, and is touted as a standby headset for infrequent passengers. It is carries a NRR of 22 dB.

There are several stereo headsets in this category as well, each a tweak or two up the scale from its neighbor. The C-20 Phoenix ($154) weighs in at 13.9 ounces, has a NRR rating of 23 dB and carries a five-year warranty. The lightweight C-35 White Knight ($154), targeted toward female pilots and passengers, weighs 11.9 ounces and has a three-year warranty. The C-40-20 Silver Fox ($145) weighs 13.3 ounces, with a three-year warranty.

SoftComm C-20 Phoenix ($154).

The C-60 Silver Edition ($169) is targeted to the flight instructor, so presumably it soaks up sweat on the right side of the face (with a tip of the cap to Rod Machado). It weighs 14.9 ounces, has a built-in PTT switch, has lots of padding and is warranted for five years. Finally, the C-80 Passive BNE ($179) includes a cell phone interface and a flexible mic boom. Weighing 14.0 ounces, it features gold-plated mic and headphone connectors.

•**Telex.** The Echelon 100 ($157) is the only entry in this category from Telex, although the company does offer several PNR headsets just above our price break of $200. Weighing 14.2 ounces, it offers a modest 21 dB NRR. This headset has a stereo/mono switch and a flexible, reversible mic boom. The ear seals are foam-filled, and it has a single volume control.

—C. E.

Telex Echelon 100 ($157).

Flightcom

We brought three Flightcom headsets along for evaluation. The first, the 4DLX Classic ($139), weighs in at 16.8 ounces and features dual volume controls for the hard-shell ear domes. The flexible boom is reversible. The headband is lined with an air pillow layer, which was reasonably comfortable though not luxurious.

The ear cup speakers had good fidelity, and with an NRR of 24 dB, did not have a great deal of sound deadening. I had to crank the volume up in cruise. The noise-canceling microphone required placement up against the lips for ideal transmission qualities. This is a decent, basic headset with no bad habits, though it did not distinguish itself, in our view.

The 5DX ($189) represents the next step up. It has a thick cushioned fleece band that wraps around the headband, closed with Velcro. It's fairly comfortable—just don't lose it. Without that removable cushion, you're left with a basic unpadded headband. The flexible mic boom can be adjusted towards or away from the ear cup on a metal slide and then twisted to tighten; the ear cups also feature dual volume controls. The ear cups offer a tight seal, and both the microphone and speakers sounded very natural with good clarity. Weighing 1.1 ounces more than the 4DLX, the 5DX has slightly less noise reduction at 22 dB. This model also features a stereo/mono switch. We liked this one and recommend adjusting the tightness of the headband before launching; it can be distracting while in flight.


Flightcom 5DX ($189).

The true lightweight of this class was the F20 headset, which retails for $119 on the Flightcom web site. At just 4.6 ounces, it rests lightly on your head, but the fact that the headset needs help to reduce the noise will remind you that it's there. You see, Flightcom has included a pair of tethered foam earplugs that are rated for up to 30 dB of noise reduction—you wear these under the headset itself. The ear seal is cloth over foam and does not cup the ear tightly; it rests on the ear, rather than surrounding it. According to Barbara Keepes, division manager at Flightcom, the F20 is largely used by commercial pilots who fly in a pressurized environment without much hearing-damaging low-frequency ambient noise. But, she says, they're also ideal for people who can't tolerate the weight of a conventional headset. Another market segment emerges: female passengers who don't mind wearing earplugs under their headset if it means they'll avoid having "headset hair" at the end of a long flight.


Flightcom F20 ($119).

Company	Model	List Price	Weight, ounces	NRR, dB	Stereo/Mono	Mic Boom	Warranty, years	Return Policy
ASA	HS-1	$149	17.0	23	Switchable	Wire spring	Lifetime	30-day money-back guarantee
AvComm International	AC-200	$113	13.4	23	Mono	Wire spring	5	Dealer/distributor exchange
	AC-454	$178	14.1	18-23	Switchable	Wire spring	5	Dealer/distributor exchange
DRE Communications	DRE-1000	$89	14.5	24	Mono	Wire spring	3	30-day money-back guarantee
	DRE-4000	$149	15.0	24	Switchable	Flex boom	3	30-day money-back guarantee
Flightcom	4DX	$115	16.9	24	Mono	Wire spring	3	30-day evaluation
	4DLX	$139	16.8	24	Mono	Flex boom	3	30-day evaluation
	5DX	$189	17.9	22	Switchable	Flex boom	3	30-day evaluation
	F20	$119	4.6	30*	Switchable	Flex boom	3	30-day evaluation
LightSPEED Aviation	QFR Solo/c	$159	11.8	29	Switchable	Flex boom	3	30-day money-back guarantee
Pilot Avionics	P-1161T Trophy	$125	15.5	24	Switchable	Wire spring/flex combo	3	30-day money-back guarantee
Sigtronics	S-20	$144	12.4	24	Mono	Metal articulating	3	Dealer/distributor exchange
	S-40	$160	12.4	24	Mono	Metal articulating	3	Dealer/distributor exchange
	S-45	$195	12.2	24	Mono	Metal articulating	5	Dealer/distributor exchange
SoftComm Products	C-20 Phoenix	$154	13.9	23	Switchable	Flex boom	5	Returns within warranty period
	C-35 White Knight	$154	11.9	22	Switchable	Flex boom	3	Returns within warranty period
	C-40 Pro-Am	$99	12.3	23	Mono	Wire spring	3	Returns within warranty period
	C-40-10 Red Baron	$119	15.4	23	Mono	Wire spring	3	Returns within warranty period
	C-40-20 Silver Fox	$145	13.3	23	Switchable	Wire spring	3	Returns within warranty period
	C-45 Prince	$99	11.4	22	Mono	Wire spring	3	Returns within warranty period
	C-60 Silver Edition	$169	14.9	24	Switchable	Metal articulating	5	Returns within warranty period
	C-80 Passive BNE	$179	14.0	24	Switchable	Flex boom	3	Returns within warranty period
Telex	Echelon 100	$157	14.2	21	Switchable	Flex boom	3	Dealer/distributor exchange

**Flightcom F20 requires separate ear plugs (included with headset) to achieve NRR.*

Fidelity was very good, producing good clear sound when tested on a consumer stereo (given our lack of a stereo PA system in the plane). The noise-canceling electret mic perches at the end of a flexible boom, which was a breeze to adjust; the mic sounded good in several positions relative to the lips. The headband was simple to adjust on the fly, and both the volume control and stereo/mono switch were located on the same ear cup.

Flightcom also offers the 4DX ($115), weighing 16.9 ounces with 24 dB noise reduction, and the listen-only 4LX ($115), a good choice for tour operators. The company offers a 30-day trial period as well as a three-year warranty.

LightSPEED Aviation

The LightSPEED QFR Solo/c is the company's only offering in this price range, but it's a nice one. The ear cups feel different: They were better than and not as constricting as some of the popular domed headset cups. There was less pressure on the ears and the area surrounding the ears. It is a different sensation when you're used to the vise-like effect other headsets can give if you don't adjust them just right. And at 28.7 dB noise reduction, the LightSPEED led the pack. The construction of the set seems to be the same as the higher-priced ANR headsets. It's light—11.8 ounces—due to its minimalist construction of a lighter headband connected to the ear cups by wire, rather than stainless steel. At $159, this set features a cell phone interface, a stereo/mono switch, a reversible mic boom and a padded nylon carrying bag.

Surprisingly, the sound through this headset was not as natural as I had expected with a somewhat hollow, colored sound. Sound characteristics, like headset comfort, are a subjective affair, so be sure that you can return any headset if you're not happy. This headset was very comfortable, and the liquid/foam ear seals may be covered with cloth covers, which increased the comfort level. The ear cups fit full-size adult male ears quite well, a plus for comfort and noise protection. The company offers a three-year warranty.

LightSPEED QFR Solo/c ($159).

Can You Hear Me Now?

In such a wide field of products, you can be picky. The major headset companies offer substantial warranty periods as well as a trial period. But ask if you don't see it advertised—the personal nature of this piece of equipment should allow you to return a headset that may work perfectly well, but doesn't suit you. Moreover, all the nifty features won't impress your passengers if they're in tears of pain halfway through the flight.

This particular product type involves a lot of technical detail and a dizzying array of features. Check the chart-view comparison on Page 27 for all the specs. Some of the more prominent manufacturers are absent from this category, you'll notice: Bose, David Clark, Peltor and Sennheiser. We'll be looking at these manufacturers next time around. And if your head starts to spin, the Sporty's web site has a nifty headset wizard that allows you to select what you want in a headset and will even provide a side-by-side comparison (look for a link at www.kitplanes.com). ✈

The Author's Picks

And if I had to choose from the array of budget options? Well, the prospect of having $200 to spend on only one of these headsets put me in a quandary. If I were a student pilot or had occasional back-seat passengers, I would go with the DRE-1000, no question. The clarity of the audio, comfort of the headband/ear cup combination and, at $89, economic value really puts it in a class by itself.

On the other hand, if I wanted one for everyday use, I would go with the LightSPEED QFR Solo/c. This headset sits very lightly on the head, and the ear cups are gentle on your ears. I liked the ability of the mic to twist relative to the lips and the sliding volume controls on the cord. While the audio quality has a different tone than I'm accustomed to, it's not a show-stopper. Ergonomically, the LightSPEED is a winner, and those features noticeably reduce the fatigue factor.

—*C. E.*

Contact Information

ASA
800/272-2359

AvComm International
800/845-7541

DRE Communications
408/993-8220

Flightcom
800/432-4342

LightSPEED Aviation
800/332-2421

Pilot Avionics
800/731-0790

Sigtronics
909/305-9399

SoftComm Products
800/342-4756

Telex
800/218-2410

Direct links to these companies' web sites can be found at www.kitplanes.com.

Avgas 2020: The Future Fuel

Will the death of 100LL prompt development of superior alternatives?

BY PAUL MILLNER

When you mention avgas to a pilot in the current market environment, the most likely reaction will be, "Gee whiz, it's expensive!" While that's true, avgas is a special commodity that allows us to accomplish aircraft performance that wouldn't otherwise be possible. For the past 25 years, the aviation press has predicted the imminent demise of avgas, yet it's still around. But how long will we have 100LL? And what comes after that? Why do we care—won't mogas be a fine substitute when the time comes? Let's look at the answers to these questions.

How is Avgas Different?

At an oil refinery, crude oil fresh from the ground is distilled into eight to 10 fractions, by boiling point. From lightest to heaviest these are natural gas, LPGs (propane and butane), straight run gasoline (about 70 octane), jet, diesel, light gasoil, heavy gasoil and residuum, also known as asphalt. Each fraction is then further processed to rearrange the molecules from what the crude oil gave to what the marketplace demands. This processing improves the environmental performance of the hydrocarbon, removing sulfur, nitrogen, aromatics, olefins and reducing vapor pressure, while increasing the performance of the final fuel by improving octane, stability and heat content. A complex refinery might generate a dozen different components available for gasoline blending. For mogas, the blending recipe varies by time of year and area of the country, for both performance and environmental reasons. For avgas, only the four most expensive components are suitable. Even then, these four components commonly need additional processing to meet avgas specifications, so avgas is difficult to make and, hence, expensive. Part of the expense comes from the impact on the overall blending "pool": typically each gallon of avgas takes the cream of the mogas component crop, causing up to another gallon of lesser components to be wholesaled off as chemical feedstocks or other lower value end uses.

Why is Octane Important?

Octane is a measure of how resistant a fuel is to detonation, which is uncontrolled rapid burning. The more resistant a fuel is to detonation, the more severe the engine operating conditions can be, with the fuel still burning slowly, delivering smooth, efficient power. Severe operating conditions translate to more power delivered to the crankshaft and propeller. We've probably all read explanations of how the U.S. ability to deliver high octane fuels won the air war in Europe during WW-II; higher octane fuel allows more power and speed to be delivered by a given weight of aircraft and engine burning a given amount of fuel. You could produce the same amount of power by building a bigger engine burning more fuel, but then the engine would weigh more, you'd have to carry more fuel and overall aircraft performance would suffer. Since aviation is weight sensitive, octane is much more critical to achieving aircraft performance and efficiency than it is to automobiles.

Different Kinds of Octane Ratings

To understand the properties of mogas and avgas, we must wrestle with octane. Octane number is experimentally determined. Models may guess at what the octane of a blend

Photos: Marc Cook

will be, but the proof is in the testing. All test techniques agree that 2, 2, 4 trimethyl pentane is *the* octane molecule that defines the benchmark, or 100 point. Among the other 200 chemicals commonly found in gasoline blends, each one can test differently in different kinds of test engines. The four test engines (octanes) most commonly used today are Automotive Research, Automotive Motor, Aviation Lean and Aviation Rich. A component that tests well in a fast turning cool (water jacketed) automotive engine might test poorly in a slow moving hot (air cooled) aviation engine.

By the time these results make their way to the consumer, you see an average of two automotive octanes on a mogas pump (R+M/2), or both the Aviation Lean and Rich Octanes specified for avgas, as in 80/87 or 100/130. There are common relationships among these octane numbers. For example, Aviation Lean is about the same number as Automotive Motor Octane. Automotive Motor is about 10 performance numbers less than Automotive Research. So 100LL sold at an automotive pump would be about 105 octane. Similarly, 91 octane Premium mogas sold at an aviation pump would be 86UL.

100LL may seem expensive until you think of the small scale of the endeavor. In the future, new technologies will likely allow us to use an unleaded equivalent.

A Short History of Avgas Production Economics

Let's look at avgas economics. Back in 1960, the airlines were still flying avgas-powered aircraft, though rapidly transitioning to jets. Five to 10 percent of the total gasoline market was avgas. There were four grades: 80-87, 91-98, 100-130 and 115-145, containing from one-half to 8 grams of lead per gallon. Of the 1000 refineries in the U.S., 80% made avgas, and of course all gasoline was leaded.

Skipping ahead to 2005, one-third of 1% of gasoline is avgas. There's only one grade, 100LL. Of the 167 domestic refineries, less than 10% make avgas, and avgas is the *only* leaded fuel manufactured. Tightly specified systems are required to handle avgas: the tanks are internally coated, regularly cleaned and segregated from mogas systems. EPA gasoline storage tank regulations have made tankage at service stations or at airports expensive to install and maintain. As a result, almost no airports have a second segregation; only 100LL is available.

What's the Deal on Lead?

Lead is not terribly toxic in fuel or exhaust, but the EPA drove the lead phaseout in the 1980s to reduce the impact on catalytic converters in automobiles (from cross-fueling and folks putting cheaper leaded gas into unleaded vehicles.) Lead use is declining worldwide, as even the Third World begins to adopt unleaded gasoline and catalytic converters to address smog problems. Only one manufacturer of tetra-ethyl lead used in gasoline remains: Octel, in Britain. What's more, Octel recently emerged from bankruptcy. The problems with having leaded fuel in refineries and distribution systems come from pipeline washing residues, tank cleaning and disposition of off-test product. If a tank of leaded gasoline is off-test, then it must be disposed of expensively as hazardous waste. As a result, it's difficult or impossible to share facilities like pipelines, ships, barges and tanks between leaded and unleaded products.

Lead also offers operational disadvantages to the pilot. Lead can foul sparkplugs, and lead deposits prevent use of O2 sensors essential to some advanced ignitions. Lead *does not* lubricate or protect valves. The FAA has corroborated this by engine flight testing. The leaded and unleaded test fuels were carefully controlled for octane, one on each wing of a twin. Running the engines from buildup to overhaul showed no difference in valve wear, so the "valve problems with unleaded" stories you've heard are largely attributable to lower octane, not the lower lead content.

Although it's not a terrible toxic, lead isn't good for most biological systems. The EPA has tried to eliminate it, and the FAA took them to court, which held that avgas regulation is in the FAA domain, not in the EPA's. So that's not the likely path to unleaded avgas. More likely is that a combination of difficulty in obtaining tetra-ethyl lead, dwindling demand and the marketplace switching to alternatives will make lead go away. As long as there's demand, folks will work to blend avgas—it's a profitable product. But let's discuss some of the alternatives.

Alternatives to Leaded Gasoline

In the April 2004 Society of Automotive Engineers General Aviation conference in Wichita, Cessna officials discussed moving away from avgas. Their first observation was that they were having trouble getting the diesel engine business case to close: diesel engines are available, but conventional metal propellers aren't durable enough. The intense power pulses reduce prop life to a few hundred hours at best. Cessna thought that perhaps small turbines, 300 hp or so, could be developed, and maybe they had a turbine like the Innodyne in mind. But turbines tend to burn close to the same amount of fuel whether at full power or idle. For a 300-hp Innodyne, that's about 20 gallons per hour. Sure, jet fuel might be 10% cheaper than avgas (generally, but not everywhere), but when you're burning 20 gph, touch and goes or a $100 hamburger quickly get expensive. It's difficult to beat the gasoline aviation engine for power, smoothness and efficiency, and that brings us to the avgas conundrum.

For avgas, it starts with the realization that the world fleet of 400,000 aircraft needs avgas octane, but lead is someday going away. It's interesting to note that 70% of the GA aircraft registered in the U.S. can be operated on mogas; there are STCs available. However, the 30% of the fleet that can't operate on mogas consume 70% of the fuel. That's because those planes are both more highly utilized and typically larger, more powerful aircraft whose engines take advantage of the octane to make more power.

Even with mogas there are concerns. Because the farmers have good lobbyists, federal regulations require oxygenate in motor gasoline. MTBE is now unpopular due to issues with persistence in cases of water contamination, so ethanol has become the only economic alternative. Doesn't ethanol help the air and save resources? Well, not really. More than 80% of the automotive fleet adjusts combustion to maintain air-to-fuel ratio. Ethanol used to work in older cars by "fooling" them into running leaner and cleaner, but modern vehicles adjust the mixture, so there's no benefit. Doesn't ethanol help us reduce oil imports? Again, not really. Producing ethanol is energy intensive, and this is reflected in the price. The only reason ethanol makes its way into the mogas pool in such great volumes is that one, the feds require it to assure votes for the guy in the White House, and two, ethanol has a tax subsidy.

Remember where the presidential primaries begin each election cycle? Iowa, where they grow corn. How do you keep corn prices up? Mandate ethanol production. If you take away the tax subsidy, gasoline is cheaper than ethanol because more resources are required to make ethanol (like diesel for tractors and fuel for distillation and distribution) than are required to make gasoline. Where do those energy resources come from? Oil imports. A vicious circle, to be sure. There are apologists all over the Internet who rationalize ethanol as being more efficient, but remember Econ 101. If it were more efficient, it would be cheaper, and it's not.

Why is this a problem for pilots? Because the FAA realized early on that

With the loss of widespread alternatives—80-octane and 91/96, for example—100LL, supposedly “low lead” fuel with an octane rating of 100, is the de facto avgas today.

ethanol in avgas is a bad idea. Ethanol is water friendly; water that makes its way into the fuel is absorbed by the ethanol. Your fuel gets a little wet, and you sump your tanks before takeoff, but the water has already been absorbed into ethanol in the fuel, so you don’t see any water in the sump. You climb to altitude, the fuel cools to ambient temperature, and as the ethanol cools, the solubility of water in it decreases. That water drops out in the fuel tank, and if it’s less than freezing aloft, your fuel system becomes blocked by ice crystals. Additionally, there are materials incompatibilities with ethanol and aviation powerplants. Hoses, gaskets, elastomeric seals and seats can swell in a gasohol environment, adversely affecting aircraft operation (as in the engine stops). The FAA wisely decided that significant certification work would be required to approve ethanol-containing gasoline, even for aircraft approved for mogas.

One possible area of flexibility is that since ethanol is added at the truck loading terminal, not at the refinery (due to some of the same problems cited above), you should be able to purchase a tanker truck full of gasoline without ethanol; subgrade, it’s called. But ethanol is good on octane, so the subgrade is even lower octane than normal mogas, anticipating the octane hit from the 5% or so of ethanol added at the terminal. If you buy 91 premium subgrade, it’s really 89 R+M/2 octane index, or about 84 aviation octane. That might be fine for 80/87 engines, but there’s no hope of using it for aircraft that require 100 aviation octane.

Other Options

What can we do for those high-powered engines that need the octane? From the fuel producer’s perspective, a solution that walks away from 70% of the demand is not a good solution. And from the aircraft owner’s perspective, a three out of 10 chance that your airplane can’t fly isn’t a good option either. These are typically the more expensive aircraft as well, making this answer even less desirable. Yet the replacements aren’t that plentiful, even if we did have the money. There are electronic ignition systems, the more fully featured known as FADEC (full authority digital engine control), but the existing ones do little to reduce the engine’s octane demand. None of the certified systems sense engine knock, for instance, which can destroy an aviation engine in only a minute or two. These systems rely on digital maps of an engine’s performance envelope, which can be complex to get just right, with the range of operating conditions. Add fuel variability, and no feedback mechanism to detect it, and the problem is nearly impossible to solve.

What has the industry been doing to address this concern? For more than 10 years now, under the auspices of the American Society of Testing Materials (ASTM), a group of the Coordinating Research Council (CRC) has been working on a potential 100UL avgas. The minutes of this group are available on the web (a direct link to which can be found at www.kitplanes.com), and while they may make for interesting reading, they certainly don't tell a story of an industry focused on a common solution. The oil companies are well represented, but each has most actively promoted its own proprietary solution as the path forward. The airframe and engine makers are more sparsely represented, but their discussions reveal some lack of cross-understanding, either by the aviation builders of the gasoline marketplace, or by the oil companies of the aviation marketplace. For instance, one oil company appeared to be applying its automotive paradigm, assuming that we only need to worry about the new airplanes, because after all, in a few years most of the old ones will be "off the road." This doesn't recognize that over half the fleet is more than 25 years since manufacture. Another observation was that Lycoming and Continental do all the engine overhauls. Although those engine manufacturers might wish that were true, it would come as a big surprise to the shops doing thousands of overhauls annually.

The oil company ideas are interesting, if not ultimately feasible. BP suggests the triptane molecule as the solution. Unfortunately, triptane is expensive, about $5/gallon before profits and costs of distribution, and it has the unfortunate property of a large negative blending bonus. For instance, if you were operating a triptane-fueled airplane and had occasion to fuel with some non-triptane fuel, the mixture in your tank would be much lower in octane than the two fuels you started with. You can see the problems that might cause.

Chevron came up with a way to blend avgas with only half the lead, and still meet the necessary specifications. That might be a holding action for a time, keeping the environmental pressures at bay for a year or two, but it's not an ultimate solution.

ExxonMobil suggested a super-alkylate that has better octane properties. Not surprisingly, this is a technology that ExxonMobil licenses to others for a fee. But remember that avgas is less than 1% of gasoline production. If a company spends the money to modify its refinery to make super-alkylate, it's now paying a license fee on *all* of its gasoline just to satisfy the octane demand of a small portion. It's far from clear that this makes economic sense for any refiner.

ConocoPhillips offered its own version of super-alkylate, which might be better than ExxonMobil's, but the economics problem persists.

Texaco suggested blending nitro-toluene into avgas. You've heard of one of its cousins, tri-nitro-toluene, also known as TNT. You only need a little nitro-toluene, maybe 1%, to sufficiently improve octane. However, even that small amount makes the avgas a handling hazard, causing burning on skin exposed to it and making the gasoline odors unpleasant—even nauseating—not a flight safety enhancement. One of the oil company reps was heard to remark, "Pilots and mechanics don't get avgas on their hands, do they?"

The Timing is Everything

Let's try approaching the problem from a different angle. Assuming that it's not practical to significantly re-engineer the U.S. refinery structure for a product representing less than 1% of gasoline production, what do we do? If we blend avgas much like it's done today, but add no lead, the result is a fuel with an aviation octane of 95 or 96. Let's call it 95UL. Would that be enough octane for the fleet?

Relatively few airports offer unleaded autogas at the pump.

The answer is that in general, yes, but only if the spark occurs at the right time. Remember that almost all of our aviation engines are fixed timing engines. The magnetos always fire the plugs 25° or 20° (or however the engine was set up) before top dead center of the piston. That doesn't vary with engine speed, or engine load. For 50 years, automotive engines have changed timing with speed and load, at first with spring advance in the distributor, later with vacuum retard and more recently with computer controlled ignition. If timing is fixed, there are some engine conditions where the timing isn't optimal, and that off-ideal operation is where a lot of the octane requirement comes from. You can't afford to have your aircraft engine detonate to destruction even some of the time. What if you were to modify the ignition system so that those poor spark timing periods didn't occur? Just maybe your engine could operate perfectly well on 95 octane avgas.

That's where future technologies such as the PRISM electronic ignition now undergoing development by General Aviation Modifications, Incorporated, in Ada, Oklahoma, will be extraordinarily useful. [*We looked at PRISM ever so briefly in the March issue—see "Around the Patch," Page 2—and look forward to flying with this system just as soon as it's available.—Ed.*] GAMI demonstrated with an acknowledged "bad boy" engine, the Lycoming TIO-540-J2BD, that even with 40 inches of manifold pressure from turbocharging, at 460° F CHTs, and with an induction air temperature of 300°—

yes, three hundred!—there's no detonation on 95UL avgas... if you make the spark at the right time.

Well, what's it take to do that? In the case of PRISM, it amounts to directly reading the size and timing of the combustion event and altering spark timing to optimize power and build detonation margins. PRISM monitors the smoothness of the pressure trace. If the pressure signal starts to get "noisy" in specific ways, it's a sure signal that detonation is getting organized in that cylinder. PRISM can then retard the timing on just that cylinder to stop the detonation.

Lots of automotive engines have detonation detectors, typically piezoelectric sensors that hear the same "pinging" you and I hear if we try to drive up a hill without downshifting a manual transmission. But folks hardly ever hear pinging in aviation engines, not because it doesn't happen, but because there's just so much other noise. Seeking detonation by monitoring the cylinder pressure signal for "pinging" seems to work.

If you think the cost of avgas is high, you're not considering all the factors of production, low volume and lead "contamination." But, yes, it can still seem pricey.

Can other systems offer the same octane flexibility? Possibly, but it will take some work. The good news is that though lead will eventually go away, it likely won't be real soon, and there are some very elegant solutions available to allow us to continue flying our current engines with relatively minor ignition-system modifications. And even if lead continues to be available, these same elegant systems will offer us other benefits. The future's so bright I have to wear shades! ✈

O2 FOR YOU

Leaving the state of hypoxia...

BY RICK LINDSTROM

Perusing the NTSB database of fatal accidents for homebuilts is one of those "eat your spinach" things— good for you in the long run, but not exactly pleasant while doing it. If there is a silver lining to the cloud of fatal accidents—in homebuilts as well as production aircraft—it's that the root cause of most of these fatalities is fairly obvious. But every now and then, an NTSB accident report is filed where the circumstances leading up to a fatal accident aren't so readily apparent.

An economical, single-user oxygen system from AeroMedix features an E-Ox bottle equipped with a Flotec regulator driving an Oximyzer cannula. The Oximyzer interrupts the O2 flow during exhalation, conserving precious oxygen.

That Sneaky Grim Reaper

Often, it's a complete mystery why a flight proceeds normally for a good deal of time, only to have it end tragically in controlled flight into terrain (CFIT). Or, the remains of an overstressed airframe are located somewhere on the ground or in the water after the aircraft fails to arrive at its destination after a flight conducted in good weather.

This typically indicates some form of sudden or gradual pilot incapacitation that prevented the successful completion of the flight and/or the ability to use the aircraft again. Airborne heart attacks and strokes can happen suddenly, and often a passenger is able to perform an emergency landing to save a life or two. But sometimes, the onset of pilot incapacitation isn't so noticeable, gradually accumulating in its degradation on crew performance until it's way too late to recover.

The family of Aerox oxygen cylinders come in all capacities and sizes, from certified metal cylinders to the latest in composite cylinders suitable for the Experimental market.

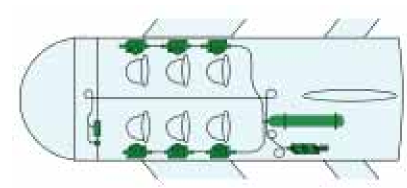
It's a fair bet that an unconscious or marginally conscious pilot won't be able to successfully complete a flight to its destination and make an acceptable approach and landing. And yet, we often embark on aerial sojourns without much thought to the physiological demands placed upon our bodies when expecting them to survive and operate under the conditions dictated by our flight plans. Worse, we're often totally unprepared when the grim reaper sneaks into a seat on the flight disguised as gradual oxygen (O2) starvation (hypoxia).

Not Just for the Flight Level Guys

The Federal Aviation Regulations (FARs) under Part 91 state that in unpressurized aircraft, supplemental oxygen must be used by the flight crew for flights exceeding 30 minutes in duration at altitudes above 12,500 feet MSL. At 14,000 feet and above, the crew must be on O2 full time. And at 15,000 feet MSL, it's time to have everyone aboard suckling at the O2 teat.

This regulation was created at a time when the highest airline route segments, save brief hops over mountain peaks, were...*you guessed it*...12,500 feet. At that time, unpressurized DC-3s were all the rage, and no doubt many a hypoxic passenger requested a blanket and pillow for a nap until a lower altitude was reached. Of course, having the two guys up front nod off was, and still is, frowned upon.

The flexibility inherent in these old, minimalist regulations places the responsibility for flying safely squarely on the shoulders of the pilot in command. Note that it specifies the minimum altitudes where supplemental oxygen *must* be used, not *should*. Because air crews come in all shapes, sizes and levels of fitness, finding the right altitude to turn on the O2 for you may vary substantially from the guidelines found in the regs. For that specific determination, an honest assessment of a few personal physiology factors is needed.



The key to a successful built-in oxygen installation is to engage the brain and plan the system before the aircraft is built. Aerox assists builders in this area whenever one of its systems is purchased.

"Everyone's different, physiologically speaking," says Dr. Brent Blue, senior AME and founder of AeroMedix, a Jackson, Wyoming, web-based outlet for aviation medical equipment. "And we all change day to day. One day I might be doing OK, oxygen-wise, and the next day I might have a cold and my oxygen requirements would be totally different. What we recommend is that you should use oxygen when your saturation level drops by five points, and you must use oxygen when it drops 10 points from your normal home field blood oxygen saturation level."

For those who want to eliminate the complexity of oxygen hoses and headset cords, Mountain High offers a boom-mounted cannula to help keep hoses and cords routed together.

Of course, smokers and people with other respiration issues will have different oxygen requirements than marathon runners. Fortunately, recent technical advances have made it possible for those of us who aren't medical professionals to get it right, every time.

Are *You* Getting Enough?

It wasn't too long ago that figuring out how much O2 was right to ward off the effects of hypoxia without wasting the precious stuff required graphs, charts and a bit of guesswork. But technology does make some things easy, and the fingertip pulse oximeter is no exception. This handy little device clips onto the end of a finger, and in a few moments displays pulse rate and oxygen saturation level of the blood. First developed for medical use only, it wasn't too long before a whole bunch ended up on the fingertips of savvy pilots.

Above 18,000 feet, a mask is required for maintaining sufficient oxygen saturation of the blood. Don't forget the internal microphone as you'll be IFR and talking to ATC.

"If your normal saturation level is 98%, you can use the pulse oximeter to precisely adjust the flow to hydrate up to within a few points of your usual level," Blue says. "You really don't need to hydrate up to your exact saturation level, but you want to be close. And it's real important not to let your saturation levels drop to the low 80s, where you start picking off brain cells. And anything lower than 10 points from your norm means you're gonna get dingy."

If you follow the offerings from those businesses that sell aviation oxygen equipment, you may have noticed that pulse oximetry devices have recently started popping up in their catalogues. The Nonin Flight Stat, which has traditionally had a price point of around $350, has been joined in the marketplace by the SPO Checkmate device that sells for just under $200 from dealers like Mountain High Equipment and Supply Company in Redmond, Oregon. There are minor differences in the engineering designs of the two, but where there's healthy competition, the ultimate winner is the consumer.

Same Problem, Different Solution

As technologically cool as fingertip pulse oximeters are, there is usually more than one way to skin the proverbial cat, and maintaining an adequate O2 flow without waste is no exception. "We call it FADOC," says Mountain High's Patrick McLaughlin, "which stands for Full Authority Digital Oxygen Control." Indeed, while discussing respiration parameters with him that include rate and dwell, there were many similarities to the latest trends in FADEC (Full Authority Digital Engine Control) ignition systems.

"You wouldn't believe what I can tell you about yourself," McLaughlin says, "just from looking at your respiration data. I can probably get really close to your age and general health. The lungs are one of the few human organs that predictably lose efficiency with age, and our metrics confirm it." Providing this crucial data to the company's electronic O2 regulator is easy—all the user needs to do is breathe. The sensitive regulator transducers take care of the rest, measuring the parameters of the inhalation cycle and providing the right amount of oxygen accordingly.

Mountain High refers to this pulse-demand oxygen system line with the prefix EDS for Electronic Delivery System and the suffix IP for Intelligent Peripheral. The only thing missing is a number between the two, indicating the number of users. Available for

The XCP (Cross Country Pilot) portable system from Mountain High provides oxygen for one or two users, with the EDS module and mask for the pilot, and a flowmeter and Oximyzer for the passenger.

both portable and permanently installed O2 systems, these pulse-demand systems will yield from 2.5 to 3 times the endurance of a similar constant-flow system by only providing the oxygen pulses precisely when they're actually needed in the inhalation cycle. Further, the system automatically compensates for altitude as well, making in-flight O2 fiddling a thing of the past.

More Delivery Economy

Getting the right amount of O2 out of the bottle is one thing, getting it into your lungs is another matter. Again, significant improvements have been made since the days when those face-eating diluter demand bags were all the rage. Up to 18,000 feet, nasal cannulas work well to maintain adequate blood saturation levels, and some can even conserve O2 as well.

The Mountain High two-place System Control and Display Head as mounted in the panel of a Lancair. This is the normal display when the system is at rest.

Photos: Rick Lindstrom and Courtesy the Manufacturers

The Mountain High Oxymizer and the similar Aerox Oxysaver are described as a "moustache-style conserving nasal cannula," which, admittedly, looks a bit funny when in use. But the benefits far outweigh the appearance, as they can decrease individual oxygen consumption by as much as 75 percent while maintaining proper blood saturation levels. Pneumatically controlled by the user's inhalation cycles, it has a diaphragm that provides a charge of oxygen-enriched air at the beginning of inhalation, getting it deep into the lungs. It can provide the same saturation levels at a 0.5 liter per minute flow rate as a straight cannula would at 2.0 liters per minute, meaning your O2 tank will last up to four times as long.

Go Boom!

One common annoyance of any oxygen system is the inevitable tangle of tubes and headset cords that seem to magically appear in the aircraft. One approach that minimizes this clutter is to mount the cannula on a headset boom, allowing the O2 tube to follow the same path as the headset wire until it diverges off to the flowmeter or regulator. This means putting on the O2 is as simple as putting on your headset, eliminating a big part of this cockpit ritual when preparing to launch.

The Oximyzer cannula uses the inhalation cycles of the user to meter the oxygen flow, providing as much as four times the oxygen endurance as straight constant-flow cannula.

Those who own Bose headsets may want to check out the AirBoom Cannula, which is approved not only by the FAA but by Bose as well. Built of anodized aluminum by Rocket Engineering in Seattle, Washington, it attaches slightly above the microphone boom on Bose headsets, following a parallel path to the nose. Introductory pricing is $399.

For those who have headsets other than Bose, the Bandit boom mounted oxygen cannula can be retrofitted to most headset earcups for the same functionality. Sold by SkyOx of Edwardsburg, Michigan, the Bandit system is designed to be used with almost any oxygen system and lists for $90.

The Nonin FlightStat is a precision device that keeps track of the user's pulse rate and oxygen saturation level, when clipped to the end of a digit just a few moments.

Portable or Permanent?

As homebuilts have become capable of higher cruising altitudes, the demand for sophisticated on-board oxygen systems has climbed as well. At least a half dozen companies sell portable oxygen products to the aviation community, but two of them are uniquely suited to assist builders in designing the ideal permanent system for their aircraft—Aerox of Limington, Maine, and Mountain High.

It's usually impractical to retrofit a flying airplane with the plumbing, receptacles, regulators, filling blocks and instrumentation found in permanent installations. But if you're in the process of building, it's never too soon to start considering the benefits and implications of a permanently installed system and plan accordingly.

Of course, if you rarely spend any time above 10,000 feet or so, one of the many portable systems will serve well when needed. In these cases, the oxygen tanks themselves

A Mountain High EDS2ip (Electronic Delivery System, two place, Intelligent Peripheral) installed system in a two-seat Lancair. It's a tight fit, but sufficient for adequate accessibility and component clearance.

are most often securely strapped to the back of the copilot seat, providing easy O2 control access to the pilot. The last thing anyone aboard wants is a loose oxygen tank flying around the cabin in turbulence, so it's imperative to ensure that the bottle won't escape its mounting in flight.

Generally speaking, most average-size installed systems will eat up about 30 pounds of useful load and a couple of cubic feet of space to accommodate the hardware and allow for sufficient access. In addition to being able to get to the bottle, external access through the fuselage to a remote filling block may also be desired for ease of recharging the system.

Not having the onus of FAA certification, the homebuilder has the flexibility of using composite O2 tanks, which have the dual benefits of being much less

An Oxygen Station O2 Distributor Unit from Mountain High mounted behind the seat of a Lancair, providing intelligent oxygen flow to the user based on respiration parameters, altitude and the interface with the system control head.

expensive and only needing to be removed every five years (as opposed to three for certified aluminum bottles) for hydrostatic testing. And, as with instruments designed for the Experimental market, there's a good deal of non-certified instrumentation and control available for permanent installation that the certified guys can only dream about.

The Checkmate SPO is a pulse oximeter that is a bit less elegant than the Nonin FlightStat, but provides the same data for about two thirds of the cost.

When Markets Collide...Overlap

There are quite a few concerns that are in the O2 for aviators business, and each have their areas of specialty. Let's take a quick look at the ones that actively pursue the homebuilt market with their individual selection of products.

The Flotec regulator features positive, one-handed click-stop operation, and displays the rate of oxygen flow in liters per minute.

AeroMedix

This web-based company specializes in providing specialized medical products for use in the cockpit and was one of the first to make pulse oximetry available to the average aviator. Their E-Ox line of portable oxygen systems, Flotec regulators, Omega flowmeters and Oximizer cannulas may have their design roots in medical use, but they also work extremely well as a cost-effective solution to airborne oxygen needs.

The components for a capable, two-place installed oxygen system from Mountain High include the tank and intelligent regulator, individual outlet stations, panel mounted System Control/Display Head, fittings, plumbing and masks.

"Oxygen is oxygen," Blue says. "And the biggest problems are either not having enough or finding someone to fill your bottle while traveling. Our portable systems are not only designed for maximum endurance, but can be easily filled wherever oxygen is available, such as compressed gas dealers or medical suppliers."

Aerox

Aerox is one of those "soup to nuts" sellers of oxygen systems, one that provides solutions to almost every facet of aviation. Owner Lloyd Boston says, "We do it all, from portable systems to built-in designs, to all the bits and pieces to make it all work." Holding STCs for built-in systems for the Cirrus SR-20 and SR-22, Aerox is ISO 9001 certified and has FAA PMA manufacturing authority as well. But the importance of the homebuilt market has not been lost on Boston. "It's becoming more and more of our market," he says, "and we offer online drawings as a starting point to help people design their own systems."

The IP (intelligent peripheral) System Control and Display Head from Mountain High allows the pilot to simultaneously monitor the oxygen status for the aircraft and each user and make any necessary adjustments.

Aerox also provides design consultation as part of their installed packages and follow-up support and repair as well. "It's all part of the sale," Boston says. "The ultimate goal is make sure the pilot has the right system for the airplane, and that it works reliably."

Mountain High Equipment and Supply Company

McLaughlin saw the need for a high-endurance, onboard oxygen system when he was flying gliders in the 1980s. Raiding the components to a dive regulator, he soon had what he was looking for, and other pilots wanted a similar system. This became the XCP system (for cross-country pilot), which has been joined by a wide variety of portable and installed systems in the following 15 years.

Now located next door to the Lancair shop at Oregon's Redmond Airport, Mountain High products have found their way into many high flying, fast-glass homebuilts. "That's how we got introduced to the Experimental market," McLaughlin says, "when Lancair's test pilot built one of our systems into his airplane. Then others would come to us and say, 'I want what Mike's got.' These days, Mountain High sells twice as many built-in systems as portables to homebuilders, and the demand isn't slowing down. I'm a pilot too, and I want any system we sell to work just as well for someone else as it does for me."

Precise Flight

Perhaps best known for its speed brakes and PulseLites, Precise Flight acquired the Nelson line of oxygen products and now provides a full line of portable systems and built-in oxygen components. Although its marketing niche for O2 system components has traditionally been certified aircraft, there's nothing to prevent the homebuilder from capitalizing on the company's wealth of real world experience in collecting the parts needed for a custom O2 system. And Precise Flight Vice President Scott Philiben has been a bit surprised by the demand for portable systems from the Experimental crowd.

"We've really improved the mounting systems for our portables," Philiben says. "We've added additional pockets for regulators and other devices and improved the snaps for added security. And it's amazing how much better my own flying has become using these systems. I always thought oxygen was for old people, but it's really made a difference, even at altitudes where it's not legally required."

O2 For You *continued*

SkyOx

Providing aviation oxygen since 1963, SkyOx provides portable systems from 6 to 50 cubic feet in capacity, ranging in base cost from $463 for the smallest unit to $600 for the largest capacity unit. These prices are for the bottle and two-place regulator; adding two more stations will add another $70 per system.

SkyOx also provides a line of O2 accessories including masks (with and without microphones), regular and conserving pendant-style cannulas, carrying bags and the Bandit Quick Donning Headset. "Business has been really good," says company president Susan Klemm. "We've positioned ourselves to be more user-friendly, and I think our product line reflects it."

No matter whose system ultimately joins you in your aircraft, the manufacturers all agree on one thing—like money, there's no such thing as too much oxygen. But having too little can, and does, put the successful outcome of high flight into question. ✢

Contact Information

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Mountain High Equipment and Supply Company
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Precise Flight
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Rocket Engineering
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SkyOX
800/253-0800

Direct links to these companies' web sites can be found at www.kitplanes.com.

TRUE TO FORM?

A year-long flight test offers a cockpit view of TruTrak's new digital autopilot.

BY JACK COWELL

For good reason, every new autopilot design is digital. Why are pilots voting for this alternative over traditional analog Georges? Because digital autopilots are more reliable, compact, easily custom configured and cost effective than their ancient analog counterparts. Not a bad list of pluses.

That describes the category, but what about the TruTrak version? In case you haven't heard, TruTrak is the autopilot that's taken the homebuilt world by storm since its introduction a few years back and made countless production aircraft pilots jealous along the way. That's right—it's not certified. And it's not that the many models in the TruTrak line *couldn't* be certified. It's just that inventor/engineer/pilot/aviation legend Jim Younkin has had more than his fill of political infighting in the certified arena, and he wanted no more of it.

And why bother? We all know the Experimental market is already plenty big and growing faster than the certified market.

How is the TruTrak Different?

Engineers define this autopilot as an orthogonal rate system. For those of us not conversant in techno speak, this means that the unit's gyroscopic rate sensors detect motion in pitch, roll and yaw. When the gyros sense a rate of change in any of these three areas, they send the information to the autopilot's computer. Then its software processes the information and sends commands to the appropriate flight-control servo to oppose any disturbance. The software also adds a rate-of-control movement to the servos to correct any errors in selected direction or altitude.

Think of it this way: the TruTrak uses short-term and longer-term information. The short-term information comes in the form of rate-of-change signals created by the gyros. The longer-term information includes the heading, altitude and vertical-speed errors, which the servos instantly correct. (These are all the inputs analog autopilots get to use to calculate servo response, which is why so many seem to lag behind the airplane by a country mile.)

And what does this mean to pilots and passengers? Because the sensors generate previously unavailable response rates, the autopilot achieves a whole new level of dynamic performance. Lots of popular analog autopilots using yesterday's technology cannot offer this caliber of performance. In flight, that means you ain't seen nothing like it, and TruTrak's benefits go far beyond just being digital.

For example, TruTrak autopilots have their own internal magnetic source for direction as well as an internal digital altimeter. In my TruTrak system, the DFC-250, this gives me triple directional redundancy and double altitude redundancy. In flight, the autopilot can take its directional commands from its own internal magnetic source or my directional gyro's heading bug or the GPS's output. When it comes to altitude control, if the altimeter or pitot-static system (downstream of where the TruTrak picks off static pressure) should have a problem, I can use the autopilot's internal altimeter to provide accurate altitude readouts as well as hold or change any altitude selected.

In either case, all I have to do is make sure, before flight, that the autopilot's directional heading agrees with my slaved DG or whiskey compass. Then I manually sync the autopilot's internal altimeter to the correct airport MSL altitude by using the unit's rotating encoder knob. That done, current, accurate directional and altitude information is displayed on the autopilot's screen.

The TruTrak line features a variety of autopilots designed to fit different budgets. It also includes an instrument called a Pictorial Pilot, a picture-based turn and bank indicator that agrees with the artificial horizon (and therefore, the real horizon).

Photos: Courtesy TruTrak Flight Systems

Taken Into Flight

Now let's sample how this digital whiz makes automated solo flight infinitely customizable, not to mention safer. For starters, you can program minimum airspeed and normal climb airspeed values into the autopilot. Once programmed, the autopilot will not let the plane fly below the minimum speed selected. In fact, in any autopilot vertical mode (Altitude Hold, Vertical Speed, Altitude Select, Glideslope or VNAV), the autopilot constantly monitors airspeed. If the speed decreases to the climb speed you preset, the autopilot flies the plane to satisfy the airspeed criterion rather than any vertical speed or altitude command.

To address a minimum airspeed situation, the pilot can add power and/or decrease the vertical speed requested. Regardless of the circumstances, the TruTrak protects you against flying slower than the specified airspeed, so there's no stalling allowed. In the busy environment of a go-around or missed approach, this is one nice safety feature. But we're getting a little ahead of ourselves. Let's sort through the autopilot's basic displays and controls, and then we'll go on a demo flight.

Powering Up

TruTrak's display and controls are intuitive. Lateral information is on the left side of the controller's screen, and vertical information is on the right. This includes actual track bearings, selected bearings, altitude readings and vertical speed measured in hundreds of feet per minute and up (+) or down (-). On the DFC-250 model, there are six buttons that either scroll through the control options or change your commands. These are labeled On/Off, Mode (lateral inputs), Alt (vertical inputs), VS up and VS dn (climb and descent). Number six is an unlabeled encoder knob that turns to change values and pushes in to enter the inputs.

The lateral modes depend on the plane's other navigational equipment. In my Lancair IV-P, this means GPS-S (GPS steering) and an external HSI. Using the Mode button, I can choose which navigational information I want to guide the plane. GPS steering is the favorite here

Here's the DFC model that guides the author's Lancair IV-P. The radio stack orientation is designated with an "AS" after the model name.

This is the same digital autopilot, different display. The "ATI" versions are designed for a 3 1/8-inch round instrument panel hole.

as it receives input from the GPS—through the AIRNC 429 databus, an RS-232 databus will not provide GPS-S—and anticipates directional changes on an approach or flight plan, so you're always on course, never overshooting the next heading and making a big, ugly correction.

It's kind of like the GA version of a flight management system. And remember, if the plane were to lose both the GPS signal and the HSI, the TruTrak has its own magnetic directional source as a backup.

The vertical modes on the DFC versions let you pre-select altitudes, climb and descend rates, as well as create VNAV profiles that include both the altitude and distance you select to create your desired VNAV profile. Now that we've gone over the basics, let's go flying.

Our Demo Flight

The TruTrak is warmed up and ready for input. The system is in the Off mode but can still accept inputs. We'll use the Alt button to select the ALTIMETER SYNC screen and turn the encoder knob to select the correct MSL field elevation value on the autopilot's internal altimeter. That done, we push in the same encoder knob, and the autopilot's altimeter is now in sync with the plane's pitot-static unit.

The weather is marginal, so we'll file IFR. Our clearance is: "Climb and maintain 3000 feet, expect Flight Level 240 in 10 minutes, maintain runway heading until advised." [*The rest of us in slower, lower-performance airplanes are now permitted a slight sneer. —Ed.*] We then press the Alt button twice to bring up the SEL ALT screen and turn the encoder knob to the right until the screen reads "3000." Push in the encoder knob to enter an input, and we're good to go on altitude.

Once airborne, we press the On button, and the autopilot automatically syncs to the plane's current attitude—both lateral direction and vertical climb. Because we expect to get radar vectors, we'll press the Mode button once to select EXT DG and just turn the heading bug to the runway heading until departure control advises otherwise. Once ATC commands us "cleared on course," we'll go back to the Mode button, press it twice to bring up GPS-S, and the autopilot will slave to the progressive flight plan waypoints entered on the ground. When we get to our first assigned altitude, the CURRENT ALT value in feet (3000) and ALTITUDE HOLD will be displayed on the screen. We're set until ATC gives us our next instructions.

Anticipating their call, we press the Alt button twice to bring up the SEL ALT page. Turn the encoder knob until the value is 24,000, and press the same knob to enter that value. Still on the same page, we can now also change or confirm the indicated airspeed value set earlier. If we want to change that, turning the encoder knob clockwise raises it, and the opposite direction lowers it in increments of 5 knots. Want more precision

The Sorcerer is TruTrak's latest top-of-the-line in-panel unit. This one does it all, simply and intuitively.

than that? Just hold the knob in when you turn it and the change increment is 1 knot instead of 5. At FL240 OK, we go to the SEL ALT page again, which already has the 24,000 cruise altitude set, and press the encoder knob; the plane will climb to that altitude at the airspeed entered.

Unless we receive the dreaded "Stand by for an amendment to your clearance" ATC message, that's all there is to the basics of TruTrak flight assistance. Of course, as you get more familiar and adventuresome, there are lots more features to explore.

Smart *and* Flexible

The model we've been flight testing was the top of the line with the most features and greatest flexibility when I bought it. It was also the most expensive at a suggested retail price of $7900. Since then, TruTrak has introduced a new, updated model called the Sorcerer. Whichever unit you select, you get an autopilot that "thinks" as well as acts. Here's a real-world example: If I inadvertently commanded a climb rate that would cause the plane to violate the airspeed limits I had already entered into the controller, the autopilot would figure out what climb rate will not bust that limit and command the plane to fly that one instead of the problematic one I had chosen. As long as I've programmed the proper airspeeds, there is not a chance of a stall, which is comforting.

A unique example of the autopilot's flexibility is that you can configure the servos' individual torque settings and response rates on the ground or in the air. If I like a setup but my co-pilot finds this a little hyper, he can hold down the Mode button for 2 or more seconds when getting the "your airplane" call so that the Lateral Activity/Lateral Torque page comes on the screen. Holding down the Alt (for altitude) button gives similar options to control vertical activity. In either of these modes, you just turn the encoder to enter the desired values, and then push in the same (now familiar) encoder knob to set the autopilot's actions to suit the whims of the pilot in command.

Other pages offer additional custom options including the Minimum Airspeed, Normal Climb Airspeed and even a Static Lag setting to allow for any delay in the plane's static system. Other programmable pages include Altitude Hold, Localizer Nav Course, Localizer Nav Course Rev and VOR Nav Course. The last three offer programmable intercept angles to the selected final approach course, and if you engage Altitude Hold below the glideslope on an ILS, the unit will intercept that vertical course from below, capture it and fly right to minimums. Actually it will fly the aircraft right to the runway, but because even the TruTrak doesn't yet feature an auto-land capability, you had best intervene with some hand flying before that point!

One optional add-on for the DFC series or Sorcerer autopilots is this yaw damper—a solid-state gyro damps out short-term yaw oscillation, and an accelerometer controls rudder position to keep the ball centered.

One last feature is called VNAV. On the Atlantic coast where I frequently fly, ATC often likes to throw pilots a curveball to keep them all properly separated and playing nicely together. The command could go something like this: "N123AZ, cross 10 miles south of Sardi intersection at niner thousand feet." To comply, all I need to do is determine how far I am from Sardi. Then I press the Alt button three times so that the VNAV screen is displayed. I dial the encoder knob to 9000 and press the knob to select that value. This brings up the Distance value, where I enter the distance ATC commanded and press the knob again. Presto! The plane changes altitude to follow my VNAV inputs and flies to intercept exactly that distance and that altitude. When it's really busy, or when the boys and girls at Center are throwing route changes at you every 50 miles, this is one valuable feature. Besides, it makes you look like an absolute ace with ATC.

Hardware Choices

One neat hardware add-on I opted for is auto trim. This feature, with its double fail-safe design, automatically controls the plane's elevator trim to match the altitude input entered (including altitude hold). The result is that no manual trimming is ever needed when the autopilot is engaged. The fail-safe feature is a bit too complicated to adequately describe here, but suffice it to say that it squarely addresses the issue of runaway trim in a novel and sensible way.

TruTrak also offers a number of servo options. You determine the torque capability your plane needs or tell the TruTrak guys what you're flying, and they'll help you choose the correct servo. They've done this on everything from 125-mph singles to Burt Rutan's Virgin Atlantic *GlobalFlyer*, so chances are good that they'll be able to handle your needs.

For airplanes like my Lancair IV-P, which has stiff controls when the pressurization is cranked up and we're in the flight levels, the proper servo choice is determined by the autopilot's ability to match the needed stick forces. The plane's previous certified unit could not do this. Up high, it had to be helped by the pilot, or it gradually wandered off course. The other manufacturer couldn't fix it, and after one too many fatiguing flights in IMC, I went looking for another system.

The Team

Founder Jim Younkin is an electronics engineer and head of TruTrak. He is also widely depicted as the father of the modern autopilot as well as being an experienced pilot and well respected aircraft restorer—and that's just the short list of his aviation credits. His right-hand man is software wizard and all-around technology ace Chuck Bilbe. Bilbe has designed ultra sophisticated military electronics including work on the Skylab space station. He has done stints at some fairly well known companies including Hewlett Packard, Motorola and Sun Microsystems—not exactly a rookie—but then many companies have experienced leaders and accomplished product specialists, so there's nothing remarkable about that, right?

True, to a point. But here's the difference: At TruTrak, these guys actually work there on a daily basis. They come to the phone to answer your questions and help solve your problems, too. No synthesized voices or tiresome promptings to wade through. In the event that you need a part or something is not functioning properly, you get a new component shipped immediately. You'll also find TruTrak at the annual fly-ins like Sun 'n Fun and Oshkosh, where the guys patiently answer questions and educate lunkhead fliers like me. In other words, the customer support is as strong as the autopilot's design, technology and capabilities.

These shots show TruTrak's DigiFlight II VSGV; at about $5K, it's a more economical choice than the DFC series or Sorcerer unit and therefore, popular with homebuilders. The DigiFlight series consists of digital two-axis autopilots that fit a standard 2 1/4-inch instrument hole. The photo on the right shows the setup page for the GPS steering feature.

It Wasn't All Rosy

At the beginning of my TruTrak odyssey, I really needed that support. In most cases, my consistent lack of mechanical ability and technical knowledge were the cause of my phone calls. Several times, however, components were just not acting as they should, and at one point during the year an updated version of the controller unit was introduced.

Regardless of the situation, if the TruTrak staff decided I needed something replaced or updated, it arrived the next day. For the cynics out there who think the company was doing favors for some magazine guy because it was looking for ink, guess what? This wasn't a loaner review unit I was using—I paid for the autopilot for real-world use in my Lancair.

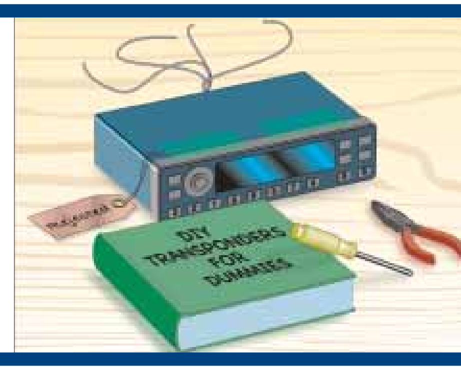
One final note. Unlike some other systems, you don't have to buy the most capable or expensive TruTrak unit to share in the digital pluses. That's because for any set of features, all TruTrak computer controller units are identical. Similarly, the servos are all equal in their response speed (though torque capabilities vary depending on the plane's needs). Whether you're flying an RV-4 or an L-39 fighter jet trainer, you'll get the same caliber of capability. When all is said and done, my extended experience with the TruTrak staff and their autopilot has been solidly positive. I'd stake my life on this system. In fact, when I rely on it in the soup, I already have. ✈

For more information, contact TruTrak Flight Systems at 479/751-0250. A direct link to the company's web site can be found at www.kitplanes.com.

DO YOU NEED A TSO?

Though a subject of long debate, the answer is really *quite clear.*

BY LEN BUCKWALTER



Way back when, there was a time when the letters *TSO* meant little more than a General's favorite chicken dish at the local Chinese joint. But that era of freedom ended on a sunny June day in 1956 when two airliners treated passengers to a spectacular view of the Grand Canyon. The flight crews reported their deviation to ATC, but the airplanes barely appeared on the primitive radar screens of the day. The equipment gave controllers little warning that the United DC-7 and TWA Constellation were closing at 700 knots from opposite directions.

The loss of 128 lives after the mid-air provoked an angry Congress into funding a new air traffic control system. At its centerpiece would be a gadget called the transponder—a veteran from WW-II, where it was known as an IFF, for *Identification, Friend or Foe*.

Nice history lesson, but what does this have to do with building an airplane in a garage, you ask? Plenty. Although the FAA gives us homebuilders wide latitude in choice of equipment, the agency draws the line when a component affects other segments of aviation or the general public. Thus, the transponder became the first item in light aircraft to require a Technical Standard Order, or TSO.

But why the transponder? Why wouldn't a simple FAA edict mandating use of *any* transponder have been sufficient? Well, the legislators were worried about the potential for cheap transponders to make an ATC display look like a Jackson Pollock painting. Surveillance radar already suffers anomalies such as "angels" and "ghosts" (targets that aren't real) and "synchronous garble," which occurs when two aircraft reply to the same interrogation and appear as one. A TSO'd transponder does as much as possible to prevent such distractions—it emits squeaky-clean pulses thanks to minimum performance standards that manufacturers must prove in formal testing known colloquially as "shake and bake."

Do You Need a Parrot?

Most of the time, yes. Transponders are still called parrots in the U.K. because that was the code name for the units during the Battle of Britain. Even now, if a controller detects a British accent in your radio calls, he may tell you to "strangle your parrot," which means squawk standby in colonial speak.

According to FAA regs, you don't *have* to install a transponder. But if you fly 10,000 feet or higher or through controlled airspace, a transponder is required—and all transponders must have a TSO.

It doesn't stop there. For a transponder to report your altitude (Mode C), it needs information from an altitude encoder—which requires its own TSO. [*Maybe. Maybe not. See the sidebar "The Encoder Question," Page 48. —Ed.]* Further, if an altitude encoder is aboard the airplane, the altimeter must be a "sensitive" type—that is, with a baro set knob (to set barometric pressure)—and be TSO'd. For IFR flight, this trio—transponder, encoder and altimeter—needs an inspection every 24 months by an FAA-certified repair station.

And even if you don't fly high, go IFR or penetrate controlled airspace, a TSO'd transponder is worth considering. You're painted as a bright image on the traffic screens of every airliner within about 40 miles and are highly visible on radar. Kind of nice for peace of mind.

Beacon Speakin'

The story behind the next TSO requirement begins like the first page of my favorite reading matter, cheap novels: It was a dark and stormy night as the tiny airplane bravely punched through the ugly clouds, killer fog and stabbing drizzle. Somewhere above the menacing Chugach Mountains, the struggle was lost. The doomed Cessna 310 crashed in southeastern Alaska, snuffing the lives of four brave souls. After one of the most heroic rescue missions in U.S. history, lasting 39 days, searchers finally surrendered. Not a rivet of wreckage has been found in 31 years.

The trouble with this tale is not the purple prose, but that it's true. The accident would normally rate three lines in the local gazette, but the fatalities included two U.S. Congressmen—Hale Boggs of Louisiana and Nick Begich of Alaska. When their colleagues in Washington learned there was no practical system for sending distress signals, they ignited legislation for a new device, which we now know as, together now, our *emergency locator transmitter*, or ELT.

It seemed so simple to package a little transmitter activated by a G switch in a crash. But the simplest is often the most difficult, and the challenge of proper ELT design proved a great underestimation. From the beginning, the ELT malfunctioned at the rate of about 95%—triggering because of hard landings, leaky batteries or just while swaying in the wind at the tiedown. Eventually, the FAA called the TSO police. Modifications were made to existing models, and today we're at the dawn of a new era—the 406 MHz ELT. Satellite-based, the new breed of ELT is designed to slash false alarms, notify rescuers more quickly and guide them to within an arm's length of downed pilots. These new

Illustration: Steve Karp; Photo: Courtesy the Manufacturer.

ELTs—and for that matter, ELTs of any type—must carry a TSO.

But must you have an ELT at all? Usually, but not always. An ELT is *not* required if your airplane has only one seat and you fly less than 50 miles from your home airport. But how many of us, even us true Part 103 pilots, *never* exceed 50 miles from home? Not many.

Pilots have gone down in the woods and perished days later, even in instances when the crash site was within walking distance of a road or house. And don't depend on a cell phone. It didn't work for me when a hot air balloon I was riding in drifted south at 700 feet AGL. The flight was fun until the pilot realized that Dulles International Airport (near Washington, D.C.) lay 10 miles dead ahead. Now I know that Steve Fossett can somehow drive a balloon left and right, but our captain had one choice only—put it down in the nearest clearing fast. After the basket came to rest, the pilot called and called but couldn't raise the chase truck. We were at the bottom of wooded bowl.

Shooting the Stars

Beyond transponders and ELTs, a third item requires a TSO: a GPS receiver used for IFR operations. The logic is the same as for the transponder—if a piece of equipment can endanger not only you, but others, it needs the quality assurance of a TSO.

Wait, so I can fly IFR with a panel full of non-TSO'd avionics including VOR and ILS receivers, ADF, DME and marker beacon, you ask? But I need a TSO for my GPS? Sounds curious, sure, but the technology powering the other components dates back earlier than the Flintstones and is well proven. While so integral to our lives as pilots today, remember that GPS is still a relative newcomer and the technology is more complicated.

A GPS approach requires awesome computation, especially for the tongue-twister called RAIM—receiver autonomous integrity monitoring. Here's a helpful analogy: RAIM operates much like my Thanksgiving visits to my nephew's home. When we arrive at his house, he isn't there. The kids are fighting on the Xbox, the wife is feeding the parakeets, and the dog is eating the hors d'oeuvres. My nephew Joe marks our arrival time as a cue to go to the grocery and buy the turkey.

Come again? This is similar to a GPS approach. You punch into the receiver that you are going to arrive at Seedy Acres Airport. This cues the receiver to shop the sky for the position of satellites in the constellation and then figures out where the birds will be later on when you arrive at Seedy. This is the "integrity" part—meaning there will be enough satellites at your destination and their geometry will provide sufficient accuracy for the approach. Because this is so critical to accuracy, the FAA insists that an IFR GPS receiver have a TSO to guarantee navigation when it's raiming out.

The Encoder Question

There are many subtle (and a whole pile of not-so-subtle) differences between production aircraft and our wonderful Experimental/Amateur-Built conveyances. We have significantly more freedom in design, of course, but there are areas where the Federal Aviation Regulations (FARs) overtake us. Sometimes it's a clear path. Other times, how we comply with specific regulations is open to some interpretation.

Interviews with avionics shops and designated airworthiness representatives have revealed little on the topic of TSO requirements for a couple of pieces of equipment: the transponder and altitude encoder. While it is generally accepted that you don't need TSO-approved instruments in the airplane to legally file and fly IFR, it is written that the transponder and encoder must meet the technical requirements of the TSO. And, as author Buckwalter points out, you could, in theory, build your own transponder and encoder; he doesn't recommend it. No worries, then; few builders we know would spend the time to homebrew a transponder.

But that leaves the encoder, and it's a slightly hot topic these days. You see, many of the new EFIS designs that incorporate their own air-data systems also, cleverly, output a serialized encoder output meant to be fed to your transponder. They are not, as far as we can tell, generally sold with actual TSO approval. (Many do, however, meet the requirements of the TSO, they're just not officially approved.) And still, many airplanes are flying with transponders being fed altitude information from these sources.

How could this be legal? Well, it's a matter of interpretation. FAR 91.217 states, "No person may operate pressure altitude reporting equipment associated with a radar beacon transponder unless:

(a) When deactivation of that equipment is directed by ATC;

(b) Unless, as installed that equipment was tested and calibrated to transmit altitude data corresponding within 125 feet (on a 95% probability basis) of the indicated or calibrated datum of the altimeter normally used to maintain flight altitude, with that altimeter referenced to 29.92 inches of mercury for altitudes from sea level to the maximum operating altitude of the aircraft, or

(c) Unless the altimeters and digitizers in that equipment meet the standards in TSO-C10b and TSO-C88, respectively."

A-ha! Paragraph (b) offers the out—as long as the manufacturer (and you, the builder) can convince your local inspector that the piece of equipment feeding the transponder has been "tested and calibrated," you should be good to go. However, the avionics shops and DARs we interviewed also said that the standards shift a bit depending upon the type of airplane. They, being humans, tend to be a bit more relaxed with day/VFR aircraft and more stringent with models clearly built for night/IFR flying as well. In that case, the advice we received was to go ahead and install a fully TSO'd transponder and pop the extra money for the TSO'd blind altitude encoder.

—Marc Cook

UMA Instruments' TSO-approved tachometer looks—and in fact is—identical to the non-TSO'd unit sold for Experimentals. According to the company, the only difference is paperwork. Oh, and a few bucks.

Roll Your Own?

There's plenty of controversy on who needs a TSO, when it's required and for what equipment. Some bloggers say you can even design and build your own transponder without ever getting a TSO. That's technically true. But if challenged by an FAA inspector, you'll have to demonstrate compliance. Frankly, building a transponder yourself would be the equivalent of designing your own electroencephalograph to use at your own brain operation. Don't even *think* about it!

It's also misleading to point out that FAA's required equipment list (Part 91.205) never mentions a TSO. And while not required, the use of TSO'd equipment for items other than the big three, nevertheless, is urged by the FAA. In its advisory circular on Amateur-Built aircraft (AC 20-27F), the FAA says, "It is recommended that FAA-approved components...produced in accordance with a TSO...be used." Note this is a *recommendation*, not a mandate. (The TSO requirement, however, still applies in all cases to the transponder, ELT and IFR GPS.)

Non-TSO'd Stuff—Any Good?

Much of the equipment offered in the Experimental world does not hold a TSO. Here at Avionics Systems (the custom panel and avionics shops where I work), we see a lot of non-TSO'd equipment that is innovative, reliable and reasonably priced. In some areas, non-certified equipment is well ahead of the avionics establishment. Last year at our booth at Oshkosh, a 777 captain dropped his jaw when he saw the large, multi-function EFIS screens. They had no TSOs!

One manufacturer of a popular autopilot is almost militant about not having a TSO. He stakes his reputation on the quality of the product, and it enjoys good sales. And because builders today are in such close contact, news of a poor performer spreads at the speed of light.

On the downside, some non-TSO'd equipment suffers from the beta syndrome. A beta test is usually a good thing—like Bill Gates letting you download a free copy of the next Windows in return for your feedback. This catches errors early. But in some instances, a kit builder may buy a non-TSO'd product and unwittingly become a beta site. In other words, you pay for the test program that should have been done by the manufacturer.

Another TSO consideration is the quality of flight instruments. There is a two-tier market of altimeter, airspeed, VSI and other mechanical instruments; one with TSO, the other without. If you fly only on clear days, the cheaper instruments are probably acceptable. But pilots of more than a few hundred hours often encounter some sort of , er, "obscuration"

Minimum Equipment—Let's Review

The table on the following page is intended to give the builder of an Experimental/Amateur-Built aircraft a ready reference for the instrument and equipment requirements for the aircraft. The builder should note that some items required by the FARs are described in the regs as needing to be approved. But since there are no certification standards established for amateur-built aircraft, no formal individual item approval, such as meeting a TSO or FAR Part 23, is required. The exceptions, as we've seen in "Do You Need a TSO?" include the transponder, ELT and IFR GPS receiver; if any or all are installed, they must be TSO'd.

And certain other items must interface properly with ATC, other aircraft or other entities external to the aircraft. Communication radios and exterior lighting are two examples of such equipment. Therefore, the builder can expect that the FAA inspector or DAR conducting the initial airworthiness inspection of the aircraft will require evidence that this type of equipment in the aircraft is acceptable to the FAA.

The Special Airworthiness Certificate issued for each Experimental/Amateur-Built aircraft includes specific Operating Limitations. Per FAA Order 8130.2F, the Operating Limitations state: "After completion of Phase I flight testing, unless appropriately equipped for night and/or instrument flight in accordance with 91.205, this aircraft is to be operated under VFR, day only." The FARs, FAA Order 8130.2F and current FAA policy have been used in constructing the below amateur-built aircraft configuration requirements table.

The table lists each item and notes its necessity (or lack of) for three types of flight: day VFR, night VFR and day or night IFR. For each listing, you'll find one of four notations: (1) AR, as required, (2) NR, not required, (3) N/A, not applicable, or (4) R, required.

And note that this table doesn't provide recommendations for best practices. Installing only the absolute minimum equipment may not be prudent or safe, as we all know. Without further adieu, here are the minimum instrument and equipment requirements for powered Experimental/Amateur-Built aircraft.

—Owen C. Baker with Richard E. Koehler

while flying, planned or not, so it's reassuring to know the TSO'd artificial horizon probably won't lean over with gyro's growling.

FAA research shows that without instruments, the lifespan of a pilot, regardless of experience level, who enters a cloud is about 5 minutes. Only Charles Lindbergh appears to have beaten this death sentence. While flying the mail in the 1920s, he would arrive at a destination while still on top. He put the airplane into a spin (the only stable maneuver when you can't see the horizon) and would break out in the clear at the bottom. Spin, anyone? +

	FAR & Item Description	Day VFR	Night VFR	Day or Night IFR
1	91.205 (b) (1) Airspeed Indicator	NR	R	R
2	91.205 (b) (2) Altimeter	NR	R	R
3	91.205 (b) (3) Magnetic Direction Indicator	NR	R	R
4	91.205 (b) (4) Tachometer for Each Engine	NR	R	R
5	91.205 (b) (5) Oil Pressure Gauge for Each Engine Using a Pressure System	NR	R	R
6	91.205 (b) (6) Temperature Gauge for Each Liquid-Cooled Engine	NR	R	R
7	91.205 (b) (7) Oil Temperature Gauge for Each Air-Cooled Engine	NR	R	R
8	91.205 (b) (8) Manifold Pressure Gauge for Each Altitude Engine	NR	R	R
9	91.205 (b) (9) Fuel Gauge Indicating Quantity of Fuel In Each Tank	NR	R	R
10	91.205 (b) (10) Landing Gear Position Indicator, If Retractable	NR	R	R
11	91.205 (b) (11) Anti-Collision Light System (small civil airplanes certified after 03/11/96)	NR	R	R
12	91.205 (b) (13) Approved Safety Belts With Metal-to-Metal Buckles for Each Occupant (two years or older)	NR	R	R
13	91.205 (b) (14) Approved Shoulder Harness for Each Front Seat (small civil airplanes manufactured after 07/18/78)	NR	R	R
14	91.205 (b) (15) ELT (if required by Sec. 91.207, i.e. >one seat and >50 miles)	AR	AR	AR
15	91.205 (b) (16) Approved Shoulder Harness for Each Seat (airplanes with nine or fewer seats manufactured after 12/12/86)	NR	R	R
16	91.205 (b) (17) Shoulder Harness for Each Seat For Rotorcraft (manufactured after 09/16/92)	NR	R	R
17	91.205 (c) (2) Approved Position (navigation) Lights	NR	R	R
18	91.205 (c) (3) Anti-Collision Light System (systems installed after 08/11/71—see reference)	NR	R	R
19	91.205 (c) (5) Adequate Source of Electrical Energy for Installed Equipment	NR	R	R
20	91.205 (c) (6) One Spare Set of Fuses or Three Fuses of Each Kind Required (must be accessible to pilot in flight)	NR	R	R
21	91.205 (d) (2) Two-Way Radio Communication System and Navigational Equipment Appropriate to Ground Facilities Used	NR	NR	R
22	91.205 (d) (3) Gyroscopic Rate of Turn Indicator (some exceptions, see reference)	NR	NR	R
23	91.205 (d) (4) Slip-Skid Indicator	NR	NR	R
24	91.205 (d) (5) Sensitive Altimeter Adjustable for Barometric Pressure, (see FAR 91.411, altimeter system inspection required every 24 calendar months)	NR	NR	R
25	91.205 (d) (6) Clock Displaying Hours, Minutes and Seconds (sweep second pointer or digital)	NR	NR	R
26	91.205 (d) (7) Electrical Generator or Alternator of Adequate Capacity	NR	NR	R
27	91.205 (d) (8) Gyroscopic Bank and Pitch Indicator (artificial horizon)	NR	NR	R
28	91.205 (d) (9) Gyroscopic Direction Indicator (directional gyro or equivalent)	NR	NR	R
29	91.205 (e) DME Above FL 240	N/A	N/A	AR
30	91.215, Transponder in Certain Airspace, (see FAR 91.413, inspection required every 24 calendar months)	AR	AR	AR

Build Your Skills

Metal Part 11

In our final installment, a close look at the *sticky (but necessary) issue* of corrosion proofing.

BY DAN CHECKOWAY

Anodes and cathodes. Oxidation and reduction. Ionic exchange. Believe it or not, this stuff right out of your high school chemistry class has quite a bit to do with airplanes—but it's not a pretty sight when these concepts come into play. It's the dreaded C word—and I don't mean "cash" or "credit"—the cancer of your airplane's skin and bones, the carnivorous plague that no airplane owner wants to confront...corrosion!

Without getting too deep into the science behind it, corrosion is an electrochemical reaction that causes deterioration of metal when it reacts with the environment. In the context of airplanes, this is never a good thing. At a minimum, corrosion creates stress concentrations and weakens the structure; in extreme cases the material is literally consumed, leaving nothing but flakes and dust. To make matters worse, many of our airframes are built predominantly from aluminum, which happens to be one of the most reactive metals as far as corrosion is concerned. Yikes!

No, Really...Metal's OK!

Relax. Before you do something rash and put your kit up for sale on eBay and—heaven forbid—switch to an airplane kit that more closely resembles a surfboard (sorry, composite guys!), let's take a closer look at what causes corrosion and methods we can employ to ensure it won't happen to us.

There are positively and negatively charged areas on a given piece of metal. If you introduce an "electrolyte" such as water (worse, salt water) to the surface, those charged areas start exchanging electrons and react with the electrolyte. The metal combines with oxygen atoms from the electrolyte to form an oxide—it oxidizes. The longer you allow that electrically conductive moisture to be in contact with the metal, the more corrosion will occur.

If you introduce dissimilar metals into this equation, such as aluminum and steel, the problem becomes even worse. "Galvanic" corrosion occurs when two metals that have different electrical potential contact one another in the presence of an electrolyte. All those steel bolts that attach various bits of aluminum to each other...those are potential

Untreated steel will rust just waiting for you to build the airplane, just as aluminum will corrode. Your goal is to keep rust and corrosion at bay, particularly in areas of the airframe where you can't see or easily treat this metallic cancer.

Photos: Marc Cook

spots for galvanic corrosion if and when they get wet.

Obviously the solution is just to prevent an electrolyte from coming into contact with the metal in the first place and to isolate dissimilar metals from each other. Yes, *it's that simple!*

Maybe Not So Simple...

So don't leave your plane underwater, right? Yeah, but even if it's only once in a blue moon, surely every once in a while you'll fly through a little rain or leave your plane outside in not-so-fair weather. Or maybe you're based at an airport near the coast, where the air is full of salt-laden moisture. It's difficult, if not impossible, to completely avoid exposure to moisture in some form. Fortunately there are numerous treatments that can be applied to the metal parts in your airplane to prevent corrosion.

In a previous installment we talked about how most of the kit components that are 2024-T3 have a mirror-like finish—a result of the Alclad coating. This is one of the simplest forms of an anti-corrosion treatment. While 2024 aluminum is alloyed with copper, the Alclad coating is a thin layer of pure aluminum. Believe it or not, that shiny, pure, perfect-looking coating is already oxidized when you receive it. That's not to say it's corroded per se, but the pure aluminum does react with oxygen to form an oxide film that bonds strongly to the surface. This is a good thing! Aluminum's high reactance is a great attribute in this regard, because if the film is disturbed, it immediately reforms in most environments. It is this layer of oxidized pure aluminum that actually protects the underlying alloyed aluminum from corrosion. Alclad is typically about 5% of the total thickness on each side of the skin. That is, on a skin that is .040-inch thick, there would be a .002-inch thick layer of Alclad on each side.

Before we start, think about safety. And, for that matter, think about your body throughout the process. Wear gloves, skin protection and, when using anything that might kick off airborne toxins, protect your lungs.

Peligro! One of the more popular (and effective) means of cleaning metal prior to application of anticorrision treatment is MEK—methyl ethyl ketone. It's nasty stuff, so be careful. Acetone works nearly as well and isn't quite as harmful.

Easy Off

While those scant thousandths of an inch do a great job inhibiting corrosion, it's altogether too easy to remove the coating if you're not careful. Let's say you accidentally dragged the tip of your drill across the skin—it's conceivable that you might have scratched right through the coating to the alloy beneath it. Sometimes just assembling parts for drilling or riveting can create unintentional scratches in the surface. Remember we mentioned that many of your kit components will come with a plastic coating? One of the biggest reasons to leave that plastic on, at least until you're done drilling and disassembling, is to protect that vital layer of Alclad.

What should you do if you scratch or scuff a part? For that matter, does Alclad even stand alone as a reliable corrosion inhibitor? What happens if coastal rainwater collects inside a wing and stagnates there for some period of time? Is Alclad really going to do the job?

Salt spray tests have shown that an Alclad surface alone is not very corrosion resistant. Granted, we're not building submarines here...and if you look inside 50-year-old airplanes you're likely to see healthy bare Alclad aluminum. In most cases these planes have stood the test of time, but there are certainly exceptions. Still, prudence dictates that we look closely at options for extra corrosion protection.

Self-etching primers—often found in the self-contained rattle can—don't need a lot of surface preparation but don't form a fully sealed surface, either.

Welcome to the Taboo Room

At this point in the discussion, I'm tempted to demand that you toss your magazine into the fire and run for the hills, because we're about to delve into extremely subjective territory. What we're about to talk about has become nothing short of taboo in builder circles. At a minimum, I'm going to don my flameproof Nomex suit at this point, because we are about to enter... *the primer zone*. Before we go head-on into complete madness about primer, let's first look at a couple of other options for anti-corrosion treatment of our beloved aluminum components.

Assuming for the moment that Alclad is all we need (just humor me for a minute), there will be other parts that come with your kit that don't have the Alclad coating. Often they are composed of 6061-T6, examples being extruded pieces like longerons or spar doublers. Is there any other recourse for protecting these parts against corrosion without mentioning that "P" word? Yep, there sure is.

Have you ever noticed the blue fittings on the ends of aircraft or high performance auto hoses? That blue coloration is not paint, and despite the fittings being

Inevitably, you'll want to mark disassembled parts prior to priming—regardless of the method you choose. Two of the most popular are scribing with an electric engraver and using a Sharpie.

aluminum, they aren't going to corrode under normal circumstances. They have been "anodized," which is an electrochemical conversion process.

Anodizing involves positively charging the aluminum with a DC voltage source and immersing it into an acid bath, with a negatively charged object present in the bath—often the tank itself. Soft oxides form on the surface of the part, which is then dipped in a bath of colored dye mixed with water. The oxides absorb the dye and then harden, forming a protective layer that is highly resistant to corrosion—and also cosmetically appealing.

Anodizing isn't exactly something you can do in your garage, because it involves using hazardous chemicals—though if you search on the Internet there are several sites that describe homebrew methods for anodizing aluminum. I'm not suggesting you go this route. In fact, some mission critical parts in your kit may already be anodized from the factory. For example, Van's ships pre-assembled wing spars that have been gold anodized for corrosion resistance. Most builders opt for other methods of corrosion protection for the parts that don't come anodized, but if you do decide you want something anodized, you can probably find a facility nearby that will do it for you. Be prepared to dish out some dough.

Anodizing Alternatives

What if you'd like to protect some aluminum part from corrosion but you don't want to deal with anodizing? There's another option that sounds remarkably similar... Alodining (not to be confused with anodizing) is a chemical chromate conversion of the aluminum surface. The part is bathed in Alodine, which is a liquid that you can buy from various sources including Aircraft Spruce (some builders use Iridite powder to make their own). Alodine 1201 has an integral gold dye that shows up when the conversion process is complete. Again, this can be confused with gold anodizing but involves a completely different process.

First you would clean the part off with MEK or acetone to remove any ink, adhesive, etc. Generally you would follow this up by scrubbing the part clean using a maroon Scotch Brite pad and a cleaning/etching solution such as Alumiprep 33. Rinse the part off with water until the water sheets off the part. Any oil or residue will show up as spots, streaks, or areas where the film of water is interrupted. If you see evidence of this, more cleaning is required. After the part is completely clean and rinsed, it is then bathed in Alodine. Some people build "troughs," while others apply it with a foam brush. After a few minutes of exposure, the surface should appear gold in color. Rinse the part thoroughly with water and let it dry. That's it. Salt spray tests have shown that aluminum treated with Alodine can withstand the abuse considerably longer than untreated aluminum before showing any signs of corrosion.

Alodined parts not only resist corrosion, but the surface helps electrical conductivity between airframe components, the process adds virtually no weight or thickness, and it even helps paint or primer "grip" better (in case you're using primer).

After a light coat of rattle-can primer, the engraved markings are hard to see but the Sharpie shines right through. Keep that in mind when you mark so that your inscriptions don't show on the exterior.

Sounds great, so what's the downside? Several, actually. First of all, Alodine is very toxic stuff. I'm not a biochemist, but even I can tell you that coming in contact with a carcinogen like a chromic solution is...uh...bad. And assuming you manage to protect yourself and your pets from it, how are you going to get rid of the stuff when you're done with it? Proper disposal, including dealing with the runoff from rinsing, is a real problem!

So we're left with this—Alclad is wonderful but not bulletproof. Anodizing is expensive and means you need to send your parts out. Alodine requires great care in the application and cleanup.

The first stages of Alodining aluminum includes scrubbing with a maroon Scotch Brite pad and then treating with Alumiprep, which removes oil and dirt. Rinse with water until it sheets off.

What About Paint?

For the sake of argument, let's assume you're planning to finish your airplane with paint (as opposed to leaving the surface as polished aluminum). That coat of paint, if applied properly, is one of the absolute best forms of corrosion protection. A good paint job will actually seal the exterior of your airplane from moisture. Since it's so effective, why not paint the inside as well? Paint is heavy and expensive, for one. But we can actually accomplish the same goal without having to use paint, but rather just using primer. The concept is that by spraying just the primer onto the internal aluminum structures, you can buy yourself extra corrosion protection compared to bare aluminum.

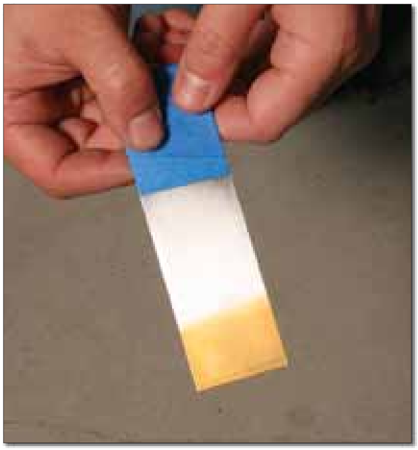
Immerse the aluminum in the Alodine for a few minutes. It will coat the metal and leave a light golden tint. Dispose of used Alodine as you would any hazmat.

Before we go any further, I need to mention that selecting a primer can be a dizzying experience, particularly if you rely on other builders' opinions. I'm not about to stick my neck out and actually recommend something specific. All primers are by far not created equal. That's not to say one is better than the other; it's just that there are major differences in terms of how they are applied and how effective they are.

How do we define effective? On one hand, if the airframe isn't affected in any major way by corrosion after 10 to 20 years of average exposure to the elements, that's considered a success. On the other hand, why not protect the airframe so it will outlive you and the next five owners? This is extremely subjective territory. What is good enough and what is operation overkill? Unfortunately, answering that question is not as cut and dried as a topic like drilling or riveting. I will at least list a few of the popular options for primer, and you can do your own research and make up your own mind.

It's What You Zinc

Zinc chromate has historically been the primer of choice until somewhat recently. If you look inside an old warbird at the museum, you'll see pieces coated in that unmistakable military-looking green shade. That's probably zinc chromate. While it has served the fleet well in general, there are more modern options that are chromate-free, and thus less carcinogenic. No primer is going to be good for you, but we can at least take strides in that direction when the opportunity is available, and when the goal isn't compromised. If it's zinc chromate you wish to use, it's still readily available—often



When the Alodine conversion process is complete, you'll see an uninterrupted layer of gold tint. If there are breaks or splotches, you probably didn't clean the part carefully enough.

in rattle-can form, which makes application simple.

If you go to your local autobody paint supply store, you can probably find some sort of self-etching primer in a rattle can. Self-etching just means you don't need to prep the surface with an acid etch (such as Alumiprep 33) in order to roughen the surface so that the primer can adhere properly. A self-etching primer has its own built-in chemical mechanism of bonding with the aluminum—which means all you have to do is clean the surface and spray the primer right on. Cleaning usually involves wiping the part down with MEK or lacquer thinner or any solution that will remove inks, oils and residues, but will evaporate quickly without leaving its own film or residue. Using a self-etching primer, particularly in a rattle can, is by far one of the simplest approaches to adding corrosion protection. Examples of rattle-can self-etching primers are Mar-Hyde, Sherwin Williams GBP-988, NAPA 7220 or SEM. They are all very similar.

There is a downside to using spray-can primers—they're not designed to stand alone. That is, they're intended for use with a top coat of paint. They provide a half decent moisture barrier, at least compared to bare aluminum, but they simply do not seal completely without paint applied over them. Maybe you're asking yourself, so why bother? I guess it comes down to the fact that something is better than nothing, and rattle-can primers are incredibly easy to apply. You won't waste a lot of precious building time on an onerous etch/alodine/mix/spray process, but taking such a shortcut comes at a slight cost—the primer is not a true sealer.

If you want the best corrosion protection your money and time can buy—without resorting to paint, I think most people will agree that using a good two-part epoxy primer is the way to go. You won't find a high quality epoxy primer in a rattle can. In fact, the best stuff isn't even self-etching. Applying a two-part epoxy primer can involve a fair amount of work—going through the motions of the clean/etch/rinse/alodine/rinse process, followed by mixing primer with catalyst, and then applying the mix to your components with a pneumatic spray gun. Don't forget to clean the gun when you're done.

Using a spray gun—particularly for two-part epoxy primers—suggests prudence toward your health. Here, the author wears a Hobbyair forced-air respirator. Smart man!

Examples of two-part epoxy primers are AKZO (available from Aircraft Spruce) or Variprime (available from a DuPont automotive finish distributor). Expect to pay more than $100 per gallon for this stuff, not to mention the cost of the etching and alodining supplies. A good epoxy primer, when applied correctly, will produce what essentially amounts to a bulletproof finish. It's not a cosmetic finish, but the underlying aluminum is completely sealed from the elements. If it's good enough for Boeing, it's probably good enough for us!

What does a company like Van's use for primer on interior components in their quickbuild kits? If you've ever seen one of these kits, you might not even realize it has been primed at all, because the primer they use is a "wash primer" with no visible pigment. It's a product from Sherwin Williams called P60G2. Van's even admits that this primer is designed to take a top coat of paint for optimum corrosion protection, but they feel it's "not necessary for the way in which most owners maintain their RVs."

So What Are the Best Options?

Confused yet? I think most new builders would probably ask the question, if you're going to bother with any primer at all, why not go with the best option available? Sure, but what is best to one builder is not necessarily the best option for another. You need to do the research and consider the environment in which you're likely to base and operate your airplane. Keeping it outside on the ramp in a coastal environment? Maybe you want to lean toward the conservative and use a two-part epoxy primer on the entire interior. Keeping it in a hangar in the desert? Maybe you'll opt for no primer at all—and you'll just keep a close eye on your airframe. If it exhibits any signs of corrosion down the line, you could always resort to using something like ACF-50 or CorrosionX to treat and protect it at that point. Or maybe you'd rather be just a bit more proactive and opt for minimal use of a rattle-can primer, sprayed only on rivet lines and where components overlap. There's definitely a balance to be struck somewhere in there that serves your mission profile. Adding corrosion protection to your airframe may increase its long-term value, if only in perception. It may give you peace of mind. But it does come at a cost—not only financially, but it adds weight, it will consume precious build time, and it will expose you and the environment to harmful elements.

Builder, Save Thyself

On that note, I can't stress enough how important it is to protect your body from potentially harmful effects of the chemicals involved in the corrosion protection process. When spraying primer, always wear gloves to protect your skin—powder-free latex should do the trick. If you're not going to wear coveralls, at least wear long sleeves and pants. Protect your eyes with painter's goggles. It would also be beneficial to wear ear plugs—nothing to do with noise, but rather minimizing exposure to toxins.

Of tantamount importance is protecting your lungs—and I'm not talking about wearing one of those cheesy dust masks. (They're fine for particulates large enough to have a part number, but nothing like good enough for the airborne toxins released by painting and priming.)

At a minimum, wear a respirator with fresh twin cartridge filters that protect from organic vapors. These supplies are readily available (and fairly inexpensive) from stores like Home Depot or Lowes. Don't skimp.

The best option when priming or painting is to use a full facemask style forced air supply system such as those made by Hobbyair. No, it's not cheap, but it's worth the expense. There is nothing good for you about these chemicals we're working with. It would be a shame to finish your airplane only to be grounded by a major nervous system disorder as a result of exposure to these toxins.

Hardware-store respirators are fine when working with solid particulates from comparatively benign sources, but they're not quite enough when there are carcinogenic toxins floating around the hangar.

Beyond Aluminum

Up until now we've been caught up discussing aluminum in particular. While it is predominantly the material you will be dealing with, there will be a number of steel components on your airframe—from tailwheel spring to engine mount. Whether the point is isolating the steel from aluminum, or just keeping the steel from rusting, it needs to be protected. A two-part epoxy primer will do a fine job at this, but with steel there is yet another option that is often more appealing. Steel parts may be powder coated, which forms a coating that is highly durable and often considered superior to paint. Powder coating involves spraying electrostatically charged, dry paint powder onto the steel part, which is oppositely charged. The powder clings to the steel, which is then baked at about 400°. The powder melts and flows smoothly and uniformly on the surface of the part. Once cooled, the coating solidifies and becomes extremely durable.

You have many choices in applying two-part primers. Inexpensive "touch up" guns (bottom) are just fine; you're not looking for a show-winning finish inside the wings, right? Check discount tool suppliers such as Harbor Freight for the best deals.

The best way to clean steel prior to priming or powder coating is by bead blasting or sand blasting. If you have parts that need to be powder coated, you can probably find a local facility that will do the bead blasting as well as powder coating.

Why not powder coat aluminum components? There are two key reasons. First of all, powder coating adds a fair amount of thickness to the surface, which would not work well in cases where parts are intended to mate under close tolerances. Also, the high temperature baking process could alter the temper of the aluminum, which could have detrimental effects on its strength (yikes!).

What about all of those steel bolts holding various aluminum parts together? Should you worry about dissimilar metal issues there? Luckily (well, deliberately), aircraft grade AN bolts, nuts, washers and cotter pins all come with a cadmium plating (gold in color) that serves to isolate the steel from the surrounding aluminum. Even so, it's not a bad idea to dab some primer inside a hole (some builders use a Q-tip to do this) before that bolt goes in, assuming you're not priming the entire part already.

The Hobbyair "compressor" should be placed outside the hangar or workshop so that it receives fresh air. No, it's not a cheap system, but lung-replacement surgery isn't a day at the beach, either.

We have just barely scratched the surface (pun intended) with respect to corrosion protection. Unlike the previous installments in this series, this particular topic is certainly the most ambiguous. Hopefully this article is food for thought and not just downright confusing. Unfortunately there's no right answer to most of the questions that come up about primer and other treatments. Ask around, and you might be surprised at how much inconsistency there is on this topic among builders. Regardless of what process you decide to use, be sure to do it safely!

It has been nearly a year since we started this series. To those readers who are contemplating building an airplane, I hope the topics we've covered have shed some light on the process involved in building a metal airframe. And to those of you who have already begun the journey, hopefully you learned a few tricks or techniques from these articles along the way. At this point I'm turning you loose, so to speak. Do the best job you can, don't hesitate to ask for help when you need it, and I look forward to seeing you and your finished airplane at a fly-in someday! ✢

SURVIVING A KIT COMPANY FAILURE

A few veteran kit builders share their wisdom for *coping* with a company closure.

BY MARY BERNARD

No one likes to see a business fail, and kit-aircraft builders are no exception. What makes such failures potentially devastating for builders, however, is that if a kit company closes, the builders may be out thousands of dollars and be hard-pressed to finish their projects. While it isn't possible to predict with any accuracy which companies will succeed, it is possible to learn from builders who have found themselves facing a company closure. We talked to a few who found themselves in such situations, and we queried a company rep who weathered the vicissitudes of just such an event.

Stoddard-Hamilton

When Stoddard-Hamilton, manufacturer of the Glasair and GlaStar kit lines, announced that it was filing for bankruptcy and closed its doors in 2000, it came as a shock to the company's customers. In S-H, there was what had appeared to be an industry fixture with a long history of successes. Yet those who had not yet completed their aircraft found themselves scrambling to find ways to finish building while the company's future remained uncertain. (Note: To avoid confusion, we'll point out here that S-H's assets were subsequently purchased from bankruptcy court, and the company that emerged, New Glasair—now renamed Glasair Aviation—has been up and running and successfully shipping kits and parts for the last bunch of years.)

Dave Prizio had started building his GlaStar in 1999. At the time of the company closure, he had the wings done along with the tail and other sheet metal parts. He was ready to start on the systems and fuselage when he learned of the bankruptcy. Prizio had most of the parts he needed, but not the engine mount, cowling and a few other key parts. Luckily for many S-H builders, there was a company called Airlink Technologies that offered parts, some pre-fabricated assemblies and builder assistance. Prizio says Airlink filled in the gaps for a lot of builders.

He also said that Sid Lloyd, who had initiated the GlaStar builders group that Prizio now runs, was able to track down vendors that builders could buy from. Lloyd called former employees from the company to glean information on suppliers, as S-H had inventory but couldn't sell it because of its creditors. It says a lot about the dedication of these employees that they would work to assist builders even for a company that no longer offered them paychecks.

One crucial element of builder success, Prizio says, was the GlaStar Net, which helped builders share information and "put the pieces of the puzzle together." Prizio counted this among his strongest assets, and he advised builders of any design to "try to connect with other builders so you can pool resources." GlaStar Net is mostly about sharing information, he said, but sometimes builders help each other with construction if they live nearby. "Together we were able to do so much more than on our own," he said. "I don't know how anyone could do it alone. Dividing the tasks up makes them more manageable."

In retrospect, Prizio considers himself among the lucky ones, because he was not delayed more than a few months in completing his plane (finished in July 2002), and his financial losses were not substantial. Others were not so lucky. He doesn't know anyone personally who threw in the towel altogether, but he said he's sure there were some. "Even a few thousand dollars is painful to lose," he said.

Prizio's story continues. At press time, he was at Glasair Aviation's Customer Assembly Center, working through the three-week program to build a Sportsman 2+2 that will replace his two-seat GlaStar.

Building a Glasair

Bruce Gray of Connecticut says he's "10 years into a two-year project" of building a Glasair III. He considers himself fortunate in that because he's in business himself, he saw the signs of financial difficulties two years before S-H closed its doors. Among the changes he noted were:

- The company quit publishing its newsletter and sold it.
- There were signs that indicated the company had ceased paying its vendors. Gray said he ordered an S-Tec autopilot through S-H and paid for it in cash. When he called S-Tec to see if it had shipped, it said no "because of an accounting problem," a euphemism that Gray attributed to the company not paying its bills.
- There was an unmet commitment for shipping kit components.
- Company employees started leaving; they simply weren't there when he would call.

As result, Gray started "screaming" on the Internet for builders to get their parts now if they wanted them. He put his money where his mouth was, ordering the last two kits of his project to the tune of $20,000. Gray said he got what he wanted through "perseverance and badgering," and eventually he had everything he needed to complete his plane.

He says it was a surprise when S-H closed "only in that I didn't think it would happen so soon." Gray took a novel approach to attempting to protect his investment—he gathered builders together as a group and tried to buy the company. The plan was to operate the company, fulfilling kit orders or recapitalizing and starting to sell kits. The strategy didn't work, however. While Gray says he raised pledges for about $200,000, it wasn't enough to buy the assets.

As with Sid Lloyd, Gray searched out vendors who made S-H parts and mined former employee contacts to develop a list of sources. "Some vendors would deal directly with builders, but some would not," Gray said. "They didn't want to sell in low quantities, so builders had to make their own or do without."

In one sense, the S-H bankruptcy was different from other company closures in that there was always some hope the company could be salvaged. Gray suggested that "it is hard to say what builders would have done if someone hadn't picked up the ball."

Finishing a GlaStar

Dennis Douglas of Bend, Oregon, completed his GlaStar after eight years and three months of building. He had purchased his engine in the third year, and the S-H bankruptcy occurred more or less in the middle of the project. "I had sent them $2500 for a $7500 (OEM price) Hartzell prop," he said. The propeller was close to being delivered when the bankruptcy was announced. Douglas says the GlaStar community "was flabbergasted, and there had been no discussion of pending bankruptcy in the discussion groups."

Douglas called S-H to inquire about the status of his propeller, and there was no answer. Then he called Hartzell, which had never heard of him. (S-H had probably ordered a given number of propellers with certain specifications rather than assigning a purchase order to a given builder name.) Douglas described Hartzell's response to his dilemma as "unsympathetic." Nonetheless, Hartzell called him a month later, saying it would sell him a propeller for the OEM price of $7500—with no credit for his deposit.

Although Douglas says the "street price" was about $9600, he decided not to buy the Hartzell unit "as a matter of principle." Instead, he tracked down a propeller with rebuilt blades for $5000. "I wound up net out-of-pocket at $7500, with not a new prop, but a good one," he said. All things considered, he didn't fare too badly, with a net loss of about $3000, including a spinner that he bought from a different vendor when S-H was legally prohibited from selling to builders. When the company was resurrected, he bought the spinner he wanted there.

Illustrations: Steve Karp

Like Prizio, Douglas felt fortunate in that he had everything he needed at his particular time in the build cycle. He says the GlaStar group had lots of good ideas and tips, especially about third-party items. The only problem is that "it's sometimes hard to vet the 'goodness' of the information," he said. "But after a while, you know those who really know their stuff."

Before you think we're picking on Stoddard-Hamilton with these examples, consider the scope of the situation. The company sold one of the most popular lines of aircraft in kitdom, indeed two of them between the Glasair and the GlaStar. Popularity brings exposure. And that popularity is a big part of why the company is thriving today: The designs are strong and the demand steady.

The Wheeler Express

When Bob Henderson saw the original Wheeler Express at Oshkosh in 1989, he was smitten. He visited the kit factory to see the demo plane and facilities and bought the first kit components for his plane in 1990, though he didn't start working on it until later. The kit came in parts, first the two wings, then the bottom half of the fuselage. He originally saw this as an advantage, because you could buy the kits as you could afford them and as you were ready to start working on the next stage.

The first blow to the company came when the demo plane crashed on takeoff in California. Although the occupants survived, Henderson says it was a setback. Nevertheless, in short order people volunteered to build another demonstrator, and it seemed as if the business would get back on track. Henderson says there was a lot of customer interest in the Express, and for the next year the company hung on and started building itself up. After a second crash, this one fatal, the company went into bankruptcy. Henderson said that at the time he "had great enthusiasm, but it was dampened."

The company was purchased out of bankruptcy, and Henderson ordered the empennage and the top half of the fuselage, which meant he would have all of the major aircraft components. He received those parts and worked sporadically for a while. Because he already had his parts, he didn't particularly follow what was going on at Express, although he did regularly attend the annual builders group meetings at Oshkosh. Nobody in his area was building an Express, so there was little local support. A subscription newsletter published in California was a useful source of information.

Henderson has continued work on the Express over the years with the help of a friend's father, who was an experienced hands-on guy. The two work together weekly on the plane, and as it stands now the Henderson Express "is together." The engine is installed and the panel is being assembled. Although there are lots of small things left to do such as the gas lines, instrument and throttle controls, brake lines and various fittings, Henderson is feeling good about his project. "It's an airplane now," he says.

Henderson pointed out that it was not the airplane's fault; it was just a run of bad luck at the company that made building difficult. "When the company goes bust," he said, "it's a blow to your enthusiasm, and you have to get started all over again." But now he says it really doesn't matter to him what happens with the company (which is not operating currently). "It would be nice to have factory support," he says, "but it's not required." He is plugged into some of the builders groups, particularly the Oshkosh meetings and the Express online forum, both of which are helpful. "You can put a question on the forum, and you get three or four answers," he says.

Looking back on his experience, Henderson says he would have purchased all of the components earlier if he had known there were going to be problems. He also recommended finding a good plane and a good company, although admittedly this is easier said than done. When he visited the Express facility in Washington, he says it seemed like a good facility, and there were lots of people working. "I wanted a 200-mph, fixed-gear four-place airplane," he said. "They were the only one offering such a thing back then."

Henderson recommends sticking to the project even through the rough times. "Just keep on it," he said. "If you want to do it, you're going to do it."

Express Success

Steve Bussey of Merritt Island, Florida, is flying his Express, but it's not finished. "It's never really finished," he says, laughing. He got his (fixed trigear, cruciform tail) kit from Wheeler Express, the original company, in 1989. "What I thought was nice at the time was that you didn't need all the money up front," he says. And truth be told, you couldn't have bought the kit all at once because complete kits weren't available, Bussey says.

Wheeler was developing the kits as it went along, and it was sold in five segments. Bussey says that after the demo plane crashed on the way to Oshkosh in 1990, he didn't work on his plane for a year while the crash investigation was conducted. When a second company bought the rights and started producing kits again, he didn't buy parts because he wasn't ready for them yet. But when the third company emerged, Bussey says, "I bought all the parts I could from them."

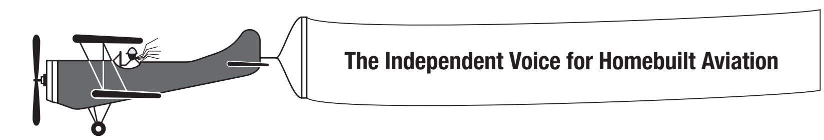
A builder newsletter kept him informed, and later a group of builders took it upon themselves to meet in New Orleans to discuss what might happen with the design. Bussey says that at that time, a number of builders thought the cruciform tail was the problem in the crash, and they requested donations from the builders group to get things rolling on development of a new tail design. He didn't contribute, but enough people did that a mold was made, and some builders bought the newly fabricated parts. The company later bought the rights to the new tail and sold a version of the kit with it until that company went out of business.

In 1998, Bussey bought the tail and upper fuselage from the newly established Express Aircraft LLC, run by Express builders Larry Olson and Paul Fagerstrom. Later, he also bought the engine cowling, wheelpants and other miscellaneous parts. At that point, he felt like he had all he needed from the company to finish the plane.

In all, Bussey endured three bankruptcies and one company closure, yet he was out less than $1000 in back-ordered parts. He first flew his plane on June 29, 2004, and when we spoke he was preparing for his first annual inspection. By way of advice, Bussey says, "Nowadays you can get a lot more support with the web. It's a lot easier to share information." But how to determine the worthiness of the information is the trick. "You have to evaluate everything," he says, "but it's a pretty high degree of being right." Bussey also offered the following advice.

•Be sure you get all the parts at the same time, even if it costs more.

•Check out the web sites and builders groups. If there aren't any, question the company.



•Find out how many aircraft have been built. You need to have some of them flying. You can be adventurous being the first, but beware.

•Get to know other builders. You can call them up and get a ride in their plane before buying your own kit.

•Figure it's going to take more time and money than the company says.

Avid Aircraft: A Management Perspective

What occurred at Avid Aircraft over the decade or so of its rise and fall is a convoluted story replete with plot turns, intrigue, subterfuge, daring rescue attempts and an ever-shifting cast of characters too numerous to mention. Steve Winder can recount it all in detail because he was present for much of it. An Avid dealer in the U.K. in the 1990s, he also handled sales operations at the U.S. headquarters in Caldwell, Idaho, during the latter part of the decade. Winder is now at Airdale LLC, purveyor of kits that he describes as "highly redesigned Avids." In that capacity he has been supplying Avid parts since even before Avid's first attempt at business failed (there have been, and will undoubtedly continue to be other attempts).

Winder recognized potential opportunity in the company's demise. With an estimated base of 1500-2000 Avid aircraft flying, Winder realized there might be a parts market, and he built the tooling to capitalize on it. In Avid's absence, there was indeed a built-in demand. The Airdale is similar enough to the Avid that the parts are transferable.

One of the main problems at Avid, as Winder sees it, was that tube-and-fabric designs are labor intensive for both the manufacturer and the builder. He says it costs $700 just to weld the kit components. The labor cost also shows up in the parts business. "It takes 12 hours to build a flaperon," he said. "In 1993, the flaperon sold for $695; now I sell it for $725. The entire kit may have cost only $10,000, so that sounds high to prospective parts buyers. But I can't produce a kit for $10,000—I wish I could."

The only way to make it on a high-labor airplane, he says, is to subcontract the labor—go where it's cheap (like overseas), which is exactly what a number of kit companies are doing for their labor-intensive assemblies these days. What Winder suggests, in essence, is that some designs, by virtue of the cost to produce them (at least here in the U.S.), may be inherently unviable in the commercial marketplace. It is tough to be profitable when the labor cost is high, and the kit price must be low enough to be competitive with other homebuilt designs of the same capability.

Avid enthusiasts have had reason to be hopeful over the years as the company has closed and then reopened. Winder explains the psychology of customer loyalty in the face of conflicting evidence to the contrary. "If people have a kit, the value of their investment takes a dive, so it's in their interest for the company to start up again," he said. "They'll think, 'Hey, I'm going to get out of this.' They're loyal to the manufacturer even if they got swindled. Their attitude is, 'It's not going to happen to me.'" Winder predicts that Avid will rise again. "What will happen next with the Avid is that someone will buy the assets again, and they'll market the kit," he says. "The people who need parts will look to the new company, for as long as it lasts."

Asked for his advice to would-be kit builders hoping to invest wisely, Winder initially came up empty. "If I say stay with a reputable company, that doesn't work," he said. However, after consideration he did offer some thoughts. "Evaluate the company and the product by the people who have the product now," he says. "So get onto a users group. There's usually no smoke without fire."

Escrow—A Solution?

Glasair builder Bruce Gray views bankruptcy as a cautionary tale. Primary among his recommendations to help builders avoid getting stung is using an escrow service for the purchase. Glasair Aviation, the current company, will do this, but it costs over and above the price of a kit. The fee is based on the escrow amount, but it probably won't be more than $400-$500, Gray says. How does it work? The buyer pays the escrow company, but the escrow company doesn't pay the kit company until the kit is shipped. You either get your kit or you get your money back.

And even if the kit company doesn't offer this service, banks typically have an escrow department. Says Gray, "If I were going to plunk down $30, $40 or $50,000 for a kit, I'd give the company a 10% deposit and put the balance in an escrow account at the bank of your choice. If the company doesn't want to do it, don't do business with them." Gray also recommended buying the whole kit at once, even though this means a larger investment up front.

GlaStar builder Dennis Douglas concurs that a lot of companies are doing business with escrow now. He also says he wouldn't make any substantial kit, airframe or engine purchase unless there is an escrow service available. "If you're buying small stuff, hundreds of dollars, escrow is probably not worth the trouble," he said. "But if you're talking thousands of dollars, that's serious money, and that's when you need it. Stoddard-Hamilton had been around in good standing for 20 years. You just never know."

Last Words

What becomes clear from talking with both buyers and purveyors of kits is that the whole proposition of making any large purchase, whether it is a house or an aircraft, is fraught with uncertainty. Furthermore, the success or failure of the purchase may have less to do with the quality of the product than how the transaction is negotiated and executed.

Few would contest the positive attributes of a Glasair, GlaStar or Avid design, yet circumstances beyond those tangible qualities are what potentially fouled their chances for success. Unfortunately, those are precisely the circumstances that may be least susceptible to public scrutiny. We have offered some warning signs to look for and some tips for protecting your investment. These, coupled with doing thorough homework, may be the best way to ensure that the dream you have in mind when buying a kit becomes the reality of flying a finished airplane. Our builders have proven that with resourcefulness and tenacity it can be done, even when conditions are less than perfect.

Jerzy Domicz' Super Pulsar 100

I finished building my Pulsar from a kit on September 27, 2002. It took me approximately 1800 hours within a year to have it completed. Its construction is compact. The cruise speed is 270 km/h (169 mph).

The Pulsar is equipped with a Continental O-200-A engine. Its maximum takeoff weight is 612 kilograms (1349 pounds). It uses a concrete runway. Flying the Pulsar is pure pleasure. It is very good to maneuver, too. All the building efforts have been a good investment. And, yes, definitely it was worth undertaking the task. If you wish to get more information, I shall be willing to share it with you. Do not hesitate to e-mail me.

Poland
office@domicz.com.pl

Bob Holliston's Kingfisher

This Kingfisher took four years to build and is my second homebuilt. I built a Long-EZ in two years and flew it 1500 hours over the next 10 years before selling it. This Kingfisher has Super Cub wings and a fiberglass-over-plywood hull. Most of the parts came from two salvaged Kingfishers, almost a kit. I built up a Lycoming O-290-G, balanced all reciprocating parts and used 7.5:1 pistons for 135 hp.

Not being much of a taildragger pilot, I could not believe my luck on October 4, 2004, when Grant Porter, local spray plane pilot, offered to do the first flight. He landed and said, "It flies fine, Bob. You won't have any trouble." I took a few deep breaths and did the second flight. He was right.

The real fun, though, is water flying. The plane is based at the Hood River Airport in Oregon, 4 miles from the Columbia River. The plane spends almost as much time step-taxiing on the river at 35 mph as it does in the air. As much fun as it is, though, I really miss having a traveling machine. My new O-360-powered Long-EZ is about two thirds done! The photo was taken by Doug Holliston, my dad.

P. O. Box 1234
White Salmon, WA 98672

Stanley H. Peterson's Fly Baby

I purchased my unfinished Fly Baby from Gary K. Ramsey on February 15, 1995. The aircraft "skeleton" included a 1940-vintage Lycoming O-145-B2. The airplane was delivered from Hunting, West Virgnia, by Gary's neighbor, Tom Larson, for $100, making my total cost upon delivery $2900.

As Tom and I off-loaded parts from his trailer, I couldn't help but query as to the age of the engine. Tom didn't know, but he was sure that the Smithsonian would be interested if I should ever want to get rid of it. In the paperwork I found that a registration number had been assigned on August 28, 1963.

With a lot of help from my friend Mike Purinton, I made the first flight September 9, 2004. Apparently taking our time paid off; the Fly Baby flew just great, and the engine purred right from the start. The first test lasted 1:05 and included three landings and airwork at 5000 feet. Testing was done from The Lone Star Executive Airport in Texas. Mike and I would be interested in any plans project that has taken longer to build than our Fly Baby. ✈

Boulder, Colorado
n727pp@aol.com

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 35-mm slides are acceptable) of the aircraft that we June keep. Please include a daytime phone number where we can contact you if necessary. Also indicate whether we June publish your address in case other builders would like to contact you. Submissions should be sent to: **Completions, c/o KITPLANES® Magazine PO Box 124, Liberty Corner, NJ 07938.** 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.

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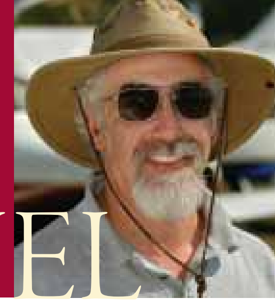


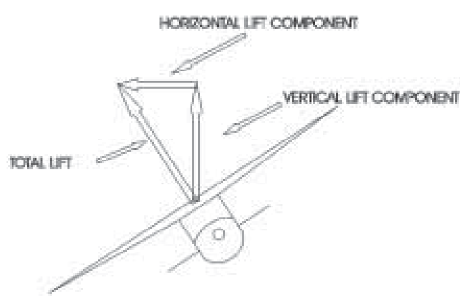
BY BARNABY WAINFAN

Back to Basics: *Understanding Stall Speed*

Keep up thine airspeed, lest the Earth rise and smite thee." Or something like that, the old pilot's adage warns. Every pilot is trained to be aware of stall speed and treat it with respect. But though it gets a good deal of attention, stall speed is still poorly understood by many pilots. Get out your No. 2 pencils—it's time for a review.

Maximum Lift

If we progressively increase the wing's angle of attack, the lift (and hence lift coefficient) will increase linearly up to a critical angle of attack where the airflow begins to separate. This flow separation reduces the lift of the stalled portion of the wing. Increasing the angle of attack further increases the extent of separated flow until at some angle of attack, increasing angle of attack can no longer increase lift. Going to still higher angle of attack causes the stall to spread so far that the lift of the wing decreases.



In a turn, part of the lift is directed horizontally by banking the airplane. The vertical component of lift supports the plane's weight.

Each wing geometry has a maximum achievable lift coefficient and an angle of attack at which it is reached. It is important to note that onset and progression of the stall are determined by angle of attack, not by airspeed. Any wing forced to an angle of attack above its stall angle of attack will stall, regardless of how fast it is flying.

How much lift (in pounds) a wing will produce is a function of three factors: wing area, lift coefficient and dynamic pressure of the airflow. The dynamic pressure is determined by the density of the air and the airspeed squared.

Stall Speed

The stall speed of an airplane is usually defined as the slowest airspeed at which the wing can generate enough lift to carry the airplane's gross weight at sea level, standard day atmospheric conditions. At the stall speed, the wing is flying at the angle of attack to develop its maximum lift coefficient.

If the pilot attempts to reduce airspeed, the dynamic pressure will drop, and the wing will need to develop a higher lift coefficient to hold the airplane up. Because the wing is already flying at its maximum lift coefficient, any attempt to increase lift by increasing angle of attack will cause the airplane to stall. It is important to note that this speed only applies to an airplane flying at 1G at gross weight.

To get a reasonably accurate determination of stall speed via flight testing, the airplane must approach the stall power off in as nearly a steady-state, 1G condition as possible. The standard method defined by the FAA is to decrease airspeed by 1 knot per second until the airplane stalls. The goal is to keep the airplane flying at a load factor of 1 and increase angle of attack slowly until the angle of attack for maximum lift is reached. Ideally, the pitch rate will be low enough that the pilot will feel the stall just as the airplane reaches this angle of attack.

More abrupt stall entries will definitely stall the airplane, but it is likely that the load factor will not be 1. Either the airplane will be in a pull-up at more than 1G, or in a nose-high deceleration at less than 1G.

Factors Determining Stall Speed

At sea level, standard day conditions, the stall speed of an airplane is given by:

V_{STALL} (knots) = 17.194 times the square root of {(N x (W/S) x (1/CL_{MAX})}

Where:

N = load factor in Gs,

W/S = wing loading in pounds per square foot,

CL_{MAX} = maximum lift coefficient of the wing.

Stall speed goes up as wing loading increases and down as the maximum lift coefficient of the wing increases. Wing loading is determined by gross weight and wing area. CL_{MAX} is a function of the wing airfoil, and the high-lift system (flaps and leading edge devices), if any.

The other important parameter is load factor, which is the number of Gs the airplane is pulling. What pilots usually know as "stall speed" is actually the 1G level flight stall speed. As load factor increases in a turn or a pull-up, the stall speed also increases.

Barnaby Wainfan's day job is in aerodynamic design for Northrop Grumman, where he serves as Technical Fellow for Aerodynamics Design and Analysis. 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.

Illustration: Barnaby Wainfan

Turns

The velocity of an object is a vector quantity—it has both a magnitude and a direction. Acceleration is a change in velocity and can be a change in *either* the direction or the magnitude of the velocity, or both. A turning airplane is continuously accelerating toward the center of the turn even though its speed, which is the magnitude of the velocity, is constant. Newton tells us that a force must act on a mass to cause acceleration. In the case of a turning airplane, this force is the lift of the wings. The pilot causes some of the lift to act horizontally by banking the airplane. This horizontal component of the lift curves the flight path in the direction of the bank.

While the horizontal component of the lift of a banking airplane is curving the flight path, the vertical component is still holding the airplane up against gravity. In a level turn, the vertical lift component must equal the weight of the airplane. The total lift required to perform the turn is the vector sum of the horizontal and vertical lift components. Accordingly, the total lift in any level turn is greater than the weight of the airplane. As bank angle increases, the horizontal component of lift gets larger in relation to the vertical component. Because the vertical lift component is constant, the total lift required increases with increasing bank angle.

The load factor, or G load, of the airplane is the total lift divided by the weight of the airplane, expressed in units of gravity or "Gs." In a constant-altitude turn, the load factor is given by:

N = 1/(cosine(bank angle))

Where:

N = load factor in Gs.

The table shows the influence of bank angle on the load factor required to maintain a level turn and the effect of that load factor on stall speed. Note that as bank angle increases, the rate of load factor and stall speed increase. Going from zero bank to 10° only increases load factor by 0.015G and stall speed by 1%. Adding 10° of bank to go from 70° to 80° increases load factor by 2.84G and stall speed by 70%.

This phenomenon is a key ingredient in the classic stall/spin on base-to-final turn scenario. In order to increase load factor, the lift generated by the wing must increase. The pilot does this by pulling back on the stick and increasing the angle of attack of the airplane. As we have just seen, the amount of extra lift required by a given bank angle increase is much larger if the airplane is already in a steep bank than it would be in a more gentle turn. This may catch the pilot by surprise if he is used to shallower turns. At the low airspeed typical in the pattern, the wing can't develop enough lift to maintain the required load factor and will stall as the pilot attempts to increase lift by pulling.

Minimum Controllable Airspeed

In general, the 1G stall speed sets the lower limit on how slow the airplane can fly. Sometimes other effects limit the minimum speed to a somewhat higher value.

As we have seen, the stall speed is set by the limits of the wing's ability to generate lift. In order to use that lift, however, the pilot must be able to trim the airplane to the maximum lift angle of attack and keep the airplane under control. On some airplanes, this might not be possible.

Some airplane configurations generate large rolling or yawing moments at a high angle of attack. If the stall starts outboard on the wing, the airplane may tend to roll off approaching the stall, even before maximum lift has been reached. If this roll-off is too severe, it might become necessary to limit the minimum airspeed to the airspeed at which the roll-off starts rather than the true stall speed.

Effect of Bank Angle on Load Factor

Bank Angle	Load Factor	Stall Speed Increase
10	1.015	1%
20	1.064	3%
30	1.150	7%
40	1.305	14%
50	1.556	25%
60	2.000	41%
70	2.924	71%
80	5.760	140%

Power effects can also define a minimum controllable airspeed. Multi-engine airplanes with wing-mounted engines have a minimum control speed (VMC), which is the slowest speed at which the rudder has enough control power to keep the airplane flying straight with one engine inoperative. On many light twins, VMC is significantly faster than the power-off stall speed of the airplane. It is possible to fly the airplane below VMC, but the pilot must take prompt action to reduce power on the good engine in order to maintain control if one engine fails. Until airspeed gets above VMC, the majority of the power of the good engine is unavailable to the pilot because it can't be used without losing control of the airplane.

Some high-power singles have a similar problem. At full power, the ailerons and rudder cannot control the torque and P-factor of the engine below a certain airspeed. For most light airplanes, this "minimum control airspeed" is below the 1G stall, but if the engine gets powerful enough, this can change. Controlling torque was a problem on many WW-II fighters. On a missed approach, the pilot had to advance the power slowly and let airspeed increase before going to full power. Applying full power suddenly at approach speed would cause the airplane to roll uncontrollably.

When homebuilders first started putting turbines in kits intended for piston engines, there were some accidents caused by this effect. The rudders of the kit airplanes were sized to match the power of the original engine. In some cases, the turbine could as much as double the power, and the airframe did not have enough control power to deal with the increased torque and P-factor at low airspeed. ✈

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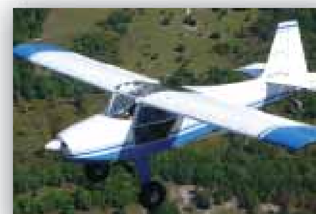

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ENGINE BEAT

BY TIM KERN

If it *ain't* broke (in)...

Engine break-in is one of those subjects easy to misunderstand. Some believe it only applies to new engines that have never experienced the joys of internal combustion. Not quite: Any engine just through certain kinds of repair or overhaul needs a proper break-in period, even if some of the components are, shall we say, experienced. You can consider as ready for break-in any assembly that has new components, as is typical with a top-end rebuild, a cylinder replacement or new bearings—however, the items we're most concerned about, that require the most careful break-in, are the cylinders.

Industry practice with a complete engine (whether rebuilt or newly manufactured) includes a runup at the builder's site. The time and intensity of such runups varies by the house. Sometimes, they are just a few minutes of full-throttle time behind a high-load propeller called a club. Other builders put each new engine through an hour or more of comprehensive testing at various loads using a dynamometer. As with anything, knowledge and skill can often trump the equipment; a careful run on an outdoor test apparatus behind a prop can be just as worthwhile as a less careful sprint on the dyno. That's another way of saying that a dyno run might be preferable from a scientific standpoint but it isn't the only way to initially run-in your engine.

You're starting from scratch, so what do you do?

Never, though, should you consider an engine thoroughly "broken in" when you receive it from the builder. There's still much for you to do.

Whom Do You Believe?

All engine manufacturers have recommended break-in procedures with some common threads. Nevertheless, don't assume that your engine company or builder wrote these procedures just to make itself feel good or to frustrate you. If you receive them, follow the specific directions that come with your engine. There are a few general truths in all new installations, summarized here, and if you have built or rebuilt your own (four-stroke) engine and you don't have manufacturer's guidelines, here is a summary of what experts have recommended.

Tim Kern's start in homebuilding came early, as he helped his dad build Luscombes and a wood glider as a kid. Since then, he's been involved in building three homebuilts: a Preceptor Pup, a Range Rider and a Baby Lakes. From a professional background in motorcycles and auto racing, Tim began his aviation career at Mosler Engines in 1990. Visit his web site at www.timkern.com.

Laying the Groundwork

You shouldn't start any engine break-in process without first determining if your instrumentation is in good condition—accurate, reliable, readable. Check new engine instruments as you install them and again before you run your new engine, to be sure they are working. (All-electronic gauges may require the manufacturer's manual to get them dialed in; "steam gauges" usually respond to shop air pressure or a pot of boiling water—depending on the gauge!) We know of one instance where a builder thought the engine was experiencing excessive oil temperature only for it to be a gauge error. He could have saved himself a lot of grief had he calibrated the gauge beforehand.

The Engine Installation

Unpack and mount the engine carefully, making sure that all external lines are properly hooked up. (It is not uncommon to see Rotax 912/914 series oil or water lines incorrectly plumbed.) Follow the engine manual carefully and double check that the oil and fuel lines are terminated and routed correctly.

If you have a dry-sump system, double-check your remote sump's placement and orientation, as well as its relation to the engine. (Sometimes, particularly with taildraggers, the sump can be too low or too high, depending on whether all the wheels are on the ground or not.) An improperly placed sump can mask—or seemingly create—oil-consumption issues.

Double-check fuel delivery. It is possible, with some tricycle-gear and many taildraggers, for a partially full tank to deliver exactly no fuel to the gas line in a steep takeoff position. If you have a header tank, make sure it is vented or plumbed so that it fills correctly, in all anticipated flight modes. Test flow the system before the first flight on your new or overhauled engine; be sure you have sufficient flow for takeoff power. Advisory Circular 90-89 recommends that gravity-flow systems have a maximum flow rate 150% of the engine's needs; it's 125% for pressurized (equipped with a fuel pump) systems. A quick way of determining your engine's needs is to take the horsepower and multiply it by 0.55 to get max-power fuel flow in pounds per hour. Divide by 6—OK, you can divide by 5.85 if you're really anal—to get flow in gallons per hour.

Make sure the installation is potential-trouble-free, with no loose things around the engine, with nothing rubbing or potentially rubbing. Double-check your baffling and ductwork, and go over all gap seals.

What About the Fluids?

Check—and, for that matter, double-check—all fluids. For most new-engine break-ins, manufacturers recommend a "straight" oil, which will be drained after the first 10 or 25 hours and then be replaced with the oil you'll use regularly. (Straight or mineral oil has none of the antiwear additives found in regular AD—for Ashless Dispersant—oil, which helps promote quicker ring break in, among other things.)

If your engine has water cooling, be sure to use the recommended anti-freeze, at the recommended strength. Though pure water is a better heat sink than an anti-freeze mix, water alone doesn't have the lubrication and anti-corrosion additives that anti-freeze contains; and water can freeze, too.

Many engine and propeller makers recommend a particular orientation of the prop. Be sure its blades are in the right orientation and that it is properly mounted and torqued. Safety wire the prop bolts/nuts, even if you're planning on just ground running.

Speaking of ground running, it's not a good substitute for flying. Ground running introduces high thermal stresses, as the high-speed air of flight never passes through the system. On taildraggers, the nose-high attitude may also play tricks on your engine sump, dry sump oil level, or water and fuel systems. So, do as little ground running as is necessary to determine the engine's—and airplane's—suitability for flight.

Pre Oiling

Before you start the engine, pull one plug from each cylinder and turn the engine over by hand, until oil pressure comes up on the gauge. This may take a while, but it ensures that you don't run the engine dry before the system's oil has a chance to get everywhere it belongs. Of course, once you've done all this, you'll run the engine, checking for leaks, vibrations, funny smells, exhaust (and external) smoke, etc. Let the engine cool off as you check everything, from the engine mounts to the spinner.

On to the Break-In Procedure

Andy Silvester, manning the Jabiru booth at the Sebring show in June, noted that his engines are run "approximately 45 minutes" before shipping, "to check for oil pressure and temperature, and to be sure there are no leaks." He said that the engine is "force-fed oil" before it is started, so that all surfaces are lubricated before the spark is turned on. He emphasized that the engines are "run, not run-in."

When you've received your Jabiru, he recommends: "Fly the airplane at various power settings, as you would flying around the pattern." This gives the engine exercise in a controlled environment. Watch your gauges, and, Silvester said, "As long as you keep it within the temperature limits, there isn't a whole lot that will hurt it."

That's fine for the Jabiru but if you're running a more traditional big-inch Continental or Lycoming, you're advised to make the first flight (either ever or with the newly overhauled components) with maximum power, with one eye on the runway and the other on the critical engine temperatures and pressures. Don't baby the engine. Lycoming, for example, recommends the first takeoff use full power according to the airframe specification and reducing to climb power when appropriate. (Not much help, is it?) Most engine builders say to keep rpm up and climb at full throttle for a non-turbocharged engine. Using all the manifold pressure available helps keep cylinder pressures high, which encourages ring seating.

Use the manufacturer's recommended break-in oil only until the rings are seated. This is often determined by a dramatic reduction in (blue) smoking from the exhaust—if there was any at all—or stabilization of oil consumption.

Climb at a shallower-than-normal angle to maximize engine cooling. All of the cylinders in a new engine and the recently overhauled cylinder among your experienced set will run hot for the first hour at least. This is normal. So is higher-than-expected oil temperature. A new engine's internal friction is very high, which creates all this heat. Your job during the break-in process is to keep these temperatures as moderate as you can—fly a flat climb and keep the fuel flow up where it can do some good—and watch for any big anomalies. Throughout the initial flights, temperatures should start coming down and the oil pressure should remain steady.

Further Noteworthy Items

Fly near airports, and vary your power settings. Lycoming says to alternate between 75% and 65% in the second hour. After the first flight, and at the recommended intervals thereafter, check the torque on your prop bolts. Fully uncowl the engine after the first and second flights to check for leaks, loose items and general mayhem.

Use the manufacturer's recommended break-in oil only until the rings are well seated. This is often determined by a dramatic reduction in (blue) smoking from the exhaust—if there was any at all—or stabilization of oil consumption.

Photo: Marc Cook

(Remember that many engines "blow out" the top quart of oil, so take that into account.) Two characteristics normally identify the end of break-in: oil consumption and a reduction in CHTs. They usually come together.

Check with your engine shop or overhauler to find out when you can switch from mineral oil. Some will say wait for the factory-recommended 50 hours, some will say sooner. Still others will allow a change to a non-synthetic AD oil early but insist on waiting to put synthetic until 25 or 50 hours have been accumulated. When pleading your case, cite the engine's current oil consumption rate and relative CHTs.

Change your oil and filter often. I have never seen an engine that was damaged by too-frequent oil changes. Changing the oil after the first ground run-up is not indicative of any mental disorder on your part—that's when the largest amount of foreign debris, shavings, manufacturing leftovers, and initial wear will be in your oil. You might as well remove it sooner, rather than later.

The first time, and every time you change oil filters, cut the filter open and check its contents. If you see anything metal, try to determine its origin. General guidelines: Bearings often leave copper or yellow-colored fine powder; pistons may leave dull grey powder; steel and iron shavings may be shiny (or worse, blue). Any items larger than powder should attract your attention.

Every time you fly, and particularly early in your engine's life, note the conditions (OAT, power setting, climb rate and time in climb, cruise speed or setting, prop setting, mixture) and all instrument readings (oil pressure and temp, water temp if any, CHTs, EGTs).

Anything that changes quickly without explanation or anything that appears not to make sense should precipitate a return to the airport and further investigation. Appreciate the normal operating ranges of your engine so that when anything is abnormal, you'll know, in time to make the right decision. ✢

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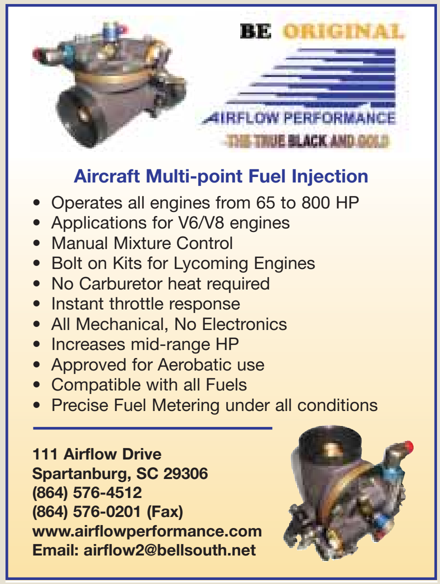
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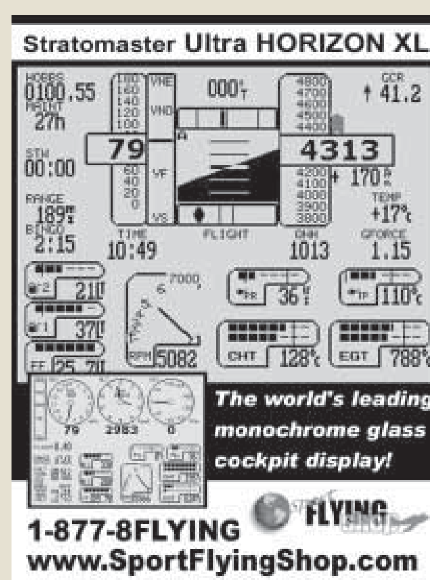
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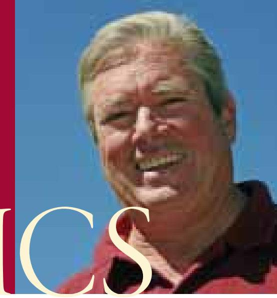


BY JIM WEIR

A switch in time saves *the design*.

Last month, we visited the wonderful world of 24-12 volt converters and found that a linear regulator is quite easy to make but that heat and efficiency are our enemies. This month, we'll see what we can do about that heating problem by means of a switching regulator.

Turn the Heat Off, Please

Switching regulators get their efficiency by not wasting heat in the regulating element. If you recall from last month's article, the pass transistor was used to drop the voltage from 24 to 12 volts, which means that the pass transistor always had voltage across it and current through it simultaneously. A quick reference to Brother Ohm tells us that in a 3-amp regulator, 36 watts of power flows to the load and 36 watts gets dissipated as heat in the regulator. We tried getting around having the pass transistor dissipate all that power by means of a power resistor in series, but all that did was transfer the problem of getting the heat out of the transistor to getting the heat out of the resistor.

The switching regulator, on the other hand, has the pass transistor either full "on" (0 volts at maximum current) or full "off" (maximum voltage at zero current) and theoretically wastes zero power in doing its job. In a practical sense, switching regulators can easily achieve 80% efficiency for any input/output voltage combination. It is by varying the "duty cycle" (the ratio of on to off) that we can regulate the output voltage.

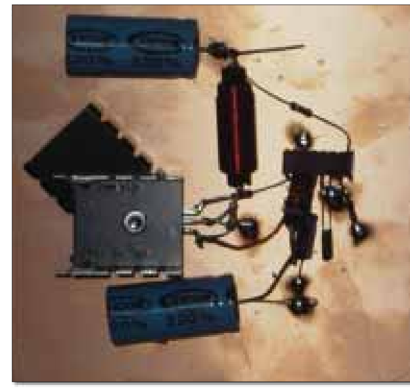
It's Not Perfect, However…

Lest you think that the switching regulator is a panacea for all the ills that befall a voltage regulator, be aware of the following downsides as you plan the use for your switcher:

First, a switching regulator is much noisier than a linear regulator. Some sort of shielded box will generally be necessary to keep all the burps and gleeps from that sharp switching transient from getting into the aircraft radios. To understand what I mean, look at the power supply in your computer. In order to become FCC approved for a *household* environment, the power supply manufacturer had to completely enclose the switching computer supply into a fully shielded metal box with tiny ventilation holes. And aircraft susceptibility to noise is much greater than the household environment, of course.

Second, a moderately expensive (a couple of bucks or so) inductor and a moderately fast "catch" diode are necessary as is a good quality low-impedance filter capacitor. While the cost of switcher parts is fairly close to the linear design, the advantage of not having to heat sink the switcher to the center of the earth overcomes any parts cost disadvantage. Where a switcher *really* shines is for moderate current (1- to 3-amp) supplies where heat is a real problem in the linear regulator.

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, Jim has owned and restored four single-engine Cessnas. These days, he runs RST Engineering and teaches electronics at Sierra College. Ask him questions at rec.aviation.homebuilt or visit his site at www.rst-engr.com/kitplanes.



The large black squares at left are the heat sinks for the pass transistor (top) and catch diode (bottom). The blue cylinders (top and bottom) are the output filter capacitor and input smoothing capacitor, respectively. The copper cylinder going vertically from the pass transistor to the output filter capacitor is the inductor. The smaller copper cylinder to the inductor's right is the short-circuit current limit set resistor (6 inches of #30 wire wound on a resistor form).

Finally, the parts volume for a switcher is marginally larger than a linear regulator for low currents (below half an amp or so) but becomes much better for the moderate current design.

Choose Your Current

Let me, then, give you two designs. One will give you half an ampere or less, and the second will give you up to 3 amps. If you want some other current or some other voltage input/output combination, I refer you to On Semiconductor applications note AN920D, which is available at www.onsemi.com/pub/Collateral/AN920-D.PDF. Caution for those of you still on dial-up—this is a 42-page PDF file.

Some notes on the low-current design: You can use the MC34063 or uA78S40 integrated circuit interchangeably in this design (and, in general, for *all* designs, both low and moderate current). The only difference between the two (besides physical size) is that the 78S40 has a

Photo and Illustrations: Jim Weir

built-in catch diode (good) of rather poor quality (bad), so you wind up buying a fast diode anyway.

For currents up to about 0.75 amps, you can use the built-in switching transistors of the IC. The measured efficiency of this design was right at 90% for a 28-volt input and 13.5-volt output. Short circuit current (set by the 0.25-ohm resistor between pins 6 and 7 of the IC) was about 1.5 amps with the output voltage going to 0 at this point. If you like, you can limit the current to about three quarters of an amp by increasing the short circuit adjustment to a single 0.5-ohm resistor.

Some notes on the high-current design: Again, the 34063 and 78S40 are interchangeable. Use whichever one is on the shelf. However, now the catch diode is going to have to take up to 3 amps of current and will wind up dissipating about 2 watts. Likewise, the series-pass Darlington transistor will wind up at the 3-watt level. In both cases they will need a small heat sink as shown in the photograph. It is certainly possible to use the metal chassis (case) as the heat sink, but use the electronic thermometer (coming in this space two months from now) to measure the package temperature of both diode and transistor under load. The inductor will not require thermal sinking, but it will require a core capable of handling the 3 amps of current without saturating.

The output capacitor is going to have to take a goodly amount of ripple current and has been specified as a "low-impedance" style capacitor. Wind 6 inches of #30 wire on a resistor form for the 0.02-ohm short circuit current resistor. Measured efficiency is right at 78%.

0.5-Ampere Design		3-Ampere Design	
Reference	*Mouser P/N*	*Reference*	*Mouser P/N*
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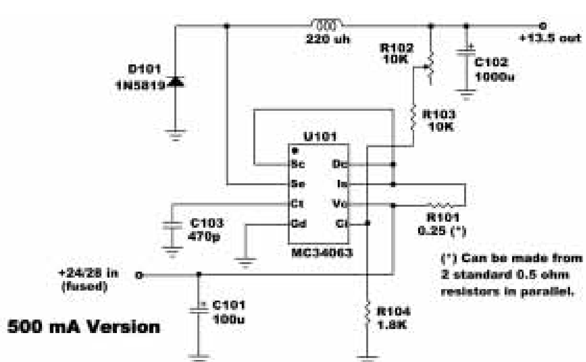
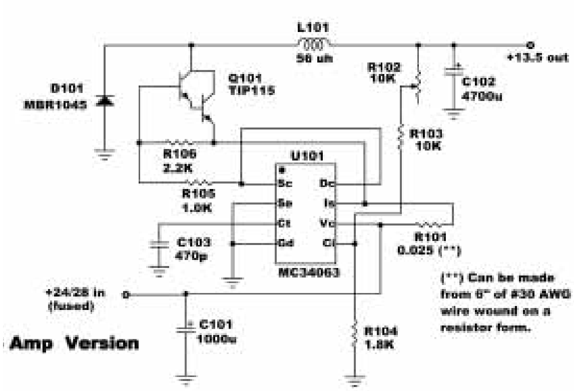
C102	647-UPW1C102MPD ($0.77)	C102	647-UPW1C472MHD ($1.82)
		Q101*	512-TIP115 ($0.25)
*Plus a small heat sink. See May 2006 column for typical part numbers.			

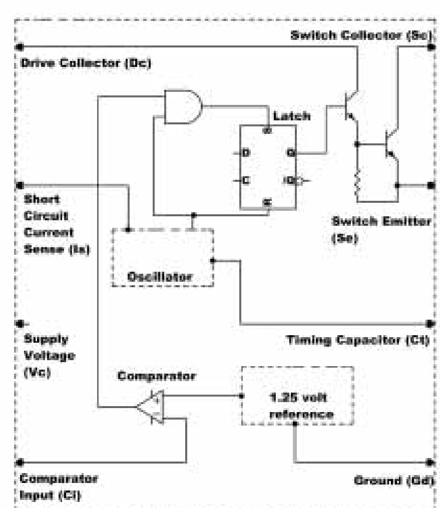
The Parts

Table 1 shows the critical parts and the Mouser part number. Those of you using Digi-Key or some other supplier can cross the Mouser part to your supplier.

Next month we'll do the 12-24 volt boost regulator and then the following month a digital thermometer to measure case temperatures of our power supplies plus a really neat method of making project PC boards at home using fish tank etchers, drug store chemistry and no photography. ✈







MC 34063
Functional Block Diagram

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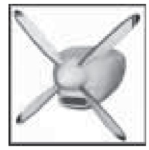

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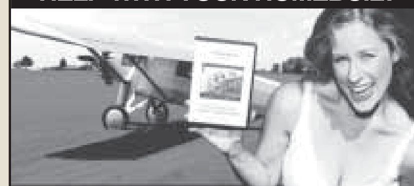

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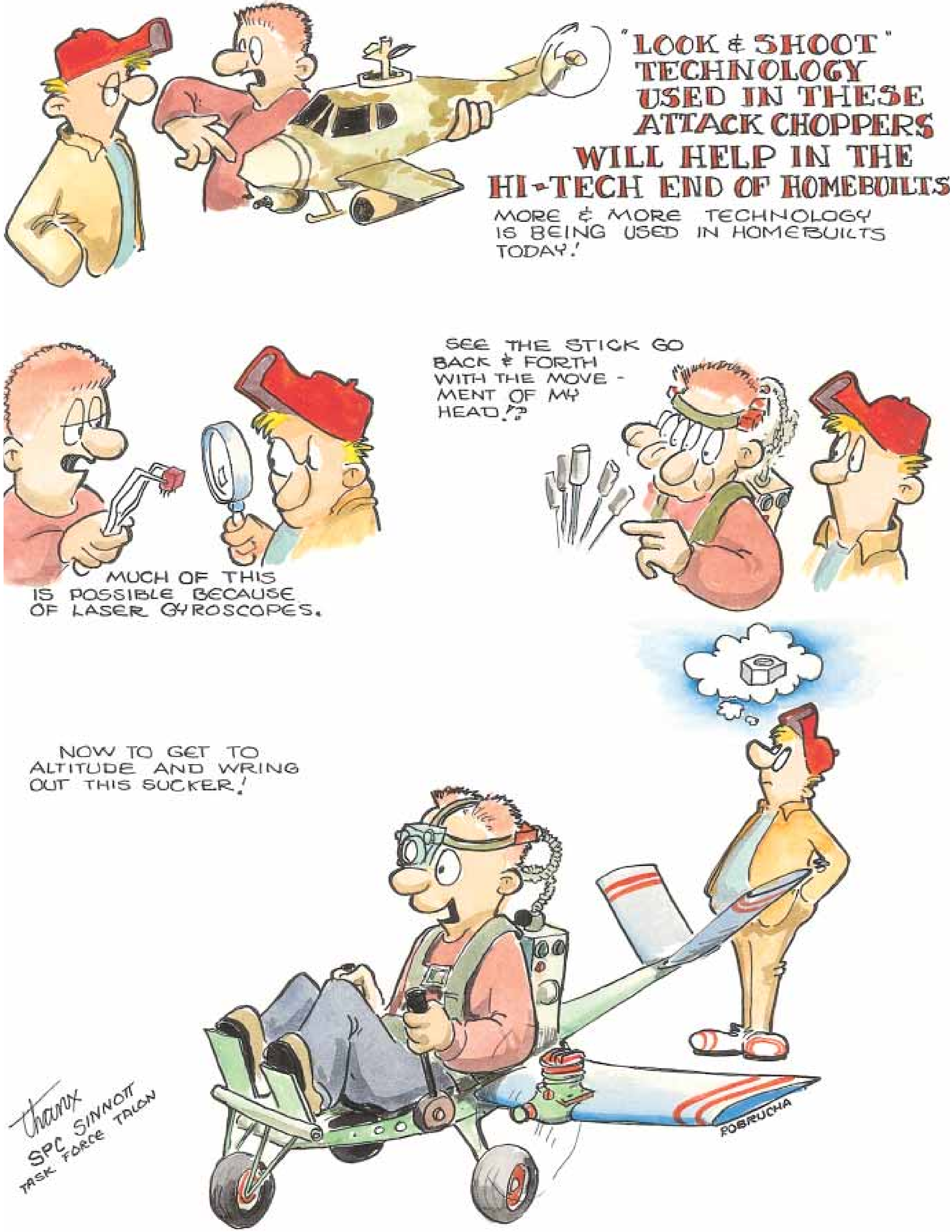

"LOOK & SHOOT" TECHNOLOGY USED IN THESE ATTACK CHOPPERS WILL HELP IN THE HI-TECH END OF HOMEBUILTS
MORE & MORE TECHNOLOGY IS BEING USED IN HOMEBUILTS TODAY!
MUCH OF THIS IS POSSIBLE BECAUSE OF LASER GYROSCOPES.
SEE THE STICK GO BACK & FORTH WITH THE MOVE-MENT OF MY HEAD!?
NOW TO GET TO ALTITUDE AND WRING OUT THIS SUCKER!
thanx SPC SINNOTT TASK FORCE TALON
ROBRUCHA