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KITPLANES
THE INDEPENDENT VOICE FOR HOMEBUILT AVIATION


On the cover: Richard VanderMeulen photographed the ViperJet MKII at company headquarters in Pasco, Washington.

# Stop over-thinking power management.

**Maybe I'm just simple.** But while I love high technology and would be a great candidate for testing something like the Precision Eagle EMS featured in this issue—I'm not hinting, just *saying*—some part of me keeps coming around to this thought: We're way too worried about engine management.

How do I know? I field questions every day on the computer and out at the hangar from pilots wanting to know the best way to run an engine. I hear from engine shops that the same questions are shot their way. This topic is as common as "What's the best primer?" on many online bulletin boards.

Let's not make it difficult. A normally aspirated—that is, not turbo- or supercharged—flat engine's performance is only "critical" in a small part of its operating envelope. It's during takeoff and the initial climb, when power output is high and cooling airflow limited, that you must pay it close attention. Fuel flow is crucial. My IO-390 is set up a tad on the rich side, burning nearly 20 gph on takeoff. A conservative max fuel flow is around 0.55 pounds per hour of fuel per horsepower. A figure of 0.5 is normally best power.

Proper high-power fuel rates slow the combustion event and help moderate cylinder-head temperatures (CHT), and both results help increase the engine's detonation margin. (This assumes fixed-timing mags or electronic ignition that runs at the specified advance during high power; anything else, and you're the test pilot.) So if it's assumed that takeoff is full rich at sea-level airports, what do you do in the climb? It really depends on the engine, but once airborne, I let CHT be my guide. From experience, I know that I can manually lean to a target average EGT of 1300° F, and the engine will stay cool unless I'm climbing slowly or it's been heat-soaked before departure. My Dynon EMS-D120 is set to give a warning


The dreaded big red knob gives plenty of pilots fits. Enough, already!

at 380° CHT, and I insist on keeping all heads below 390°. The EGT bars can be color coded, too, and I have them set to turn from yellow to green at 1300°. One glance at the monitor, and if everything is green during the climb, the engine is happy. If I see yellow bars, I know to lean slightly as the climb progresses. If I see a yellow CHT block, I've leaned too far. Simple as that.

In cruise, it's easy. Prop stays at 2500, where it's been since passing 1000 feet AGL, and throttle wide open, where it's been since the start of the takeoff roll. That leaves the mixture: Below 8000 feet MSL, it's lean of peak EGT to a target fuel flow of 9.5 gph. The beauty is that at low altitudes where full-throttle/2500 rpm is a lot of power, that fuel flow takes the engine quite lean of peak, broadening the detonation margin; at higher altitudes, that fuel flow is closer to peak, but I don't care because the power output has diminished. Above 8000 feet, it almost doesn't matter—the amount of fuel being consumed only controls speed. On descent, it's throttle as necessary for speed and change the mixture back to near peak EGT, which I do once at the top of the descent and once or twice through to landing; going to a richer mixture in the descent produces more power, sure, but it also moderates CHT cooldown, which is more significant to me.

The important thing is that if I get busy flying the airplane, I don't worry about the engine. At cruise-and-lower power, it won't hurt itself while I sort out my new IFR clearance or find the airport.

## The Starks Reality

Dick Starks' new book, a collection of essays, some of which have been published on our pages, is finally out. *Fokkers at Six O'clock* can be found at *Amazon.com* or ordered directly from the author at *www.kcdawnpatrol.com*. I have a copy on my desk, and use it often when this job seems too much like work. In fact, Dick's storytelling is such a good stress reliever it should require a prescription. ✈

Marc Cook *has been in aviation journalism for 20 years and in magazine work for more than 25. He is a 4000-hour instrument-rated, multi-engine pilot with experience in nearly 150 types. He's completed two kit aircraft, an Aero Designs Pulsar XP and a Glastar Sportsman 2+2.*

 *Photo: Marc Cook*

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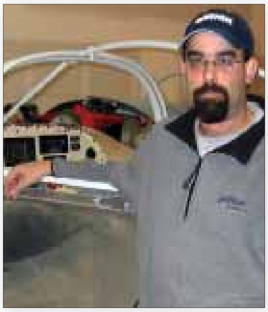

**STEIN BRUCH**

Minnesota-based Stein Bruch, who no doubt is hunkering down for the last six months of winter right about now, returns to our pages with an engine monitoring roundup. Stein is in a unique position of running a successful avionics shop that caters to the Experimental crowd. As such, he's seen, installed, trouble-shot and fixed just about everything on the market. In other words, he knows what he's talking about. The engine monitor article begins on Page 17.

**DOUG ROZENDAAL**

Santa came early for Doug this year. Knowing that the ViperJet had gone through an extensive restoration, we wanted another crack at it. (The last report was three years ago.) Doug, who packs a lot of high-performance and turbine time in his logbook, was the natural choice for the assignment, so he spent a few days in November of last year in Pasco, Washington, shamelessly squeezing his adrenal gland. His report on the ViperJet begins on Page 8.

**KEN SCOTT**

This month we wrap up the four-part miniseries—not as long and involved as, say, *Roots*, but we were beginning to wonder—on the KK-1 one-off homebuilt. When all is said and done, Ken and building partner Ken Krueger achieved what they set out to: create a light, strong, inexpensive airplane that didn't sacrifice handling qualities to get there. Ken's wrap-up story begins on Page 38.


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EDITORIAL

**Editor-in-Chief** Marc Cook
editorial@kitplanes.com
**Managing Editor** Mary Bernard
**Art Director** Suzanne Stackle
**Senior Editor** Bob Fritz
**Contributing Editors** Chuck Berthe, Stein Bruch, Cory Emberson, Geoffrey Jones, Ed Kolano, Amy Laboda, Howard Levy, Rick Lindstrom, Dave Martin, Dave Prizio Dick Starks, Barnaby Wainfan, Jim Weir, Ed Wischmeyer
**Webmaster/Data Manager** Julia Downie
**Cartoonist** Robrucha

ADVERTISING

**Publisher/Ad Director** Cindy Pedersen
cindy@kitplanes.com
**Sr. Advertising Manager** Chuck Preston
chuck@kitplanes.com

BUSINESS OFFICE

531 Encinitas Blvd., Suite 105, Encinitas, CA 92024
Main Number: 760/436-4747, Fax 760/436-4644
Editorial: 562/608-8251, Fax 562/372-3288

PRODUCTION & CLASSIFIED ADVERTISING

**Production Manager** Marsha Blessing
717/731-1405 ads@kitplanes.com
**Classified Advertising** Allyson Patton
717/982-0744 ads@kitplanes.com

CIRCULATION

**Circulation Director** Lisa Evans
**Circulation Manager** Laura McMann

SUBSCRIPTION DEPARTMENT

800/622-1065; 386/447-6318
www.kitplanes.com/cs
Box 420235, Palm Coast, FL 32142-0235
For Canada: Box 7820 STN Main, London, ON N5Y5W1

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# LETTERS

EDITORIAL@KITPLANES.COM OR KITPLANES@MAC.COM

## Hummel We Go Along

I just received the January 2009, KITPLANES® and was surprised to see that Hummel Aviation was not included in the Plansbuilt Buyer's Guide. All three designs should have been there based on the information you requested and we submitted. I am certain this is a huge project each year, and mistakes happen. Please let me know what happened if possible. I expect a call from the designer, Mr. Hummel, any minute.

**TERRY HALLETT**
**HUMMEL AVIATION**

*We'll take this opportunity to remind everyone that we segregate our buyer's guides into kits, plans, rotorcraft and engines. A good many kitbuilt designs are also available for plansbuilders, and rather than double up on the entries, we simply note which aircraft can be built from plans in the December Kit Aircraft Buyer's Guide. We hope Mr. Hummel goes easy on you.—Ed.*

## Where Did He Go?

Please tell me the crybabies didn't get Dan Checkoway fired and "Dan's World" trashed. He was a breath of fresh air!

**ROB SIMMONS**

*No, not at all. In fact, Dan asked for a rest from the column as he made some major life changes, and we were happy to give him the space. He's welcome back when he can find the time.—Ed.*

## Foiled Again

The article "Wag-Aero Sport Trainer" in the January 2009 issue stated, "Yes, it's a J-3 at the core. Overall dimensions, airfoil choice, basic materials and concepts all closely follow the J-3 blueprint. That flat-bottomed, USA-1 airfoil wing..." Congratulations—you didn't make the common error of naming the Clark Y as the airfoil used on the J-3! Unfortunately, naming the USA 1 is a far greater error. The USA 1 has a prominent undercamber, whereas the airfoil on the J-3 has a barely noticeable undercamber (but enough to prove that it's not a Clark Y, which is perfectly flat over the last 70% of the bottom). I won't hold you in suspense any longer: The J-3 used the USA 35B.

**WILLIAM H. FRANK**

*We'll say this about that: D'oh!—Ed.*

## Home Machinist Question

I have a Shoptask drill mill lathe. I am wondering where you got the compound slide and quick change tool post that I saw in the magazine? My compound slide is mounted on the side of my tool post, but I would like to set it up like yours, where the tool post is mounted on top of the slide.

**FRANK STRASSER**

*Bob Fritz replies: "That tool post you see is from Enco* (www.buyenco.com). *I just looked there to get the part number, but the site was down. Just search for tool posts; it was about $100. There are two versions, and either would work."*

## Stein Survives

I just received my January issue and didn't find the section "All About Avionics" by Stein Bruch. Have you dropped that section? I found it very interesting and helpful and would like to see more from him.

**BUD SHAFFER**

*Not to worry. We put Stein on a short sabbatical while we worked through the largest of our buyer's guides for the year. He's back this month with a feature on engine monitors, and we'll have him regularly the rest of the year.*

## Our Crazy Email System

*It's come to our attention that our company email system has become a tad overzealous in filtering out genuine reader feedback from the hundreds of get-rich-quick schemes and physical enhancement offers we receive every day. If you feel like you haven't been getting through, try us again at* kitplanes@mac.com.*—Ed.* ✛


It's a Cub, it's not a Cub. It's a Clark Y (ah, no, it isn't), it's a USA 1 (no, not that, either), it's a USA 35B. Now we've got it. Phew.


## PERSONALIZED WHEEL CHOCKS

If you're looking for the perfect accessory for an aviation enthusiast, consider Thunderbird Aviation's personalized wheel chocks and flight bag. The wheel chocks come in four different colors—red, blue, black and silver—and are personalized with the aircraft's N number CNC engraved on them. The chocks are made of aircraft-grade aluminum with an anodized finish, which makes them both light and durable. They come with a black carrying case that is also personalized with the plane's N number. Also available is a flight bag that can be personalized with an N number for no additional charge.

The wheel chocks and carrying bag are $49.95, and the flight bag is $19.95. For more information, contact Thunderbird at 586/468-8444 or visit *www.hiperlightaircraft.com*. Find a direct link at *www.kitplanes.com*.

## Spruce Offers Web-Based Panel Planner

Aircraft Spruce & Specialty has introduced the Aircraft Spruce Panel Builder, an online tool that allows builders to plan their panel from a single source. Using drop-down menus, builders can search Aircraft Spruce's inventory of avionics and instruments by category. The Panel Builder will display everything needed to complete a panel, whether the builder intends to build it or have Aircraft Spruce produce one that's ready to install. Panel Builder will readily provide quotations on any variations in the panel that the builder wishes to consider, and then avionics specialists will work with the builder to finalize the layout, provide a final quote and estimate production time.

For more information or to access the Panel Builder, call 1-877-SPRUCE or visit *www.aircraftspruce.com*. Find a direct link at *www.kitplanes.com*.

## Flexible TIG Welding Kits

Weldcraft has announced its new AK-150 and AK-225 MFC (modular flex complete) kits, which are designed so that welders can customize specific TIG torches into multiple configurations. There are options for both air- and water-cooled TIG torches. The MFC kits help reduce downtime from changing out torches and also minimize the costs associated with purchasing and inventorying extra parts.

The AK-150 MFC kit converts a standard WP-17 series air-cooled torch into 28 different torch styles while still using the existing cable; the AK-225 kit converts a single WP-255 water-cooled torch package into five additional styles. Both kits include collet bodies, nozzles, torch heads and other accessories needed to create the custom torch configurations.

For more information on prices and distributors, call 920/882-6800, or visit *www.weldcraft.com*. Find a direct link *at www.kitplanes.com*.

## Windshield Faring for RV, Dimmers

Britta Imports has announced its windshield faring for the popular line of RV-6, -7, and -9 kit aircraft. It is designed as a full-size, one-piece windscreen fairing for the RV models using the slider canopy option. The fairing simplifies the process of securing the windscreen to the aircraft during the construction process, the company says. The fairing is built from epoxy resin and multiple layers of heavy fiberglass cloth. Generously sized to allow for custom trimming, the fairing is contoured for a good fit. The price is $499.

Also from Britta are two new light dimmers for use with instrument panel or utility lighting in Experimental aircraft. There is a single-channel model (12VDimmer01) and a two-channel model (12VDimmer02). Both use pulse wave modulation electronic design for precise control of LED lighting. They're rated at 18 watts per channel and sell for $29.95 to $45.95.

For more information, call 214/616-9228 or visit *www.pilotlights.net*. A direct link can be found at *www.kitplanes.com*. ✈

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# ViperJet Redux

**A turbofan Viper is coming to replace the rowdy, thirsty turbojet version—here's to one last ride.**

BY DOUG ROZENDAAL

**Whether our airplane**-building budget supports a Pietenpol or an RV-8, most folks who have the gumption and the skill to build and fly their own airplanes were not born sucking on a silver spoon. Most of us in the homebuilt world grew up reading about BD-5s or Teenie Twos in *Popular Science* and *Mechanics Illustrated*. And most of us have reached beyond our grasp to build and/or fly airplanes far more sophisticated than we ever dreamed possible when we were parsing the words in those *Readers Digest*-sized science magazines so many years ago. It's the nature of progress and aspiration.

Without that ability to imagine, we would never build or buy an airplane we assembled or put together by others in a garage, much less fly it. So let's relax our cynical side that says, "I could never afford to build nor have the skills to fly a ViperJet" and do some of that youthful dreaming that served us so well and has brought us so far. What could it hurt? Believe me, it's fun!

## Recalling Reno

I first saw the ViperJet at the Reno Air Races in 2006. I walked by and marveled at the little airplane with a General Electric J85 engine. The J85 is the military version of the CJ-610, the engine that powered the -20 series Learjets and the Jet Commander as well as some other 1960s vintage business jets. In the great tradition of the Pontiac GTO or Mustang Cobra, the J85 is powerful, loud and sucks down Jet A like there's no tomorrow.

I flew the Jet Commander years ago, and while I fell in love with its instant power response and bulletproof dependability, I learned early that flying pure jet engines was an exercise in preflight planning and judicious fuel management. I flew with a pilot named Keith, who grew up flying pure jet engines, and he taught me the rules. Rule No. 1 was you are out of gas and on fire at brake release, and the situation deteriorates from there. Rule No. 2 was never, ever let ATC fly your airplane. Unnecessary vectoring or an early descent meant landing with the low-fuel lights flashing, or worse.

When I saw the compact ViperJet at Reno, I knew it was an animal. I knew, too, that it was not for the faint of heart, and I wanted desperately to fly that little rocket ship. But as far as building or buying one, that was a dream that involved lottery tickets, and I don't buy lottery tickets. That didn't stop me from dreaming about flying the ViperJet.

When the call came, "Would you be willing to go to Pasco, Washington, and fly the ViperJet?" it was a short conversation. I packed my hard hat and a Nomex flight suit. I planned to fly a prototype with parachutes and utilitarian cockpit—much like the airplane KITPLANES® reported on in March 2006. Arriving there I found an air-conditioned airplane with glove leather interior and rosewood inlaid circuit-breaker panels. When demo-pilot Greg Bennett appeared in Levi's and a ball cap to fly with me, I realized the airplane was farther down the development path than I expected.

## Continued Development

The ViperJet project has been in the making for a while. Brothers Scott and Dan Hanchette started the company in 1995 with the plan to build an airplane called the ViperFan, which was to be a piston-powered, propeller-driven pusher. Early in the program the brothers saw the difficulty of producing the drive train for a pusher prop. "If we had a problem with the drive system, we fail," Scott said.

The fighter-style tip-up canopy comes down via a low-tech strap. Hey, it works...

The brothers were involved in buying and selling French Fouga Magisters. They called an associate, and two weeks later a Turbo Mecca jet, the same engine that powers the French jet trainer, arrived. Thirty days later they were taxiing.

The first flight was in 1999. They flew for a year and then switched to a T-58 turboshaft from a CH-46 helicopter. The drive portion of the engine was replaced by a tailpipe, converting the shaft engine into a jet with 700 pounds of thrust. That engine was underpowered, and when the military gave the firefighters first chance at the surplus engines, the supply dried up and another engine choice was needed.

Fortuitously, a Lear 23 landed at Pasco one day. The brothers measured the engine and realized it would fit, and it would provide more than enough thrust. At that point they had sold five kits. "We upgraded those kits to the MKII configuration (with a carbon-fiber wing) at no charge," Scott said. The first flight of the MKII was on June 12, 2005.

## Winging It

The MKII airplane has 25° of wing sweep in the leading edge and 6° in the trailing edge, but the airplane handles and flies like a straight-wing airplane. All of the controls are actuated by pushrods except the rudder, which has cables. The nosewheel casters, and the gear, flaps and speed brakes are electro/hydraulic.

Clever features are incorporated throughout. Some of the most ingenious are the electromagnetic landing-gear-up locks. The down-locks are integral in the actuators, using a ball/collar system that snaps down by either hydraulic pressure, carbon dioxide blow-down or gravity, and are released by the hydraulic pressure on retraction.

The cockpit looks more like a luxury car than a hot-rod jet—a big change from the previous iteration of this aircraft. The canopy is rear hinged and opens manually on a gas strut, pulled down by a convenient and simple hanging strap. The canopy hinge seems strong enough to handle the strongest winds; locks are robust and designed to hold the 5.5 psi cabin differential that will be in subsequent airplanes. The limited amount of panel space in the front cockpit is used efficiently by a pair of Op Technologies integrated EFIS screens that include navigation, com and engine instrumentation. The rear cockpit has a third EFIS panel integrated with the front cockpit.

The airplane always had a tail stand in place, and the crew at ViperJet were careful to tend the nose when it did not. Without the tail stand, and with no passengers in the airplane, the weight on the nosewheel was minimal. A step slides into a receptacle on the left side for boarding, and the front cockpit is comfortable. I was relegated to the rear seat, which was also comfortable, with good head and legroom, but the canopy longerons were tight just above my elbows.

The battery is adequate for starting the turbo-jet, but the J85 and the CJ-610 are single-shaft engines, and the starter must spin the entire rotating element; using ground power ensures cooler starts and lower engine maintenance costs. Starting is simple: Turn on the boost pump, the igniter and the starter. When the engine reaches 10% rpm, turn on the fuel and monitor the Internal Turbine Temp (ITT) for a hot start. When the engine is idling, the starter becomes the generator, the ignition is turned off, and the fire is self sustaining.

## Gulp...

Even at idle power the J85 burns 75 gallons per hour. *That is not a misprint*. The airplane holds only 300 gallons in three tanks, so once the engine is running, getting airborne becomes a priority.

Little additional thrust is needed for taxi, and once the airplane is moving it rolls easily. The rudder seems effective at low speeds, and little braking is needed to steer. There is no need to run up a jet, and the before takeoff checklist is short.

Cleared for takeoff, we took the runway and the fun was about to begin. I was a passenger for the takeoff, but it was straightforward and fast. To say the acceleration was brisk is an understatement. A boot in the butt is a better assessment. The airplane sits nose low, and it appeared to require a tug to unstick the nose at around 90 knots. By the time the nose was up, we were airborne and the gear was quickly retracted to avoid overspeeding the gear. The nose continued to rise, the airspeed continued to accelerate, and in moments we were at 250 KIAS at a ridiculous deck angle with the VSI pegged. In moments we leveled at 10,500 feet, accelerating in spite of a healthy power reduction.

I looked at the fuel flow on takeoff, but it was off scale. Leveling at 10,500, we did a speed run. Burning 240 gph—again, not a misprint—the airplane was accelerating briskly. The flight-test program had not exceeded 325 KIAS, which is 420 KTAS, and we reached that quickly. We took off with 200 gallons of fuel on board, so our time flying at that power setting was limited. Pulling the power back to a miserly 120 gph yielded a more reasonable 230 KIAS, which equated to 300 KTAS.

## Nature of the Pure Jet

These numbers seem ridiculous, and they are. Pure jet airplanes are intended to climb quickly to their maximum operating altitude, and they do best when they can remain there until an idle thrust descent takes them to their destination. With the pressurization functioning, the airplane would climb quickly to FL270 or FL280, where the 5.5 psi cabin differential would yield a 10,500 foot cabin pressure.

At those flight levels the ViperJet folks say the airplane will true 320 KTAS, burning 90 gph. The J85 or its CJ-610 cousin would be much happier at FL390 or even FL410, but reduced vertical separation minimums (RVSM) require strict certification and autopilot requirements, making FL280 the practical ceiling of the airplane.

Once it was clear that the airplane would go really fast it was time to find out if the airplane would go slow. I took the stick for some air work. The stick forces were comfortable in pitch and slightly heavy in roll. The rudder forces are immaterial because without any torque there is little need for rudder. The vertical seems large enough that the airplane is stable in yaw.

Steep turns are not difficult, but the airplane changes altitude so easily that flying to check ride standards requires close attention. Some slick, fast airplanes have a dark underbelly that appears at the bottom end of the airspeed tape. I pulled the airplane to flight idle. Airplanes without propellers don't slow down. The only way to get the airplane near its stall speed was to pull the thumb switch on the power lever aft. This deployed the speed brake with a significant pitch down and rumble.

Clean, the airplane started a noticeable buffet just below 100 KIAS and broke straight ahead at 96 KIAS. Easing the back pressure got the airplane flying again quickly, and with a slight bump on the power lever the airplane accelerated. Extending the flaps lowered the buffet to 90 and the stall to just under 85. At 85, I held full aft on the stick and the nose dropped, the airplane hooked up, the nose came up again, stalled and dropped again. Just like a Cherokee 140, which would qualify it for impeccable manners status (for a high-performance jet). All this occurred with no roll off on a wing or any tendency toward a deep stall. Add power, and the airplane flew out of the stall instantly. One of our tasks was a photo session, so we joined up with a Seneca at 140 KIAS; the airplane was solid and flew formation easily even in the afternoon bumps.

Another one of Keith's rules was the less time the engine is run, the less fuel you burn. The ViperJet has an automatic system that transfers fuel from the wing tanks to the fuselage tank that feeds the engine. When the wings are dry, that leaves 15 gallons to burn before the bingo fuel light comes on, signaling the end of the party. We turned to the airport and pushed the nose down. Even at low power in descent, it's easy to bump the 250 KIAS limit below 10,000 feet.

Sliding the thumb switch back on the throttle slows the airplane to a comfortable 140 KIAS on downwind. The speed brake was deployed, and we used the approach flaps. Back to 120 KIAS on base, full flaps on final and then slow to cross the threshold at 105 KIAS. Again, I was a passenger for the landing, but it was clear that it provided no unreasonable challenge, even in the crosswind.

Retract the speed brakes, flaps and lean on the throttle, and the airplane leaps into the air. In seconds, it's at pattern altitude, on downwind, at 140 KIAS. With the power back and the gear, flaps and speed brakes extended, the airplane again becomes docile and flies easily around to another landing.

Without reverse and with significant residual thrust, the only way to stop is the brakes. Prop jockeys, especially turbo-prop jockeys spoiled by reverse, will be uncomfortable leaning so heavily on the brakes, but the airplane has large disk brakes built specifically for the airplane by ViperJet. We burned lots of fuel and lots of adrenaline in our 45-minute flight, but what a ride!

## Where We Go from Here

ViperJet has sold 20 MKII kits, a second airplane has flown, and others are close. Zero Gravity Builders Studio, a builders assistance shop owned and operated by Rob Huntington, is adjacent to the ViperJet facility and has several airplanes in various stages of completion.

Even with decreasing fuel prices, the market for an airplane that burns over $5 per minute at idle and four times that at full power is small. The insatiable thirst of the pure jet engine outweighs the low acquisition price. That leads to

ViperJet's next project, which is in the tooling phase now: the FanJet.

The FanJet is a slightly larger version of the ViperJet that uses a Pratt & Whitney JT-15D. This is the engine that powers the early Cessna Citations and Beechcraft Beechjet. The specific fuel consumption of the fan jet engine is nearly half that of the pure jet, and the engine is able to operate more efficiently at lower altitudes where homebuilt jets will most likely be forced to operate because of RVSM. The FanJet will share many parts and systems with the ViperJet, making the development process much faster than the 13 years the company has been working on the ViperJet.

The Hanchette brothers have no vision of certifying the ViperJet or the FanJet and selling hundreds. Their business model is to focus on low-volume production of the ultimate kit plane with incredible performance. The FanJet will also be designed to accommodate

## VIPERJET MKII

| | |
|---|---|
| Price | $541,000 |
| Estimated completed price | n.p. |
| Estimated build time, after quickbuild | 3000 hours |
| Number flying (at press time) | 4 |
| Powerplant | General Electric J85-17 2850 lb thrust |
| Powerplant options | GE CJ-610 |

### AIRFRAME

| | |
|---|---|
| Wingspan | 27 ft 10 in |
| Wing loading | 50 lb/sq ft |
| Fuel capacity | 300 gal |
| Maximum gross weight | 5650 lb |
| Typical empty weight | 3100 lb |
| Typical useful load | 2550 lb |
| Full-fuel payload | 495 lb |
| Seating capacity | 2 |
| Cabin width | 36 in |
| Baggage capacity | 125 lb |

### PERFORMANCE

| | |
|---|---|
| Cruise speed | 403-460 mph (350-400 kt) TAS 25,000 ft, 125 gph |
| Maximum rate of climb | 5000 fpm |
| Stall speed (landing configuration) | 85 mph (74 kt) IAS |
| Takeoff distance | 1200 ft |
| Landing distance | 2500 ft |

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



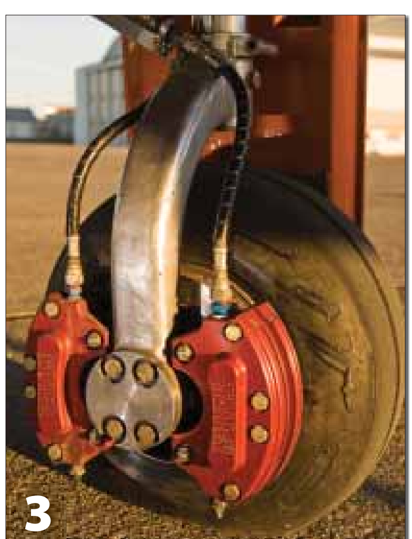
1. The ViperJet's command center is manned, if you will, by a pair of Op Technologies EFIS screens.

2. Room for only two, but what nice accommodations! The revised ViperJet aircraft now sports sumptuous leather seats.

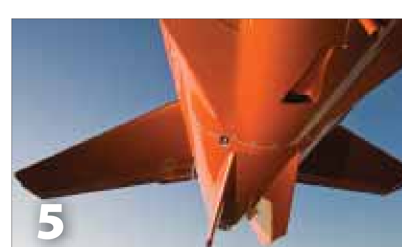
3. Without the benefit of propeller drag or thrust reversers, the ViperJet relies on stonking-big brakes to get slowed down after landing. They're up to the task.

4. What you'd call the business end. A GE J-85 engine converts lots of Jet A into noise and thrust—thank you very much—while elevator trim is via a simple tab. Most aircraft with a wide speed range use an adjustable stabilizer.

5. Small ventral fins help improve low-speed stability. They must work, because the ViperJet has a docile stall.







ejection seats should some small country choose the FanJet for a military trainer.

ViperJet has suspended sales of the MKII kit in anticipation of the FanJet. A flying ViperJet, fully equipped, will end up north of $1 million, and with a more expensive engine the Fanjet will cost more. Those price points will leave most of us dreaming, but there is a market for a high-performance airplane with capability as a cross-country cruiser and aerobatic fighter-like handling and performance—even if it's a small one.

## Who Wants to Be a Millionaire?

Most of us know the answer to the question, "Can I afford it?" A more interesting question might be, "Could I fly it?" That's a different query altogether, and the answer might not be as clear.

From what I observed and the flying I did, I can report the Viper is easy to fly. Most jets are easy to fly, but high-performance airplanes have lower margins for error. An extra 10 knots on final is not an issue on most runways in a Kitfox or a GlaStar, but 10 knots extra in a jet without reverse can mean an excursion off the end. The ViperJet has excellent stall manners, and while we didn't go poking in the corners looking for snakes, none was evident. This is an airplane that could be flown by a current competent pilot with proper training.

Flying IMC would require a functioning autopilot, thorough preflight planning and a high level of currency, but so would a TBM, Cessna, Mustang or a turbine Lancair. Whether it is the airspeed control on final or the fuel planning on a cross country, high-performance airplanes require a greater level of discipline because even small errors could have large consequences. The biggest difference between the ViperJet and those other airplanes is managing fuel for the ever thirsty pure jet engine. The FanJet will go some ways to resolving that problem.

That leaves only one more difficulty: I still can't afford one. But 40 years after I lusted for the BD-5 in *Popular Science*, I can still dream. After all, my mother-in-law gives me a lottery ticket every year for Christmas. ✈

*For more information, call 509/543-3570, or visit www.viper-aircraft.com. Find a direct link at www.kitplanes.com.*

# Loran and GPS Take Over

**Area navigation reached maturation 25 years ago, and hasn't looked back.**

BY MARC COOK

**When this magazine** was founded in 1984, aircraft navigation systems were just starting what would be seen as a paradigm shift. Before that time, orthodoxy prevailed. Most certified aircraft and the larger homebuilts had a pair of nav/coms—one with ILS capability and one just a VOR, a transponder, maybe DME (distance measuring equipment) and ADF (automatic direction finder). Higher-end aircraft might have a rho-theta area nav system, sometimes just called RNAV, which calculated a point in space based on the radial and DME from a VOR. Woo, heady stuff.

Change was on the horizon. A company called II Morrow developed a line of loran-C receivers for aircraft that promised true area navigation. Loran, which stands for long range aid to navigation, was developed from a British long-range system called GEE during WW-II. Using low-frequency, high-power fixed transmitters, loran calculated the receiver's location based on the difference in time signals from two ground stations. Because it was first employed in marine applications, the transmitters were placed near the coasts, making airborne use of loran sketchy in the middle of North America. The signals were also subject to atmospheric disturbances and precipitation static in the aircraft. What's more, the early lorans had no internal database. You typed in the latitude and longitude of your destination, and it took you there.


Garmin GPS 100.

Eventually, of course, loran developed into a vital and useful navigation aid, with Arnav, Northstar and II Morrow the industry leaders for many years. Gradually, receiver technology improved and databases became more common and more detailed. For many pilots, the loran became the de facto primary navigator because it provided accurate ground track and speed, particularly useful when the aircraft was out of DME range. Northstar led the way in human factors, with a simple one-line display and a pair of concentric knobs that determined nav modes and entered new waypoints.

## Kaboom!

Loran didn't stand a chance against a new technology, though, in GPS. The military had begun launching navigation satellites in the 1970s, but it wasn't until December 1993 that GPS achieved "initial operational capability," and in April of the next year it was declared fully operational. By this time, computer technology and component miniaturization had become far more sophisticated, so even the earliest consumer GPS products seemed fantastic.

The Northstar M-1 loran. Hot stuff in the late 1980s.

A small two-man start-up company named Garmin jumped in with a ruggedized, battery-powered model called the GPS 100. It was sized to fit in a panel, but many certified pilots carried the unit atop the glareshield. Then, as today, enterprising homebuilders constructed the miracle navigator right into the panel.

Overnight, GPS's accuracy and reliability put the serious hurt on loran. It worked all over North America, needed only a tiny antenna, and generally had a full database of airports and navaids, making its integration into the IFR mindset (as a means of situational awareness) complete. Although II Morrow, before its purchase by UPS and, later, by Garmin, developed a slick GPS/loran combo unit, other companies essentially abandoned loran for GPS.

About this time, we begin to see homebuilts eschewing the traditional pair of nav/coms plus DME for a single nav/com and GPS. In some cases, for pilots never intending to penetrate a cloud, the ground-based navigation receiver was completely forgotten. Give us a GPS and a com radio and we're good to go, thanks.

*Photos: Marc Cook*

# TIMELINE MAY 1987 - FEBRUARY 1988

## MAY 1987

Concern over the structural integrity and durability of composites was expressed in the magazine's "Intercom" column (a Q&A where readers' queries could be addressed). Designer Ed Swearingen was cited as having said that, "No one knows for sure how long composite structures will last." However, the use of structural fiberglass went back to the 1960s, and many of those aircraft were still flying. The short answer was that the jury was still out, but general indications were that a properly designed, well-built composite aircraft would last a long time, especially if it was protected in a hangar.

This column also marked the demise of the SP 440 rotary engine, which had been developed for small aircraft and was used on the Dawnstar ultralight.

Dave Martin, in the "Twice Around the Patch" column, discusses the FAA's call for greater restrictions on airspace near urban areas. The announcement required that aircraft have transponders with Mode C (altitude reporting), and the change had been set in motion before a summer 1986 collision between a lightplane and an airliner in Cerritos, California. However, that accident may have hastened the process. It was also predicted that the FAA would soon require Mode-C transponders in all areas—in, under and around TCAs, all the way to the ground.

The all-new Phoenix aircraft, out of Oceanside, California, is touted as the "Aircraft for the Future: Speed, Safety, Economy and Performance." Not to be confused with the three-seat amphibian called the Phoenix, out of Woodland, Washington, also new this year.

Stan Hall's plansbuilt Cherokee II wood motorglider is profiled. Said the article, "Hall's hope was to offer anyone with a modicum of woodworking, model-airplane-building, handyman talent and willingness to work, the means to glide and soar!"

The exotic Legeti Stratos closed-wing composite debuted at Oshkosh in 1986 and was featured in May 1987. Described as an ultra-aircraft—ultra-light, ultra-compact and ultra-high performing, the Stratos weighed just 172 pounds empty and claimed a max cruise of 112 mph (which placed it out of the U.S. ultralight category). It was the brainchild of Romanian-born Charles K. Ligeti. Power was from a three-cylinder Koning engine producing 28 hp at 4200 rpm. Price: $8000 for the kit.

## JUNE 1987

An advertisement for the Zenair STOL CH 701 lists the kit price as $11,300. Twenty-one years later, the Zenith Aircraft web site lists the current CH 701 prices as $10,975 for the airframe kit and $3195 for the finishing kit (total $14,170).

An article by Richard Finch seeks to allay skepticism about auto engine conversions for aircraft, which continue to be a topic of interest to homebuilders, despite some reservations. As ever, the lower cost of the engine is the primary motivator. The Fred Geschwender Ford V-8 and Offenhauser Oldsmobile 225-hp V-8 are featured.

A full-page ad touts II Morrow's Apollo 64 Equalizer, with an expanded "Flybrary" database cartridge and nav displays. This loran features a huge database that can be updated every 56 days by simply changing a cartridge! Additionally, it keeps track of the five nearest airports, five nearest VORs and the five nearest user waypoints.

## JANUARY 1988

The new Murphy Renegade Spirit ultralight prototype is reviewed. Fully aerobatic, the Renegade had a patented extruded aluminum gusset system used to join the aircraft tubular members together. Power is from a two-stroke Rotax 532.

The first 25 production positions for the Gambit 600 from Israel is advertised. For only a $500 deposit, you could reserve an early delivery position. Complete kit: $17,950. Dealerships also available.

A feature details how P.H. "Spence" Spencer is looking for new, younger management for his Spencer Air Car company. Spencer, then 90 years old, was the oldest licensed pilot in the U.S. at the time. He designed the Republic Seabee at the end of WW-II. His partner, Andy Anderson, was 77. Air Cars were flying in New Zealand, Brazil and Canada. Asking price for the company: $160,000.

A letter to the editor makes a request: "Address the question we low-time, spam-can fliers ask: Can a good Experimental design offer the docile, forgiving handling qualities of a Cherokee or C-172, equivalent or better payload, and give better cruise speed and fuel economy?" The writer claims that articles have hinted at the answer, but he wants the question addressed head-on. "That's what everybody asks," he writes.

## FEBRUARY 1988

Ken and Gail Wheeler's four-seat Wheeler Express composite kit, introduced at Oshkosh in 1987, is reviewed. Also in the works was a Wheeler Alaskan amphibian. Ken Wheeler said that though building an Express would never be a casual enterprise, he wanted to make it manageable for a novice.

Vision Microsystems offers a new line of engine instruments for homebuilt aircraft, estimated to have an error rate of from 1% to 3%, as opposed to a 14% to 25% error for gauges of the old days. Lance Turk, company president, prompted to innovation by looking for gauges for his Glasair, explains how computer technology allows for high precision, fast action, direct reading, lightweight, minimum-depth gauges.

# Engine Monitoring Today

## In 2009, engine-monitoring products continue to evolve—no revolution in sight.

BY STEIN BRUCH

**Virtually all modern** engine monitors provide a plethora of information to the pilot. All basic functions are expected to be included with the offerings for our airplanes—you could say we're information spoiled. I'm happy to say that most builders with a sizable investment ahead of the firewall are seeing the value of all-inclusive monitoring. It's not just for the retentive types anymore.

At a minimum, you'll be monitoring these temperatures: exhaust (EGT), head (CHT), turbine-inlet (TIT) outside-air (OAT) and oil (OT). You'll also be watching these pressures: manifold (MP), oil (OP) and fuel (FP). And you'll have displays for fuel level, volts, amps, engine speed (rpm). The list grows to include checklists, weight-and-balance calculations as well as external inputs for various inputs such as a CO detector, landing gear and flap position, trim indication, data logging and more. It's possible with today's best engine monitors to watch and annunciate just about everything in the airframe, ridding your panel of extraneous displays, meters and dials (if that's what you have in mind).


Advanced Flight's engine monitor can be displayed on an EFIS screen (left). A weight-and-balance screen helps loading (right).

For the old-schoolers in the crowd who prefer discrete gauges for fear of putting all of their eggs in the same basket—and ending up with an omelette—in my shop's experience, the modern engine monitors are dully reliable.

### Public Displays of Attraction

Most systems present the information graphically on color LED or LCD type screens, though a good many monochrome (single color) displays that are completely useful remain. (The market has voted overwhelmingly for the living color versions.) Size varies from small to large. User interfaces are similar, and most allow the user to configure some or all of the parameters in the system such as limits, trends, minimum and maximum limits, colors and more. These functions vary by manufacturer and model, but all we've used and been exposed to are designed to be pilot- and user-friendly. I generally prefer instruments that can be fine-tuned by the builder, so things like operating limits and color arcs can be determined by the pilot through simple programming. Units that require a trip back to the factory to reset limits are a lot less useful, I think.

*Photos: Courtesy the Manufacturers, Richard VanderMeulen*

We're seeing the maturation of the products as they gradually add features and improve reliability—all of the popular choices today were around last year. (And some, like Sensornetics, which we featured last year, just haven't shown up in the marketplace yet.)


Dynon's EMS-D120 is functionally identical to the smaller EMS-D10.

The current market leaders are Advanced Flight Systems (AFS), Dynon Avionics and Grand Rapids Technologies (GRT). These three companies still account for the majority of Experimental engine monitors being sold and installed throughout the world. The reason for these three companies getting out front and staying there is easy to understand: They all make EFIS displays, and in this part of the market, consumers are choosing like brands because of the interoperability. (Kind of like the heady days of the 1970s, when it was desirable to have an all-King stack.)

## Grand Rapids Technologies

The leader in terms of units sold for the Experimental market is Grand Rapids. The company's venerable EIS (Engine Information System) probably has more systems flying than any other. While the EIS box by itself isn't as flashy as the competitors', it is affordable and easy to install thanks to the company's premade and provided wiring harnesses. Grand Rapids now has an optional LCD screen that couples with the EIS box to display the engine information graphically on a dedicated screen or interface to its popular EFIS.

The EIS box may also be purchased with an air data computer built into it that feeds other EFISes such as Chelton, or to provide a rudimentary VFR flight instrument for many ultralights. A complete engine-monitoring system including probes and sensors starts at less than $1000. Optional probes and sensors can increase the cost, but it's still one of the most affordable systems available today. Grand Rapids is one of the few companies that supports automotive and alternative engine conversions, as well as radial and turbine installations. It also supports integration and interfaces with the Vertical Power system and Chelton EFISes. It's worth noting that the GRT engine monitor display has undergone a major overhaul in its screen resolution and display layout.

## Dynon Avionics

Dynon had one of the first small and affordable graphical engine monitors with the introduction of its 3.125-inch EMS-D10. Sized to fit into a standard instrument cutout, it has been a very successful product. Expanding on the 10, Dynon also offers a larger screen D120 as a standalone engine monitor or to combine with its EFIS in the FlightDEK-D180. These units, like their competitors, are easy to use, pack in a ton of information and are also user-friendly to install with the provided installation harnesses. Dynon has expanded its support team and has a dedicated online support forum for its users, which has proven to be popular.

Dynon has also made inroads with many of the Light Sport Aircraft manufacturers, and its systems have become some of the most popular OEM-installed graphical engine monitors in LSAs. Like most of its competitors, Dynon offers complete probe and sensor packages for a multitude of engines options, but at the moment the company does not support turbine or radial engine configurations. The basic EMS-D10/D120 currently supports both four- and six-cylinder engines—including Rotax and Jabiru—with all-cylinder EGT and CHT, plus the usual other measurements. You can hook up your trim and flap-position sensors and have them read out on the EMS as well as a linked Dynon EFIS. Last year, the company released a new piece of software that included a percent-of-power meter that takes into account whether you're running rich or lean-of-peak EGT. Data logging is standard, too.

Interactivity is important. The Grand Rapids models can be connected to share engine information with the EFIS.

## Advanced Flight Systems

Early in the new millennium, RV builder and electronics guru Rob Hickman desired a fully functional and affordable graphical engine monitor. When he found there were no options that met his requirements, Hickman simply made his own. Advanced Flight Systems was born, and was one of the first to offer a color


Vision Microsystems VM1000C.


Xerion AuRACLE.

graphical engine monitor. As demand grew, so did the product line, and now the AFS engine monitors are some of the most popular systems around.

These monitors have several features that are not in competitors' units such as a backup battery, Ethernet cable connection to its other products, as well as data recording/logging direct to a front loading SD card, and AFS is one of few companies to provide a complete "no hidden charges" package of probes and sensors without making some of them available at additional cost. (Most other companies make some probes/sensors such as a fuel flow sensor optional at additional cost). It should also be noted that AFS systems will integrate with other EFISes and products from companies such as Vertical Power and Chelton. AFS also offers online support.

## Electronics International

Electronics International has created a niche as one of the highest quality premium engine monitors available. Its history with a respected line of digital engine instruments led to the creation of its flagship product, the MVP-50. With a mid-sized LCD screen, EI's MVP-50 is frequently found in high-end and high-performance aircraft. It is one of the few companies that has experience supporting complex turbine and jet installations as well as radial engines and other alternative engine configurations. It is also one of the only companies I know of that designs and manufactures its own probes and sensors, and they're even used by other engine monitor manufacturers. EI has many optional configurations and supports outputs for some other EFISes by offering an air-data module. Its products are FAA certified, and the company has an excellent reputation for outstanding customer support and strong support of Experimental aviation.


J.P. Instruments EDM-930.

Advanced Flight, Dynon, EI and GRT compose the majority of units installed by homebuilders, but they are by no means the only options available. Other companies have offerings for aircraft from ultralights to Bonanzas.

## J.P. Instruments

J.P. Instruments is arguably the biggest player in the certified market, and its 3.125-inch round engine monitors are ubiquitous in the store-bought fleet. The company's products are widely seen in, for lack of a better term, pre-EFIS homebuilts—that is, the aircraft built, say, five to 15 years ago. In addition to its line of round instruments, JPI has the EDM-900 and EDM-930, which are all-inclusive systems. The 900 is a gas-discharge single-color (with color overlays) display, while the 930 is a full-color LCD.

In the last three years, JPI purchased Vision Microsystems and its line of engine monitors. The news now is that Vision's founder, Lance Turk, has left the soggy Northwest to work at JPI headquarters in Southern California. Vision Micro was one of the first companies to offer a graphical engine monitor, and they were quite popular for some time. However, with the introduction of modern graphical engine monitors, the popularity of the VM systems languished. Nevertheless, there are many VM installations out there, and they remain via-

MGL Avionics/ Stratomaster E-3


ble. Under JPI, the VM systems have been adapted to use JPI probes. With Turk back in the fold, we can expect some exciting new products in this lineup.

## MGL Avionics

MGL Avionics is a relative newcomer to the mainstream homebuilding community, but it has been quite popular in ultralight aircraft for years and has delivered many units worldwide. Based in South Africa, the company is run by Ranier Lamers, whose small business offers some of the most affordable units available. The Stratomaster is popular and is offered in various configurations for many types of aircraft. MGL also offers a suite of 2.25- and 3.125-inch instruments that cover a wide range of functions such as pressure instruments, electrical measurement, CHT/EGT, temperatures and more.

In fact, the smaller Infinity singles have been redesigned this year. Instead of the angular front panel, the instruments have a round bezel so they fit handsomely in a 2.25-inch hole. As before, MGL's singles line includes a "partial" engine monitor in the E-3, though it doesn't display all of the engine parameters at once, and can watch only a limited number of EGTs and CHTs. The E-3 has


I-K Technologies AIM-Lite.

essentially four inputs plus rpm. If you choose to watch a pressure and temperature, then two are left for your choice of EGT or CHT or one each. The Infinity line also includes a fuel computer, dedicated temp/pressure gauges and others. You could build a modular engine monitor from the components, but for many with simple engines—the Rotax 912 in particular—the E-3 probably fits the bill just fine.

## And the Rest...

I-K Technologies is another small business that, like MGL Avionics, offers a number of systems at affordable prices. Several options are available with a unique display that mixes an LCD readout along with a number of LED bars in red, yellow and green. With the I-K Technologies engine monitors it's easy to quickly glance at your display and notice the status of all of your parameters. The I-K systems are somewhat customizable, and they provide a number of possible configurations.

Xerion has received FAA certification for its Auracle graphical engine monitor, and though not focused on the homebuilt market, it has some systems installed in Experimental aircraft. With the focus on certified aircraft, its costs are a bit higher than its competitors. The Auracle is a graphical engine monitor that offers most of the expected functionality.

| Manufacturer | Model | Price | Includes Probes/ Sensors | No. of Cylinders | Screen | EFIS Compatible | Lean-Find Mode | MP/Tach Displays | HP Computer | OAT/Carb Temp |
|---|---|---|---|---|---|---|---|---|---|---|
| Advanced Flight Systems | AF-3400 | $2541-$2741 | N | 4-6 | Color LCD | Y | Y | Y / Y | Y | Y / Y |
| | AF-3500 | $2965-$3165 | N | 4-6 | Color LCD | Y | Y | Y / Y | Y | Y / Y |
| | AF-4500 Deck | $4465 | N | 4-6 | Color LCD | Y | Y | Y / Y | Y | Y / Y |
| Dynon Avionics | D10 | $1700 | N | 2-6 | Color LCD/TFT | Y | Y | Y / Y | Y | Y / Y |
| | D120 | $2000 | N | 2-6 | Color LCD/TFT | Y | Y | Y / Y | Y | Y / Y |
| Electronics International | MVP-50 | $4995-$5485 | Y | 4-9 | Color LCD | Y - option | Y | Y / Y | Y | Y / Y |
| Grand Rapids Technologies | EIS-4000 | $995 | Y | 4 | Color LCD | Y - option | Y | Y $60 option/Y | Y with graphical screen | Y / Y |
| | EIS-6000 | $1185 | Y | 6 | Color LCD | Y - option | Y | Y $60 option/Y | Y with graphical screen | Y / Y |
| I-K Technologies | AIM-1 | $1499 | N | 4 | Backlit LCD | Y / $100 option. ** | N | Y /Y | N | Y / $100 option |
| | AIM-2 | $1499-$1799 | N | 4-9 | Color LED | Y / $100 option. ** | N | Y /Y | N | Y / Y |
| | AIM Lite | $749 | N | 4 | Color LED | Y / $100 option. ** | N | Y /Y | N | N / N |
| | AIM 3000 | $1749 | N | 6 | Backlit LCD/Color LED | Y / $100 option. ** | N | Y /Y | N | Y / $100 option |
| | AIM 4000 | $1999-$2299 | N | 4-6 | Backlit LCD/Color LED | Y / $100 option. ** | N | Y /Y | N | Y / $100 option |
| J.P. Instruments | EDM-900 | $4910-$5141 | Y | 4-6 | Color plasma | N | N | Y /Y | Y | Y / Y |
| | EDM-930 | $4910-$5141 | Y | 4-6 | Color LCD | N | Y | Y /Y | Y | Y / Y |
| MGL/Stratomaster | E-2 | $750 | N | 2-4 | Backlit LCD | Y | N | Y/Y | N | Y/N |
| | E-3 | $295 | N | 2-4 | Backlit LCD | Y | N | Y/Y | N | Y/N |
| Vision Microsystems | VM1000C | $2870-$3038 | Y | 4-6 | Color transre-flective | N | Y | Y /Y | Y | Y / Y |
| Xerion Avionix | AuRACLE I | $5650-$5925 | Y | 4-6 | Color LCD | N | Y | Y /Y | Y | Y / Y-$65 option |
| | AuRACLE II | $6000-$6300 | Y | 4-6 | Color LCD | N | Y | Y /Y | Y | Y / Y-$65 option |

*** Optional in place of manifold pressure on all units except AIM-Lite.**

**** All units can be configured to output serial RS-232 data stream.**

## Why We're Here

The market has none-too-subtly shifted to a "one manufacturer" philosophy at the mid-level and up, and that's so the engine monitor and EFIS can communicate, share data and provide information across multiple displays. If you intend to install an EFIS in your airplane, then it's a natural fit to install an engine monitor from the same company. Many of them are even available integrated into an EFIS, so in the end you have a complete and integrated system. Some mixing and matching can take place, but it's generally wise to stick with the same manufacturer. It's getting increasingly difficult to differentiate systems because most are offering expanded functionality, great displays and affordability. All of them are almost universally far more accurate than their outdated steam-gauge counterparts and will offer greater reliability over the long term. Ultimately, as I said last year, I can offer *three main rules* for purchasing an engine monitor.

1. Purchase the same brand engine monitor as your EFIS if you're going to use an EFIS.
2. Don't buy more than you need. If you're building an ultralight, you simply don't need 80 different data points for your engine (like fuel flow, fuel pressure, OAT, etc.).
3. Don't buy an engine monitor and then install backup engine instruments.

| Fuel Flow | Fuel Level/ Pressure | Vacuum/ Hydraulics | Volts/ Amps | Check-lists | Data Log-ging | Width (in.) | Height (in.) | Depth (in.) | Weight (lb.) | Remote Sensor Module | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Y | Y / Y | Through general-purpose inputs | Y / Y | Y | Y | 6.6 | 5.7 | 5.5 | 3.3 | N | |
| Y | Y / Y | Not specified | Y / Y | Y | Y | 7.8 | 6.8 | 5.5 | 6.0 | N | |
| Y | Y / Y | Not specified | Y / Y | Y | Y | 8.6 | 7.6 | 5.8 | 6.0 | N | Front mounted tray. |
| Y / $200 option | Y / Y | Through general-purpose inputs | Y / Y | Y / Y | Y | 4.1 | 3.4 | 5.3 | 1.3 | N | |
| Y / $200 option | Y / Y | Through general-purpose inputs | Y / Y | Y / Y | Y | 7.0 | 4.9 | 4.5 | 2.4 | N | Bright screen option $200. |
| Y | Y | Y | Y | Y | Y | 5.5 | 5.2 | 2.4 | 5.3 /5.6 | Y | MVP-50T available for turboprop and jet engines. Both include Chelton interface. Tie-ins for CO detectors. Customer configurable. |
| Y / $375 option | Y / Y | N | Y / Y | N | N *** | 5.9 | 2.75 | 2.4 | N/A | N | Special versions available for Rotax 912, Jabiru 2200. 4000TT available for turbine/turboprop. |
| Y / $375 option | Y / Y | N | Y / Y | N | N *** | 5.9 | 2.75 | 2.4 | N/A | N | Special version for Jabiru 3300. |
| Y | Option / Y | Y / option * | Option /N | Y / $100 option | N *** | 6.25 | 2.5 | 1.8 | < 2.0 | N | FADEC interface option is $100. |
| Y | Option / Y | Y / option * | Y / N | N | N *** | 6.25 | 2.5 | 1.8 | < 2.0 | N | FADEC interface option is $100. |
| Y / $300 option | N / Y | N / N | Option / N | N | N *** | 3.6 | 3.6 | 1.8 | < 2.0 | N | FADEC interface option is $100. |
| Y | Y / Y | Y / option * | Y / N | Y / $100 option | N *** | 6.25 | 3.0 | 1.8 | 2.0 | N | FADEC interface option is $100. |
| Y | Y / Y | Y / option * | Y / Y | Y / $100 option | N *** | 5.0 | 5.5 | 1.8 | 2.0 | N | FADEC interface option is $100. |
| Y | Y / Y | N | Y / Y | N | Y | 5.1 | 5.0 | 2.0 | 2.0 | N | |
| Y | Y / Y | N | Y / Y | N | Y | 6.0 | 4.0 | 2.9 | 2.0 | N | |
| Y/$185 | Y/N | N/N | Y/N | N | Y | 8.0 | 3.6 | 3.8 | 1.3 | Y | |
| Y | Y/N | N/N | Y/N | N | Y | NA | NA | NA | NA | Y | Fits into a 2.25-inch instrument hole. |
| Y | Y / Y | N/N | Y / Y | Y | Y | 5.1 | 5.0 | 1.5 | 0.8 | Y | Price is for carbureted engines. Vision Config system allows user to program on laptop and upload. |
| Y | Y / Y | Y / Y | Y / Y | N | Y | 6.25 | 4.5 | 2.0 | 1.8 | N | |
| Y | Y / Y | Y / Y | Y / Y | N | Y | 6.25 | 4.5 | 2.0 | 2.5 | Y | |

***** Data logging through serial data output to another device.**


I-K Technologies AIM-3000.

If your engine monitor were to fail, the fan on the front does not immediately stop. You generally cannot share sensors, so that means extra sensors, extra wiring, extra complexity and little extra functionality or usability. Trust me, it's not worth the effort.

Overall I encourage everyone to get an engine monitor. If you haven't used one before, you'll be pleasantly surprised. Stay tuned for more changes in what becomes available! ✈

**CONTACTS**

**Advanced Flight Systems Inc.**
*www.advanced-flight-systems.com*
503/263-0037

**Dynon Avionics**
*www.dynonavionics.com*
425/402-0114

**Electronics International**
*www.buy-ei.com*
877/318-6060

**Grand Rapids Technologies**
*www.grtavionics.com*
616/245-7700

**I-K Technologies**
*www.i-ktechnologies.com*
818/302-0606

**J.P. Instruments, Inc.**
*www.jpinstruments.com*
800/345-4574

**MGL Avionics**
*www.mglavionics.com*
877/835-9464

**Vision Microsystems**
*www.visionmicrosystems.com*
830/755-6330

**Xerion Avionix**
*www.xerionavionix.com*
800/405-8608


# Vertically Integrated

It's hard to put the Vertical Power system into one category, because it touches and integrates with so many different areas of your airplane. In short, the VP system is a sophisticated, computer-managed electrical distribution system married to an external engine monitor. In the high-end version, the VP-200, the engine monitor is presented on the VP screen, integrated with the electrical-system specifics. It's slick.

It's been just about a year since we had our first direct exposure and experience with the VP system. We've installed both the VP-200 system as well as its little brother, the VP-100.

The display of the VP-200 system is large, big enough to prominently display several different things at once. For example, the engine monitor section intelligently displays a different set of engine parameters depending on the mode of flight. The instruments that are displayed in each mode (Preflight, Before Start, Start, After Start, Taxi, Run-up, Take-off, Cruise, Maneuver and Landing) can be custom configured and chosen by the builder.

Where the VP system really shines is in the management of your electrical system. While most engine monitors will display your volt or amp draw (based on an installed shunt or hall affect sensor), the VP system takes this functionality to a whole new level. It keeps track of current draw by each unit that it is controlling and monitoring. This means that not only can you see represented on the graphical display the entire system load in real time as you turn components on and off, but the system allows you to see the current draw of each individual component.

Because of this core functionality, there is a neat feature on the VP system. If a component such as a landing light is burned out, the system will alert you (it expects that component to draw X amps, and if it doesn't then it'll tell you)! Marc Ausman of Vertical Power says, "It's important that a graphical display of the electrical system shows overall electrical system health and be able to show specific problems, like battery contactor failure or over-voltage conditions. With an all-electric aircraft, it is important to monitor the electrical system just like you monitor the engine."

Our experience with installation of the VP system has been good overall. It's imperative that as a builder you spend the time to accurately put together your load-planning worksheet. This is the core of the entire installation, and without it you will find yourself scratching your head. Perhaps the most difficult part of the installation is the same as with other EFISes and engine monitors—setup and programming. If you are relatively comfortable working with electrical devices, this won't be difficult. However, it still takes a fair amount of time to set up each and every device, give it a physical name, assign the appropriate loads/amperages to it, and then assign it to a circuit. This can be tedious, but once it's done you can save that information to a USB thumb drive.


We've been pretty happy with the VP systems. The wiring is not difficult because of your previously completed load planning worksheet, but it is different than traditional switches and circuit breakers.

**—S.B.**

# 2009 Engine & PSRU BUYER'S GUIDE

COMPILED BY JULIA DOWNIE

**Every airplane builder needs an engine.** OK, that's not true if you're crafting a sailplane, we'll give you that. But for the rest of us, the powerplant will be among the more expensive components of the whole project, calling for extreme care in the shopping.

In general, the engine market has changed little from last year—most of the same companies are soldiering on with mature product, doin' alright. The big news was the collapse of Thielert AG in Germany, whose subsidiary, Superior Air Parts, has been left to chart its own course. Rumors have circulated since last summer about possible suitors for the firm. As we went to press, Superior continued to stand alone, though we understand interest to be high in adding Superior's product line to another company's.

Engine Components and Lycoming join Superior in continuing to supply engine parts and kits into the marketplace—in the last few years, the choices for builders seeking a conventional powerplant have either been to buy a new, certified-style engine through the kit manufacturer or purchase a "kit engine" built by a reputable shop. The high price of gasoline—both avgas and auto fuel—continues to spur interest in low-power engines for lightweight aircraft as a means of economizing. Look around here, and you'll see some enticing options in the 70- to 100-horsepower range. Finally, the ground for new technology and auto-engine conversions remains fertile, though it's another year we have not seen scores of DeltaHawk diesels or Mistral rotaries darkening the skies. New-engine development is always a challenge, requiring surprisingly deep pockets and rewarding patience and persistence over marketing. After all, you don't fly a brochure.

### Aero Sport Power
250/376-2955
www.aerosportpower.com

#### O/IO-320, 160 HP
Price: $21,000
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, 278-291 lb. dry weight.
Output: 160 hp at 2700 rpm.
Propeller: Constant speed or fixed pitch.
Notes: 300+ engines delivered, 200+ hours on highest time engine, 6 weeks shipping time.

#### O/IO-360, 180 HP
Price: Starting at $21,200
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, 290-299 lb. dry weight.
Output: 180 hp at 2700 rpm.
Propeller: Constant speed or fixed pitch.
Notes: 700+ engines delivered, 2000+ hours on highest time engine, 6 weeks shipping time.

#### IO-360-AIB6, 200 HP
Price: $34,900
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected, 330 lb. dry weight.
Output: 200 hp at 2700 rpm.
Propeller: Constant speed or fixed pitch.
Notes: 75 engines delivered, 2000+ hours on highest time engine, 10 weeks shipping time.

#### IO-375, 190 HP
Price: Starting at $23,000
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, 299 lb. dry weight.
Output: 190 hp at 2700 rpm.
Propeller: Constant speed or fixed pitch.
Notes: 30+ engines delivered, 6 weeks shipping time.
*Editorís note: This engine is essentially a long-stroke parallel-valve IO-360.*

#### IO-390, 210 HP
Price: Starting at $32,500
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected, 330 lb. dry weight.
Output: 210 hp at 2700 rpm.
Propeller: Constant speed or fixed pitch.
Notes: 40 engines delivered, 8 weeks shipping time.

#### O/IO-540, 260 HP
Price: $38,900
Configuration: Horizontally opposed, 6 cylinder, air cooled, carbureted or fuel injected, 404-412 lb. dry weight.
Output: 260 hp at 2700 rpm.
Propeller: Constant speed.
Notes: 150+ engines delivered, 2000+ hours on highest time engine, 8 weeks shipping time.

### AeroConversions
920/231-8297
www.aeroconversions.com

#### Aero Vee 2.1, 80 HP
Price: $6495
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected, 161 lb. dry weight.
Output: 80 hp at 3400 rpm.
Propeller: Fixed-pitch wood propeller.
Notes: 388 engines delivered, 1000 hours on highest time engine, 3-4 weeks shipping time.

### Aerotek Aviation Inc.
418/802-5278
www.aerotekaviation.ca

#### PT6 Turbine, 450-750 SHP HP
Price: $144,500 (firewall-forward package)
Configuration: Turbine, 335 lb. dry weight.
Output: 450-750 SHP at 2200 rpm.
Propeller: Hartzell 3 blade with reverse (included).
Notes: 15+ engines delivered, 10,000+ hours on highest time engine, 3 months shipping time.

*Photos: Courtesy the Manufacturers, Kevin Wing, Marc Cook*

## Air Parts Sales Unlimited, LLC
**954/788-6660**
**www.apso-hks.com**

### HKS 700E, 60 HP
Price: $9371
Configuration: Horizontally opposed, 2 cylinder, air cooled, carbureted, 120 lb. dry weight.
Output: 60 hp at 6200 rpm.
Propeller: 70-inch PowerFin "F" 2- or 3-blade, ground adjustable.
Notes: 1300 engines delivered, 800 hours on highest time engine, 2 weeks shipping time.

### HKS 700T, 75 HP
Price: TBD (April 2009 in production)
Configuration: Horizontally opposed, 2 cylinder, air cooled, fuel injected, 126 lb. dry weight.
Output: 75 hp at 5300 rpm.
Propeller: 70-inch PowerFin "F" 2- or 3-blade, ground adjustable.

## Alturair
**619/449-1570**
**www.alturair.com**

### A650, 100 HP
Price: $10,500
Configuration: Air cooled, carbureted, 100 lb. dry weight.
Output: 100 hp at 6000 rpm.
Notes: 2 engines delivered, 100 hours on highest time engine, 12 weeks shipping time.
*Editorís note: In last yearís guide, the number of engines delivered was the same: 2.*

## American Rotary Engines
**253/848-7776**
**www.americanrotaryengine.com**
*Editor's note: American Rotary Engines, despite repeated attempts to obtain the latest information, failed to meet our deadline. Because we believe the company to be in business, we are listing the information from last year's Buyers Guide.*

### AC 13B-180, 180 HP
Price: $16,250 (2008)
Configuration: Upright, water cooled, fuel injected, 275 lb. dry weight.
Output: 180 hp at 6300 rpm.
Notes: 20+ engines delivered, 2500 hours on highest time engine, 4-6 weeks shipping time.

### AC 13BT-200, 200 HP
Price: $23,250 (2008)
Configuration: Upright, water cooled, fuel injected, 300 lb. dry weight.
Output: 200 hp at 6300 rpm.
Notes: 10 engines delivered, 1000 hours on highest time engine, 6-8 weeks shipping time.

### AC 20B-270, 270 HP
Price: $22,450 (2008)
Configuration: Upright, water cooled, fuel injected, 385 lb. dry weight.
Output: 270 hp at 6700 rpm.
Notes: 8 engines delivered, 2500 hours on highest time engine, 8-12 weeks shipping time.

### AC 20B-300, 300 HP
Price $29,450 (2008)
Configuration: Upright, water cooled, fuel injected, 400 lb. dry weight.
Output: 300 hp at 6200 rpm.
Notes: 4 engines delivered, 2500 hours on highest time engine, 12 weeks shipping time.

## Barrett Precision Engines, Inc.
**918/835-1089**
**www.bpaengines.com**

### O/IO 320-X, 150-160 HP
Price: $22,550-$24,100
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, 285 lb. dry weight.
Output: 150+hp at 2700 rpm.
Notes: 200+ engines delivered, 12 weeks shipping time.

### O/IO 360-X, 180-195 HP
Price: $23,000-$29,385
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, 280-300 lb. dry weight. Option for vertical or horizontal induction and high compression pistons.
Output: 180+ hp at 2700 rpm.
Notes: 200+ engines delivered, 12 weeks shipping time.

### O/IO 360-X, 200-215 HP
Price: $37,085-$39,595
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, 280-300 lb. dry weight.
Output: 200+ hp at 2700 rpm.
Notes: 200+ delivered, 12 weeks shipping time.

### IO/AEIO 390-X, 210-215 HP
Price: $33,350-$34,900
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected, 308 lb. dry weight.
Output: 210+ hp at 2700 rpm.
Notes: 50+ engines delivered, 1400 hours on highest time engine, 12-14 weeks shipping time.

### O/IO-540-X, 260-298 HP
Price: $41,975-$47,895 HP
Configuration: Horizontally opposed, parallel head, 6 cylinder, air cooled, fuel injected, 397-469 lb. dry weight. Options include high compression pistons and forward facing cold air induction.
Output: 260+ hp at 2700 rpm.
Notes: 200+ engines delivered, 12-14 weeks shipping time.

### IO/540-X, 300-325 HP
Price: $57,272
Configuration: Horizontally opposed, angle head, 6 cylinder, air cooled, fuel injected, 380-395 lb. dry weight. Options include high compression pistons and forward facing cold air induction.
Output: 300+ hp at 2700 rpm.
Notes: 200+ engines delivered, 12-14 weeks shipping time.

### IO/TSIO 520, 300 HP (available only as 0 SMOH)
Price: $36,857-$39,657
Configuration: Horizontally opposed, 6 cylinder, air cooled, fuel injected, 440 lb. dry weight.
Output: 300 hp at 2700 rpm.
Notes: 200+ engines delivered.

### IO/TSIO-550-X, 350 HP (available only as 0 SMOH)
Price: $43,000-$77,000
Configuration: Horizontally opposed, 6 cylinder, air cooled, fuel injected, 442 lb. dry weight.
Output: 350+ hp at 2700 rpm.
Notes: 200 engines delivered.

### IO-550/TSIO-550 Lancair Reno Engine, 310-350 HP
Price: Available through Lancair
Configuration: Horizontally opposed, 6 cylinder, air cooled, fuel injected, 442 lb. dry weight.
Output: 310-350 hp at 2700 rpm.
Notes: 10 engines delivered, 14-16 weeks shipping time. Offered in partnership with Lancair using factory reman. or factory new engines.

### M-14P, 365-400 HP (in development)
Price: $35,000 (with high-performance modifications, stock overhaul: $20,000).
Configuration: Radial, 9 cylinder, air cooled, carbureted, 471 lb. dry weight.
Output: 365-400 hp at 2950 rpm.
Notes: 3 engines delivered, 14 weeks shipping time. Specifically developed modifications to reduce oil consumption and increase power.

Aerotek on a Murphy Moose.

Compact Radial MZ202 with gearbox.

**Compact Radial Engines**
**604/590-2950**
**www.compactradialengines.com**

### MZ-34, MZ-35, 27 HP
Price: $2970-$3140
Configuration: Upright, 1 cylinder, air cooled, carbureted, 37 lb. dry weight.
Output: 27 hp at 6250 rpm.
Propeller: Powerfin.
Notes: 2600 engines delivered, 2 weeks shipping time if not in stock.

### MZ-100, 18 HP
Price: $2120
Configuration: Upright, 1 cylinder, air cooled, carbureted, 31 lb. dry weight.
Output: 18 hp at 9700 rpm.
Propeller: Powerfin.
Notes: 100 engines delivered, 1 month shipping time if not in stock.

### MZ-201, 45 HP
Price: $4290
Configuration: Upright, 2 cylinder, air cooled, carbureted, 65 lb. dry weight.
Output: 45 hp at 4700 rpm.
Propeller: Powerfin.
Notes: 440 engines delivered, 2 weeks shipping time if not in stock.

### MZ-202, 60 HP
Price: $5660
Configuration: Upright, 2 cylinder, air cooled, carbureted, 85 lb. dry weight.
Output: 60 hp at 5800 rpm.
Propeller: Powerfin.
Notes: 1000 engines delivered, 2 weeks shipping time if not in stock.

### MZ-301, 85 HP
Price: $9230
Configuration: Upright, 3 cylinder, air cooled, carbureted, 85 lb. dry weight.
Output: 85 hp at 5800 rpm.
Propeller: Powerfin.
Notes: 50 engines delivered, 2 weeks shipping time if not in stock.

### SC-430, 24 HP
Price: $3750
Configuration: 3 cylinder, carbureted, 37 lb. dry weight.
Output: 24 hp at 4200 rpm.

### SD-570, 28 HP
Price: $4480
Configuration: Direct drive, 4 cylinder, carbureted, 41 lb. dry weight.
Output: 28 hp at 4200 rpm.

**CONTINENTAL ENGINES**
**Teledyne Continental Motors**
**251/438-3411**
**www.tcmlink.com**

*Editor's note: Teledyne Continental Motors does not sell directly to consumers. Engines are available used through independent shops and new from certain original-equipment kit manufacturers.*

### IO-360-ES, 210 HP
Price: Contact dealer
Configuration: Opposed, 6 cylinder, air cooled, fuel injected, 330 lb. dry weight.
Output: 210 hp at 2800 rpm.

### IO-550-G, 280 HP
Price: Contact dealer
Configuration: Opposed, 6 cylinder, air cooled, fuel injected, 465 lb. dry weight.
Output: 280 hp at 2600 rpm.

### TSIO-550-E, 350 HP
Price: Contact dealer
Configuration: Opposed, 6 cylinder, air cooled, fuel injected, 565 lb. dry weight.
Output: 350 hp at 2700 rpm.

**DeltaHawk**
**262/634-9660**
**www.deltahawkengines.com**

*Editor's note: The DeltaHawk engines must still be considered in development. While we, and consumers, recognize that engineering an all-new engine is a daunting task, this design has been on the verge of widespread application and availability for many years.*

### DH 160 A4 (inverted)/V-4 (upright)/R4 (vertical shaft), 160 HP
Price: 2009 prices will be announced on company web site
Configuration: Upright or inverted V-4, 4 cylinder, water cooled, fuel injected, 330 lb. dry weight. Mechanical fuel control.
Output: 160 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or constant speed.
Notes: Certification summer 2009.

### DH 180 A4 (inverted)/V-4 (upright)/R4 (vertical shaft), 180 HP
Price: 2009 prices will be announced on company web site
Configuration: Upright or inverted V-4, 4 cylinder, water cooled, fuel injected, 330 lb. dry weight. Mechanical fuel control.
Output: 180 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or constant speed.
Notes: Certification summer 2009.

### DH 200 A4 (inverted)/V-4 (upright)/R4 (vertical shaft), 200 HP
Price: 2009 prices will be announced on co. web site
Configuration: Upright or inverted V-4, 4 cylinder, water cooled, fuel injected, 330 lb. dry weight. Mechanical fuel control.
Output: 200 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or constant speed..
Notes: 12 engines delivered, 200+ hours on highest time engine. Certification fall 2009.

## Eagle Engines
**530/221-4470**
**www.ameritech-aviation.com**

### EXP Titan Series 320 or 360 HP
Price: $20.000-$21,156
Configuration: Horizontally opposed, 4 cylinder, air cooled, 270-285 lb. dry weight.
Output: 320 or 360 hp at 2700 rpm.
Propeller: Varies per aircraft application.
Recommended governor is PCU 5000.
Notes: 25 engines delivered, 3-4 weeks shipping time.

### EXP Titan 340 S Stroker, 185 HP
Price: $21,000-$21,900
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, lb. dry weight. FADEC available on piston engine series.
Output: 185 hp at 2700 rpm.
Propeller: Varies per aircraft application.
Recommended governor is PCU 5000.
Notes: 1 engine delivered, 3-4 weeks shipping time.

### Xtreem 320, 150-160 HP
Price: $21,000-$24,686
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, 285 lb. dry weight. FADEC available on piston engine series.
Output: 150-160 hp at 2700 rpm.
Propeller: Varies per aircraft application.
Recommended governor is PCU 5000.
Notes: 12 engines delivered, 100+ hours on highest time engine, 4-6 weeks shipping time.

### Xtreem 360, 180 HP
Price: $22,700-$26,750
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, 288-294 lb. dry weight. FADEC available on piston engine series.
Output: 180-200 hp at 2700 rpm.
Propeller: Varies per aircraft application.
Recommended governor is PCU 5000.
Notes: 250+ engines delivered, 300+ hours on highest time engine, 4-6 weeks shipping time.

### Xtreem 390, 210+ HP
Price: $32,800-$35,010
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected, 308 lb. dry weight.
Output: 210 hp at 2700 rpm.
Propeller: Varies per aircraft application.
Recommended governor is PCU 5000.
Notes: 3 engines delivered, 4-8 weeks shipping time.

### Xtreem 400, 220+ HP
Price: $30,995-$32,195
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted or fuel injected, 316 lb. dry weight. FADEC available on piston engine series.
Output: 220 hp at 2700 rpm.
Propeller: Varies per aircraft application.
Recommended governor is PCU 5000.
Notes: 1 engine delivered, 4-8 weeks shipping time.
*Editor's note: This engine is based on the Superior XP-400, which hould be considered still in development.*

## Eggenfellner Aircraft Inc.
**386/566-2616**
**www.eggenfellneraircraft.com**

### Subaru E6, 200 HP
Price: $29,995
Configuration: Horizontally opposed, 6 cylinder, water cooled, fuel injected, 370 lb. dry weight.
Output: 220 hp at 2700 rpm (to 14,000 feet).
Propeller: Sensenich.
Notes: 40 engines delivered, 300+ hours on highest time engine, 6 months shipping time.

### Subaru E6T, 200 HP
Price: $24,995
Configuration: Horizontally opposed, 6 cylinder, water cooled, fuel injected, 350 lb. dry weight.
Output: 220 hp at 2700 rpm.
Propeller: Sensenich.
Notes: 175 engines delivered, 100 hours on highest time engine, 6 months shipping time.

### Subaru E6-T1 (turbo/intercooled), 220 HP
Price: $31,995
Configuration: Horizontally opposed, 4 cylinder, water cooled, fuel injected, 375 lb. dry weight.
Output: 220 hp at 2700 rpm (to 20,000 feet).
Propeller: Sensenich.
Notes: 15 engines delivered, 1100+ hours on highest time engine, 6 months shipping time.

## Engine Components, Inc.
**800/324-2359**
**www.eci.aero**
*Editor's note: ECI's kit engines are furnished and built by special engine builders listed on the web at www.eci.aero. Each engine builder sets the final price of the completed engine, which is why weire not listing prices here. Call Engine Components for more information.*

### Titan Kit Engine O-320, 160 HP
Price: Contact authorized Eci Titan kit engine supplier
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, lb. dry weight.
Output: 160 hp at 2700 rpm.
Notes: 2 weeks shipping time.

### Titan Kit Engine OX-320, 164 HP
Price: Contact authorized Eci Titan kit engine supplier
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted.

Compact Radial MZ34.

Lycoming TIO-360.

Output: 164 hp at 2700 rpm.
Notes: 2 weeks shipping time.

### Titan Kit Engine EXP IOX-320, 166 HP

Price: Contact authorized Eci Titan Kit Engine Supplier
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected.
Output: 166 hp at 2700 rpm.
Notes: 2 weeks shipping time.

### Titan Kit Engine EXP OX-340, 177 HP

Price: Contact authorized Eci Titan kit engine supplier
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted.
Output: 177 hp at 2700 rpm.
Notes: 2 weeks shipping time.

### Titan Kit Engine O-360, 180 HP

Price: Contact authorized Eci Titan Kit Engine Supplier
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected.
Output: 180 hp at 2700 rpm.
Notes: 2 weeks shipping time

### Titan Kit Engine EXP IOX-340, 185 HP

Price: Contact authorized Eci Titan Kit Engine Supplier
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected.
Output: 185 hp at 2700 rpm.
Notes: 2 weeks shipping time.

### Titan Kit Engine OX-360, 185 HP

Price: Contact authorized Eci Titan Kit Engine Supplier
Configuration: Horizontally opposed, 4 cylinder, fuel injected.
Output: 185 hp at 2700 rpm.
Notes: 2 weeks shipping time.

### Titan Kit Engine EXP IOX-360, 188 HP

Price: Contact authorized Eci Titan Kit Engine Supplier
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected.
Output: 188 hp at 2700 rpm.
Notes: 2 weeks shipping time.

## FlyCorvair.com
904/529-0006
www.flycorvair.com

### Fly6Corvair.com Corvair, 100-130 HP

Price: $7995 base price, options extra
Configuration: Horizontally opposed, 164-169 cid, 6 cylinder, air cooled, carbureted, 218-230 lb. dry weight.
Output: 120 hp at 3200 rpm.
Propeller: Wood or composite.
Notes: 55 engines delivered, 500 hours on highest time engine, 90 days shipping time.

## FlyDiv
360/490-6268
www.flydiver.com

### Verner Scarlett 5, 125 HP

Price: Call or visit web site
Configuration: Radial, 5 cylinder, air and oil cooled, carbureted (Bing 92), 187 lb. dry weight plus muffler and oil cooler (12 lb.).
Output: 125 hp at 3000 rpm.
Propeller: 68-72 inch.
Notes: 8-12 weeks shipping time.

### Verner Scarlett 5R, 170 HP

Price: Call or visit web site
Configuration: Radial, 5 cylinder, air and oil cooled, carbureted (Bing 92), 195.8 lb. dry weight plus muffler and oil cooler (12 lb.).
Output: 170 hp at 3600 rpm.
Propeller: 68-72 inch.
Notes: 8-12 weeks shipping time.

### Verner Scarlett 5RS, 190 HP

Price: Call or visit web site
Configuration: Radial, 5 cylinder, air and oil cooled, carbureted (Bing 92), 195.8 lb. dry weight plus muffler and oil cooler (12 lb.).
Output: 190 hp at 4600 rpm.
Propeller: 68-72 inch.
Notes: 8-12 weeks shipping time.

## Geared Drives
**936/827-5126 or 936/672-6639**
**www.geareddrives.com**

### LS Series Aluminum Chevrolet Corvette for RV-10, 320 HP
Price: $29,900, FWF package
Configuration: V-8, water cooled, fuel injected, 445 lb. dry weight. with all accessories except radiator, coolant and hoses.
Output: 320 hp at 4300 rpm.
Propeller: Customer's choice of hydraulic, electric or fixed pitch..
Notes: 120-180 days shipping time. Includes PSRU, engine mount, starter, alternator, exhaust system, cooling system, baffling, engine wiring harness and computer.

### LSJ Aluminum Chevrolet, 150-245 HP
Price: $29,900, FWF package
Configuration: V-8, water cooled, 370 lb. dry weight with all accessories except radiator, coolant and hoses.
Output: 150-245 hp at 4800.
Notes: 2 engines delivered, 120-180 days shipping time. Includes PSRU, engine mount, starter, alternator, exhaust system, cooling system, baffling, engine wiring harness and computer.

## Global Rotary Power Inc.
**905/697-4400**
**www.rotaryengines.ca**
*Editor's note: As was true last year, Global Rotary declined to give us the number of engines delivered or current prices.*

### GRP-NRR-CA, 40 HP
Price: Available on request
Configuration: Rotary, 1 rotor, water cooled, carbureted, 38 lb. dry weight.
Output: 40 hp at 6000 rpm.
Notes: 2 weeks shipping time.

### GRP-WAG-Fi 1, 40 HP
Price: Available on request
Configuration: Rotary, 1 rotor, water cooled, fuel injected, 65 lb. dry weight.
Output: 40 hp at 6000 rpm.
Notes: 10 weeks shipping time.

### GRP-WST-MF-1, 65 HP
Price: Available on request
Configuration: Rotary, 1 rotor, water cooled, fuel injected, 143 lb. dry weight.
Output: 65 hp at 6000 rpm.
Notes: 6-8 weeks shipping time.

### GRP-WAG-Fi 2, 80 HP
Price: Available on request
Configuration: Rotary, 2 rotors, water cooled, fuel injected, 115 lb. dry weight.
Output: 80 hp at 6000 rpm.
Notes: 10 weeks shipping time.

### GRP-WST-MF-2, 130 HP
Price: Available on request
Configuration: Rotary, 2 rotors, water cooled, fuel injected, 176 lb. dry weight.
Output: 130 hp at 6000 rpm.
Notes: 1500 hours on highest time engine, shipping time.

### GRP-DAFi-13B, 180 HP
Price: Available on request

Geared Drives firewall-forward on an RV-10.

Configuration: Rotary, 2 rotors, water cooled, fuel injected,  lb. dry weight.
Output: 180 hp at 6000 rpm.
Notes: 3 weeks shipping time.

### GRP-WST-MF-3, 195 HP
Price: Available on request
Configuration: Rotary, 3 rotors, water cooled, fuel injected, 220 lb. dry weight.
Output: 220 hp at 6000 rpm.
Notes: 1500 hours on highest time engine, 4 weeks shipping time.

### GRP-DAFi-13BT, 200 HP
Price: Available on request
Configuration: Rotary, 2 rotors, water cooled, fuel injected,  lb. dry weight.
Output: 200 hp at 6000 rpm.
Notes: 3 weeks shipping time.

## Great Plains Aircraft Supply Co.
**800/922-6507**
**www.gpasc.com**

### 1600cc VW Direct Drive, 50 HP
Price: $2900-$3500
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 145-164 lb. dry weight.
Output: 50 hp at 3400 rpm.
Propeller: Wood.
Notes: 1500 hours on highest time engine, immediate shipping time.

### 1835cc VW Direct Drive, 60 HP
Price: $3500-$4200
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 145-163 lb. dry weight.
Output: 60 hp at 3400 rpm.
Propeller: Wood.
Notes: 1800 hours on highest time engine, immediate shipping time.

### 1915cc VW Reduction Drive, 80 HP
Price: $4500-$5500
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 178 lb. dry weight.
Output: 80 hp at 4200 rpm.
Propeller: Wood or composite.
Notes: 17 engines delivered, 175 hours on highest time engine, immediate shipping time.

### 2180cc VW Direct Drive, 76 HP
Price: $4500-$5500
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 164.5 lb. dry weight.
Output: 76 hp at 3400 rpm.
Propeller: Wood.
Notes: 1800+ engines delivered, 2500 hours on highest time engine, immediate shipping time.

### 2180cc VW Flywheel Drive, 80 HP
Price: $6000-$6500
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted,  185 lb. dry weight.
Output: 80 hp at 3400 rpm.
Propeller: Wood.
Notes: 21 engines delivered, immediate shipping time.

### 2180cc VW Redrive, 103 HP
Price: $5500-$6500
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 188 lb. dry weight.
Output: 103 hp at 4200 rpm.
Propeller: Wood or composite.
Notes: 32 engines delivered, 175 hours on highest time engine, immediate shipping time.

## HCI Aviation
**573/237-3605**
**www.hciaviation.com**

### R-180, 75 HP
Price: $12,000
Configuration: Radial, 5 cylinder, air cooled, 122 lb. dry weight.
Output: 75 hp at 2150 rpm.
Propeller: 72x42 inch, fixed pitch, wood.
Notes: Selling machine drawings and castings for homebuilder machinist.

### R-220, 125 HP
Price: $16,800
Configuration: Radial, 7 cylinder, air cooled, 138 lb. dry weight.
Output: 125 hp at 2500 rpm.
Propeller: 72x42-inch, fixed pitch, wood.
Notes: Selling machine drawings and castings for homebuilder machinist.

## Hexatron Engineering Co. Inc.
**801/363-8010**
**www.hexadyneaviation.com**

### P60, 60 HP
Price: $8800
Configuration: Twin opposed, 2 cylinder, air cooled, fuel injected, 94 lb. dry weight.

Compact Radial MZ100.

Output: 60 hp at 5750 rpm.
Propeller: Warp Drive, PowerFin, Kiev, fixed or adjustable.
Notes: 40 engines delivered, 4 aircraft flying, 1800 hours on highest time engine, 4 weeks shipping time.
*Editor's note: This engine should be considered in development.*

### HIRTH ENGINES

**Recreational Power Engineering**
**419/585-7002**
**www.recpower.com**

#### F-23, 50 HP
Price: $4423 (includes complete exhaust, air filters and fuel pump)
Configuration: Horizontally opposed, 2 cylinder, air cooled, carbureted, 70 lb. dry weight.
Output: 50 hp at 6150 rpm.
Propeller: Fixed pitch or adjustable.
Notes: 1000+ engines delivered, 1500 hours on highest time engine, immediate shipping time.

#### F-30, 100 HP
Price: $8586 (includes complete exhaust, air filters and fuel pump)
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 105 lb. dry weight.
Output: 100 hp at 6300 rpm.
Propeller: Fixed pitch or adjustable.
Notes: 500+ engines delivered, 1200 hours on highest time engine, immediate shipping time.

#### F-33, 28 HP
Price: $2600 (includes complete exhaust, air filter and fuel pump)
Configuration: Upright inline, 1 cylinder, air cooled, carbureted, 35 lb. dry weight.
Output: 28 hp at 6000 rpm.
Propeller: Fixed pitch or adjustable.
Notes: 1500+ engines delivered, 600 hours on highest time engine, immediate shipping time.

#### 2702, 40 HP
Price: $3476
Configuration: Upright inline, 2 cylinder, air cooled, carbureted, 76 lb. dry weight.
Output: 40 hp at 5500 rpm.
Propeller: Fixed pitch or ground adjustable.
Notes: 1000+ engines delivered, 1200 hours on highest time engine, immediate shipping time.

#### 3202, 55 HP
Price: $4423 (includes complete exhaust, air filters and fuel pump)
Configuration: Upright inline, 2 cylinder, air cooled, carbureted, 76 lb. dry weight.
Output: 55 hp at 5500 rpm.
Propeller: Fixed pitch or adjustable.
Notes: 500+ engines delivered, 1200 hours on highest time engine, immediate shipping time.

#### 3203, 65 HP
Price: $5143
Configuration: Upright inline, 2 cylinder, air cooled, carbureted, 76 lb. dry weight.
Output: 65 hp at 6300 rpm.
Propeller: Fixed pitch or adjustable.
Notes: 1000+ engines delivered, 1000 hours on highest time engine, immediate shipping time.

#### 3503, 70 HP
Price: $5988
Configuration: Upright inline, 2 cylinder, water cooled, carbureted, 79 lb. dry weight.
Output: 70 hp at 6500 rpm.
Propeller: Fixed pitch or adjustable.
Notes: 350 engines delivered, 350 hours on highest time engine, immediate shipping time.

#### 3701, 100 HP
Price: $9815 (also available in 80-hp, high-torque, low-rpm version)
Configuration: Upright inline, 3 cylinder, water cooled, carbureted, 109 lb. dry weight.
Output: 100 hp at 6000 rpm.
Propeller: Fixed pitch or adjustable.
Notes: 150+ engines delivered, 500 hours on highest time engine, immediate shipping time.

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**Aviation Publishing Group**
**800 Connecticut Ave, Norwalk, CT 06854**

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Verner Scarlett rotary.

**Hummel Engines**
**520/723-5283, 520/518-4708**
**www.hummelengines.com**

### Hummel 2- & 4-Cylinder VW, 28-85 HP
Price: $2700-$6100
Configuration: Horizontally opposed, 2/4 cylinder, air cooled, carbureted, 80-167 lb. dry weight.
Output: 28-85 hp at 3000 rpm.
Propeller: 54x20 to 60x20.
Notes: 300+ engines delivered, 1200 hours on highest time engine, 4-6 weeks shipping time.

## JABIRU ENGINES

**Jabiru Pacific**
**559/431-1701**
**www.jabirupacific.com**

**Jabiru USA Flight Center**
**931/880-2800**
**www.usjabiru.com**

**Lancaster Aero**
**613/347-3155**
**www.jabirucanada.com**

### 2200A, 85 HP
Price: $12,900
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 140 lb. dry weight.
Output: 85 hp at 3300 rpm.
Propeller: 62x42.
Notes: 3100 engines delivered, 6000 hours on highest time engine, immediate shipping time.

### 3300A, 120 HP
Price: $17,400
Configuration: Horizontally opposed, 6 cylinder, air cooled, carbureted, 180 lb. dry weight.
Output: 120 hp at 3300 rpm.
Propeller: 64x51.
Notes: 2100 engines delivered, 2700 hours on highest time engine, immediate shipping time.

### 5100A, 180 HP
Price: $25,900
Configuration: Horizontally opposed, 8 cylinder, air cooled, carbureted, 275 lb. dry weight.
Output: 180 hp at 5100 rpm.
Notes: 75 engines delivered, 500 hours on highest time engine, 8 weeks shipping time.

## LYCOMING ENGINES

**Textron Lycoming**
**570/323-6181**
**www.textron.com**

*Editor's note: For pricing on certified engines, contact a Lycoming distributor; a list can be found at www.textron.com. Thunderbolt is Lycoming's brand of non-certified engines offered in build-to-order form in 235, 320, 360, 390, 540 and 580 displacements. Contact Lycoming Thunderbolt at 888/MY-TBOLT.*

### Lycoming 235 Series, 108-118 HP
Price: See note above
Configuration: Horizontally opposed, air cooled, carbureted, 213-218 lb. dry weight.
Output: 108-118 hp at 2400-2800 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.

### Lycoming 320 Series, 140-160 HP
Price: See note above
Configuration: Horizontally opposed, air cooled, carbureted or fuel injected, 244-271 lb. dry weight.
Output: 140-160 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.

### Lycoming 360 Series, 180-200 HP
Price: See note above
Configuration: Horizontally opposed, air cooled, carbureted or fuel injected, 265-293 lb. dry weight.
Output: 180-200 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.

### Lycoming IO-390-X, 210 HP
Price: See note above
Configuration: Horizontally opposed, air cooled, fuel injected, 308-315 lb. dry weight.
Output: 210 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.

### Lycoming 540 Series, 235-350 HP
Price: See note above
Configuration: Horizontally opposed, air cooled, carbureted or fuel injected, 356-595 lb. dry weight.
Output: 235-350 hp at 2400-2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.

### Lycoming IO-580 Series, 315-330 HP
Price: See note above
Configuration: Horizontally opposed, air cooled, fuel injected, 444-480 lb. dry weight.
Output: 315-330 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.

**M-14P, Incorporated**
**928/681-4400**
**www.m-14p.com**

### M-14P, 360 HP
Price: $22,500-$40,000
Configuration: Radial, 9 cylinder, air cooled, carbureted, 471 lb. dry weight.
Output: 360 hp at 2950 rpm.
Propeller: V-530 T/A, Avia, MT, Hoffman, or Hartzell.
Notes: 60+ engines delivered, 1200 hours on highest time engine, overhauled in stock shipping time.

**Maxwell Propulsion Systems, Inc.**
**360/474-8118**
**www.maxwellpropulsion.com**

### MX1 (Subaru EJ25/7), 165 HP
Price: $20,115
Configuration: Horizontally opposed, 4 cylinder, water cooled, fuel injected, 338 lb. dry weight.
Output: 165 hp at 5200 rpm.
Propeller: MPS CAP II.
Notes: 14 engines delivered, 8 weeks shipping time. Tuned to use 87 octane mogas. Two-year limited warranty on FWF engine packages including PSRU and propeller, starting at $29,175.

### MX2, turbocharged (Subaru EJ25/7), 195 HP (in development)
Price: $26,115
Configuration: Horizontally opposed, 4 cylinder, water cooled, fuel injected, 362 lb. dry weight.

Barrett IO-540.

low pressure turbocharged.
Output: 195 hp at 5200 rpm.
Propeller: MPS CAP II.
Notes: 8 weeks shipping time. Tuned to use 87 octane mogas. Two-year limited warranty on FWF engine packages including PSRU and propeller, starting at $29,175.

### MX3, turbocharged (Subaru EJ25/7), 240 HP (in development)

Price: $29,115
Configuration: Horizontally opposed, 4 cylinder, water cooled, fuel injected, 375 lb. dry weight. intercooled turbocharged.
Output: 240 hp at 5200 rpm.
Propeller: MPS CAP II.
Notes: 8 weeks shipping time. Tuned to use 87 octane mogas. Two-year limited warranty on FWF engine packages including PSRU and propeller, starting at $29,175.

## Mistral Engines
## 386/624 6904
## www.mistral-engines.com

### G-200, 200 HP (in development)

Price: Contact company
Configuration: Rotary, 2 rotor, water cooled, fuel injected, 291 lb. dry weight. Multi-fuel (leaded or unleaded, avgas, mogas, ethanol-blended fuels, mixtures thereof), dual injection and ignition engine management, fully redundant digital engine management (DEM) with dual ECU.
Output: 200 hp at 2250 rpm.
Propeller: Hartzell or MT, 3 blade.
Notes: FAA and EASA type certification expected beginning 2010.

### G-230TS, turbocharged, 230 HP (in development)

Price: Contact company
Configuration: Rotary, 2 rotor, water cooled, fuel injected, 328 lb. dry weight. Multi-fuel (leaded or unleaded, avgas, mogas, ethanol-blended fuels, mixtures thereof), dual injection and ignition engine management, fully redundant digital engine management (DEM) with dual ECU.
Output: 230 hp at 2250 rpm.
Propeller: Hartzell or MT, 3 blade.
Notes: FAA/EASA type certification spring 2010.

Superior XP-360.

### G-300, 300 HP (in development)

Price: Contact company
Configuration: Rotary, 3 rotor, water cooled, fuel injected, 390 lb. dry weight. Multi-fuel (leaded or unleaded, avgas, mogas, ethanol-blended fuels, mixtures thereof), dual injection and ignition engine management, fully redundant digital engine management (DEM) with dual ECU.
Output: 300 hp at 2250 rpm.
Propeller: Hartzell or MT, 3 blade.
Notes: FAA type certification expected end of 2009.

### G-360TS, turbocharged, 360 HP (in development)

Price: Contact company
Configuration: Rotary, 3 rotor, water cooled, fuel injected, 420 lb. dry weight. Multi-fuel (leaded or unleaded, avgas, mogas, ethanol-blended fuels, mixtures thereof), dual injection and ignition engine management, fully redundant digital engine management (DEM) with dual ECU.
Output: 360 hp at 2250 rpm.
Propeller: Hartzell or MT, 3 blade.
Notes: FAA type certification expected middle of 2010.

## Powerplant Developments-USA, Inc.
## 214/404-3981
## www.ppdgemini.com

### Gemini 100, 100 HP (in development)

Price: $18,000
Configuration: 3 cylinder, 6 piston, water cooled, fuel injected, 155 lb. dry weight.
Output: 100 hp at 2500 rpm.
Notes: April 2009 estimated shipping time.

## Powersport Aviation
## 715/294-2557
## www.powersportaviation.com

### RE-215 Rotary, 215 HP

Price: $24,500
Configuration: Rotary, 2 rotor, water cooled, fuel injected, dual ECU controlled, 257 lb. dry weight.
Output: 215 hp at 2620 prop rpm.
Propeller: MT 3 blade, electric constant speed.
Notes: 9 engines delivered, 200 hours on highest time engine, 12 weeks shipping time.

### RE-245 Rotary, 245 HP

Price: $28,500
Configuration: Rotary, 2 rotor, water cooled, fuel injected, dual ECU controlled, 257 lb. dry weight.
Output: 245 hp at 2700 prop rpm.
Propeller: MT 3 blade, electric constant speed.
Notes: 8 engines delivered, 280 hours on highest time engine, 12 weeks shipping time.

### RE-360 Rotary, 360 HP

Price: $40,000
Configuration: Rotary, 2 rotor, water cooled, fuel injected, 330 lb. dry weight.
Output: 360 hp at 2700 prop rpm.
Propeller: MT 3 blade, electric constant speed.
Notes: 250 hours on highest time engine, 20 weeks shipping time.

Engine Components, Inc.

## RAM Performance Ltd.
## 330/882-6255
## www.ramengines.com

### Subaru RAM, 115 HP

Price: $13,600, with re-drive, motor mounts
Configuration: Horizontally opposed, water cooled, fuel injected, 150 lb. dry weight, 176 lb. wet weight.
Output: 115 hp at 5000 rpm.
Propeller: Prince P-Tip.

### Subaru RAM SC, 140 HP

Price: $17,600, with re-drive, motor mounts
Configuration: Horizontally opposed, water cooled, fuel injected, supercharged, 140 lb. dry weight, 188 lb. wet weight.
Output: 140 hp at 5500 rpm.
Propeller: Prince P-Tip.
Notes: 2000 engines delivered.

### Subaru RAM 2.3L, 200 HP

Price: $15,995, with re-drive
Configuration: Horizontally opposed, water cooled, fuel injected, 200 lb. dry weight, 220 lb. wet weight.
Output: 200 hp at 5400 rpm.
Propeller: Prince P-Tip.

### Subaru RAM 2.3L SC, 300 HP (in development)

Price: $20,295, with re-drive
Configuration: Horizontally opposed, water cooled, fuel injected, supercharged, 188 lb. dry weight, 235 lb. wet weight
Output: 300 hp at 5700 rpm.
Propeller: Prince P-Tip.

## Raven ReDrives
## 303/440-6234 or 575/737-9656
## www.raven-rotor.com

### 1000 ULDD, 38 HP

Price: $4795 complete engine package, $1295 direct-drive reduction kit
Configuration: Upright inline, 3 cylinder, water cooled, carbureted, 93 lb. dry weight.
Output: 38 hp at 3400.
Propeller: 2 blade wood.
Notes: 3-4 weeks shipping time.

### 1000 ULX, UL, UL-T, 60 HP

Price: $5749/$5995/$6295 complete engine package, $2195-$2695 belt reduction drive kit
Configuration: Upright inline, 3 cylinder, water cooled, fuel injected, 130-138 lb. dry weight.

Output: 60 hp at 5700 rpm.
Propeller: Ivoprop, Powerfin, GSC, wood.
Notes: 225+ engines delivered, 1000+ hours on highest time engine, 4-6 weeks shipping time.

### 1000 ULRS, ULRS-T, 60 HP

Price: $5995/$6095 complete engine package, $2695/$2795 belt reduction drive kit
Configuration: Upright inline, 3 cylinder, water cooled, fuel injected, 140 lb. dry weight.
Output: 60 hp at 5700 rpm.
Propeller: Ivoprop, Powerfin, GSC, wood.
Notes: 20+ engines delivered, 650+ hours on highest time engine, 2-3 weeks shipping time.

### 1000 UL, UL-T, ULRS-T Turbo, 80 HP

Price: $7850/$8295 complete engine package
Configuration: Upright inline, 3 cylinder, water cooled, fuel injected, 152 lb. dry weight.
Output: 80 hp at 5700 rpm.
Propeller: Ivoprop, Powerfin, GSC, wood.
Notes: 12 engines delivered, 500+ hours on highest time engine, 2-3 weeks shipping time.

### 1300 SV/1300 SVS, 90 HP

Price: $8595-$8895 complete engine package
Configuration: Upright/flat inline, 4 cylinder, water cooled, fuel injected, 185/175 lb. dry weight.
Output: 90 hp at 5700 rpm.
Propeller: Ivoprop, Powerfin, GSC, wood.
Notes: 25+ engines delivered, 250+ hours on highest time engine, 4-6 weeks shipping time.

### 1300 SV/1300 SVS Turbo, 115 HP

Price: $11,995/$11,495 complete engine package
Configuration: Upright/flat inline, water cooled, fuel injected, 205/195 lb. dry weight.
Output: 115 hp at 5700 rpm.
Propeller: Ivoprop, Powerfin, GSC, wood.
Notes: 5 engines delivered, 50 hours on highest time engine, 4-6 weeks shipping time.

## Revmaster Aviation
760/244-3074
www.revmasteraviation.com

### R2100-D, 75 HP

Price: $6500
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 175 lb. dry weight.
Output: 75 hp at 3200 rpm.
Propeller: Standard fixed, oil controls.
Notes: 3370 engines delivered, 2000 hours on highest time engine, 1-2 months shipping time.

### R2200-D, 80 HP

Price: $6700
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 175 lb. dry weight.
Output: 80 hp at 3250.
Propeller: Standard fixed, oil controls.
Notes: 15 engines delivered, 400 hours on highest time engine, 1-2 months shipping time.

### R-3000, 110 HP (in development}

Price: Call
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 205 lb. dry weight.
Output: 110 hp at 3200.
Propeller: Fixed.
Notes: 8 prototype engines delivered.

## ROTAX ENGINES

*Editor's note: For global list of Rotax Distributors, see www.rotax-owner.com. Listed are the Rotax Service Centers for North America for our readers' convenience. Due to fluctuations among the U.S., Canadian and Euro currencies, no pricing is shown.*

**U. S. SERVICE CENTERS**
**California Power Systems**
**510/357-2403**
**www.800.airwolf.com**

**Copperstate Aero LLC (Arizona)**
**520/471-9328**
**www.copperstateaero.com**

**Leading Edge Air Foils (Wisconsin)**
**800/532-3462**
**www.leadingedge-airfoils.com**

**Lockwood Aviation (Florida)863/655-5100**
**www.lockwood-aviation.com**

**South Mississippi Light Aircraft**
**601/947-4953**
**www.flymla.com**

**CANADIAN SERVICE CENTERs**
**Aero Propulsion Technologies (East)**
**450/510-1561**
**www.rtx-av-engines.ca**

**Light Engine Service (West)**
**780/418-4164**
**www.rtx.av-engines.ca**

### Rotax 447 UL, 40 HP
Price: Call Service Center
Configuration: Inline, 2 cylinder, air cooled, carbureted, 57.1 lb. dry weight.
Output: 40 hp at 6500 rpm.
Propeller: Fixed pitch or adjustable.
Notes: Immediate shipping time.

### Rotax 503 UL, 50 HP
Price: Call Service Center
Configuration: Inline, 2 cylinder, air cooled, carbureted, 69.2 lb. dry weight.
Output: 50 hp at 6500 rpm.
Propeller: Fixed pitch or adjustable.
Notes: Immediate shipping time.

### Rotax 582 UL, 65 HP
Price: Call Service Center
Configuration: Inline, 2 cylinder, water cooled, carbureted, 64 lb. dry weight.
Output: 65 hp at 6500 rpm.
Propeller: Fixed pitch or adjustable.
Notes: Immediate shipping time.

### Rotax 912S, 100 HP
Price: Call Service Center
Configuration: Horizontally opposed, water/air cooled, carbureted, 133 lb. dry weight.
Output: 100 hp at 5800 rpm.
Propeller: Fixed pitch or adjustable.
Notes: Immediate shipping time.

### Rotax 912UL, 81 HP
Price: Call Service Center
Configuration: Horizontally opposed, 4 cylinder, water/air cooled, carbureted, 121.3 lb. dry weight.
Output: 81 hp at 5800 rpm.
Propeller: Fixed pitch or adjustable.
Notes: Immediate shipping time.

### Rotax 912 ULS, 100 HP
Price: Call Service Center
Configuration: Horizontally opposed, 4 cylinder, water/air cooled, carbureted, 124.8 lb. dry weight.
Output: 100 hp at 5800 rpm.
Propeller: Fixed pitch or adjustable.
Notes: Immediate shipping time.

### Rotax 914 UL, 115 HP
Price: Call Service Center
Configuration: Horizontally opposed, 4 cylinder, water/air cooled, carbureted, 144 lb. dry weight.
Output: 115 hp at 5800 rpm.
Propeller: Fixed pitch or adjustable.
Notes: Immediate shipping time.

## Rotec Engineering Pty. Ltd.
**+61 3 9587 9530**
**www.rotecradialengines.com**

### R2800 Radial, 110 HP
Price: $14,750
Configuration: Radial, 7 cylinder, air cooled, carbureted, 220 lb. dry weight.
Output: 150 hp @ 3700 rpm.
Propeller: 2 blade, 76x50.
Notes: 325 engines delivered, 650 hours on highest time engine. Reduction crank to prop 3:2.

### R3200 Radial, 150 HP
Price: $21,010
Configuration: Radial, 9 cylinder, air cooled, carbureted, 275 lb. dry weight.
Output: 150 hp @ 3600 rpm.
Propeller: 2 blade, 84x55.
Notes: 46 engines delivered. Reduction crank to prop 3:2.

## Stratus 2000
**541/754-4114**
**www.stratus2000.homestead.com**

### EA81, 105 HP
Price: $7445
Configuration: Horizontally opposed, 4 cylinder, water cooled, carbureted, 200 lb. dry weight.
Output: 105 hp at 5900 rpm.
Propeller: Warp Drive 3-blade, wide chord, ground adjustable.
Notes: 150+ engines delivered, 1200 hours on highest time engine, 2-3 months shipping time.

## Superior Air Parts
**972/829-4600**
**www.superiorairparts.com**

*Editor's note: Superior is continuing to develop the XP-400 engine, which was announced in 2006, but has decided not to list it here until the final specifications are set and flight testing is complete. According to the company (at press time), deliveries were to begin in January 2009 if testing went well.*

### XP-O-320, 150-160 HP
Price: Call
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 276 lb. dry weight.
Output: 150-160 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.
Notes: 8 weeks shipping time.

### XP-IO-320, 150-160 HP
Price: Call
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected, 283 lb. dry weight.
Output: 150-160 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.
Notes: 8 weeks shipping time.

### O-360, 180 HP
Price: Call
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 287 lb. dry weight.
Output: 180 hp at 2700 rpm.

Propeller: Lycoming compatible, fixed pitch or adjustable.
Notes: 8 weeks shipping time.

### IO-360, 180 HP
Price: Call
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected, 290 lb. dry weight.
Output: 180 hp at 2700 rpm.Propeller: Lycoming compatible, fixed pitch or adjustable.
Notes: 8 weeks shipping time.

### O-360 Vantage, 180 HP
Price: Call
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 287. lb. dry weight.
Output: 180 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.
Notes: 8 weeks shipping time.

### IO-360 Vantage, 180 HP
Price: Call
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected, 290 lb. dry weight.
Output: 180 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.
Notes: 8 weeks shipping time.

### XP-O-360 Plus, 180 HP
Price: Call
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 287 lb. dry weight.
Output: 180 hp at 2700 rpm.
Propeller: Lycoming compatible, fixed pitch or adjustable.
Notes: 8 weeks shipping time.

## Teledyne Mattituck Services
## 800/624-6680 Ext.309
## www.mattituck.com

### TMX O-200, 100 HP
Price: $19,455
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 215 lb. dry weight.
Output: 100 hp at 2700 rpm.
Propeller: Per kit manufacturer.
Notes: 49 engines delivered, 6-8 weeks shipping time

### TMX IO-240, 125 HP
Price: $20,135
Configuration: Horizontally opposed, 4 cylinder, air cooled, fuel injected, 240 lb. dry weight.
Output: 125 hp at 2800 rpm.
Propeller: Per kit manufacturer.
Notes: 25 engines delivered, 6-8 weeks shipping time.

### TMX O-320, 150-160 HP
Price: $21,100 (various configurations available)
Configuration: Horizontally opposed, parallel head, 4 cylinder, air cooled, carbureted, 273 lb. dry weight.
Output: 150-160 hp at 2700 rpm.
Propeller: Per kit manufacturer.
Notes: 46 engines delivered, 8-10 weeks shipping time.

### TMX IO-320, 156-166 HP
Price: $21,100 (various configurations available)
Configuration: Horizontally opposed, parallel head, 4 cylinder, air cooled, fuel injected, 276 lb. dry weight.
Output: 156-166 hp at 2700 rpm.
Propeller: Per kit manufacturer.
Notes: 7 engines delivered, 8-10 weeks shipping time.

### TMX O-360, 180 HP
Price: $21,800 (various configurations available)
Configuration: Horizontally opposed, parallel head, 4 cylinder, air cooled, carbureted, 281 lb. dry weight.
Output: 180 hp at 2700 rpm.
Propeller: Per kit manufacturer.
Notes: 184 engines delivered, 6-8 weeks shipping time.

### TMX IO-360, 180 HP
Price: $22,200 (various configurations available)
Configuration: Horizontally opposed, parallel head, 4 cylinder, air cooled, fuel injected, 285 lb. dry weight.
Output: 180 hp at 2700 rpm.
Propeller: Per kit manufacturer.

### TMX IO-360, 186 HP
Price: $23,900 (various configurations available)
Configuration: Horizontally opposed, parallel head, 4 cylinder, air cooled, fuel injected, 291 lb. dry weight.
Output: 186 hp at 2700 rpm.
Propeller: Per kit manufacturer.
Notes: 87 engines delivered, 12-16 weeks shipping time.

### TMX IO-360, 200 HP
Price: $35,960 (various configurations available)
Configuration: Horizontally opposed, slant valve, horizontal induction, 4 cylinder, air cooled, fuel injected, 315 lb. dry weight.
Output: 200 hp at 2700 rpm.
Propeller: Per kit manufacturer.
Notes: 2 engines delivered, 12-16 weeks shipping time.

### TMX IO-390, 210 HP
Price: $31,960 (various configurations available)
Configuration: Horizontally opposed, slant valve, horizontal induction, 4 cylinder, air cooled, fuel injected, 308 lb. dry weight.
Output: 210 hp at 2700 rpm.
Propeller: Per kit manufacturer.
Notes: 41 engines delivered, 6-8 weeks shipping time.

### TMX O-540, 250-260 HP
Price: $38,500 (various configurations available)
Configuration: Horizontally opposed, parallel head, 6 cylinder, air cooled, carbureted, 397 lb. dry weight.
Output: 250-260 hp at 2700 rpm.
Propeller: Per kit manufacturer.
Notes: engines delivered, 12-16 weeks shipping time.

### TMX IO-540, 260 HP
Price: $39,200 (various configurations available)
Configuration: Horizontally opposed, parallel head, vertical induction, 6 cylinder, air cooled, fuel injected, counterweighted crankshaft, 410 lb. dry weight.
Output: 260 hp at 2700 rpm.
Propeller: Per kit manufacturer.

### TMX IO-540, 300 HP
Price: $55,188
Configuration: Horizontally opposed, slant valve, horizontal induction, 6 cylinder, air cooled, fuel injected, counterweighted crankshaft, 469 lb. dry weight.
Output: 300 hp at 2700 rpm.
Propeller: Per kit manufacturer.
Notes: 1 engine delivered, 12-16 weeks shipping time.

## Trace Engines LP
## 432/618-7223
## www.traceengines.com

### OE600, 600 HP
Price: $200,000
Configuration: V-8, 8 cylinder, water cooled, fuel injected, 600 lb. dry weight. mechanical fuel control.
Output: 600 hp at 4400 rpm.
Propeller: McCauley.
Notes: 2 engines delivered, 1300 hours on highest time engine, immediate shipping time. FAA type and production certified.

Jabiru 3300 on a Jabiru airplane.

### Vair Force
### 386/290-3727
### www.vairforce.com

#### Corvair 2700cc - 3300cc, 100-120 HP
Price: $8750
Configuration: Horizontally opposed, 6 cylinder, air cooled, carbureted/fuel injected, 208-218 lb. dry weight.
Output: 100-120 hp at 3300 rpm.
Propeller: Warp Drive or Sensenich.
Notes: 58 engines delivered, 900 hours on highest time engine, 60-90 days shipping time.

### Valley Engineering
### 573/364-6311
### www.valleyengineeringllc.com

#### Big Twin 992 4 stroke, 40 HP
Price: $4995 (includes electric start, PSRU, prop and exhaust).
Configuration: V-twin, 2 cylinder, air cooled, carbureted, 120 lb. dry weight.
Output: 40 hp at 3600 rpm.
Propeller: Culver two-blade wood included.
Notes: 30 engines delivered, 150 hours on highest time engine, 1 month shipping time.

#### VE 85, 85 HP
Price: $7500 (includes Diehl case, electric start, PSRU and prop)
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 180 lb. dry weight.
Output: 85 hp at 3800 rpm.
Propeller: Culver two-blade wood included..
Notes: 2 engines delivered, 100 hours on highest time engine, 1 month shipping time.

#### VE 100, 100 HP
Price: $9995 (includes Diehl case, electric start, PSRU and prop)
Configuration: Horizontally opposed, 4 cylinder, air cooled, carbureted, 185 lb. dry weight.
Output: 100 hp at 3800 rpm.
Propeller: Culver two-blade wood included.
Notes: 30 engines delivered, 750 hours on highest time engine, 1 month shipping time.

### Vesta Inc.
### 908/238-9522
### www.vestav8.com

#### Ecotec 2.2L-2.4L, 160-200 HP
Price: $11,900
Configuration: Inline, 4 cylinder, water cooled, fuel injected, 300 lb. dry weight, FADEC.
Output: 160-200 hp at 5000-5400 rpm.
Propeller: Vesta GT2, GT3 68-78, LT2 80-83.
Notes: 16 weeks shipping time.

#### Chevy 572 Big Block, 550 HP
Price: $26,900
Configuration: V-8, water cooled, fuel injected, 780 lb. dry weight.
Output: 550 hp at 4500 rpm.
Propeller: Vesta HT 84-102.
Notes: 16 weeks shipping time.

#### Chevy 6.6L Duramax Diesel, 500 HP (in development)
Price: $29,900
Configuration: V-8, water cooled, fuel injected, 780 lb. dry weight. mechanical fuel control
Output: 500 hp at 3800 rpm.
Propeller: Vesta HT3, HT4 84-102.
Notes: 20 weeks shipping time.

#### Honda 3.5L-3.7L V-6, 240-310 HP
Price: $13,900
Configuration: V-6, 6 cylinder, water cooled, fuel injected, 340 lb. dry weight, FADEC.
Output: 240-310 hp at 5000-5400 rpm.
Propeller: Vesta GT2, GT3, GT4 68-78,LT4 80-83, VP3-82, VP4 70-82.
Notes: 16 weeks shipping time.

#### LS3-376 V-8, 380-430 HP
Price: $15,000
Configuration: V-8, 8 cylinder, water cooled, fuel injected, 460 lb. dry weight, FADEC.
Output: 380-430 hp at 4500-4800 rpm.
Propeller: Vesta VT3, VT4 76-84, RT3, RT4 89-92, HT3 84-102, VP3 82, VP4 70-82.
Notes: 16 weeks shipping time.

### Wilksch Airmotive
### 44 870 1709678
### www.wilksch.com

#### WAM-120, 120 HP
Price: £15,000
Configuration: Inverted inline 3-cylinder, water cooled, 220 lb. dry weight.
Output: 120 hp at 2700 rpm.
Notes: 30+ engines delivered, 1000+ hours on highest time engine, shipping time varies.

# PSRUs

### Alturair
### 619/449-1570
### www.alturair.com

#### A650 PR
Price: $9500
Configuration: planetary gear, 3:1 ratio; maximum engine power 100 hp, weight 25 lb.

### American Rotary Engines
### 253/848-7776
### www.americanrotaryengine.com

Price: $6500
Configuration: Straight gear, 2.29:1 ratio; maximum engine power 300 hp, weight 55 lb.

### Belted Air Power
### 702/384-8006
### www.beltedair.com

Price: $5600
Configuration: Belt drive, 1.43:1 ratio; maximum engine power 260 hp, weight 48 lb.
Propeller Limitations: 71 in., 35 lb.
Notes: 200 delivered, 2 weeks shipping time

### Compact Radial Engines
### 604/590-2950
### www.compactradialengines.com

Price: $350-$700
Configuration: Belt drive, 4 ratios, maximum engine power 45 hp, weight 7 lb.
Notes: 100+ PSRUs delivered, 2 weeks shipping time if not in stock.

Price: $1580
Configuration: Helical gear (complete with clutch), 5 ratios, maximum engine power 130 hp, weight 21 lb.
Notes: 700 delivered, 2 weeks shipping time if not in stock.

### Geared Drives
### 936/827-5126 or 936/672-6639
### www.geareddrives.com

Price: $8900-$9500
Configuration: Straight spur gear, 1.562:1 - 1.72:1 ratio; maximum engine power 400+, weight 63 lb.
Propeller Limitations: Customer's choice of fixed pitch, hydraulic or electric.
Notes: 20 delivered, 120-180 days shipping time.

### Global Rotary Power Inc.
### 905/697-4400
### www.rotaryengines.ca

Price: $1370
Configuration: Belt drive, 2:1, 3:1 ratio; maximum engine power 80, weight 14.33 lb.

### Great Plains Aircraft Supply Co.
### 800/922-6507
### www.gpasc.com

#### Valley Series 3
Price: $1595
Configuration: Belt drive, 1.6:1, 2.0:1, 2.47:1 ratio; maximum engine power 120 hp, weight 17 lb.
Propeller Limitations: Wood or composite.
Notes: 88 delivered, immediate shipping time.

Price: $1595
Configuration: Belt drive, 1.6:1, 1.9:1, 2.5:1 ratio; maximum engine power 105 hp, weight 17 lb.
Propeller Limitations: Wood.
Notes: Immediate shipping time.

### Maxwell Propulsion Systems, Inc.
### 360/474-8118
### www.maxwellpropulsion.com

Price: $8950
Configuration: Helical gear, 2.13:1 ratio; maximum engine power 300 hp, weight 72 lb. including flywheel and starter.
Propeller Limitations: Reverse rotation, tractor or pusher, recommend CAP-220.
Notes: 10 delivered, 8 weeks shipping time.

Price: $3500-$4800
Configuration: Helical gear, 1.9:1, 2.2:1, 2.4:1, 2.9:1 ratio; maximum engine power up to 300 hp, weight 38-52 lb. including flywheel and starter.
Propeller Limitations: Reverse rotation, tractor or pusher, recommend CAP-220.

### Mistral Engines
### 41 22 795 84 19
### www.mistral-engines.com

Price: Contact company
Configuration: 6 pinion planetary, 2.8235:1 ratio; weight 32 lb.
Propeller Limitations: Hydraulic CS propeller governor drive.

Geared Drives PSRU.

## Powersport Aviation
## 715/294-2557
## www.powersportaviation.com

Price: $6500
Configuration: Straight internal gear and pinion, 2.291:1 ratio; maximum engine power 300 hp, weight 60 lb.
Propeller Limitations: standard prop rotation.
Notes: 12 delivered, 4-12 weeks shipping time; 3-rotor engines must use our special torsonial pulley, $2200.

## RAM Performance Ltd.
## 330/882-6255
## www.ramengines.com

Price: $3600
Configuration: Helical gear, 1.9:1, 2.1:1, 2.47:1, 2.9:1 ratio; maximum engine power 160 hp, weight 36 lb.
Propeller Limitations: 72-inch.

Price: $3895
Configuration: Helical gear, 1.9:1, 2.1:1, 2.47:1, 2.9:1 ratio; maximum engine power 200 hp, weight
Propeller Limitations: 72-inch.

Price: $4230
Configuration: Helical gear, 1.9:1, 2.1:1, 2.47:1, 2.9:1 ratio; maximum engine power 300 HP, weight 42 lb.
Propeller Limitations: 80-inch.

## Raven ReDrives
## 303/440-6234, 575/737-9656
## www.raven-rotor.com

### 1000ULDD for Geo three cylinder
Price: $1295
Configuration: Conversion kit for direct drive 38 hp, 95 lb. engine.
Propeller Limitations: 2 blade, wood.
Notes: 3-4 weeks shipping time.

### 1000ULX, UL, UL-T for Geo three cylinder
Price: $2295-$2695
Configuration: Belt drive, 2.26:1 ratio; maximum engine power 80 hp, weight 17 lb.
Propeller Limitations: Ivo, Powerfin, GSC, wood.
Notes: 155 delivered, 3-4 weeks shipping time.

### 1000ULRS, 1000ULRS-T for Geo three cylinder
Price: $2695-$2795
Configuration: Belt drive, 2.26:1 ratio; maximum engine power 80 hp, weight 19 lb.
Propeller Limitations: Ivo, Powerfin, GSC, wood.
Notes: 30 delivered, 3-4 weeks shipping time.

### 1300SV, 1300 SVS for Geo three cylinder
Price: $3595/$3459
Configuration: Belt drive, 2.26:1 ratio; maximum engine power 120 hp, weight 22/17 lb.
Propeller Limitations: Ivo, Powerfin, GSC, wood.
Notes: 35 delivered, 3-4 weeks shipping time.

## Real World Solutions
## 386/935-2973
## www.rotaryaviation.com

### RD-1B
Price: $3315 + shipping
Configuration: Six pinion planetary drive for rotary engines, 1000 hours estimated TBO, 2.176:1 ratio; maximum engine power 300 hp continuous, weight 43.7 lb.
Propeller Limitations: Fixed pitch or electric constant speed.
Notes: 69 delivered, 6-8 weeks shipping time.

### RD 1-C
Price: $3215 + shipping
Configuration: Six pinion planetary drive for rotary engines, 1000 hours estimated TBO, 2.83:1 ratio; maximum engine power 300 hp continuous, 300 hp takeoff/climb, weight 43.7 lb
Propeller Limitations: Fixed pitch or electric constant speed.
Notes: 102 delivered, 6-8 weeks shipping time.

## Recreational Power Engineering
## 419/585-7002
## www.recpower.com

### Cogbelt Re-Drive
Price: $1550
Configuration: Belt drive, 2.36:1, 2.5:1 ratio; maximum engine power 85 hp, weight 15 lb.
Notes: 35 delivered, 3-4 weeks shipping time.

### G-40
Price: $1665
Configuration: Helical gear, 2.03:1, 2.25:1, 2.64:1, 2.96:1, 3.33:1, 3.79:1 ratio; maximum engine power 120 hp, weight 24 lb.
Notes: 850 delivered, immediate shipping time.

### G-50
Price: $1467
Configuration: Helical gear, 2.16:1, 2.29:1, 2.59:1, 3.16:1, 3.65:1 ratio; maximum engine power 100 hp, weight 19 lb.
Notes: 1650 delivered, immediate shipping time.

## ROTAX
## See Rotax Engines for list of distributors.

### B (for use with Rotax engine only)
Price: Call Service Center
Configuration: Helical gear, 2.1:1, 2.24:1, 2.58:1 ratio; maximum engine power 64 hp, weight 9.91 lb.
Propeller Limitations: 3000kg/cm$^2$.
Notes: 3500+ delivered, immediate shipping time.

### C (for use with Rotax engine only)
Price: Call Service Center
Configuration: Helical gear, 2.62:1, 3:1, 3.47:1, 4:1 ratio; maximum engine power 75 hp, weight 17.61 lb.
Propeller Limitations: 6000kg/cm$^2$.
Notes: 3500+ delivered, immediate shipping time.

### E (for use with Rotax engine only)
Price: Call Service Center
Configuration: Helical gear, 2.62:1, 3:1, 3.47:1, 4:1 ratio; maximum engine power 75 hp, weight 24.71 lb.
Propeller Limitations: 6000kg/cm$^2$.
Notes: 3500+ PSRUs delivered, immediate shipping time.

## Stratus 2000
## 541/754-4114
## www.stratus2000.homestead.com

### EA81 Subaru
Price: $2695
Configuration: Belt drive, 2.2:1 ratio; maximum engine power 125 hp, weight 45 lb.
Propeller Limitations: Any SAE #1 bolt pattern.
Notes: 175+ delivered, 1 week shipping time.

## Valley Engineering
## 573/364-6311
## www.valleyengineeringllc.com

### VW Type One
Price: $1595
Configuration: Belt drive, 1.6:1 - 2.92:1 ratio; maximum engine power 120 hp, weight 7.5 lb
Propeller Limitations: None, recommend Culver wood 2 blade.
Notes: 3 weeks shipping time.

### V-Twin
Price: $1295
Configuration: Belt drive, 1.6:1 - 2.92:1 ratio; maximum engine power 50 hp, weight 6 lb.
Propeller Limitations: None, recommend Culver wood 2 blade.
Notes: 25 delivered, 3 weeks shipping time.

## Vesta Inc.
## 908/238-9522
## www.vestav8.com

Price: $3500-$6500
Configuration: HyVo chain (1-inch, 1.5-inch, 2-inch, 3-inch, 4-inch width available), 1:1 - 3.1:1 ratio; maximum engine power 150 hp to 600 hp, weight 45-100 lb.
Propeller Limitations: Manufactured for Vesta propellers.
Notes: Supports hydraulic governor. Internal isolated lubrication.

# Roll Your Own


## In this final installment, the one-off KK-1 scratch-built airplane graduates from living room to airport.

BY KEN SCOTT

**In January 2006,** the KK-1 began to come together for the final time. The wing, tail and fuselage were bolted together. The canopy, fastened to the frame, was fitted to the parallelogram slide bars. The rudder cables were hooked up. The engine was hung—which, in our case, meant that two guys lifted the engine up and aligned it with the "mounts," small steel tubes with flanges riveted to the firewall.

Early in February we had the major systems hooked up and were looking forward to starting the engine. To that end, we poured a couple of gallons of gas into the tank to flush the system and carburetor. We flushed, all right, but not where we'd hoped. The tank promptly leaked in at least three places, which we found mystifying. There was certainly enough sealant in it! There was nothing to do but remove the tank and pressure test it—something we should have done months earlier. We cut a hole in the bottom of the tank, went in and sealed the offending corners and pop-riveted a patch over the hole on the way out. The tank spent a few days curing while we did other tasks. Another pressure check proved our fix.

### Fire in the Hole

By now it had been five years since my building partner Ken Krueger and I started this project, something we never imagined when we began. It was getting to the point where we wanted to get the airplane done just so we could get it out of our lives. We definitely needed some sort of boost.

We finally got it on March 2. We bolted on the prop, rolled the airplane onto the ramp, turned on the fuel pump and, for the first time, hit the starter switch. The little VW cranked a few times and spun to life. Hoo boy…it lives!

After a few seconds it settled into a smooth hum. That muffler really did the job, because the engine was very quiet. As Krueger revved it up, there was some noise off the prop, but nothing more than a sort of throaty purr from the exhaust. At half throttle, it jumped the chocks, and we found out for sure that the brakes worked.

Shortly after the taxi tests, we put the airplane on the scales to get some idea of how accurate our predictions were. Besides, Krueger wanted a preliminary weight and balance before he positioned the seat. This was a moment we'd been anticipating, both eagerly and with trepidation. I got on my hands and knees and braced my back on the bottom of the wingspar. It was easy to lift a mainwheel off the ground while Krueger slid a digital scale under it. We put another under the nosewheel, set the meter to zero, hooked up the wires and pushed the button.

When we peeked though our fingers, we saw the bad news: 538 pounds. (The final weight, with all components, was 551 pounds.) More than we'd hoped, but it could have been worse. An airplane with a 22-foot wingspan, a four-cylinder engine with a muffler, slotted flaps and a tricycle gear that weighs 550 pounds is still a pretty good achievement.

Ken Krueger's extensive preparations for the first flight included a helmet and some fireproof clothing.

## First Flight

Some years ago I became the second person on earth to fly an RV-9A. I wrote an article for the company newsletter about how I appreciated the experience, as I'd probably never make the first flight of an entirely new design. But now I had the chance to do exactly that.

I staked my claim to the first flight early on, even though Krueger is probably a better pilot—certainly a better test pilot—than I am. I justified it by noting that I didn't have young children and I was older; therefore, I had less future to lose and would leave no orphans if it all turned out ugly. This, of course, was bullpucky. I have a wife and two stepsons who are as important to me as any family I could ever have, and nobody knows how long their personal future is. Maybe it has something to do with the fact that my father was a flight test engineer for North American in the early F-86 days and held test pilots in high regard. I am not a risk-taker by nature, and I don't pretend to understand the psychology at work here. All I know is that I *wanted* to do it.

But I didn't do it.

Quietly, Krueger had been preparing for his own first flight in the airplane. He didn't regard himself as my mentor or my mother, so he left me to make my own preparations. I figured that I'd avoid alcohol for a couple of days, study a checklist or two, borrow a parachute, and go fly.

That wasn't good enough for Krueger. He bought a fireproof balaclava and gloves. He acquired a helmet. He flew spin recoveries and unusual attitude training with Steve Wolf. He actually jumped out of an airplane so he could learn how to use a parachute. He downloaded Google Earth photos of the area surrounding the Aurora Airport and carefully marked possible emergency fields. He prepared contingency and emergency checklists.

Faced with this, I had to reexamine my own preparations. After a long talk with my wife, I realized that I was trying to join an exclusive club without paying any dues. The people who have made successful first flights of new designs took great pains to prepare themselves for every eventuality. I had not. I was going on hope and denial.

I swallowed hard and got out of the way. There was no question about which of us was better prepared. Krueger would make the first flight. On May 17, we assembled at 7:00 a.m. I sneaked the RV-9A out of Van's hangar to use as a chase plane and installed Camilla in the right seat as camerawoman and

As the plane was finally coming together, plans for the first flight were anticipated by both builders.

*Photos: Kevin Wing, Ken Scott*

Preferred Sharer of Important Moments. Susan and Amy (Krueger's wife and daughter) and Mel Ellis (our engine builder) had video cameras. Krueger donned the paraphernalia, we had a last minute chat on exactly who was going to do what, then he climbed in and cranked the engine.

Naturally, it wouldn't start.

We pulled the cowl and found that the choke plate was out of position. We corrected that and, with a fresh battery, it fired up instantly. The next morning, the same group assembled. This time the engine cooperated, and we taxied out to Runway 35 at Aurora. I took off first and circled around, lining up a quarter mile behind the runway threshold, and slowed to about 90 mph. We watched as the little silver airplane accelerated down the runway and after 500 feet or so, separated from its shadow. It was…so…cool.

We climbed at about 600 fpm to 4000 feet. We flew some lazy circles, then I pulled up underneath and had a look. There were no liquid streaks, no smoke, no stains—everything looked perfect. Krueger went to the next item on the test card—slow flight and approaches to stalls. That seemed completely straightforward, so he proceeded to stalls. After hanging a few seconds nose high, the airplane dipped and leveled out. The flaps came down, and the nose came up again. This time the right wing dropped about 10° as the nose dipped. Nothing scary, from the outside anyway.

Mel Ellis drills the VW sump for installation of an oil temperature sender. Hint: Grease on the bit captures drill chips.

So we learned that it flew, climbed and stalled conventionally. This boded well for the first landing, and so it proved. I circled overhead while Krueger set it down 200 feet past the numbers and made the 950-foot turn off with ease. I landed long and joined the grins. Ellis, especially, was pleased because the engine had run strong and stayed cool. The cabin tunnel surrounding the exhaust hadn't even gotten warm to the touch. In Krueger's words, the whole flight was anticlimactic…exactly what you want to hear after a first flight.

After Krueger did the basic test flying, the author got his chance.

## My Turn

Finally, on May 22, I flew it. Krueger had briefed me that the elevator had a bit of pulse, probably caused by the lack of mass balancing, and to climb at around 70 mph. I worked my way through the checklist. The engine started without hesitation, and I taxied out.

Everything went well on the runup and pre-takeoff checklist, so it was time to go. Full power—well, 55 to 60 horsepower doesn't exactly jerk it out of the hole—but once it starts moving, acceleration is decent and gets better. I elected to take off without flaps, which would have shortened the run, because I didn't want anything to do on the climbout other than capture the airspeed. The elevator did feel different—light and a bit vague. Without Krueger's briefing I would have wondered what was going on back there. Even with this little airplane, I found myself slightly behind events, and by the time I started climbing and set the trim, I'd already reached almost 90 mph.

I climbed up to 2000 feet and just flew around for a while. I wanted to enjoy the moment (a long time coming!) and get my senses connected to this machine. It is a light airplane, certainly the lightest I've flown, (and, I realized after I landed, my first single-seater) and every movement in the surrounding air is transmitted to the pilot, especially through the elevator. This doesn't mean the airplane is being thrown around or is difficult to fly. It is actually quite stable and docile. It's a bit like a small dinghy compared to a big cabin cruiser—the surrounding motion is much more noticeable even though you are still in control. In this airplane, you have to participate in the atmosphere, rather than subdue it.

I slowed to about 60 mph IAS and lowered the flaps to half. That all seemed normal enough. Below 60 you could hear the turbulent air off the inboard end of the flaps rattling on the thin belly skins. Full flaps made it more pronounced. After finding that it handled nicely with full flaps at Krueger's recommended approach speed of 60 to 65, I decided to leave stalls for the next flight and see if I could land without hurting anything. Landing turned out to be the easiest part of the whole flight—it's a baby carriage. The decision to use a nosewheel was a good one.

## Flight Test Time

As we proceeded with flight testing, we found that the airplane is reasonably fast—a little over 120 mph if you push it to 4 gph. (If we ever get the landing gear and wheel fairings on, it should gain several more mph.) At 3 gph, it will cruise at just under 100 mph. Stall speeds are in the low 40s, and the big flaps make quite a difference in pitch attitude. Climb rates are leisurely, especially with me in it: 500 to 600 fpm under most conditions. With lighter pilots and fuel loads you can see 800 fpm. Krueger flew it from Aurora, Oregon, to Bishop, California, cruising at altitudes of up to 12,500 feet and averaging 109 mph over the ground.

Yeah, yeah, so much for numbers. What's it like to fly?

In a word, pleasant. It isn't overpowered, so the initial takeoff acceleration is moderate. Aft stick has the nosewheel off quickly, and a few seconds later the wing does its thing and off it comes. It all happens at speeds that would seem normal to a Cessna 152 pilot, though it takes considerably less runway. Because the VW turns the "other" way, it requires left rudder on takeoff and climb.

Once aloft and leveled out, the fun starts. The ailerons are excellent, every bit as good as an RV. Roll is quick and positive and takes almost no rudder to coordinate. Pitch trim is powerful and easy to use. The C.G. doesn't change much with fuel load, so the airplane feels much the same at different tank levels. Slow flight characteristics are solid and it's easy to drive around at 50 mph in perfect control. Power-off stalls are a non-event. The stick goes limp in your hand, the nose drops a few degrees, and as soon as you relax the back pressure, it's flying again.

Visibility is superb. The big bubble gives a tremendous view. The nose drops away quite steeply and it took a couple of tries to learn the climb attitude picture.

The landings are just ridiculous. The slow landing speed, excellent sight picture, great low-speed control authority and that tricycle gear make them absurdly easy. The tiny wheels like pavement, but they cause no trouble on a well-kept grass strip. With so little inertia, once the wheels are on, the airplane slows quickly.

We really wanted a quiet airplane, and we seem to have succeeded. The cabin noise is less than most small single-engine airplanes, though you wouldn't want to fly for long without a headset. The noise print on the ground from 1000 feet or higher is negligible. We can't get our wives to come out and wave when we circle our homes—they never hear us.

The four-into-one exhaust is coupled to an aftermarket auto muffler. Heavy, but the result is an extremely quiet airplane.

But no airplane is perfect out of the box. There were a few anomalies to investigate and fix. We sealed the 0.040-inch gap between the wing and fuselage side, eliminating the low speed rumble. As a bonus the glide and inertia through the landing flare were noticeably improved—evidently the gap had been acting as a vortex generator at high angles of attack.

We also noticed that we could smell exhaust in the cockpit, even with the fresh air vent wide open. We sealed around the flap actuator rods and other small openings in the belly. The improvement was immediate. We added mass balance weights to the elevators, and the imprecise, vague feel disappeared.

We are quite pleased with the engine. It runs well and seems robust and happy, even though it doesn't exactly overwhelm an airplane this big with power. It is somewhat temperature limited. The stock VW oil cooler mounted on top of the case can't quite keep oil temperatures in check on steady climbs on warm days, so we have to lower the nose and let it cool. In cruise, it is fine. We will be investigating better ducting and more efficient coolers.

## How'd We Do?

Way back at the beginning of this adventure, we set ourselves some goals. How well did we meet them? To refresh your memory, they were: A 45-mph landing speed; at least utility category strength (limit load of 4.4 G); it had to carry both of us—not together, but individually; it had to stay in the air for at least 1.5 hours; it had to have sufficient climb performance with me aboard to avoid frightening me; and we could not spend more than $6000. Less would be better.

We came close on the landing speed. We fly final at 55 mph IAS and a tickle of power to keep the descent rate under control. With full flaps and the engine at idle, the KK-1 will develop an impressive sink rate—typical of low-aspect-ratio wings. Touchdowns can be quite nose-high, and rollouts are short.

Every building adventure should end with a happy flight into the sunset.

The airplane will carry either of us. In fact, the cockpit would accommodate much bigger people. The fuel tank holds almost 23 gallons—far more than we'd originally envisioned—and at the +/-4 gph burn of the VW, we can stay aloft for 5 hours.

Price is a bit harder to figure because we did have some advantages. Mel Ellis charged ridiculously little for building the engine, Rob Hickman at Advanced Flight Systems has yet to present us with a bill for his wonderful engine monitor, and Jeff and Becki Rodgers at Airplane Plastics keep waving their hands when we try to give them money. Dick VanGrunsven never asked a nickel for using Van's Aircraft's tooling and shop space, and we repaid his generosity by buying all of the hardware at cost with our employee discount! All in all, my best guess is that if someone were to build the same airplane and pay full retail for everything, the cost would be $13,000 to $14,000.

However, if you built your own engine, used simple instrumentation and were handy with a welder, I really think $8000 to $9000 is possible. You could have an airplane for the cost of a used Toyota, a small travel trailer or a decent violin bow. (No, not the violin, just the bow. Don't ask me how I know!)

## What's Next?

As we mentioned in the beginning of this series, we have absolutely no intention of making plans, parts or kits for the KK-1 available, so there is no requirement to develop the design for production. The requirement to commute to work is long over—we both bought houses within a few miles of Aurora years before we finished the airplane. We never envisioned the KK-1 as a traveling machine, though the speeds are good enough and the VW has been reliable enough that the idea seems more practical than it did at first. For right now, we will probably use the airplane to take us around the Pacific Northwest while we enjoy the economy, the wonderful view and the satisfaction of having taken an idea and persevered until it became a real, live flying machine. ✈

# Oh, That Canopy

**You may have noticed a suspicious lack of reference to the canopy amongst all the construction details. Canopies are always a pain. After discussing and discarding several ideas, Krueger designed an elegant parallelogram mechanism that lifted the canopy up and back. We made the frame of pressed aluminum "ribs" that we could match exactly to the fuselage and then rivet together. I just love curved structures that can be built with tools no more advanced than a mallet, lead bar and pop rivet gun. Even better, it was extremely light.**

**A crank handle, just like the window crank in a car (remember them?) is mounted on the outside of the fuselage and turns a shaft that passes behind the seat. Two small gears are attached to the shaft, which engage gears that are part of the canopy frame. Krueger laid it all out on the computer, and we sent the files electronically to a company that specializes in water-jet cutting. In a few days we had extremely accurate gears, cut from hard quarter-inch-thick aluminum. Inside the airplane, we planned a tiny bicycle chain and hand crank to spin the gears. It is way more complicated than a simple swing-over canopy and fixed windshield but, hey, engineers have to have some fun.**

**The frame was one thing; the big plexiglass bubble was quite another. Originally we'd planned on using a partial RV-8 canopy—there are several damaged ones in Van's "attic"—but the geometry just didn't match. Our friends Jeff and Becki at Airplane Plastics, in Ohio, rode the white charger on this one. For many years they have made the canopies for RV kits. Krueger supplied them with a drawing, and a couple of months later a shipment of RV-7 canopies arrived with two smaller, narrower canopies tucked inside. They were beautifully made, with fine optics.**

**It was a relatively simple matter to drill the plexi bubble to the aluminum frame and fasten it with fuel tank sealant and aluminum pop rivets. The joint between the front of the "windshield" and the front deck of the airplane was bridged by a fillet of epoxy and fiberglass, laid up directly on the airplane. A similar strip around the back covered the gap between the plexi and the tank.**

**The canopy is a little wiggly in the up position, and the gear drive has to be handled with care. But the finished product goes up and down easily, seals well, has enough room for entry and provides a completely unobstructed view of the surrounding sky. There aren't many pilots who can see out of their airplanes better than we can see out of this one.**

***—K.S.***

The scissor-action lifting canopy solves many problems, but it demands careful operation.

# THE EAGLE TAKES OFF

## Precision's engine management system isn't a full-authority engine controller, but it's close. . . *and surprisingly inexpensive.*

BY MARC COOK

**Ask most builders** and pilots who have chosen alternative powerplants derived from modern car engines to explain their choice, and you won't be far into the discussion when electronic engine management comes up. Fully automatic fuel injection. Variable ignition timing with a hot spark far better than any magneto could produce. These are the big reasons to want something beyond a traditional engine with a carburetor (or mechanical injection) and mags.

Cited as upsides are lower maintenance costs—in theory, a modern injection and ignition system will require less care than a mechanism-laden magneto or carburetor—and reduced pilot workload. Pilots have long desired the combination of power and efficiency brought by a constant-speed (or adjustable-pitch) prop and precise fuel metering without the need to mother-hen the throttle, prop and mixture controls. Not just in flight, but for the dreaded hot start. Wouldn't it be nice if we could get in, turn the key, start the engine and *fly*?

### The Future Is Now

Until recently, electronic engine management has been the province of auto-engine conversions (at least those that start with such devices, excepting the Corvair and Ford V-6s, for example) and a few hardy builders who have adapted electronic systems to traditional aircraft engines. More popular, of course, are

electronic ignitions that feature variable timing, reliable hot starting (from a hot spark right at top-dead-center [TDC]) and efficiency gains.

More than a decade ago, Continental and Lycoming announced new FADECs for the certified market, but they really failed to sell in big numbers and were, at the time, too expensive for most homebuilts. Meanwhile, north of Seattle, Precision Airmotive, current owner of the Bendix mechanical fuel injection systems and, until last year, the venerable Marvel carburetors, sat quietly and developed its own system. Intended for low-horsepower trainers with the primary focus being ease of use for new pilots and reduced maintenance costs,

This knob is the pilot's only onboard control of the fuel/air mixture.

The heart of the Eagle EMS is this ECU module, which is intended to be mounted on the hot side of the firewall.

the Eagle EMS is now being promoted in the Experimental market. Alan Jesmer, Precision's marketing director, pointed out: "We worked on the certified version but couldn't get OEM interest." Not surprising when you consider the not-invented-here bias of many airframe manufacturers.

In 2006, Precision began displaying the system at airshows to ramp up interest. Finally, in late summer 2008, Eagles

Bob Newell pulls his RV-6A from the hangar at Paine field near Seattle, while Precision's Alan Jesmer offers verbal assistance.

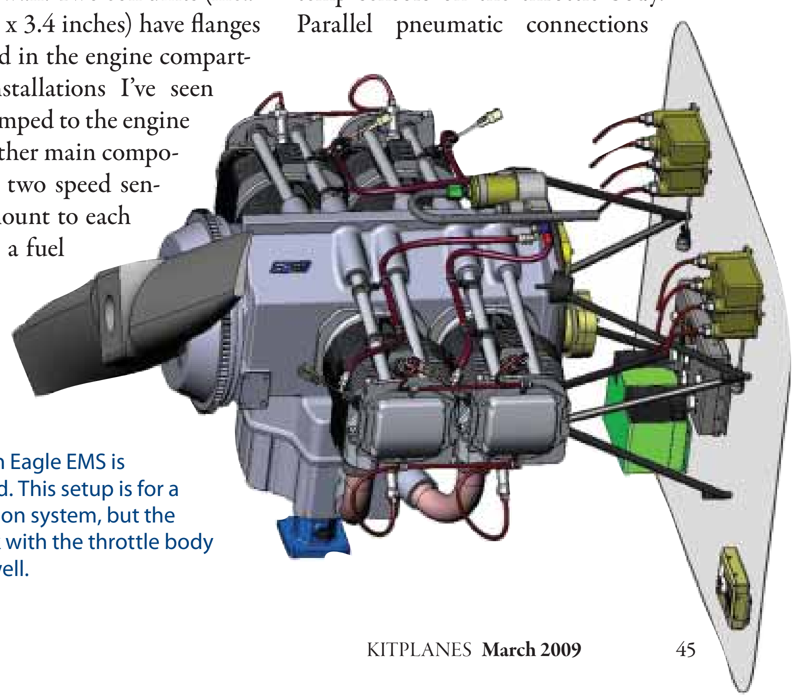
were starting to be delivered to builders and engine shops: Two are currently set up for new builds and conversions, Aero Sport Power in Canada and G&N Engines, in Griffith, Indiana. When we visited a factory prototype of sorts, the RV-6A, it had amassed many hours flying with O-360-based Eagle power, and a second aircraft, an RV-8, was also flying. All told, 14 systems were out in the world as of late 2008.

## Configure This

In terms of general layout, the Eagle is reasonably simple. A main electronic control unit (measuring 18 x 6 x 2.5 inches) is meant to be located in the engine compartment. A power management unit (measuring 5.5 x 3.3 x 1.4 inches) is also to be located on the hot side of the firewall. Two coil units (measuring 4.1 x 5 x 3.4 inches) have flanges to be mounted in the engine compartment; the installations I've seen have them clamped to the engine mount. The other main components include two speed sensors, which mount to each magneto pad, a fuel distribution block, and a throttle body the same length as a Precision Silver Hawk throttle body.

Fuel is delivered by single electronic pulse-type injectors at each cylinder, screwed into the conventional injector holes above the intake ports. The fuel system between the tanks and the injectors is mostly standard Lycoming, with mechanical and electric fuel pumps and no need for a return line. The fuel distribution block takes the place of the flow divider normally found along the engine's spine, and houses a 10-micron filter and dual fuel-pressure sensors.

For sensors, the ECU depends on the twin speed sensors for engine-speed and TDC reference, and the aforementioned twin fuel-pressure senders. In addition, the Eagle EMS has dual barometric pressure sensors plus twin incoming air temp sensors on the throttle body. Parallel pneumatic connections



The general architecture of the Precision Eagle EMS is straightforward. This setup is for a vertical induction system, but the Eagle will work with the throttle body horizontal as well.

*Photos: Marc Cook and Courtesy Precision Airmotive* between the ECU and the throttle body feed twin manifold-pressure sensors inside. Except for the injectors themselves, virtually everything in the Eagle EMS is redundant. To coordinate with your existing engine instrumentation, the EMS outputs a pulsed mag signal for an electronic tachometer, and even emulates a FloScan fuel-flow transducer for your engine monitor. Nice.

Power management is always a concern when in order to keep the engine running, the aircraft's electrical system has to function. Precision has taken an interesting tack here: Rather than set up a backup electrical system or battery, it requires a separate battery that runs the system full time—it is the primary source of power. The aircraft's electrical system merely keeps this battery's charge topped off. Why? Because the transition from ship's power to backup caused a hiccup, which is eliminated when you're running on your backup all the while. The battery is supplied by the buider, and the system pulls 1.6 amps running.

Individual fuel injectors are located in the normal location, and are fed by standard pumps running between 20 and 60 psi.

## Trying to Simplify

Precision's ECU contains two computers with parallel "maps." In electronic engine control parlance, these maps are really "lookup" tables. Imagine an Excel spreadsheet, with the row across the top being manifold pressure and the column along the left side as engine speed. For any combination of engine speed and

# The Aerosance Experience

*Multi-aircraft builder and hang-glider impresario Chris Wills is a FADEC convert with a good deal of real-world experience behind the Aerosance system in two airframes. We thought you might be interested in his take. A longer version of his report was published in the* GlaStar & Sportsman Association Flyer *magazine last year. Continental has stopped selling new installations while it works on Aerosance Version 2.*

I have installed the FADEC system in both my GlaStar and my Sportsman airplanes. I have about 120 hours of time on the Sportsman and there have been about 300 hours of time on the GlaStar between myself and Paul Oswald, who is the new owner.

It gives about 15% to 20% better fuel consumption by operating lean of peak and individually controlling all of the needs of each cylinder, and about 5% better power by giving a better stoichiometric mixture. With both aircraft, before FADEC, I was burning around 10 gph in fast cruise, and with the FADEC, I burn around 8 gph at the same settings. There is no longer a mixture control, and the computers control all of the engine parameters. Initially, I had a fuel-injected IO-360 with the GlaStar and a regular O-360 with the Sportsman. The fuel injection is a little better than the carburetor overall, and each has its benefits and drawbacks. But neither compares to the FADEC. Although the fuel savings is an extremely good deal that gets better all the time with the increasing cost of fuel (and will eventually pay for the pretty hefty initial price of the system), the big deal is the better range of the plane and better power. When you are talking about a total of 50 gallons, the difference between 10 gph and 8 gph in range is large. It is 5 hours versus 6.25 hours minus reserves.

The service from Aerosance has been incredible. Although the initial time of delivery for the first system was significantly delayed, the second system arrived earlier than promised. The service has since been phenomenal.

I have had a rare and momentary "caution" light that goes on for a few seconds with both systems, but there was no problem in how the engine operated. After the new recording system was installed, this happened again. The engine was running fine, and I would have had no idea there was a problem if I did not have the light. I was able to download all of the data from that flight and email it to Aerosance for analysis. They were able to see (as was I eventually) that there was probably an intermittent clog in the fuel injector to cylinder #3, which the computer was correcting by increasing the fuel flow to that cylinder. They sent me a new injector for no charge.

I have been really impressed with the system and would never consider going back now that I have seen what it can do. The installation is not particularly difficult, and if you love computer toys—or even if you don't—it is well worth the investment. This is particularly true (and much easier to justify to your family) once you consider that it will eventually pay for itself through decreased fuel costs.

*—Chris Wills*

manifold pressure—the two variables that most influence power output at rich-of-peak EGTs—there is a value determining how long to hold each injector open. With progressively more manifold pressure and/or rpm, the value gets bigger and the injector stays open longer, providing more fuel.

This simplified reference system is used on virtually all modern motorcycles to great effect, and is considered open loop. (Cars need much tighter control for emissions needs; most run in a pure closed-loop mode much of the time.) The Eagle EMS does not monitor EGTs, so it can't see the effect of the fuel delivery, though it does watch two CHTs to protect the engine from damage—it can retard ignition timing or add more fuel to keep within predetermined CHT limits. However, until the preset CHT limit is reached, the system works solely off the internal map.

## Igniting the Possibilities

On the ignition side, Precision follows standard modern practice, with user-defined advance curves and an intelligent starting procedure.

Precision's engine-start capability includes a separate algorithm that determines whether the engine is hot or cold. If it's cold, the injectors pulse more often to provide a priming function, while the ignition fires multiple times at TDC to

Twin coils feed a spark plug for each cylinder, so loss of an entire coil pack leaves the second system functional, and the engine running.

A simplified throttle body has pickoffs for induction air temperature and manifold pressure.


Each magneto pad is populated by a speed sensor. This is the back side (left) and the engine side, less the drive gear (right).

get the engine running. Once started, the engine returns to normal cold-start injection durations, and the timing gradually builds to follow the preset map. When the engine is hot, the priming function is not used; however, because the fuel lines right up to the injectors are at full system pressure, vapor lock (the reason most injection engines are hard to start hot) is effectively eliminated.

## Variables for Experimenters

Two elegant ideas underpin the Eagle EMS for homebuilders. First, Precision's engineers realized that even though the map-based system works well for most conditions, there are times when the pilot needs to have a hand in the proceedings. That's why you'll find a knob on the instrument panel allowing a manual skew of the injection map. Depending on the setup, the knob can either go rich or lean from the base map, and it's up to the builder to decide. The total skew is 15% of fuel flow (ignition is not affected).

But even better for knowledgeable builders, the base map itself can be modified. Let's say you find that a certain manifold pressure/rpm combination makes the engine run richer or leaner than you'd like. The solution is to alter the fuel duration in that cell of the lookup table to get what you want. Naturally, going way off the base map opens you up to mixtures that could damage the engine under certain conditions, so it pays to experiment carefully, but it's good news to engine-savvy builders that the base map can be just a starting point to achieving ideal mixture control.

The Eagle EMS leaves no outside indication of its presence, unless you peek into the inlet and see the injectors.

Moreover, the ignition map can be highly tailored. You can select the maximum advance and the general shape of the curve with reference to manifold pressure/rpm combinations.

## So Now We Fly It

In truth, I've been hammering on Precision to let me fly the system for a couple of years. Finally, this summer, the company's testbed, a 1998 Van's RV-6A owned by Bob Newell was available for a flight. Fitted with a fresh O-360, the testbed has seen many, many flights getting the system validated in a homebuilt, and it shows in the seamless nature of the system. After a slightly rocky initial startup—setting the throttle position is important plus the airplane had been sitting for awhile—the engine ran smoothly and cleanly, with expected EGTs (well balanced) and otherwise normal temps and pressures during the warm-up, taxi and runup.

Sometimes we use the term FADEC incautiously. In this case, it's not full authority in the sense that the constant-speed propeller is still managed by the pilot. Next to the blue knob in the throttle bracket was a hole—no red knob at all. Runup procedures involve checking each ignition system independently as you would mags, and ensuring that the ship's electrical system is healthy.

On application of takeoff power, the Eagle system responds beautifully. The RV accelerated normally as the EGTs came up, the highest reaching 1460° F. As we all know, the absolute value of EGTs is unimportant because of all the variables of probes and probe placement, but this struck me as slightly too lean at high power, despite the mixture knob

Precision has provided the EMS with the ability to output tach signals and a FloScan-like waveform so that modern engine monitors can be plugged right in.

being in the full-rich slot. By 1000 feet AGL, the hottest CHT was 360 at a fuel flow of 14.4 gph. As we climbed, the fuel flow gradually and smoothly decreased as did the manifold pressure. Climbing through 2500 feet AGL, there was 25 inches of manifold pressure and 2500 rpm, fuel flow of 14 gph even, EGT steady at 1430° and the CHT climbing through 380°. At the top of the climb, the hottest CHT was 410° with the EGTs all in the mid-1400s.

In the cruise phase, with the mixture knob pulled back to the 2.5 position, fuel flow fell to 9.6 gph, EGTs rose to the high 1400s and low 1500s, with the hottest CHT settling on 376°. The engine was butter smooth. Response to changes in throttle position and rpm were handled without a hitch and minus big EGT excursions. It's clear that all the time Precision spent on the dyno fine-tuning the base map has paid off.

But cruise is easy. It's the descent, maneuvering and landing phase that normally requires pilots to fiddle with the mixture when they should be looking outside. We descended with the mixture leaned, and the Eagle system tracked changes in manifold pressure well, with the EGTs remaining steady and even. In fact, the engine was well behaved all the way from the top of the descent to shutdown back at the hangar. As a precaution for a potential go-around, Bob reset the mixture knob to zero just before landing, but that was about all the mixture meddling he did the entire way down.

## Worth the Effort?

The Eagle EMS lists for $8935 complete, and will be offered by Aero Sport Power and G&N as both retrofits and as fresh builds on Experimental engines. The final price is set by the shops, but remember that you'll be getting credit for mags and a carburetor or fuel injection setup, so the final price delta will be lower by a useful amount.

According to Precision, the weight is about a wash, though there's no denying that installation is going to be more demanding than a traditional setup. Will the Eagle pay for itself? That's hard to say, but if you're the type of pilot who isn't always tweaking the mixture to get it "just right," chances are that the EMS will run the engine overall more efficiently than you would, and at today's fuel costs the initial price delta doesn't take all that long to cover. That the system is high tech and an experimenter's delight is just a bonus. ✈

*For more information, call 360/651-8282, or visit www.precisionairmotive.com. Find a direct link at www.kitplanes.com.*

Build Your Skills


The second coat of Poly-Brush is being applied to the prepared fabric. The first coat is brushed on after being properly thinned.

# FABRIC

## Once you have your structures covered and the surfaces prepared, it's time to spray on the chemical coats.

BY RON ALEXANDER

**The steps involved** in covering an airplane are essentially the same for all available fabric-covering systems until you are ready to apply the chemicals. Differences among the systems do exist, but they are somewhat minor until reaching this stage. We'll review the steps we have discussed that must occur prior to spraying the chemical coats, and then we will begin this application process.

To begin with, the surface you are covering must be properly prepared. This is accomplished using an epoxy primer or an epoxy varnish following a thorough cleaning. After preparing the surface, it should then be carefully inspected for any defects. Remember that you will probably not have access to the inside of the surface for a number of years. After the inspection it is time to select the proper weight of fabric and then attach it to the structure using fabric cement.

Once the fabric is secured in place on a component part, it is then heat shrunk using a regular household iron. The iron is calibrated to the required temperature, and then the fabric is ironed until all areas have received the proper heat, ensuring that the fibers are adequately shrunk. With the Poly-Fiber covering system, the next step is to seal the fabric by brushing on a coat of Poly-Brush. This encapsulates all of the fibers and provides the necessary adhesion for all subsequent coats. This is an important step because the bond of this coat is essential for the remaining coats to properly adhere.

Next we attach the fabric to the wings and to all surfaces that provide lift. This important step prevents the fabric from "ballooning up" during flight due to the low pressure created on the top of the wing as a result of lift. The inspection rings and drain grommets are then cemented in place. Finally, several areas are covered, using tapes that are precut from the fabric into various widths. The most common width is 2 inches. This last step brings us to the spraying of the chemical coats.

Spraying with a high volume low pressure (HVLP) system such as the one shown here reduces the amount of overspray.

## The First Step

When you reach this stage of fabric covering most of the hard work is done. Many individuals are unsure whether they have the ability to spray paints and dopes on their airplane. Let me assure you that you can learn easily. It is not difficult to spray. This is particularly true when spraying the fabric-covering chemicals. They are more viscous and have fewer tendencies to run than regular enamels. This way you can learn the spraying techniques with a chemical that is easy to spray before you get to the color coats. Don't be afraid to spray your own surfaces. With practice you will become proficient.

The first step in spraying is to select the proper spray outfit. Perhaps you already have a spray gun and compressor. If so, be sure it is a high-quality gun. Do not begin the spraying process with a cheap gun. Not using proper equipment will cause you untold grief as you spray. If you do not have a spray rig, I would suggest you consider purchasing a high-volume-low-pressure (HVLP) setup. These systems are easy to use, especially for those who have little or no spraying experience. They also plug right into a 110-volt outlet and come complete with everything you need. In addition, they will save you money by using fewer chemicals, because this type of outfit creates little overspray. In other words, the chemicals go on the fabric surface and not into the air.

Before you begin to spray, make sure you take the proper safety precautions. This involves purchasing a high-quality charcoal filtered face mask or a forced-air breathing system. If you will be painting your airplane with polyurethane paints, a forced-air breathing system is absolutely necessary. If you are not going to be using polyurethane paints, a good quality charcoal mask is sufficient. When mixing chemicals be sure to protect your eyes and skin. You should also protect your eyes and skin while spraying the various chemical coats.

## Where to Spray?

A clean, well-ventilated area is necessary for spraying. Do not spray outside in direct sunlight. (The photos that accompany this story were taken at various hands-on clinics using non-flying components.) Try to find an area where you can construct a small spray booth using PVC pipe and clear plastic sheets. If this is not possible, find an area that is free from dust and dirt. Cover the floor if you want to keep it clean. Overspray will coat a floor over time. Good lighting is mandatory. Otherwise, you will miss areas, and create runs and sags, with the overall result being a poor finish. Be sure you have adequate ventilation and then begin to practice by spraying chemicals on pieces of cardboard, fabric panels, etc. A little practice will save you problems when you actually begin to spray your surface.

Another point to remember is that you should start out by spraying a small control surface. Don't begin by spraying a wing. Start with a small surface so you can gain experience. You will be painting your entire airplane one piece at a time while it is apart. This is much easier than painting the entire airplane while it is assembled, which requires a lot more experience and practice.

## Preparation

Now that you have practiced, you are ready to spray the first coat of Poly-Brush on a control surface. There are several considerations before you begin. First of all, the temperature of the area should be at least 60° to 65° F. Anything lower than 60° will impede the drying process. If the temperature is above 85° F, you must use a reducer that contains a retarder. If the temperature is above 95°, or if the humidity is high, you will have to use a retarder to reduce the drying time. Again, do not spray in direct sunlight or if the wind is blowing.

Before you begin spraying you must

The first coat of Poly-Spray will highlight imperfections that will need attention prior to additional coats. (We'll talk more about this in the next installment of this series.)

*Photos: Richard VanderMeulen, Rick Lindstrom, Marc Cook* be sure the surface of the structure is clean, which is best accomplished by passing a commercial tack rag over the area just prior to spraying. This slightly sticky rag is designed to pick up small pieces of lint, dirt, etc. Lightly pass the cloth over the surface. Do not rub the surface, though, because it could transfer unwanted chemicals to the area.

Next you must prepare the Poly-Brush for spraying. As you recall, we applied one coat of Poly-Brush after the fabric was shrunk using a brush. We will now spray a coat of Poly-Brush over the entire surface we are covering. Again, this is done after we have completely taped and prepared the structure we are going to spray. Poly-Brush must be properly thinned before applying. Use R65-75 Reducer if the ambient temperature is less than 85°. If the temperature during the spraying operation will be higher than 85°, then you must use R8500 Reducer. Thin the Poly-Brush using the formula of one part thinner to three parts of Poly-Brush. Mix it thoroughly and then pour it through a paint strainer. Use a 60x48-mesh paint strainer available from Poly-Fiber distributors. You can pour the mixture from the can through a strainer directly into your spray cup.

## Play Misty for Me

You are now ready to spray. Start out by spraying a "mist" coat over the entire surface. This coat should put a fine layer of Poly-Brush over the area. It will not look wet when completed, because you have placed so little chemical over it that it does not create a uniform film. This mist coat will allow the next full coat to adhere to the surface properly. Trying to spray a thick coat on first will only cause runs and other imperfections. Wait about 15 minutes after the mist coat, and then spray a wet coat over the surface. This coat will be sprayed on heavier and will appear wet and shiny. Be careful not to spray too much chemical onto the surface, or runs and sags will result. If runs and sags occur, they should be immediately removed using reducer and a brush. Lightly brush out the runs before they dry.

Poly-Brush is normally tinted slightly to a pinkish color to allow you to apply it more easily. Still, you must have a good source of light when spraying. The Poly-Brush will appear to have a deeper pink color than the coat that was brushed on. As it dries it will become glossy.

Poly-Brush is also available without the pinkish tint. The untinted product is used where the backside of the fabric will be visible. An example of this would be on the fuselage of an open-cockpit airplane where you will actually see the backside of the fabric. You would not want the pinkish color showing in this area. The untinted Poly-Brush is a bit more difficult to apply.

## Problem Areas

You may observe some problems while spraying. If the Poly-Brush sprays filaments that look like cotton candy, or if the surface dries rough, it has probably not been adequately thinned. Be sure you thin the mixture as directed. If the temperature is excessive, you may have to add BR-8600 Blush Retarder. This retarder simply slows the drying process so that the chemical has a chance to adhere to the surface before it begins to dry.

Of course, runs and sags may be a problem. Simply use a brush with thinner to brush out the run as soon as you discover it. Spray Poly-Brush over the area again. Do not try to sand out a run or sag at this point. Poly-Brush will not sand. Sanding will

A gravity-fed spray gun may be used with an HVLP system.


Poly-Brush is the first chemical that is brushed onto the prepared fabric. An additional two spray coats should follow.


The R8500 retarder-reducer is used to thin both Poly-Brush and Poly-Spray. It is used when the temperature is above 75° F.

You must wear some type of respirator when spraying chemicals. The charcoal filter respirator pictured here is adequate for both Poly-Brush and Poly-Spray.


Poly-Spray is applied by spraying at least three cross coats over the Poly-Brush. We will discuss this in our next segment.

be done at a later stage of the process.

Pinholes may appear. These are tiny areas that have the appearance of a small hole. Insufficient filling of the fabric or tape weave during the brush coat may cause this problem. Spraying in direct sunlight can also cause pinholes. At this point the only way to cover a pinhole is to rub the area with a soft cloth and reducer. This will soften the Poly-Brush and force it into the unfilled weave. You must then spray the area again with thinned Poly-Brush with retarder added.

You may notice an "orange peel" appearance. This is often the result of using too much air pressure if you are using a pressure spray gun. It can also be caused by the coat being too thick.

If you notice some of the small edges of pinked tape lifting up, this is normal. The solvents sometimes cause small areas to release. This is easily resolved using a small iron calibrated to 225° F. Simply iron the edges down. They will then stay in place. Be careful not to leave the iron in one place too long.

## Second Spray Coat

After allowing the first coat of Poly-Brush to dry thoroughly, you then should spray on a second coat. I recommend waiting a few hours between coats. If you spray on the first coat in the morning, wait until the afternoon to spray on the second coat. It should also be thinned according to our formula of one part thinner to three parts of Poly-Brush. Normally, one coat of Poly-Brush brushed on the surface followed by two spray coats of Poly-Brush will be adequate. You will then be ready to apply the Poly-Spray. We will discuss this important step in next month's installment of the series.

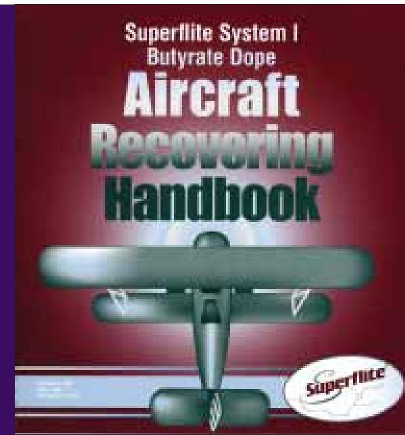
## Chemical Coat Application

| Poly-Brush | Application | Time Between Coats |
|---|---|---|
| First coat | Brush on | |
| Second coat (initial mist) | Spray on | 2 to 4 hours |
| Second full coat | Spray on | 15 minutes |
| Third coat | Spray on | 2 to 4 hours |

## Helpful Hints

Spray in well-ventilated area, and use a respirator.
Thin the Poly-Brush 3:1 (Poly-Brush to thinner) before application.
Use R65-75 Reducer if temps are less than 85°; R8500 if temps are higher than 85°.
The "wet coat" will appear wet and shiny. Remove any runs or sags immediately, before the coat dries.
Use non-tinted Poly-Brush in areas where the backside of the fabric will be visible.
An "orange peel" texture is the result of either too much air pressure in the pressure spray gun or a too-thick coat.
Areas with pinholes may be rubbed with a soft cloth and reducer, and then resprayed with thinned Poly-Brush with retarder added.

# Superflite: Hittin' the Books




Wandering around Oshkosh last year, with my shopping bag becoming increasingly heavy, my thoughts turned to the prospect of adding a couple of half-inch thick, 10-inch square books to it. I've learned over the years to take a half-filled suitcase, but never learned to say "No, thanks" when offered bits of printed material or a sample.

A week after getting home, the pile diminished as the trash can filled. Fat books appeal to my readaholic nature, so they easily made it to the "keep" pile. With winter upon us, it was time to delve into them.

I'm a neophyte here. I've built a riveted aluminum airplane and a composite one, but the next project will be tube and fabric, so I was interested in every word in the *Superflite Recovering Handbook*. As I watched the accompanying DVD, I made notes.

## And Now the Movie

About 4 minutes in, the narrator said "two parts MEK plus one part U-500…" and I did a double take. The screen showed two cans of U-500 and one of MEK, the opposite of the narration. I immediately called Superflite and was told, "Follow the narration, not the graphic!" The books have the same problem. On Page 5.3, it should be two parts MEK plus one part U-500.

Despite the musical score, I would encourage anyone interested in building or owning a fabric aircraft to watch the DVD. It is a gold mine of information and will leave you enthusiastic about an area of aviation that is fast becoming, if not extinct, at least a dark art.

Not all of the useful lessons are intentional. For instance, they use an excellent glue gun that I want even if I'm not doing fabric. Also, it's nice to see the work being done, and I'd never have guessed that bubbles and small distortions in the fabric could be removed during the shrinking process.

I was also surprised to see that inside corners could be cut to a sharp, zero radius; on my previous projects, I'd have used a paper punch to get a curve to eliminate those stress concentrations. Not here, though.

I also learned that shrinking is a three-stage/temp process, so you'll likely tire of it before you overdo it. Says Superflite, "Don't go over 375° F, and you'll be OK. It shrinks just so far and no further."

Does the weight of the iron affect the process? Although that question is not addressed, watching the technique illustrated that this is not like ironing your shirt before going out on a Saturday night. It's easier—except for those glued areas, which should not be retouched.


Typical of the books is this clear illustration with concise do's and dont's.

## Armed & Ready

I had read elsewhere that a heat gun has no place in this fabric-covering process, but I wondered why. The DVD shows a large hole quickly being burned through the fabric in a scene that only Freddy Krueger would enjoy.

Rib-stitching. Old movies of aircraft construction showed legions of ladies intent upon tying knots that would make Nelson's sailors blush. I'd seen several printed examples showing the thread's path, but this demonstration made it look downright easy!

## Safety

One area needing improvement might be safety. Tyvek suits are emphasized, but what about MEK? I looked up the MSDS on it and found that it causes droopy eyelids and lack of coordination, but does not inhibit reproduction. Tyvek suits are those white, protective suits used to protect the skin from airborne chemicals. Forget using your old jeans and long-sleeve shirt. Superflite offers two options for painting your aircraft, and both are fairly toxic. You'll need a filtered room for the project, filtered air for you to breathe and something to keep all that airborne particulate off your skin.

MEK, methyl ethyl ketone, is a manufactured organic chemical sometimes known simply as ketone, less often by its parent group butanone. Working with all chemicals, wear rubber gloves, no open flame, don't drink it, and dispose of it properly.

MSDS, material safety data sheets. These are government approved fact sheets that all chemicals must have available. They're not difficult to interpret, and if you're going to be around MEK and similar liquids, you should become familiar with them. Google the chemical name and MSDS, and you'll eliminate one cause of a shortened flying career.

## Circling Back Around

I'd like to offer the expert painters out there an opportunity to agree, disagree or elucidate. The Superflite video shows spraying of the various coats, be they hardeners, UV protectants or color coats, by hitting the major flat surfaces first, and then the corners. I'm a proponent of doing the corners and difficult surfaces first, then the easy parts. What say you? (Your thoughts to *editorial@kitplanes.com*, please.)

## If It's in Print, It Must Be True

Having watched the 50-minute DVD, I moved more diligently into the books. Titled *System I - Butyrate Dope* and *System VI – Urethane*, the differences are tough to spot; they use many of the same illustrations, they're laid out in identical fashion, and even the text is identical, so how to determine which process is right for your project?

Molly McNamara, the author of both books and daughter of Superflite's owner, answered that question. "The books are identical in many ways if for no other reason than both address the issue of recovering and finishing fabric aircraft," McNamara said. "The real differences come after Chapter Six, where we talk about the finishing."

Fair enough. But how does someone choose which process?

"Well, System I Butyrate Dope is usually used on classic aircraft. It produces a matte-satin finish," she said. "It's also about 5 pounds lighter for a typical aircraft. The System VI Urethane process is quicker and easier to apply, and is what we recommend for show planes that want a super high-gloss. It can be used on metal and fiberglass as well as fabric."

Laundry? No, this is just the company's advice on preserving the evidence.

Having started my first airplane in a condo with a bedroom above the garage, I was interested in smell and toxicity issues. "Dope smells strong and urethane less so, but it's still not recommended for application in your basement," McNamara said.

So what's the story on Systems II through V? Are there other books or videos?

"We'd made a lot of revisions over the years and when we decided to publish these books. Systems I and VI were, and are, current," McNamara added.

Both books are well illustrated, easy to follow, spiral bound to lay flat, well organized so finding what you need is easy, and colorful so they're fun. Superflite also sent a project kit; look for a report in a future issue.

For more information, visit ***www.superflite.com.*** *—Bob Fritz*

# To Launch A LIGHT SPORT

## We'll fit the cowl on the Jabiru J250 and find some tricks that work for all glass aircraft.

BY BOB FRITZ

**Last month** we hung the engine and exhaust, so it seems a good time to fit the cowl around it all. You'll recall that installing the engine went so smoothly that all seemed right with the world.

The first order of business, then, is to lay the upper half of the cowl on the fuselage so that the leading edge rests on the crankshaft and the trailing edge centers on the fuselage just above the firewall. That allowed me to see that my repositioning of the engine/mount put the crankshaft on-center. From there, it was a simple job to mark the high point, measure the diameter of the crankshaft, add a half-inch to that value, and then scribe a semi-circle on the upper cowl. A quick pass with a pneumatic saw, and I had a nice fit.

I want to emphasize here that if you are going to work in composites, you really need to buy the right tools. They're not expensive, but not having them is, and this $20 pneumatic saw is one of the most valuable.

Back to the cowling: I wanted to minimize the gap between the spinner and the cowl, so the next fun step was to add the spinner. This is the sort of progress that makes me go into the house saying, "Hey, Honey, guess what I did?" It allowed me to eyeball the front end of the cowl into being symmetrical around the crankshaft. I should explain here that the requisite engine offset, if properly done, shifts the aft end of the engine, allowing the crankshaft to go through the center of the cowling.

### Long Way 'Round

As is so frequently the case, getting from New York to Paris, so to speak, required going through Nova Scotia and Ireland (think of Lindbergh's transatlantic flight). On my project, the prop bolt-holes were a mess, so cleaning them had to be done with care. A tap and a liberal amount of cutting fluid to flush out the junk was needed, but once that was done, the bolts moved smoothly.

A pneumatic reciprocating saw is a must for working in glass. Those two cuts were done without benefit of a guide.

The lower cowl makes contact with the upper at the front, but the rear, that's a different story of about a $^5/_8$-inch gap.

I had heard of some problems with the spinner. A neighbor, James, with the same engine/prop combination, had found that the front and back of the spinner base were not parallel, the result being that the prop blades did not follow the same track. Once they were installed, curiosity demanded that I check it. Easy job: Just turn blade one (your choice) to horizontal, put a chair so that it just clears the blade, rotate the prop so blade two is close to the chair, and see the difference. I found none.

What I did find was that the spinner itself was not drilled on-center. It's a snug fit against the six mounting bolt bushings, so there's no way I could have installed it incorrectly. The wobble was noticeable, so I put a dial indicator on it and found that the hole pattern in the spinner base was 0.120 inch off center.

I contacted Sensenich about this, and a new one (personally inspected) was in the mail the same day. When it arrived, another go with the dial indicator showed it at 0.010 inch, and that seemed good enough. These spinner components are balanced, so you should resist the temptation to modify them; just take advantage of the great service Sensenich offers.

With the spinner in place, I was ready to resume my fitting of the upper cowl. Taping a spacer onto the crankshaft allowed the forward end of the cowl to sit at the right height; another spacer taped between the spinner and the cowl gave me the longitudinal position. Now it was time for the aft end.

## Cheap Homemade Tools Redeemed

This is a little trickier, because there's no guarantee that the joggle in the fuselage is not a wave as it curves around in front of the windshield. As it turns out, wave it did. But a fit was accomplished with a little tool that's really nothing at all, but amazingly functional. Its use is based on a deep and subtle mathematical principle that a yard stick is 36 inches long no matter which end you measure from. Really! The tool is simply a scrap of aluminum with one end bent over to catch the joggle and the other bent as a handle. The length between is up to you, but about an inch seems sufficient. If your cowl requires the removal of more than a half-inch of material, you might want to rough-cut it to that range.

With the front of the cowl in position, use a couple of pieces of tape to hold the aft end of the cowl in place. Now slip the little tool under the cowl, hooking it on the joggle. Use a Sharpie to put a mark on the tool where it comes out from under the cowl. Next, remove the tool and turn it 180°, hooking it on the cowl in the same place that made a mark. Transfer that mark to the cowl.

You should repeat this sequence as many times as you like until you get a dotted line on the cowl. All that remains is to cut on the dotted line, and there you are: The trailing edge of the cowl will make a nice fit regardless of any wave in the joggle.

If you opt to simply cut the trailing edge using only two or three dots, you might be surprised to find that the straight line of the cowl makes an imperceptible wave on the joggle stand out like a pumpkin in a horse trough.

The little tool can also be used to get an equally nice fit on the lower cowl. However, in my case, the devil was in the details. Having defined and cut

This simple improvised aluminum tool hooks onto the fuselage joggle.

*Photos: Bob Fritz*

the opening for the crankshaft into the upper cowl, it was a task of but a moment to transfer that geometry and cut the lower half. Again, with the upper cowl resting on its spacer and taped into place on the joggle (wonderful fit!), I brought the lower half up into place and...what's this? There's a gap between the upper and lower cowl. These should overlap so that I can trim them to being a butt joint. This won't do, no, this won't do at all!

The relative position of the front end of the upper and lower cowls is restricted by their own joggle, so there's no help there. The upper half is limited in its vertical position by dropping in to the upper joggle and the lower half of the cowling is similarly vertically restricted. There's just no way to bring the upper half down or the lower half up.

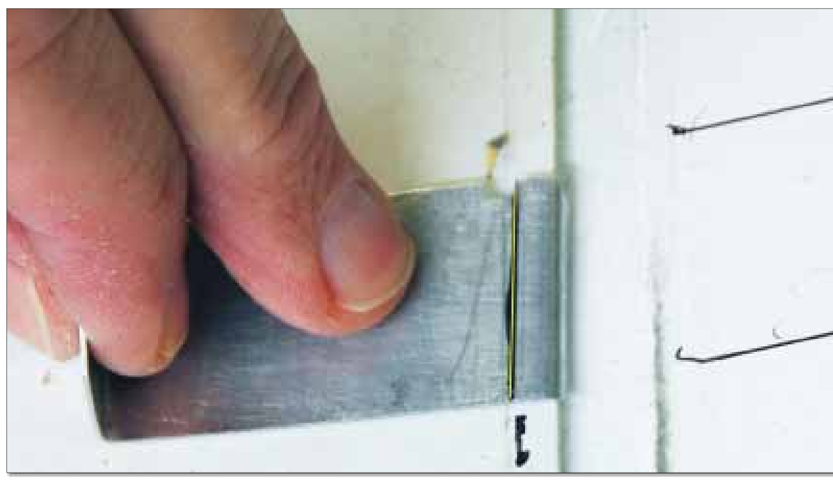
## Nothing New Here

A bit of investigation revealed that mine was not an isolated instance. It seems that during manufacture, the cowl material was laid into the mold and then, when it hardened, trimmed off using the upper edge of the mold as a guide. You guessed it: The mold was trimmed as well, so each succeeding part was just a little bit shorter than the previous part.

The most surprising aspect, though, is that I didn't view this as an unmitigated disaster. I guess that with all that's gone before, I have a been-there-done-that attitude. Now it's "Aw nuts...I can fix that." When do I get the T-shirt?

I received a suggestion to slit the lower aft end of the cowl at the 4 and 8 o'clock positions to allow the sides to come up. I was told that this would enlarge the air exit and help the engine cooling "That's what a lot of guys do in Australia to keep the engine temps down."

Hook the tool on the joggle, and then mark (yellow/black line) the overlap on the tool with a Sharpie.



Now transfer the mark to the cowl. Repeat to create a dotted cutting line, and you'll get a conformal line between the cowl and the fuselage.

Although that might work, I just didn't like it. There's a large opening down there as it is, so I couldn't see that making it larger would address this issue. The only answer, for me at least, was to extend the edges of the lower fuselage. And as it turns out, what at first seemed a job for an expert was not particularly difficult. As in so much else, preparation is everything. In this case a flat, smooth workbench large enough for the cowl was the first requirement.

The idea here is to use the surface of the bench as a mold/backing plate for the glass. Of course, we start with a sanding job of any areas that will be contacted by epoxy. A layer of slick packing tape was laid upon the bench because, while it might have been amusing, I did not eagerly anticipate permanently attaching the cowl to the bench.

Next, it was necessary to support the cowl in a position where the edge to be extended was as flat as possible and in contact with the taped bench. Various clamps and buckets sufficed, but it wasn't pretty. Step one was to cut several lengths of glass a few inches longer than needed, lay out the needed tools, take a deep breath, and have a go.

Painting the cowl edge with epoxy was followed by mixing a separate bit of

Roven glass keeps its shape, so for long applications it works best.

Brown packing tape on the table, cowl in position, glass is cut and ready for application.

epoxy and flox and then "thumbing" it onto the sharp corners to fill any gaps. I chose to lay dry cloth in place, pour a little epoxy on it, cover it with plastic sheeting and roll out the excess.

A better technique would have been to use roven glass and work the epoxy in with a separate operation. Not having any, though, I cut my strips from larger cloth and, long and skinny as they were, they'd have disintegrated when moving them. This was done during cold weather, so it took a heat lamp and two days for it to set up, but eventually it did. Popping it off the table and repeating the operation on the other side was easy.

Several layers of glass extending beyond the needed zone gave the author more than enough to trim off with the saw.

With the upper cowl in place and the lower cowl aft-end trimmed to fit the joggle, I was now able to mark the line of overlap on the new extension and then, using the ubiquitous pneumatic reciprocating saw, cut off the excess.

## Almost There

The home stretch! Eiffel Tower in sight! Just add the hinges. The hinges on a Jabiru cowl line up nicely with the cabin doors, so, using a 12-inch drill bit, I extended the hinge pin line right through the firewall and then on through the door frame. The problem of getting through multiple walls was solved by inserting a brass tube along the pin path. It also served to closely guide the pin so that it was on track for the hinges.

One more little trick here and I'm home: Grind the tip of the hinge pin to a point, but put the point off center. The aft end of the pin is bent over 90° and about an inch long, so that when I rotate the pin I'm actually moving the point of it in a circle—and it all works! Now the hinge pins are inserted/extracted only if the doors are open.

I finished this off with 8-32 Torx screws in the lower aft end of the cowl, but I've seen much nicer jobs where hinges and pins are holding it directly onto the firewall. I'll take that route a bit later perhaps, but for the moment I'm going back in the house with another, "Hey, Honey, guess what I did?" ✢

One threaded hole cleaned, five to go.

# Lock Washer Redux

Sensenich had supplied its special lock/flat washers for the prop, so there was a bit of cogitation attached to studying them. I mean, how do you put a washer on backwards? I've been looking forward to explaining these ever since I toured the Sensenich factory in Florida in October of 2007. Steve Boser, vice president of engineering, had explained their function, and I was duly impressed.

Start with the concept of a lock washer. You take a thick flat washer, cut through one side, offset the circle into a spiral, heat treat it for stiffness, and the result is a one-turn coil spring that will keep the tension induced in the bolt when the spring is compressed.

Not too bad for its day, but there's a better way. Where the typical lock washer will decrease in holding power as the bolt loosens, the Sensenich washer does just the opposite; it becomes more powerful as the bolt loosens its first eighth of a turn.

This neat trick is accomplished by making the washer in two identical rings, each of which has radial serrations on one side and radial ramps on the other. Stack the two parts with the ramped sides facing one another and place it on the bolt. The serrated sides yield a grip into the base metal and bolt head.

When tightening the bolt, the washer halves don't move relative to one another and, using your torque wrench (you do use a torque wrench, don't you?), all feels normal. What's not normal is loosening them. Those serrations cause the lower half of the washer to remain stationary and the upper half to turn with bolt. But in doing so, the ramps come into play and increase the tension on the bolt. The result is a definite "click" that is a bit unnerving when you first encounter it. Once you understand it, it's a reassuring sound.

They're supplied with a bit of what appears to be rubber cement holding the two halves together. This is to help you install them correctly; it's little details like this that mark a supplier as a quality outfit. The only drawback is that they are about $1 each, so using them throughout the project would be expensive.

*—B.F.*

**SPORTPLANES MARKETPLACE**

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

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

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

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



# Flying qualities and the horizontal tail.

**The horizontal tail** has several functions, all of which are vital to providing acceptable flying qualities. The tail must stabilize the airplane in pitch. It must also trim out pitching moments caused by the wing, body and C.G. changes. Finally, the tail must provide control power so the pilot can maneuver the airplane. The designer must take all of these requirements into account when defining the size and configuration of the tail.

## Stabilization

The pitch stability of an airplane determines how it responds to an angle-of-attack disturbance. The disturbance can come from a variety of sources including turbulence, control movements or power changes. A stable airplane is self-correcting. It will resist any perturbation that tries to deflect its flight path. If the nose of the airplane is raised, a nose-down pitching moment will be created, which will push the nose back down. If the nose is lowered, a nose-up pitching moment will be created, which will tend to raise the nose.

On a conventional airplane, this is the horizontal tail's job. As the angle of attack changes, the tail's lift changes in response, producing a moment opposing the change. If angle of attack increases, the lift of the tail increases and generates a nose-down (negative) pitching moment. Conversely, if the angle of attack decreases, the tail's lift decreases, causing a nose-up (positive) change in pitching moment. These moment changes tend to drive the airplane back to its original trimmed angle of attack.

The stabilizing influence of the tail is a function of several factors. To the first order, the stability increment produced by the tail is proportional to the product of the tail arm multiplied by the tail area. Because this quantity has units of feet cubed, it is referred to as "tail volume."

Tail aspect ratio also affects stability. A higher aspect ratio surface has a higher lift-curve slope. This means that a 1° change in angle of attack on a high aspect ratio surface produces a greater change in lift than on a low aspect ratio surface. Accordingly, a high aspect ratio tail is more stabilizing than a low aspect ratio one of the same area. The proper tail aspect ratio is a compromise. High aspect ratio surfaces provide more stabilization per unit area, but they are heavier, and stall at a lower angle of attack than lower aspect ratio surfaces.

Control surface characteristics also play a major role in determining the stabilizing effect of a tail. With the stick free, the elevators will tend to float with the wind. This means that they do not provide as much stability as they would have if they were held fixed. The floating tendency of the elevators is very dependent on details of the elevator geometry. Aerodynamic balance tends to reduce elevator float. Elevator chord and the details of the trailing-edge shape can also have a large effect.

Float can be a major issue with an all-moving tail. If the tail is hinged too far forward, the whole tail will float with the wind if the stick is free. From a stability viewpoint, this is aerodynamically equivalent to removing the tail. Designers counter this by hinging the all-moving tail at or near the 25% chord point, which eliminates both float and, unfortunately, any tendency for the tail to resist being deflected by the pilot. This will cause the airplane to be oversensitive in pitch, so an anti-servo tab is added to provide artificial pitch feel. A properly done all-moving tail can actually have some advantage over a fixed tail plus elevator setup because it does not have elevator float. This means that the stick-free and stick-fixed stability will be the same for the properly balanced all-moving system. The same effect can be achieved with an elevator by proper use of aerodynamic balance and either an anti-servo tab or centering springs. The Questair Venture used such a system.

## Trim

The second function of the horizontal tail is to trim the airplane. When the airplane is in steady flight, all of the moments acting on it must be balanced so that there is no net moment about the center of gravity. An airplane that is in this state of moment equilibrium is trimmed. If the airplane is not trimmed, it will pitch either up or down.

The wing and body both produce aerodynamic pitching moments. For a conventional airplane, the tail-off (wing plus body) pitching moments are not balanced. The airplane will not be in trim without the addition of a pitching moment to counteract the wing and body moments. The horizontal tail provides this pitching moment by producing a force on the aft end of the fuselage that

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


The Van's RV-12 is unusual in light Experimental aircraft for use of a stabilator—the all-flying horizontal tail. Choosing the proper hinge line for this configuration is critical. Randy Schlitter's RANS S-19 LSA also uses a stabilator.

trims out the other moments. This trimming tail load may be either up or down, depending on the details of the airplane configuration, airfoil and c.g. position.

The tail load required to trim will change with angle of attack of the airplane and the position of the c.g. To trim the airplane at differing flight conditions, the pilot must be able to control the lift (or down force) of the tail. There are two ways of doing this. The first is to hinge the trailing edge of the tail to form an elevator surface attached to the back of a fixed tailplane. The pilot can change the camber of the tail by deflecting the elevator and hence change the lift of the tail.

The second approach is to pivot the whole tailplane so that the pilot can control the angle of attack of the tail directly. Combinations of these two approaches are not uncommon. Some airplanes have an elevator as the primary pitch control but also have variable-incidence tails. The pilot can adjust the incidence of the fixed portion of the horizontal tail to trim the airplane. Conversely, most airplanes with all-moving tailplanes have large, elevator-like tabs hinged to the trailing edge of the tail to control hinge moments and increase control power.

Variable-incidence tails with elevators are standard practice on large transport airplanes. Light airplanes typically use trimtabs set into the elevators to adjust the stick-free floating position of the elevators for trim. Variable incidence tails are used on some light airplanes, notably the venerable Cub, and the Mooney line of airplanes. The Mooneys are unusual because the whole tail unit, including the fin and rudder, move to change the incidence of the horizontal tail.

## Pitch Control

The third function of the horizontal tail is pitch control or maneuvering. It is similar to trim in that the tail is used to generate pitching moments. When the pilot wishes to change the attitude or flight path, he must generate a moment that will pitch the airplane. This moment is different from the moment required to trim the airplane, as the pilot is deliberately putting the airplane out of trim to generate a pitch rate.

The horizontal tail of an airplane must be able to generate enough pitching moment so that the pilot can control the attitude and flight path at any point in the flight envelope. There are some flight conditions that require special attention when considering the control power required from the horizontal tail.

One of these critical conditions is nosewheel liftoff during takeoff. If the airplane has tricycle landing gear, the pilot must be able to rotate the airplane to a positive angle of attack for liftoff. It must be possible to lift the nose wheel at an airspeed below the stall speed with the airplane loaded to its most forward c.g. position. FAR part 23 requires that an airplane be able to lift its nosewheel when rolling at 85% of stall speed.

If the airplane has a tailwheel landing gear, there is a similar requirement that the airplane be able to lift the tailwheel off the ground when loaded to its aft c.g. limit while traveling at 80% of its stall speed. This tailwheel liftoff requirement can be troublesome if the airplane has an all-moving tail. If the choice of tail airfoil and travel is not correct, the pilot may stall the tail during the ground run and consequently be unable to rotate the airplane into a more level attitude for takeoff.

Another critical flight condition for tail sizing is the landing flare. With an airplane at its most forward c.g. and the flaps and landing gear down, the pilot must have enough pitch control available to trim the airplane and to bring the nose up in the final flare maneuver. To satisfy this last requirement, the airplane must have somewhat more control power available at normal landing speed than is necessary to simply trim the airplane. The pilot must be able to produce a nose-up pitch rate from the trim condition to flare the airplane and arrest its sink rate before ground contact.

*Photo: Kevin Wing*

A final flight condition that must be considered is pitch recovery from high angles of attack. The pilot must be able to lower the nose and reduce angle of attack to break the stall and retain control of the airplane. The elevator must have enough control power to produce a nose-down pitch rate at the highest angle of attack that the airplane is expected to achieve. The designer should note that this maximum angle of attack will be well beyond the angle of attack at which the wing first stalls. If the airplane approaches the stall with a large nose-up pitch rate, it will continue to nose up for some time after the wing has started to stall. By the time the pitch rate is zero, the angle of attack will be well above the nominal stall angle of attack. In extreme cases such as tail slides the angle of attack reached by this type of dynamic overshoot can be large.

It is also possible to reach larger than expected angles of attack because of gusts or turbulence. If the airplane is flying near the stall angle of attack and encounters a strong up or tail gust, the gust will induce a positive angle of attack change, and this may put the angle of attack above the stall angle of attack. It is of utmost importance that the pilot be able to force the nose down at any angle of attack to prevent a hung stall and loss of control.

## Tail Design Considerations

The need for trim, stability and pitch control power place requirements on the design of the horizontal tail.

1. The airplane must have sufficient tail volume to give the desired C.G. range. The aft limit is set by stability considerations, and the forward limit is set by nose-up control power considerations. Both are a function of tail volume.

2. The pilot must be able to trim the airplane at all C.G. positions, and at all flap and landing gear configurations over its entire angle of attack range. It is desirable to provide a trim control that will allow the pilot to trim the airplane without exerting a continuous pressure on the controls.

3. The airplane must have sufficient control power to produce pitch rates at all angles of attack. The most critical conditions are usually stall and high angle of attack recovery at aft C.G. positions, and nosewheel liftoff and landing flare at forward C.G. positions.

4. Control surface hinge moments must be relatively linear and small enough for the pilot to overcome easily at all points in the flight envelope. Stick force reversals and unstable control surfaces should be specifically avoided.

5. The tail must remain unstalled throughout the flight envelope.

Stalling of the horizontal tail will usually result in loss of control, and it is of particular concern for airplanes that use all-moving tails because the pilot can change the tail angle of attack over a large range.

There are several situations in which tail stall can be encountered, and some can be extremely dangerous. One condition that has proven troublesome is the full-flap, forward C.G. configuration. In this situation, the tail must produce a large download to trim the airplane. If the tail is too small or stalls at too small a negative angle of attack, a small change in tail incidence such as the deflection required to trim the airplane in a turn can cause the lower surface of the tail to stall. If this happens, the airplane will pitch down, and the pilot will not be able to prevent it from doing so.

On early versions of one production light airplane, the pilot could not regain control until the airplane had pitched over to an inverted attitude. This caused accidents before the condition was diagnosed and could be fixed. The remedy was to put fixed slots in the leading edge of the tailplane to increase its stall angle of attack. Increasing tail size, changing tail airfoil or restriction of tail travel and C.G. can also solve this problem. Tail stalling can also be a problem when trying to recover the airplane from high angle of attack flight. This problem is more typical of modern fighters that fly at very high angles of attack. ✈

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# COMPLETIONS

## Alan Negrin's Glasair

N2CQ started as a big pile of parts on September 5, 2006, and first flew on October 4, 2006, less than 30 days from start to finish. I completed the airplane in the Glasair Aviation "Two Weeks to Taxi" program, and was the first customer to go through the program. It is IFR-equipped, with an Advanced Flight Systems AF-3500 EFIS, Garmin 430W, SL30 and TruTrak DigiFlight II autopilot. My wife and I made our first of many airplane camping trips to Idaho on Memorial Day weekend 2007. Cruise speed is 150 knots TAS.

KIRKLAND, WASHINGTON
ALANNEGRIN@MSN.COM

## Paul Taylor's RV-8

RV-8 N70PT's initial flight occurred on June 9, 2007. Four years and 2700 hours is all it took, and that included the homemade paint job. The 40-hour fly-off was completed in a month, and my brother Joe and I flew to Oshkosh 2007. The engine is a 180-horsepower Superior XP IO-360 I built at the Superior engine build school. The propeller is a Hartzell constant speed; the paint is Randolph Ranthane. Empty weight painted is 1110 pounds. This airplane is a joy to fly, and my Cessna looks sad every time I pull the RV-8 out to go fly. Many thanks to Van's for putting out a super product.

OVERGAARD, ARIZONA
PKTAYLOR@FRONTIERNET.NET

## Sal Capra's RV-8

I completed and test-flew my Van's RV-8 in February 2007. The plane was constructed from a quickbuild kit over a 2.5-year period. An O-360 with a constant-speed prop makes sure all Van's published numbers are achieved. A Dynon EFIS and EMS are in the panel, and the plane is a joy to fly. The Grove gear smooths out the bumps. The Van's product and support are great. Thanks to Brian Parrish for his knowledge and help, and to Duke Raven for bucking those rivets. "Life is great in an RV-8."

LAKELAND, FLORIDA
CBRXXDRV@AOL.COM

# BUILDERS SHARE THEIR SUCCESSES

Submissions to "Completions" should include a typed, double-spaced description (a few paragraphs only—250 words maximum) of the project and the finished aircraft. Also include a good color photograph (prints or 35mm slides are acceptable) of the aircraft that we may keep. Please include a daytime phone number where we can contact you if necessary. Also indicate whether we may publish your address in case other builders would like to contact you. Send submissions to: Completions, c/o KITPLANES® Magazine, 203 Argonne Ave., Suite B105, Long Beach, CA 90803. 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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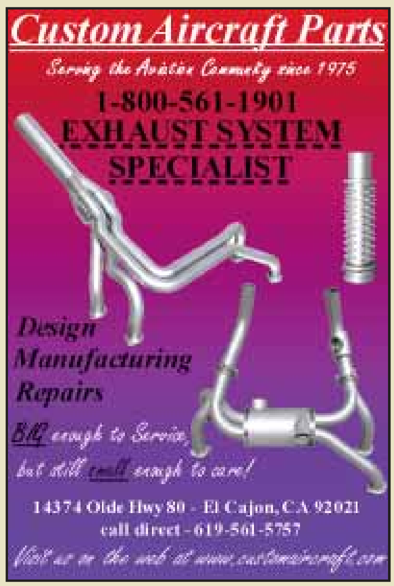
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# Ask the DAR

## Does your inspector have to be local, and how do you amend operating limitations?

BY MEL ASBERRY

**Question: I'm getting ready to call for an airworthiness inspection. I know of a DAR who is very familiar with my particular design, but he is in another state. Can I hire a DAR outside of my general area?**

Answer: Absolutely. Even though each DAR is assigned the same area of coverage as his FSDO, there is nothing in the regulations that prohibits him from performing inspections outside of his area. Almost half of my inspections take place outside of my designated area. Of course, this action must be approved by my FSDO and coordinated with the geographically responsible FSDO. The process goes something like this.

After being contacted by the applicant, the DAR fills out a geographic expansion form 8130-13 and forwards it to his reporting FSDO. That FSDO then forwards the form to the geographically responsible FSDO where the inspection will take place to make sure they don't have any objections. The only reason they can refuse is if for some reason they want to perform the inspection themselves.

Another reason for having the geographically responsible FSDO involved is that the Phase I test area will be within their jurisdiction, and they need to be aware of this. The local FSDO may want to talk with the applicant to make sure he is aware of any special airspace issues in the area.

Once the form has been signed and returned to the DAR, the only remaining requirement is for the DAR to notify the geographically responsible FSDO of the inspection date and time. This will allow a local inspector to come out and observe if so desired.

The only negative aspect as far as the applicant is concerned is that he/she will likely have to pay extra travel expenses for the DAR. But this is offset by getting an inspector who is familiar with your aircraft design and has the expertise to provide you with a quality inspection.

**Question: My original operating limitations restrict the airplane to daytime VFR. How can I get my operating limitations upgraded to allow night and/or IFR operations?**

Answer: There are a couple of possible ways to do this. Up until last year only the FAA (not DARs) could amend operating limitations. Early in 2008, there was a change that allows some DARs to amend them. The catch is, the DAR must have function code 33 on his "letter of authority." Therefore not all DARs may amend.

Looking at your situation more closely, it appears that your operating limitations were issued in 1988 and that you are not the original builder. There have been quite a few changes since then. Some inspectors may be willing to simply amend your operating limitations to the latest edition and that is certainly legal. However, because your aircraft and operating limitations are more than 20 years old, most inspectors would want to see the aircraft before issuing new operating limitations. My recommendation would be to apply for a recurrent airworthiness certificate. Because a recurrent airworthiness inspection does not constitute a condition inspection, this would require that the aircraft have a current condition inspection signed off by an A&P mechanic or the original builder, if he holds the repairman certificate for this aircraft. In this case the DAR would not have to have function

*Photos: Mel Asberry, Marc Cook*

code 33 to do the inspection.

The new operating limitations will not state that the aircraft is "certified" for night and/or IFR. They will simply stipulate that for night and/or IFR operations, the aircraft and installed equipment must comply with FAR 91.205.

**Question: What happens if my aircraft doesn't pass the DAR's inspection?**

Answer: I've been doing these inspections for more than 11 years and have yet to find the "perfect aircraft." It is very easy for a builder to overlook some things when he is so close to a project.

During the inspection the DAR will make a list of discrepancies. In most cases he will point them out as he goes along and have you make your own list. By doing it this way, the best method to correct each individual problem can be discussed. Usually discrepancies are minor, such as missing labels, loose jam nuts, missing cotter pins, etc.

Most often the inspector will allow you to correct any problems while he continues the inspection or immediately thereafter. The DAR will then compare his list with yours to make sure that nothing has been missed. If the issues cannot be resolved at that time, the inspector will leave the discrepancy list with you and advise you to reschedule another inspection after the corrections have been completed. At this point, your aircraft hasn't failed, it simply hasn't passed.

Now if you disagree with the inspector about anything or refuse to correct a problem that was found, the DAR must deny the airworthiness certificate. In this case, he will issue a "letter of denial." This letter will be sent to you, and a copy will go to the FAA in Oklahoma City. Notice of the denial will immediately go out by FAA email to every inspector in the U.S. If you wish to call another DAR, and that is your right, just remember his first duty after being contacted is to check with Oklahoma City to see if a letter of denial has been recorded. So it's not like you're going to "hide" the problem from someone else. It's also good to point out here that even if your airworthiness certificate is denied, you are still obligated to pay the DAR. He is paid to perform the inspection, not to sign off the aircraft.

In over 11 years, I've had only one individual argue with me about a problem. This was unquestionably a "safety of flight" issue. After he refused to correct the discrepancy, said he was not going to pay, and told me he was going to call someone else, I explained how the system works. At that point, he changed his tone and agreed to fix the problem and pay for my services. ✈

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

Amending your operating limitations can be done by a DAR with a "function code" of 33 on his letter of authority, and it will involve a new inspection.

AERO 'LECTRICS

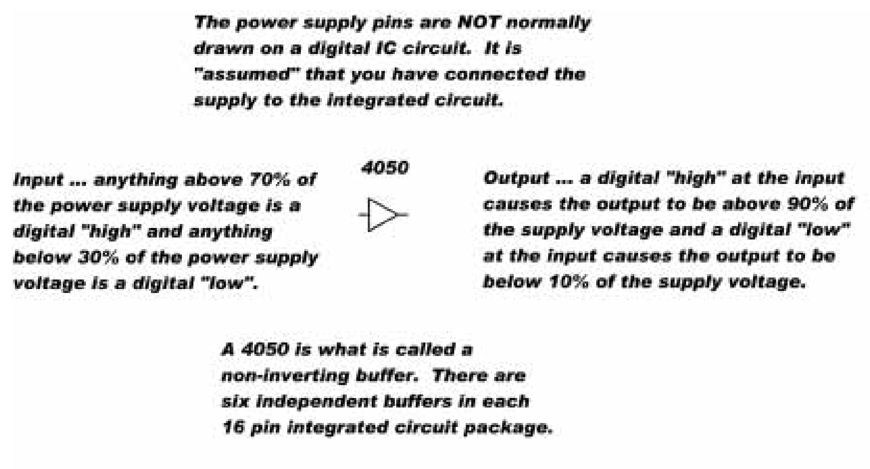
# Airplanes and white rabbits.

**Ah, yes, Janis Joplin** rockin' the Fillmore, the Grateful Dead packing 'em into the Cow Palace, and Grace Slick and the Jefferson Airplane giving out with "… *When logic and proportion…have fallen sloppy dead* …." We can't bring back the wonder that was the 1960s (and if you can remember the '60s, you certainly didn't experience them), but we can draw a line from the lyrics of the Airplane's "White Rabbit" to avionics. Proportion may be dead, but logic is still with us, and we can make the case that logic can be your friend when doing simple tricks with your airplane systems.

Suppose, just suppose, that you want to sound a horn when (a) the airspeed drops below 60 knots *or* (b) the throttle is brought back below 20% power *and* the gear is still up and locked. Most aircraft engineers will go through a long song and dance with microswitches, cams, limit switches and other mechanical means to make this happen, but you and I know that electronics are more reliable, cheaper and weigh a lot less.

Normally, I would give you a design that is complete in and of itself. For example, when I did the nav light series, I didn't just give you the specs on the LEDs and tell you the rest is up to you. No, I did the LED, plus the power supply, plus the optics, plus the flasher circuit. Complete.

However, in the next few months, I will be giving you a toolbox of circuits that you can interconnect in limitless combination to make your airplane systems do what *you* want them to do… logically.




A 4050 non-inverting buffer.

## A Logical Explanation

A brief history of "digital logic" is in order. The first electronic logic circuits were built out of vacuum tubes. As a matter of fact, the first modern "digital computer" (ENIAC) wouldn't fit in the average high school classroom, weighed 30 tons, used 18,000 vacuum tubes and consumed 150 kilowatts of power[1]. As things progressed and the transistor became a reality, and then later the integrated circuit, things shrank until today's home computer is a billion times more powerful than an ENIAC, and it uses a thousand times less power to do the computing. There were several iterations of digital logic, but the most successful family wound up being a power-sipping extremely powerful series called CMOS (complimentary metal oxide semiconductor). There are several versions of CMOS, but my personal favorite is the 4000 series, which is the logic family we are going to use in this series of articles.

The 4000 logic isn't the fastest, nor the cheapest, nor does it have the most variety of functions. Those belong to, respectively, ECL, RTL and TTL. However, it does represent the "sweet spot" of all three parameters.

So let's talk about digital logic for a bit. For the last 23 years (April 1985 was my first KITPLANES® article), I've been expounding on linear circuits: head-


**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.*

phone amplifiers, audio switching panels, lighting, engine instruments and the like. This is my first foray into the digital world with you all.

Analog circuits have an infinite number of input and output levels. Headphone amplifiers can have microvolt inputs to millivolt inputs and put out millivolts to volts. But digital circuits have only two inputs and two outputs. They can have either high or low states. That is, they can be "near" the power supply voltage or they can be "near" ground. There is no in-between. That is why they are called digital. High or low, zero or one (0 or 1), up or down, black or white, north or south, but nothing in-between. There is no east or west in a north-south digital system. And there is no north or south in an east-west digital system. They are in either one state or the other, but nothing else is allowed.

## Dissecting a Circuit

Just for explanation's sake, and before we get to understanding the circuits we are going to be using, let me take the simplest 4000 series digital logic circuit and give you some idea of what we will be talking about.

Take the 4050 buffer. A logical one (high) on the input produces a logical one (high) at the output. That is singularly uninteresting unless you are beginning your study of digital logic. You put in something near the power supply, and you get out something near the power supply. What's the big deal?

Here's the big deal: You've transcended analog to digital. You've taken an analog level and translated it to digital values. If the input is greater than 70% of the power supply voltage, then the output is guaranteed to be within 90% of the power supply voltage. If the input is less than 30% of the power supply voltage, the output is guaranteed to be less than 10% of the power supply voltage. Digital switching!

Whew. Some numbers, please? If the power supply voltage is 5 volts[2], then an input to our buffer of greater than 4.5 volts (70% of the supply volts) is going to appear at the output of this buffer as a logical 1. If the input to our buffer is less than 1.5 volts, then the output of the buffer is going to be a logical 0.

CMOS says this: A logical 1 at the input has to be more than 70% of the power supply; a logical 0 has to be less than 30% of the power supply. A CMOS logical 1 output will be more than 90% of the power supply, and a CMOS output logical 0 will be less than 10% of the power supply.

Whoa. What happens to those input analog signals between 30% and 70% of digital limits? What happens to the vast universe of analog signals that fall between these limits? For right now, we'll call them "digital no-no" levels and not allow them. The very first part of next month's installment will take care of that little problem.

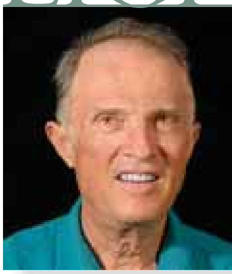
Stay tuned. We have lots of digital stuff to talk about. But for right now, I'll pass on a little digital joke: There are only 10 kinds of people in the world, those who understand binary arithmetic and those who don't.

*Footnotes:*

*1. There is an argument that the first digital computers are the abacus and the slide rule, followed by the Antikythera mechanism from 100 BC, then the Babbage mechanical computer (1837), the Hollerith census machine built in 1899 by the Computing Tabulating Recording Company (later to change its name to International Business Machines, or IBM), then the German Zuse Z3 in 1941, and then along came ENIAC, which is considered to be the first electronic general-purpose machine.*

*The first "bug" found in a digital computer was a moth trapped between the contacts of a relay in ENIAC. Ever since then, computer programming errors are said to be bugs.*

*2. Five volts is the standard voltage supply for a lot of digital integrated circuits, but CMOS is happy to run anywhere from 3- to 18-volt supplies. I use 5 volts simply for compatibility with other logic families.*



# Homegrown LSA: CubCrafters' Sport S2

CubCrafters owner Jim Richmond talks about his company's Sport S2 SLSA contender.

**There was a time**—not many decades ago—when the non-aviation public referred to any light plane as a "Piper Cub." The success of Piper's J-3 Cub in the post-WW-II GI Bill training frenzy overshadowed other trainers, including even the Aeronca 7AC Champ despite its larger cockpit, better (front seat) pilot visibility and slightly faster speed on the same 65-horsepower engine. Many thousands of pilots liked both the Champ and the Cub, but it was the well maintained or restored J-3 Cub that appreciated to 10 or even 20 times its original price.

My memory of flying J-3 Cubs dates to 1970 and a grass-strip airport south of Norfolk, Virginia, where the FBO had several Cubs and rented them for $7 an hour wet. I was a back-seater in a Navy Phantom II squadron based nearby, and on several Saturday mornings one of the bachelor Phantom pilots and I rented J-3s and engaged in mock air combat. I usually won, because Al made the mistake of taking his girlfriend along; dogfighting without the stick and throttle in your hands is not for the occasional or weak-stomached passenger.

## More Cub Nostalgia

Over the years, the popularity of the J-3 Cub exceeded the availability at reasonable prices, which led to the development of plans and kits that helped homebuilders produce replicas. One of the earliest was the Wag-Aero CUBy, which was too close to the original in form, function and name for Piper Aircraft to ignore. Piper convinced Wag-Aero to make a change, which is why today's Wag-Aero kit that builds into what sure looks like a J-3 Cub is known as the Sport Trainer (our cover subject in January).

The ultralight movement spawned numerous "Cubalikes," and the Light Sport Aircraft (LSA) category has further extended the likeness of the Piper Cub. Two U.S. firms—American Legend Aircraft in Sulphur Springs, Texas, and CubCrafters of Yakima, Washington—manufacture ready-to-fly versions of the Cub that qualify as Special (factory-built) Light Sport Aircraft.

## Meet the Sport S2

Last summer I flew with CubCrafters owner Jim Richmond in his company's SLSA offering, the Sport Cub S2. Started in 1980, CubCrafters has developed a reputation for its PA-18 Piper Super Cub restorations and upgrades. The Sport Cub S2 is one of the few SLSAs made in the U.S.; the great majority are European or other foreign imports.

The company's Sport Cub S2, powered by a Continental O-200, is a composite of features found in the Piper J-3 and the smooth-cowled Piper Super Cub. Standard features include round instruments, a Garmin SL40 com transceiver and an ELT. Also standard is airbag protection for the pilot and passenger. A long list of options includes flat-panel displays, custom paint, big wheels and floats.

Designed for the LSA maximum gross weight of 1320 pounds on wheels or 1430 on floats, the Cub S2 features a useful load of 472 pounds and a fuel capacity of 25 gallons (24 usable). With full fuel in the wheeled version, about 326 pounds are available for people and baggage.

Dave Martin

*served as editor of this magazine for 17 years and began aviation journalism evaluating ultralights in the early '80s. A former CFI (airplanes, gliders, instruments), he's flown more than 160 aircraft types plus 60 ultralights (including a single-seat, no-basket hot air balloon). Now living at a residential airpark in Oregon, he flies his Spacewalker II homebuilt as a Sport Pilot.*

*Photos: Dave Martin*

A Garmin GPS receiver has been added to this standard-equipment panel.

Cargo capacity is 120 pounds including 100 pounds behind the rear seat.

## Flying It

Wittman Field at Oshkosh, Wisconsin, during the annual EAA AirVenture convention is not the ideal locale for a leisurely checkout in a new airplane. Therefore, companies with aircraft to promote often arrange to base at least one of their planes at a nearby small airport. For my flight with Richmond, I drove to Hickory Oaks Airport, a pretty little grass strip and recreational-vehicle campground a few miles north of Oshkosh. Surrounded by cornfields, the taxiway and narrow runway were reminiscent of my flights decades earlier in actual Piper Cubs.

Richmond and I walked around the Sport Cub, which belonged to a customer and was equipped with optional tundra tires. Invited to occupy the front seat, I donned the lap and shoulder harness, which contains the standard air-bag system. The extra bulk compared with a standard harness was not distracting, and I soon forgot I was wearing the safety device. The cockpit is large and comfortable. Quickly apparent was the good front-seat visibility. Even with my short sitting height and without a seat pad, I could almost see the horizon over the nose, which is unusual for me in a taildragger with the tailwheel on the ground.

The factory-built Sport S2 resembles the original Piper Cub, but with improvements.

With prestart checks complete, I held back stick, pressed the toebrake pedals, cleared the area, and started the Continental. At this point, three improvements to the Piper J-3 configuration were already apparent: the previously mentioned better cockpit visibility, toebrakes instead of the much-derided heelbrakes, and no need for a volunteer prop-swinger up front.

With oil pressure in the green and plenty of fuel in the selected tank, we rolled onto the taxiway defined by late-July cornstalks on both sides. Taxiing was easy and kept us close to centered, but at this point I decided that I had nothing to prove by making the takeoff and mentioned to Richmond that I'd like him to do that task. Turning north onto the runway after checking both ways for air traffic, I noted that during our back-taxi, we were lined up on one of the observation towers at the large local prison, which is close to the end of the runway. We planned a south takeoff away from the prison, but with a north wind you would need a low-altitude crosswind turn at this strip in most airplanes to avoid over-flying the prison.

Raising the tail early in the takeoff run improved runway visibility for both of us, and a climbout at 60 knots resulted in a climb rate close to the book spec: about 800 fpm. (The ASI was marked in mph, but I've converted to knots because LSA airspeeds are listed that way.)

Shortly after takeoff, I took the controls and quickly found stick and pedal forces in the climb were pleasantly responsive but not overly sensitive. Control balance is nicely harmonized: At a given airspeed, the required aileron, elevator and rudder pressures are similar. After making gentle clearing turns during the climb, I tried a partial-power departure stall. A mild break came at a high deck angle and 36 knots indicated, and neither wing dropped.

Several power-at-idle approach stalls followed. Each time, the break, such as it was, occurred at about 35 knots. Recovery from the first stall was achieved without adding power. I simply released back pressure, and the S2 immediately returned to feeling solid with no tendency to enter a secondary stall. Using engine power for recovery on the second stall, we appeared to lose only about 20 feet after the break.

Positive pitch stability is required in an LSA, and the hands-off pitch check showed a quickly damped return to trimmed attitude and airspeed in a single cycle. With or without flaps—trimmed or with back pressure—slow flight at 45 knots felt solid and completely controlled. The flap handle is accessible to the front pilot only, and there is considerable pitch change initially when lowering flaps. But if you allow the S2 to slow before re-trimming, not much change is needed. A full-power level run at about 2000 feet yielded 95 knots indicated.

After running out of items on my flight card, I headed us back toward Hickory Oaks in what seemed like very little flight time. (Maybe I should find more items for my flight card.) Still, I like everything about the way the Sport S2 flies. On the right base approach, I flew a few feet outside the south fence of the prison, turned final and let Richmond put it down between the cornfields.

## Buying One

Base price for the SLSA Sport S2 is listed at $119,500, and each one is built to order. The order form makes it clear that delivery will be some months away, which gives the buyer time to decide on options such as a paint change from the déjà vu yellow with a black lightning stripe. Fly before buying is a recommended policy. You'll enjoy it. ✈

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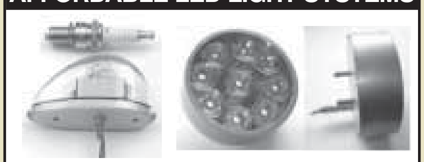

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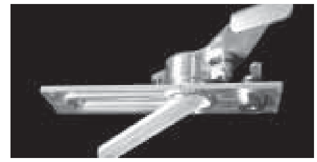

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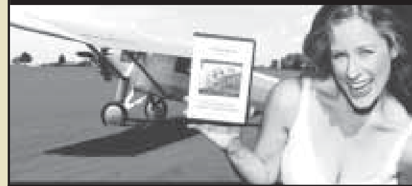

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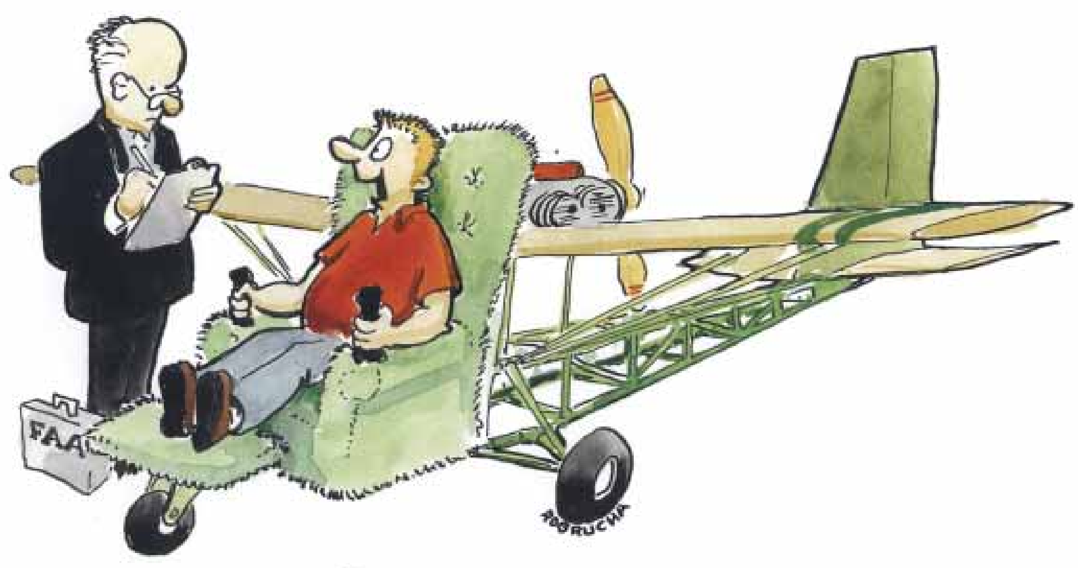


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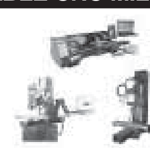

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**Classified Line Ad**

| Rate/word: | 1 time | 6 times | 12 times |
|---|---|---|---|
| | $1.25 | $1.15 | $1.00 |

**20 word minimum per ad.**

**Classified Box Ad**

4 word heading, 25 words of copy, plus your company name, address, and up to 3 contact numbers.
1 time $94 • 3 times @ $89 ea.
6 times @ $84 ea.
12 times @ $73 ea.

**Classified Photo Box Ad Includes**

4 word heading, 1" x 2⅛" B/W photo, 25 words of copy, plus your company name, address, and up to 3 contact numbers.

1 time $188 • 3 times @ $177 ea.
6 times @ $167 ea.
12 times @ $146 ea.

Digital Photo Specifications:
1200 dpi resolution for B/W,
Tiff and EPS formats accepted.

**Subscriptions:**
Ph: 800-622-1065 (US & Canda) • 386-447-6318 (International) • Fax: 386-447-2321

# KIT STUFF
BY ROBRUCHA