2016 BUYER'S GUIDE EXPANDED EDITION

KITPLANES®

YOUR HOMEBUILT AIRCRAFT AUTHORITY

Flying a Taildragger

Homebuilt Aircraft DIRECTORY 2016

OVER 1000 KITS & PLANS LISTED!

ENGINE THEORY
Fuel Injection

FUEL SYSTEM DESIGN
If It Ain't Broke…

VORTEX GENERATORS
Improve Your Cooling

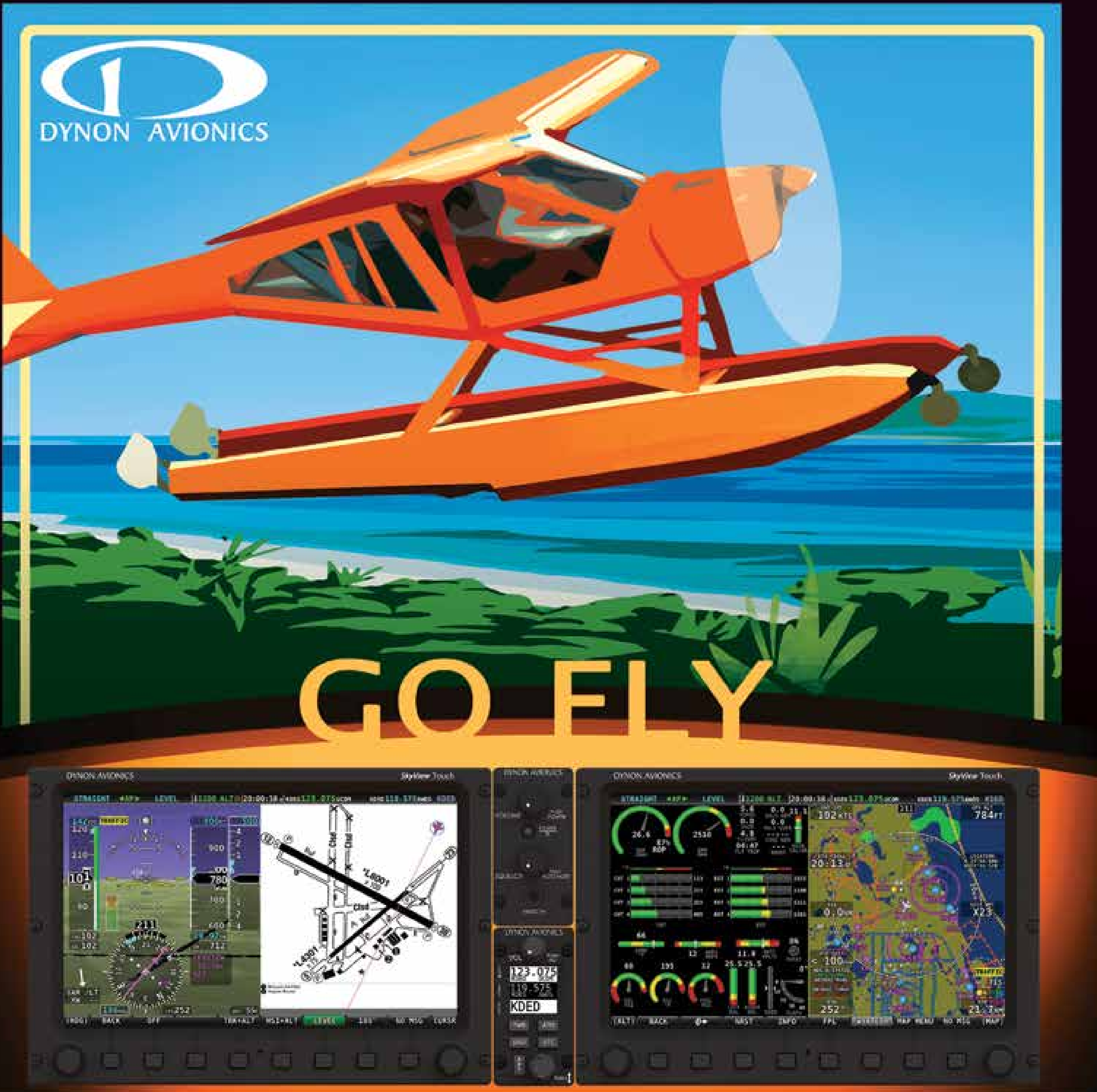
DECEMBER 2015

In the Shop
- Wiring Flaps & Trim
- Mold Making

$4.99US

www.kitplanes.com

KITPLANES DECEMBER 2015 2016 Buyer's Guide • Pole to Pole • Vortex Generators • Trim and Flaps • Column Buckling • Taildragger Transition • Fuel Injection • Mold Making BELVOIR PUBLICATIONS


DYNON AVIONICS
GO FLY

KITPLANES

CONTENTS

December 2015 | Volume 32, Number 12

On the cover (clockwise from upper left): Just Aircraft SuperSTOL, Lancair Turbine Evolution, Stolp Starduster Too, Searey LSX, Vortex M912 Gyroplane, Sport Performance Aviation Panther, Sonex Aircraft SubSonex, and Groppo Trail.

For subscription information, contact KITPLANES® at 800/622-1065 or visit www.kitplanes.com/cs.

Are you crazy?

I started fooling around with real airplanes in my early teens, hanging around with men who rebuilt and built their own airplanes. I went to school to learn how to design and build airplanes. I have spent most of my life working on my own airplanes. So it is completely normal that I live and breathe homebuilt, Experimental aviation. During the years I owned and flew a certified two-seater, it was never a matter of "if" I would build my own plane—only a matter of "when." I expect that for the majority of our readers, this is considered normal behavior, and you can all relate.

But how often do you get into a friendly discussion with a pilot in an FBO lounge, or on the flight line, or even at a major airshow, and when the topic of homebuilt aircraft comes up, the response is something on the order of, "Are you crazy? Build and fly a machine you built? Why would you want to do something as risky as that when there are lots of certified airplanes out there?" The non-believer then goes back to his cell phone where his mechanic is waiting to tell him the bad news about the $657 nav light cover that he is going to have to install because the 40-year-old part on the owner's airplane is not only crazed, but opaque.

In a world where there are more new Experimental airworthiness certificates issued each year than those given to certified airplanes, I find it amazing how many committed aviation people are still ignorant—or at least unaware—of the huge and growing presence of homebuilt aircraft in the flying community. Rare is the local airport that doesn't have at least one Kitfox, RV, or Glasair waiting for flight in a hangar down the row. Take a look at the ramp in front of the airport restaurant on a sunny Saturday—if there aren't at least three RVs parked along with one or two Cessnas or Pipers, the RV bunch must have decided to meet somewhere else that day.

For a long time homebuilt aircraft (and their pilots) were considered marginal, scruffy things out on the fringe of aviation at best. Flip through the pages of any aviation magazine and look at the ads—certified airplanes dominate, even in the ads for headsets, watches, and insurance. Homebuilts were for lunatics and those who wanted to stay close to the airport for when the worn-out engine failed. Now we all know better; the capability of modern kit aircraft far exceeds most of their certified brethren equipped with the same engines. I can hop in my middle-of-the-road RV in Oshkosh at dawn, and be on the West Coast before cocktail hour in the afternoon. That's tough to do in all but the most expensive certified hardware.

Do these people look crazy? Looks like fun to me!

Paul Dye

Paul Dye retired as a Lead Flight Director for NASA's Human Space Flight program, with 40 years of aerospace experience on everything from Cubs to the space shuttle. An avid homebuilder, he began flying and working on airplanes as a teen, and has experience with a wide range of construction techniques and materials. He flies an RV-8 that he built in 2005, and an RV-3 that he built with his pilot wife. Currently, they are building a Xenos motorglider. A commercially licensed pilot, he has logged over 4800 hours in many different types of aircraft. He consults and collaborates in aerospace operations and flight-testing projects across the country.

And let's not forget the advantages of the word "Experimental." While most aircraft are well proven, reliable, and easy to maintain when they do have rare issues, that pink airworthiness certificate allows us to carry all sorts of the latest technological wizardry in our panels, under the hood, and spread throughout the airframe. The capability of many Experimental panels rivals that of most airliners these days. And if we see something new, we can install and try it out for ourselves that afternoon. We take responsibility for what we do, of course, and that means we are given a tremendous amount of flexibility by the FAA.

Unfortunately, you probably already know all of this. Since you're already here in KITPLANES®, we have at least reached you. Now the question is: How do we go about spreading the word to the rest of our aviation fellowship? My experience has been that most non-Experimental aviators actually embrace our part of the community once they find out about it. In fact, Experimental is a pretty easy sell. It costs less, gives better performance, has fewer restrictions and regulations that tell you what you can't do—what's not to like? Most aviators I know chafe at overregulation to begin with, and their reaction to a few minutes of exposure is not derision, it is outright amazement.

One way we can spread the word is through publications like KITPLANES®. Better yet—last year, KITPLANES® started a free, monthly, online newsletter called the Homebuilder's Portal. The sole purpose of the portal is to spread the word and introduce those already in aviation to the Experimental world. It features a chance to read some of the best articles in the KITPLANES® library for free, and each month is centered around a specific topic that educates and informs the reader of what the homebuilding world is really like. Subscriptions to the portal continue to rise—and that tells me that we are building interest in our chosen field. So point your friends to *www.kitplanes.com/homebuilders-portal* for their free subscription.

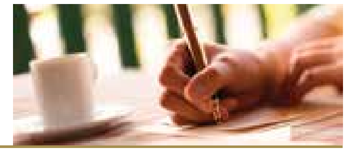
This month, we bring you our annual Aircraft Buyer's Guide issue—another good way to spread the word about what is actually out there in terms of kits, plans, and materials. The printed guide is but a glimpse at what is available online in terms of detailed information on many different models of aircraft.

The guide intentionally includes models that are no longer available as kits because many of those models are flying and available on the used market. The market for used homebuilts is, in fact, growing—and we want to support those out shopping for their perfect airplane, even if they buy instead of build.

So if you have friends that need just a little nudge toward the Experimental side of aviation, maybe this is the issue you should hand them. Get them to sign up for the portal, and then give them a chance to ride in your Experimental. You might just find that it's the easiest conversion you'll ever make—homebuilt, Experimental aviation can almost sell itself. ✈

Photo: Dave Prizio

LETTERS



EDITORIAL@KITPLANES.COM

EDITORIAL
Editor in Chief Paul Dye
editorial@kitplanes.com
Managing Editor Mark Schrimmer
Art Direction Dan Maher
Editorial Director Paul Bertorelli
Contributing Editors Larry Anglisano, Marc Ausman, Roy Beisswenger, Chuck Berthe, David Boeshaar, LeRoy Cook, Robert Hadley, Dan Horton, Louise Hose, Amy Laboda, Dave Martin, Sid Mayeux, David Paule, Dave Prizio, Dean Sigler, Dick Starks, Eric Stewart, Vic Syracuse, Barnaby Wainfan, Jim Weir, Tom Wilson.
Web Editor Omar Filipovic
Cartoonist Robrucha

ADVERTISING
Sr. Advertising Manager Chuck Preston
805/382-3363
chuck@kitplanes.com

BUSINESS OFFICE
Belvoir Media Group, LLC
535 Connecticut Avenue
Norwalk, CT 06854-1713

EDITORIAL OFFICE
535 Connecticut Avenue
Norwalk, CT 06854-1713
832/851-6665
editorial@kitplanes.com

CIRCULATION
Circulation Manager Laura McMann

SUBSCRIPTION DEPARTMENT
800/622-1065
www.kitplanes.com/cs
P.O. Box 8535, Big Sandy, TX 75755-8535
For Canada: Box 7820 STN Main, London, ON N5Y5W1

REPRINTS FOR PUBLICATION
AND WEB POSTING AVAILABLE
Minimum Order: 500
Contact Jennifer Jimolka, 203/857-3144

CHANGE OF ADDRESS?
MISSING ISSUE?
SUBSCRIPTION QUESTION?

Visit www.kitplanes.com/cs.
Or call 800/622-1065
from the U.S. and Canada.

Foreign *903/636-1112 or fax 203/857-3100.*

Belvoir
MEDIA GROUP LLC

Becoming a Test Pilot

I'm intrigued by Elliot Sequin ["Becoming a Test Pilot," September 2015]. One gets the impression that he is going to become a legend in the world of Experimental aviation. His writing is superb, and I appreciate his obvious humility which, after all, is the key to real greatness. Keep up the fine work.

JONATHAN TAGER

We agree—Mr. Seguin is keeping all of us on the editorial staff jealous with his current mix of flying.—Ed.

Boring on the Vertical

Thanks to Bob Hadley for a very informative article on boring on a vertical milling machine ["Home Shop Machinist," October 2015]. I might add that a key factor in getting a good bore is to dial in the spindle to the table to assure they are absolutely perpendicular. I have seen too many jobs killed because the machinist neglected to check this. Before any boring operation, the machinist should mount a dial indicator on the table, extend and lock the spindle, then move the table and dial indicator up, and/or down, with the dial indicator shaft riding against the side of the spindle. If a zero reading is not indicated the entire length of the spindle, the mill head is moved to achieve a zero reading. Note: Moving the spindle up or down against the dial indicator does not accomplish this. The table must be moved.

CHRIS BRAMMER

Bob Hadley responds: An excellent point indeed! As Chris points out, checking the mill for square before making parts is good practice. His technique is spot-on for Bridgeport-style knee mills. Small bench-top mills can be checked with a tramming tool (which is a bar with one or two indicators to check the table level) or with a precision machinist's square.

Designer's Notebook

Just wanted to drop a note thanking you for a great mix of editorial content. In particular I always enjoy Barnaby Wainfan's "Wind Tunnel" column, and I'm now a huge fan of David Paule's "Stressing Structure" articles as well. It's nice to see someone picking up the "design baton" that other magazines rarely cover. Keep up the good work!

BOB JOHNSON

Thanks for the feedback, Bob. We are hearing from a lot of builders who enjoy Dave Paule's little math exercises each month, and we'll try to keep them going, so long as they don't interfere with the time he needs to finish his RV-3 project.—Ed.

Watch Mr. Wizard

Back in the day when baby boomers were still babies, there was a TV show called "Watch Mr. Wizard." As far as I can tell, Mr. Wizard is alive and well, living at RST Engineering Laboratory and writing for KITPLANES®. His writing style is a refreshing throwback to when we all were kids and WW-II vets ran the world. Always a delight to read his articles. Keep it up Mr. W!

ALAN TLUSTY

We have asked the relevant agencies to do a background check on Mr. Weir and will let you know if any of his aliases show up including the term "Wizard." We like him either way.—Ed.

WEB SITE INFORMATION: General homebuilt aircraft information, back issue availability, online directories ordering info, plus a KITPLANES® article index and selected articles can be found at www.kitplanes.com.
Unsolicited manuscripts: Are welcome on an exclusive basis, but none can be acknowledged or returned unless accompanied by a stamped, self-addressed envelope. No responsibility is assumed for loss or damage to unsolicited material.
KITPLANES® (ISSN 0891-1851) is published monthly by Aviation Publishing Group, LLC, an affiliate of Belvoir Publications, 535 Connecticut Avenue, Norwalk, CT 06854-1713, Robert Englander, Chairman and CEO; Timothy H. Cole, Exec. Vice Pres./Editorial Director; Philip L. Penny, COO; Greg King, Exec. Vice Pres./Marketing Dir.; Ron Goldberg, CFO; Tom Canfield, Vice Pres., Circulation.

Subscriptions: One year (12 issues) is $29.95 U.S. $41.95 in U.S. funds in Canada, includes GST. $41.95 in U.S. funds for Foreign Surface Mail or $57.95 in U.S. funds for Foreign Air Mail. Single copy price $4.99 U.S., $5.99 Canadian.
POSTMASTER: Please send address changes and subscription inquiries to: KITPLANES®, P.O. Box 8535, Big Sandy, TX 75755-8535, or Canada Post: Return undeliverables to P.O. Box 2601, 6915 Dixie Rd, Mississauga, ON L4T 0A9 or call 800/622-1065.
KITPLANES® is a registered trademark of Aviation Publishing Group, LLC.

LEARNING HOW TO DRAG YOUR TAIL

Making the transition from trigear to tailwheels.

BY LEROY COOK

"I want you to work on a taildragger checkout with me; can we get started this afternoon?" I get that a lot. Pilots see me taxiing out with my 1946 Champ or some other conventional-gear airplane, and they instantly succumb to the "that looks cool" urge. It's then up to me to administer the reality check.

When they say "checkout," what they really mean is a logbook endorsement attesting to their proficiency to fly a tailwheel aircraft (unless grandfathered-in by having logged time in such aircraft before April, 1991). There is no written test or minimum number of hours specified, but I always begin the conversation by preparing them for at least 10 hours of tailwheel dual. If you can acquire the necessary skill sooner, fine, but it'll usually take all of that.

What's so different? Pilots of tricycle-gear airplanes are accustomed to a friendly conveyance on the ground. You probably learned to taxi in about 10 minutes, during your first hour of instruction. You've found you can relax during taxi, most of the time. Tailwheel airplanes are, by comparison, always in a state of rebellion. Think of them, I tell students, like a mean horse; that nag is always looking back at his rider to see if he's paying attention. He'll curl his neck around and try to bite your foot unless you slap his nose with the end of the reins. After a while, he'll settle down, but he never gives up trying. That's how it is to fly taildraggers; be alert at all times you're in motion and take immediate action to forestall diversions.

While we're at it, let's not overuse the term "taildragger." I've operated taildraggers only a few times in my 55 years of flying, and that was after I broke a tailwheel spring and left the tailwheel behind on the runway, or when I was flying a replica early-day plane with only a tailskid. It's a tailwheel airplane, not a taildragger. I will not belabor the once-common term for tailwheels, "conventional gear," which would now more aptly describe tricycle gear.

Tailwheel aircraft won't keep going in a straight line while taxiing. Staying active on the rudders and watching for the slightest swerve is critical. *(Photo: Tom Wilson)*

The Basics

The intractability of tailwheel airplanes stems from the reaction to their center-of-gravity location while rolling on the ground. The maingear is ahead of the CG, and the tail, if in contact, is carried by a small, readily swiveling caster. Said tail would like nothing better than to bring the CG, which is somewhere around the pilot's seat, around in front of the maingear. Think of a hand-truck carrying a refrigerator; push it, and it'll constantly try to move out of the direction of your push. Pull it, and it'll trail along obediently.

Dare I mention the effect of wind on your endeavors? In your tricycle flying, you've considered wind to be largely a non-factor, once you've landed and gotten the nosewheel planted. After a tailwheel aircraft touches down, the fun is just beginning. You have a decidedly smaller contact patch to steer with, a swiveling tailwheel, and a naturally unstable machine. Add some wind (it doesn't take much), and your best efforts at control may not be enough. Respect the aircraft's limitations and revise your wind-operating standards downward.

Brakes are decidedly more important appliances in a tailwheel airplane than in a tricycle. In training modern tricycle pilots, I demand that they stay off the brakes unless a lack of planning requires their use. But with a tailwheel, you'll need to resort to differential braking quite often, at least until thoroughly proficient. In light winds, I can maneuver the Aeronca out to the end of the runway without touching its infamous heel brakes, but a beginner won't be able to do that.

When she couldn't find a good tricycle model in her price range, Louise Hose bought a conventional-gear RV-6 and earned her tailwheel endorsement during transition training. *(Photo: Kai Hansen)*

To Begin

We'll start with simply taxiing the airplane up and down a long parallel taxiway or runway, learning to deal with its instability and limited steering response. Sometimes the transitioning pilot will have to handle several new concepts: obscured forward vision, stick controls, tandem seating, crew-assisted starting (propping) and, in older airplanes, heel-operated brakes.

Turf is a wonderful surface for takeoff and landing practice—it's much more forgiving of minor boo-boos than pavement. *(Photo: Jared Yates)*

Restricted visibility over the nose is just something one learns to cope with, by careful clearing of blind spots, frequent S-turning, and employing a right-seat observer in side-by-side airplanes. Rather than boring, straight-line taxiing, it's more productive training to do sinusoid wobbles from one side of the taxiway to the other, which will teach anticipation of rudder pedal reversing when changing direction and proper speed management. You will soon learn why old texts say to "taxi at a walk."

Common Errors

Getting behind the airplane, requiring the instructor to intercept the wayward airplane before it runs off into the weeds, comes from not being aggressive enough with steering inputs, and that's a result of expecting the tailwheel aircraft to keep going straight on its own, like a nosedragger would. Staying active on the rudders and watching for the slightest swerve cures this. It's also important to keep the tailwheel firmly planted with up-elevator to maximize its effectiveness, given its small size.

The most important rule is to never let the tailwheel's track get outside the span of the maingear. If it does, the steering is likely to unlock and the tailwheel will go into full-swivel mode; when it does, a stab of the outside brake is the only way to avoid a groundloop, the uncontrolled spinout that displays pilot ineptitude.

Up To Speed

Once low-speed taxiing is mastered, it's time to raise the bar. We're now going to run up and down the runway, lifting the tail and setting it back down. It is important to have plenty of room, such as a 75-foot-wide runway with open margins, because of the risk of losing control. If there's more than a breath of wind, do not attempt two-way runs. When forward motion matches a tailwind's speed, rudder control disappears, and only judicious braking can save the day until the tailwheel is back on the ground.

As the CFI and designated lifeguard, I'll be in charge of the throttle. Once lined up as if taking off, full power is applied and active steering is used to hold the centerline, "walking the rudders," as the old-timers put it. If the student is not holding the stick back to keep weight on the tail tire, the nose will skate left immediately. As rudder effectiveness is gained, I'll have him raise the tail to bring the runway into full view, with only rudder power to keep straight. I'll reduce power to keep the airplane from lifting off, and we'll fast-taxi along the runway tail-up, chopping throttle while there's plenty of room left to stop.

This is the moment of truth, when the airplane is most vulnerable to swerving. Under deceleration, the instability of the aft-located CG is even more pronounced. The sudden loss of power alters the torque's left-hand pull, and judicious steering will be needed as the tail is allowed to sink to the surface. Upon touchdown, the stick should be pulled back to assure maximum steering force.

Common Errors

Most new tailwheel pilots will have to fight for control as rudder forces change when speed increases and decreases, and when the tailwheel lifts and falls. Overcontrol has to be tempered with steadily damping use of opposing control inputs, until the airplane stays in a straight line. Most often, the student will relax at this point, letting the stick go forward and unloading the tailwheel, and the plane will swerve out of control. "It's not over yet!" is my constant mantra, transferred into the student's vocabulary. You can relax, I insist, only when the tires are not turning.

Typical landings in Just Aircraft's SuperSTOL are three-point, at the slowest speed possible, with a very short rollout. *(Photo: Richard VanderMeulen)*

Once off the ground, tailwheel aircraft fly exactly the same as planes that have the steering wheel attached to the front. *(Photo: Richard VanderMeulen)*

Flying Solves Everything

Once the runway runs have exhibited a chance of success, it's best to proceed to a full takeoff and the eventual landing. There's less risk of control loss than in the previous tail-high launch-and-recovery exercises, with the shorter exposure. All that's necessary to get airborne is to counter torque with right rudder, steer down the centerline, and adjust inputs as airspeed increases, transitioning from a rolling vehicle to a flying airplane. Now that we're off the ground, we're flying a normal aircraft, just as if the steering wheel was on the front.

As we approach to land, everything is the same—but it has to be stressed that touching down perfectly aligned with the runway is critical. Sideload on the landing gear invites a swerve because the aft-located CG is always ready to get around in front. No lateral movement can be tolerated, and the nose can't be cocked sideways. One gets away with these little imperfections with self-centering tricycle gear, but any misalignment has to be dealt with instantly in a tailwheel machine.

Touchdown takes place, hopefully, with the tailwheel making contact at the same time as, or even slightly before, the maingear's arrival. Should the tailwheel be off the surface as the maingear touches, the unsupported tail will come down, the angle of attack will increase, lift will be generated and you'll have a bounce to deal with. If it's only a small skip, keep the airplane straight and land it again. If it's a "ker-sproing" crow-hop, pour on the power and go around. Get the tail down on the next try.

The good news is, the landing rollout rapidly decelerates into a more-survivable speed range. The bad news is, new tailwheel pilots tend to relax as this happens, just as if they had a nosewheel, and they'll lose it by letting the stick float forward, allowing the tailwheel to get light.

My preference is to always begin takeoff and landing practice on a nice, wide grass runway. Turf is wonderfully friendly; it allows slipping without tripping, minor boo-boos stay minor, and if the touchdown is a little cockeyed, the grass will lubricate the tires while you correct it. That said, we'll have to use pavement eventually, and it's the ultimate test of tailwheel ability.

Common Errors

During takeoff, delaying liftoff by letting the tail get too high is a waste of energy. I tell the student to lift the tail as he feels the controls become effective, but to almost immediately start moving the stick back, keeping the tailwheel about a foot off the runway and allowing the airplane to fly as soon as it can.

Not employing aileron to help maintain a straight path is also common. Rudder is, of course, primary to tracking the centerline, but not equalizing the rolling friction of the maingear with correct aileron use makes the job harder.

Not fully stalling the airplane before touchdown just leaves excess energy to be dissipated during an unstable rollout. Even if it doesn't bounce, the airplane is not in full contact with the surface and will require extra control measures. Do not allow the tail to swerve far enough to exceed the maingear span—ever! Keep saying, "It's not over yet!"

Success, like familiarity, breeds contempt. I find that tailwheel students with a few hours of takeoffs and landings tend to bask in the glow of their own radiance, thinking they have it mastered. That's when the tailwheel will humble them. At five hours or so, the student's tailwheel-flying reflexes are not fully formed and still require concentration. When stressed by a bit of wind or lateral movement, they will probably panic and revert to tricycle-gear habits, forget to pin the tail down, and not steer quickly enough. I've learned not to sign them off too early; competence must be demonstrated on multiple occasions.

And Then There are Wheelies…

After gaining confidence that the tailwheel airplane can be landed fully-stalled, it's necessary to learn how to get the plane down if conditions turn rough, when you might not want to give up aerodynamic control to land three-point.

Wheel landings, with the tailwheel purposely kept off the ground while touching down, offer better visibility than 3-point landings. *(Photo: Tom Wilson)*

The wheel landing, with the tailwheel purposely kept off the ground while touching down on the maingear, takes different technique, but will be useful on windy days. Also, visibility is better, and heavy airplanes are generally landed tail-high to lessen stress on the tailwheel.

What we're attempting to do is to "fly" the airplane onto the runway, not hold it off until it stalls. This means we have to avoid letting the tail get too far down as we roll onto the runway, the reverse of what's been the goal up until now. To keep the unsupported tail from sagging and initiating a bounce, forward pressure on the stick will need to be applied—but at just the right moment.

Initially, it's easier to teach wheel landings with a little extra speed added to the approach, as you would do in gusty conditions, or perhaps with some power retained into the flare, to give a little more time to adjust and feel for the runway, while learning how to "pin" the maingear on the surface. With experience, one reacts quickly enough to get the touchdown accomplished without this aid, but students need a little more time.

The secret of a wheel landing is to let the airplane land while it's still flying, and only then move the stick forward and raise the tail slightly, holding the wing's angle of attack down so the airplane can't bounce. There can't be any sink rate at touchdown, or the maingear will rebound into the mother of all bounces. The goal is to roll smoothly onto the pavement.

Once down, the tail is held up while speed dissipates, and the tailwheel is brought down to the runway decisively when rudder control begins to fade. Then, it's a matter of fighting off the swerves and darts until the tires are stopped.

Common Errors

Most students want to "make" the wheel landing happen, and they'll attack the runway with a shove on the stick, while still a foot above the pavement. This generates a good rate of sink, the still-flying aircraft rebounds, and the only recourse is to go around or perhaps turn the landing into a three-point stalled arrival. Patience, Grasshopper; learn to hold the aircraft off in a level, tail-high attitude, allow it touch down without sink, and then move the stick forward a millisecond later, holding the tail up before it can dip. Do not be overly concerned about nosing over; the higher the horizontal tail rises, the more the relative wind pushes it back down. Just stay off the brakes until you get the tail down.

In retrospect, we have to admit that tricycle gear was invented for a very good reason. The charm and nostalgia of flying tailwheels wears thin when landing in a 20-knot crosswind, or after you've just ridden through another wild groundloop with your valuable, prized bird. If you want, or need, to learn how to fly tailwheel airplanes, get the most-experienced instructor you can find and respect what he or she has to say. Know the limitations of whatever you fly. ✈

Light Aircraft Fuel System Design

Part 1: If it's not broken, don't fix it!

BY KEN KRUEGER

The fuel system is surely the least appreciated of all systems on a light aircraft. A well-designed fuel system is so reliable that pilots rarely give it more than a passing thought, and, being deceptively simple, aircraft builders often fail to recognize it as the single most critical system in the aircraft.

If asked what powers an airplane, aircraft builders and pilots think primarily about the engine. In reality liquid hydrocarbon fuel powers our airplanes, and the engine is merely the device where the heat created by burning the fuel and atmospheric oxygen is turned into shaft power. The fuel system does the work of storing, supporting, transporting, and conditioning the fuel so that it can be transformed into useful shaft power by the engine. The fuel system must function, without fail, no matter the attitude of the aircraft, as well as in all possible extremes of temperature, altitude, and humidity. Besides such "normal operation" considerations, the fuel system must also contain and isolate the fuel during emergencies such as landing gear failure or a full-blown crash. A properly designed fuel system is absolutely reliable, simple to operate, easy to inspect, and accessible for maintenance. Few realize that the fuel system is as essential to flight as the engine, and it is as decisive in crash survivability as occupant restraint.

Given the importance of the fuel system to flight safety, one could reasonably expect that homebuilders would be about as eager to change the design of a proven fuel system design as to make modifications to primary structure. Amazingly, fuel system failures, due mostly to improperly designed changes, remain a leading cause of accidents among Amateur-Built aircraft. In fact, the very first recommendation made in the NTSB's May 22, 2012 *Safety Study on Experimental/Amateur-Built Aircraft* is to define aircraft fuel system functional test procedures and require applicants for an airworthiness certificate for an Amateur-Built aircraft to conduct that test and submit a report of the results for Federal Aviation Administration acceptance.

The goal of this article is to promote a better understanding of fuel system functionality. It is desired that a deeper knowledge of fuel system design will result in improved safety because it will lead to more careful consideration before any fuel system changes are made.

Aircraft using the Rotax 912, such as this RV-12, have fuel systems specifically designed for auto fuel.

Overall Function

A fuel system's basic functional requirement is to provide adequate fuel flow and fuel pressure for proper engine operation in the attitude most critical with respect to fuel feed and the quantity of unusable fuel. For the majority of light aircraft, the most critical attitude for fuel flow occurs during a full-power climb at V_X (speed for best angle of climb) from sea level with the aircraft lightly loaded. In contrast, the fuel system for a fully aerobatic aircraft must be able to provide fuel to the engine even when flying inverted, straight up, straight down, knife-edge, or any attitude in-between, so this presents a much greater fuel system design challenge.

In the same way that aircraft structure must be designed to be "more than strong enough," so also must a fuel system be designed to provide the required amount of fuel flow plus a safety margin. If the fuel system uses gravity to move the fuel from the tank to the engine, then the flow rate must be 150% of the engine's takeoff power fuel consumption. For a fuel system that uses a pump to move the fuel, the flow rate must be 125% of the fuel consumption of the engine at takeoff power.

The fuel system must be free from vapor lock when using fuel at its critical temperature with respect to vapor formation. Vapor lock is a condition in which the fuel vaporizes in a fuel line (or other component downstream of the tank) and interrupts proper flow of fuel to the engine. Avgas at 100° F must not vaporize at a pressure of less than 5.5 pounds per square inch. The vapor pressure of "summer blend" auto fuel is higher than that of avgas and "winter blend" auto fuel's vapor pressure is higher yet. As more new aircraft are using engines designed for operation on auto fuel, this requirement has become more relevant than ever before.

The fuel carried in an aircraft has a considerable amount of stored energy, and a key function of every fuel system is to contain the fuel not only during all phases of normal flight, but also during landing mishaps and crashes.

The large wing fuel tanks make this Micco SP-26 unable to meet the spin recovery requirements for an aerobatic aircraft.

Aircraft Design and Fuel System Integration

Beginning early in the conceptual design phase of any powered aircraft, the fuel system is a major consideration. The intended mission of the aircraft dictates the amount of fuel that must be carried by the aircraft and supported by the structure. Because the weight of the fuel can be a significant percentage of the takeoff weight and is in constant flux during any given flight, the placement of the fuel in the aircraft and its impact on the center of gravity must be considered.

Photos: Ken Krueger; Air-to-air photos: Ed Hicks

To minimize the difference in flying qualities between tanks full and tanks empty, the designer seeks to locate the fuel as close to the center of gravity as possible. Having multiple tanks in a system affords the designer greater flexibility in finding the optimum location in the aircraft for the fuel. It is generally most advantageous for reasons of structural efficiency, space utilization, and crashworthiness to place fuel in the wing. Two wings, two tanks…it makes sense and this is why most aircraft have more than one fuel tank.

Aircraft designers must also consider the inertia of the fuel carried by the aircraft as this has an effect not only on performance, but on handling qualities and spin behavior as well. The farther away the fuel is placed from the center of gravity of the airplane, the greater the impact. One of the more common "improvements" that homebuilders make to an established design is to increase fuel capacity. Many builders think that enlarging the fuel tanks is a harmless change, but spin behavior and spin recovery will be adversely affected by the increased rolling and yawing inertia that comes with increased fuel mass. The fuel system design of the Micco SP-26 illustrates this point. Miccos with two tanks in each wing, inboard and outboard, are acrobatic category aircraft because they can fly with the outboard tanks empty, whereas Miccos with a single tank in the outboard portion of the wing are certificated as utility category aircraft. The inertia of the fuel in the outboard wing tank degraded spin recovery to the point that it couldn't meet the FAR Part 23 acrobatic category requirement.

Analysis showed that adding wing fuel to the Polen Special would have lowered its flutter speed.

Another important consideration is how the mass of fuel contained in a wing or stabilizer changes the natural frequency of vibration in bending and torsion. The amount of fuel and its location may change the critical flutter speed, and this is why a proper flutter analysis takes the presence of fuel into account. An interesting case study involves a well-known homebuilt aircraft, the Polen Special. A team from the Aerospace Engineering department at the University of Texas at Austin performed a flutter analysis to determine the effect of carrying additional fuel in the wing. The analysis results showed that, for the proposed tank configuration, flutter speed decreased significantly as internal fuel was added to the wings. (A summary of the results can be found by doing a search on "Polen Special flutter analysis.")

The tip tank on a Cessna 310 places the fuel well forward on the wing.

In contrast to storing fuel internally, many light aircraft carry fuel external to the wing in tip tanks, which enable placement of fuel well forward on the chord of the wing. This configuration allows fuel to be carried without a significant change in flutter speed. The photo of the tip tank on a Cessna 310 illustrates the forward location of the fuel.

Crashworthiness

A well-designed fuel system is also a crashworthy fuel system. Appendix C of the *Small Airplane Crashworthiness Design Guide* is a fuel system design checklist. The entire document (414 pages long!) can be downloaded and should be required reading for every

aircraft designer or for anyone contemplating a modification to an existing fuel system. In a nutshell, a crashworthy design prevents post-crash fire by eliminating the spillage of fuel and by controlling sources of ignition. Some of the key recommendations pertaining to fuel system design are:

- To locate fuel tanks as far as possible from anticipated impact areas (such as wing leading edges) as well as large weight masses (such as engines or batteries) and primary ignition sources (such as exhaust systems or batteries).
- That fuel tanks should be located where there is little chance that a collapsing landing gear leg will puncture or breach the fuel tank.
- To design fuel tanks and fuel lines such that they can displace in the airframe structure without tearing or inducing leaks. For the fuel tank, special attention should be given to the area around the filler, points of fuel line entry and exit, the quantity indicator, and the tank to structure attach points.

The amount of fuel carried in the aircraft is one of the earliest and most influential conceptual design considerations, and the weight and placement of the fuel either directly or indirectly affects how every other part of the aircraft is designed. For existing designs, there are a number of basic design considerations that should be addressed before additional fuel tanks are added or existing tanks are enlarged.

Next time, we'll continue looking at fuel systems, but with a focus change from overall fuel system functional requirements and "whole-airplane" design considerations to specific design requirements applicable to each part of the fuel system.

Basic Fuel Systems

Shown are diagrams for the two basic types of fuel systems: a gravity-feed system common to most high-wing aircraft with carbureted engines, and a pump-feed system typical of low-wing aircraft with carbureted or injected engines. The two systems share many components, but there are some key differences.

As implied by the name, a mechanical pump is used to move fuel through a pump-feed fuel system. To ensure a continuous flow of fuel to the engine, two pumps having independent power sources are required in a pump-feed fuel system. The engine drives the main fuel pump and, should that pump fail, there is an airframe-mounted emergency pump that is almost always electrically powered.

A gravity-feed system enjoys the advantage of not needing a mechanical pump and, because the fuel is always under positive pressure, tends to keep the fuel in the lines from vaporizing as can happen in pump-feed systems. A fuel-injected engine requires more pressure than is practically available from gravity, so gravity feed works only with carbureted engines.

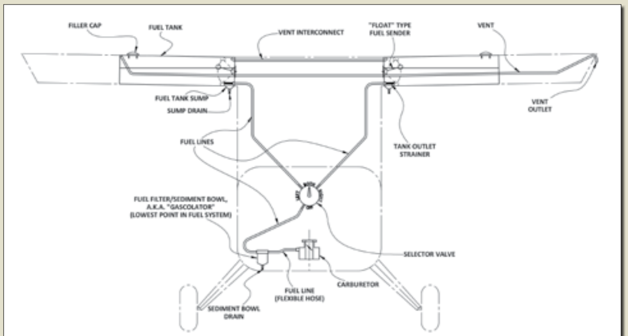
With gravity pushing the fuel from the tank to the carburetor, fuel will continue to flow to the carburetor even if one of the tank outlets is no longer submerged in fuel. This is why it is possible to have a "both" position on the gravity feed selector valve. In fact, in some gravity-feed systems, the valve is simply a shutoff and there is no option to draw from only one tank at a time.

In a pump-feed system, if fuel is being drawn from two tanks at the same time, any time *one* of the two tank outlets is exposed to air, fuel stops flowing and the engine stops. This is why the selector valve in a pump-feed system does not have a "both" position.

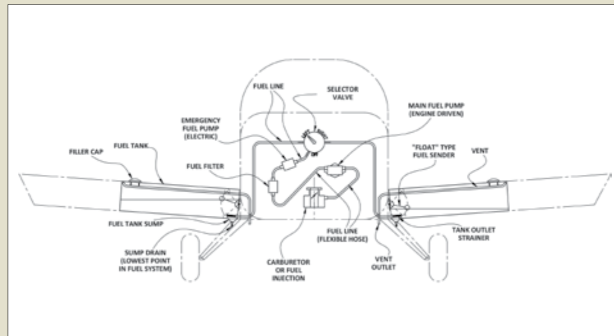
The venting of tanks is also different between gravity-feed and pump-feed systems. Each tank of a pump-feed system is required to be vented independently of the other, whereas the airspaces of the two tanks of a gravity-feed system are interconnected and then there is only a single vent for both tanks. The gravity-feed system is vented in this way so that fuel flows out of each tank at the same rate.

Water and particles can and do get into the fuel. For this reason, each fuel tank must have a low spot or sump where the heavier contamination will tend to collect. It is also required that a drainable sediment bowl be placed at the lowest point in the fuel system. Drain valves at the tank sumps and sediment bowl allow for removal of accumulated contamination as part of every preflight inspection. The lowest point in the fuel system of some low-wing aircraft is the fuel tank sump. In these cases, the system does not require a separate sediment bowl. A gravity-feed system requires that the tanks be higher than the rest of the system so a separate sediment bowl is necessary. All gravity-feed systems, as well as many pump-feed systems, use a component called a gascolator, which is a combination fuel filter and drainable sediment bowl.

—K.K.



Gravity-feed fuel system.



Pump-feed fuel system.

Airdrome Aeroplanes Sopwith Baby–Page 20

Arion Lightning–Page 21

Blue Yonder EZ Fun Flyer–Page 23

Kitfox Super Sport– Page 31

SubSonex Personal Jet– Page 40

FD-Composites ArrowCopter AC20– Page 47

Homebuilt Aircraft DIRECTORY 2016

Homebuilt aircraft have been around since Wilbur and Orville started fooling around with man-carrying kites on the sands of Kitty Hawk at the turn of the last century. For many years, *all* airplanes were essentially homebuilt, with little consistency in design, materials, or construction. The idea that airplanes could be used for commerce (and warfare) brought standardization and—of course—certification. It wasn't until the 1950s that the idea of building powered, man-carrying aircraft by individuals once again came into fashion, and the regulations allowing such planes became codified. Ever since then, a myriad of designs have become available in plans, parts, and kit forms. And the goal at KITPLANES® is to bring a complete directory of these designs to these pages every year.

We are often asked why the list we publish includes many aircraft for which kit or plans production is on hiatus or just plain stopped. The answer is that there are literally thousands of such "orphaned" aircraft out there in the real world, and many of them are for sale. We don't just cater to those building Experimental aircraft—we want to help inform those who are looking to purchase as well. To aid that, we are very careful when it comes to pruning the list. We'll admit that we aren't always successful. As soon as we publish our Directory issue, we get notes from astute readers asking what happened to the "Whiz-Bang 9000," or the "Fast-Flivver 150." After all, the letter writer asserts, they have the tail for one under construction in their garage, so why isn't it listed?

Well, if you know of a design that we have missed (and we freely admit that such is possible), we need your help! Send us information for our guide, we'll quickly add it to the online database, and it will appear next year in print!

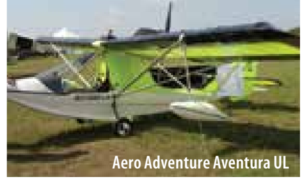
So what's all this about an online directory? Isn't print good enough? Why doesn't KITPLANES® provide a complete and unabridged directory of all pertinent data every year? Well, the answer is that with well over a thousand listings, we'd never have enough pages—and we'd be contributing to the back pain of countless U.S. Postal Service workers. Seriously though, the listings have truly gotten too large, and the Internet has become so ubiquitous, that it is more efficient for most people to look for details in our searchable database. The fact that you now hold this issue in your hands gives you access to this database, and that allows you to look for—and compare—airplanes by type or other attribute.

We know that some readers would rather be able to leaf through all this information in these physical pages, but I'll ask them to give the online database a chance. We update it as new information arrives, so you don't have to wait for the latest information that comes out next month to make its way to your mailbox this same time next year. So give it a try—I use it all the time, and it is a fast way to find out just how fast that Whiz-Bang will actually go.

Paul Dye, Editor in Chief


A-Air X-Air H


Ace Baby Ace


Aero Adventure Aventura UL


Aeroplane Manufactory Beaver RX-550 Plus


Aero Concepts Discovery

Aircraft Buyer's Guide Online Access

This year the online Aircraft Buyer's Guide follows the format we established a few years ago and provides many useful features for users. Among them is the ability to do a side-by-side comparison of more than one aircraft using various selection criteria.

Unlimited access to the online Aircraft Buyer's Guide is free for subscribers, but for a limited time only, we are offering non-subscribers a chance to sample the site, too.

Here's how it works: Newsstand buyers may visit *www.kitplanes.com*. There will be a button labeled "Newsstand readers' access" that will take you to a signup page. The access code is kpbg16. This will give you 30 days' access (from signup date) to the online Aircraft Buyer's Guide and will also allow you to explore the entire KITPLANES® web site. So go log in and have a look around.

Fixed-Wing Aircraft

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
A-Air LLC (XAir) *www.x-airlsa.com*	X-Air F	2	75	50	28	●			$22-26k
	X-Air H	2	106	81	28	●			$25-30k
	X-Air S (Standard)	2	75	63	28	●			$21-25k
AC Millenium Corp.	Griffin IV	2	160	150	45	●			–
	Griffin Mk III	2	170	150	45	●			–
ACD *www.klscomposites.com*	SQ-2000	4	250	215		●			$85-125k
	SUA-7	7	160	160	70	●			–
Ace Aircraft, Inc. *www.aceaircraft.com*	Baby Ace	1	110	100	35	●	●	●	$35-75k
	Junior Ace	2	115	109	38	●	●	●	$37-78k
Aceair SA	Aeriks 200	2	178	161					–
Acro Sport, Inc.	Acro Sport	1	152	130	50		●		$40-55k
	Acro Sport II	2	152	123	53		●		$40-55k
	Nesmith Cougar 1	2	195	135	53		●		$38-40k
	Pober Junior Ace	2	130	85	40		●	●	$32-42k
	Pober Pixie	1		83	30		●	●	$25-35k
	Pober Super Ace	1	160	110	44		●	●	$21-26k
Acrolite Aircraft *www.acrolite.org*	Acrolite 1B	1	130	110	45		●	●	$10-25k
	Acrolite 1T	1	110	90	44		●	●	$8-20k
	Acrolite 2M	2	125	105	43		●	●	$12-30k
Adams Aeronautics Company, Inc. *www.adamsaero.com*	CA-2 (formerly Hummel)	1	80	63	26		●	●	$4-8k
	T-100D Mariah	1	80	63	27		●	●	$4-8k
Aeroplane Manufactory *(was A.S.A.P.)* *www.amplanes.com*	Beaver RX-550 Plus	2	85	73	37	●		●	$21-28k
	Beaver SS	1	85	67	30	●		●	$15-17k
	Chinook Plus 2	2	95	83	35	●		●	$21-37k
Aeriane SA *www.aeriane.com*	P-Swift	1	93	72	25	●		●	–
Aero Adventure Aviation *www.sea-plane.com*	Aventura HP	1	90	75	32	●		●	$24-32k
	Aventura II	2	105	85	30	●		●	$23-29k
	Aventura UL	1	60	55	24	●		●	$20-24k
	Barracuda	2	105	85	41	●		●	$20-26k
	Toucan	2	85	62	28	●		●	$20-27k
Aero Concepts, LLC *www.itsdiscovery.com*	Discovery	2	240	225	58	●			$60-150k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


AeroCad AeroCanard SB


Aircraft Spruce Acrolite


Aircraft Spruce Christavia MK1

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Aero-Systems *www.ibeatyouthere.com/culver*	Cadet Model STF	2	145	130	50		●		$35-48k
Aero-Works, Inc. *www.aerolite103.com*	Aerolite 103	1	75	60	26	●		●	–
AeroCad Inc. *www.aerocad.com*	AeroCanard FG	4	225	205	71	●	●		$50-100k
	AeroCanard RG	4	225	210	78	●	●		$50-100k
	AeroCanard SB	4	220	200	78	●	●		$50-100k
	AeroCanard SX	4	225	205	71	●	●		$50-100k
Aerochia *www.aerochia-lt1.com*	LT-1	1	140	140	48	●		●	–
Aerolab Mfg, Inc. ***(was Aerolab s.a.s.)*** *www.aerolab.it*	LoCamp	2	132	106	45	●		●	$60-75k
AeroLites, Inc. *www.aerolites.com*	AeroMaster	1	90	75	32	●		●	$25-39k
	AeroSkiff	2	90	65	38	●		●	$26-35k
	Bearcat	1	70	65	27	●		●	$15-22k
Aeromarine Marketing *www.ppawd.com/aeromarine*	Harrier	3	120	100	40	●			–
Aeromarine-LSA *www.aeromarine-lsa.com*	Aviad Zigolo MG12	1	58	42	22	●		●	–
Aeroplanes DAR Ltd ***(was DAR Aviation)*** *www.aeroplanesdar.com*	DAR Duo	2	90	75	35	●		●	$32k
	DAR Solo	1	75	65	25	●			$25-28k
	DAR-21	2	88	78	38	●			–
	DAR-21S	2	125	110	38	●			–
	DAR-23A and Enclosed	2	95	75	37	●			–
Air Command International, Inc. *www.aircommand.com*	Falcon 2000	2	84	70	36	●			–
Aircraft Designs, Inc. *www.aircraftdesigns.com*	Stallion	6	250	235	81	●			$500k
Aircraft Spruce & Specialty *www.aircraftspruce.com*	Acroduster Too SA-750	2	185	155	55	●	●		–
	Acrolite 1B	1	130	110	43	●	●	●	$7k
	Baby Great Lakes	1	135	118	55	●	●	●	$40k
	Buddy Baby Lakes	2	135	118	55	●	●		$40k
	Christavia MK 1	2	135	105	40	●	●		$8-14k
	Cozy Mark IV	4	200	185	69	●	●		–
	One Design DR 107	1	180	160	60	●	●		–
	Starduster One SA-100	1	147	132	50		●	●	–
	Starduster Starlet SA-500	1	130	105	55		●		–
	Starduster Too SA-300	2	170	130	56	●	●		–
	Starduster V-Star SA-900	1	90	75	35		●	●	–
	Super Baby Great Lakes	1	155	135	55	●	●		–
	Super Starduster SA-101	1	225	170	55		●		–
	Wittman V-Witt Racer	1	180	150	48		●		–
	Wittman W10 Tailwind	2	230	180	45	●	●		$12-40k
Aircraft Technologies, Inc. *www.airshowunlimited.com*	Atlantis	2	255	180	65	●			–
	Meyer-360	1	255	180	60	●			–

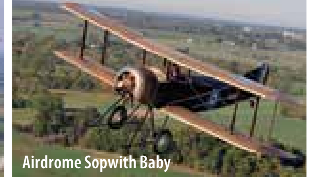
Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

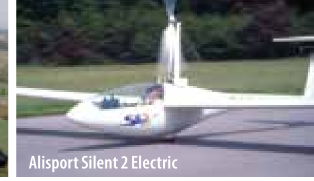
For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory.*


Airdale Airdale


Airdrome Aeroplanes Fokker D-VIII


Airdrome Aeroplanes Nieuport 28


Airdrome Sopwith Baby


Alisport Silent 2 Electric

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Airdale LLC *www.airdale.com*	Airdale	2	130	108	48	●			$26-56k
	Airdale LSP	2	120	90	35	●		●	$18-23k
	Avid Plus	2	120	90	35	●		●	$25-55k
Airdrome Aeroplanes, Inc. *www.airdromeaeroplanes.com*	Bleriot Model XI (Full Scale)	1	55	50	32	●		●	$14-21k
	Bleriot Model XI (3/4 Scale)	2	43	40	28	●		●	$8-13k
	DeHavilland DH-2	1	63	61	29	●		●	$10-12k
	Dream Classic Strut Braced	1	63	54	26	●		●	$6-9k
	Dream Classic Wire Braced	1	63	57	26	●		●	$6-9k
	Dream Fantasy Twin	2	52	45	27	●		●	$8-15k
	Eindecker E-III	1	63	57	28	●		●	$8-13k
	Fokker D-VI (3/4 Scale)	1	78	73	30	●		●	$9-15k
	Fokker D-VII (80% Scale)	1	105	94	34	●		●	$13-18k
	Fokker D-VIII (3/4 Scale)	1	92	80	32	●		●	$9-15k
	Fokker DR-1 (3/4 Scale)	1	78	64	34	●		●	$13-15k
	Fokker DR-1 (Full Scale)	1	94	72	32	●		●	$16-19k
	Fokker E-III Eindecker (3/4 Scale)	1	65	54	26	●		●	$9-15k
	Fokker E-III Eindecker (Full Scale)	1	81	68	34	●		●	$10-10k
	Morane Saulnier L	2	65	63	31	●		●	$9-11k
	Nieuport 11 (7/8 Scale)	2	80	74	34	●		●	$12-15k
	Nieuport 17	1	97	89	40	●		●	$17-22k
	Nieuport 24 (Full Scale)	1	95	83	36	●		●	$15-18k
	Nieuport 28	1	95	84	39	●		●	$25-30k
	Sopwith Baby	2	95	81	40	●		●	$14k
	Sopwith Camel (Full Scale)	1	103	85	40	●		●	$33-40k
	Sopwith Pup (Full Scale)	1	95	81	37	●		●	$27-30k
	Sopwith Schneider	2	91	78	40	●		●	$18-22k
	Sopwith Tabloid	2	91	78	40	●		●	$18-22k
	Spirit of St. Louis	2	105	93	39	●		●	$28-32k
	Taube	2	80	65	35	●		●	$18-20k
Alfa Air Service LLC *www.aboutalfa.com*	ALFA HB-207	2	187	161	52	●			–
Alisport *www.alisport.com*	Silent 2	1	136	50	37	●		●	$47-53k
	Silent 2 Electric	1	136	56	40	●		●	$116-122k
	Silent 2 Self-Launch	1	136	56	40	●		●	$60-68k
	Silent 2 Targa Self-Launch	1	136	56	40	●		●	$69-76k
	Silent Club	1	124	50	36	●		●	$40-46k
	Silent Club Electric	1	112		40	●			–
	Silent Club Self-Launch	1	124	53	38	●		●	$55-60k
Alpaero *www.alpaero.com*	Exel	1		75	39	●			–
Altitude Group LLC *www.altitudegroupllc.com*	Formula GT	2	230	218	68	●			–
	P85	2	283	252	70	●			$95-105k

Information based on manufacturer-supplied data. All speeds are in mph.

**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Altitude Group Radial Rocket RG


Amphibian Airplanes of Canada Super Petrel


Arion Lightning

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Altitude Group LLC *www.altitudegroupllc.com*	Radial Rocket RG	2	267	254	70	●			$111-151k
	Radial Rocket TD	2	255	242	70	●			$105-145k
Alturair *www.alturair.com*	BD-5B	1	232	205	66	●			$20-35k
	BD-5G	1	232	229	55	●			$20-35k
Ameri-Cana Ultralights	Eureka	1	63	60	27	●			–
American Ghiles Aircraft Inc. *www.aircraftkit.com*	Lafayette 4S Revolution	4	199	178	51	●			–
	Lafayette Bushplane	2	208	188	40	●			–
	Lafayette Classic Storch	2	84	78	35	●			–
	Lafayette Mountain	2	185	181	40	●			–
	Lafayette Sportster	2	226	204	57	●			–
	Lafayette Super Storch	2	132	118	35	●			–
	Lafayette Texan	2	149	140	40	●			–
	Lafayette Touring	2	211	190	49	●			–
	Lafayette Wallaby	2	81	71	31	●			–
American Homebuilts Corp.	John Doe	2	125	110	30	●		●	$35-45k
American Legend Aircraft *www.legend.aero*	Legend Cub	2	115	98	38	●		●	$60-84k
	Super Legend	2	108	100	35	●		●	$150-240k
	Texas Sport TX-3	2	115	98	38	●		●	$55-84k
American Patriot Aircraft LLC *www.americanpatriotaircraft.com*	Patriot II	2	138	135	44	●		●	$33-36k
	Patriot Supercruiser	2	138	135	50	●		●	$35-75k
AmeriPlanes/MitchellWing *www.ameriplanes.com*	A-10B	1	80	63	28	●		●	–
	A-10D	1	76	60	28	●		●	–
	T-10D	2	78	65	32	●		●	–
Amphibian Airplanes of Canada Ltd. *www.seastaramphibian.com*	SeaMax	2	125	115	38	●		●	–
	Seastar Sealoon	2	112	100	40	●		●	$85-105k
	Super Petrel	2	112	100	45	●		●	$80-100k
Andrew Budek-Schmeisser ***(was Townsley, Mike)*** *www.sites.google.com/site/ jungsterbipe/home*	Jungster 1 Biplane	1	150	110	55		●		$12-25k
	Jungster 2	1	200	160	50		●	●	$10-20k
Apis Sailplanes Inc. *www.apisgliders.com*	Apis 13 Meter	1	139	55	34	●			–
	Apis 15 Meter	1	139	51	36	●			$34-37k
	Apis Electric Self-Launch	1	139	51	36	●			$72-76k
Arion Aircraft, LLC *www.flylightning.net*	Lightning	2	184	155	46	●			$60-85k
	Lightning LS-1	2	138	138	51	●		●	$96-115k
	Lightning XS	2	195	180	63	●			$80-100k
Arnet Pereyra, Inc.	Buccaneer II	2	90	70	32	●			–
	Buccaneer SX	1	90	70	29	●			–
	Sabre II	2	90	70	32	●			–
	Zephyr II	2	90	70	32	●			–
Associate Air LLC	Liberty 181/183	4	145	135	35	●			–
Atec Aircraft USA *www.atecaircraft.com*	Zephyr	2	170	130	41	●			–

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Auriga Design Aerocat SRX


Aviat Pitts S-1-11B


Backcountry Super Cubs Mackey SQ2


Ballard Pelican Sport 600


Bearhawk Patrol

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Auriga Design Inc *www.auriga.on.ca/aerocat.html*	Aerocat SR	4	219	170	53	●			$225-350k
	Aerocat SRX	4	204	150	53	●			$250-300k
	Aerocat TR	4	220	201	53	●			$200-350k
	Aerocat TRX	4	205	185	53	●			$200-350k
AviaBellanca Aircraft Corporation *www.aviabellanca.com*	SkyRocket III	6	340	327	68	●			–
Aviat Aircraft, Inc. *www.aviataircraft.com*	Eagle II	2	184	165	58	●			$200-225k
	Pitts S-1-11B (Super Stinker)	1	205	187	54		●		$100-300k
	Pitts S-1S	1	176	155	62		●		–
Aviation Development International Ltd	Alaskan Bushmaster	4	150	125	44	●			–
Aviator Enterprises, Inc.	Aviat Solo	1	115	85	35		●		–
Avid Aircraft *www.avidair.com*	Avid Champion	1	65	63	26	●			–
	Bandit	2	95	80	30	●			–
	Catalina	3	80	75	36	●			–
	Magnum	3	155	130	40	●			–
	Mark IV Aerobatic Speedwing	2	135	120	46	●			–
	Mark IV High-Gross STOL	2	135	95	36	●			–
Azalea Aviation *www.azaleaaviation.com*	Saberwing	2	200	160	55	●			$40-45k
Backcountry Super Cubs (Turbine Cubs of Wyoming LLC) *www.supercub.com*	Mackey SQ2	2	120	115	20	●			$106-126k
	Super Cruiser	3	130	115	28	●			$100-120k
	Super Cub Replica	2	120	112	28	●			$100-120k
Bakeng Deuce Airplane Factory *www.bakengdeuce.com*	Bakeng Deuce	2	140	110	51	●	●		$75-100k
Ballard Sport Aircraft *www.ballardsportaircraft.com*	Pelican PL Turbo	2	155	152	50	●			$65-85k
	Pelican Sport 600	2	135	130	44	●		●	$55-75k
Barr Aircraft *www.barraircraft.com*	Barr 6	6	248	207	62	●			$145-310k
Barry Jay Aviation, Inc. *www.barryjay.com*	Acroduster 1	1	180	165	70		●		–
BD-Micro Technologies, Inc. *www.bd-micro.com*	BD-5B	1	190	170	62	●			$44-67k
	BD-5J Microjet	1	290	240	67	●			$100-145k
	BD-5T Turboprop	1	240	195	66	●			$89-105k
	FLS Microjet	1	288	184	74	●			$200-220k
Bearhawk Aircraft Co. (AviPro Aircraft, Ltd.) *www.bearhawkaircraft.com*	Bearhawk	4	175	155	40	●			$45-65k
	Bearhawk LSA	2	140	125	30	●		●	$45-65k
	Bearhawk Patrol	2	165	150	35	●			$60-90k
Bede Corp LLC *www.bedecorp.com*	BD-12C	2	215	200	54				–
	BD-17	1	150	141	54	●			$32-38k
	BD-17 E-LSA	1	148	142	56	●		●	$32-60k
	BD-18	2	190	180	56	●	●		$24-70k
	BD-22L	2	–	–	–			●	–

Information based on manufacturer-supplied data. All speeds are in mph.

**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Bede BD-4C


Belite UltraCub


Better Half VW Legal Eagle XL

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Bede Corp LLC *www.bedecorp.com*	BD-4B	4	240	190	55	●	●		$46-66k
	BD-4C	4	240	190	61	●	●		$29-90k
	BD-6	1	134	128	48	●	●	●	$13-14k
Belite Aircraft LLC *www.beliteaircraft.com*	Belite UltraCub	1	80	62	28	●			$10-20k
	ProCub Lite	1	80	62	28	●		●	$15-20k
	Superlite	1	63	62	28	●		●	$13-15k
	Trike	1	63	55	28	●		●	$10-26k
Berkut Engineering *www.berkut.com*	Berkut	2	298	275	65	●			–
Better Half VW *www.betterhalfvw.com*	Double Eagle	2	85	70	35	●	●	●	$10-13k
	Legal Eagle	1	63	60	25	●	●	●	$3-5k
	Legal Eagle UL	1		55	28	●		●	$4-5k
	Legal Eagle XL	1	63	60	25	●	●	●	$5-7k
Biplanes of Yesteryear *www.mifyter.com*	Mifyter	1	95	75	40	●		●	$22-25k
	Mifyter II	2	85	70	43	●		●	$28-32k
Blanton, D. L.	Sport Racer	2	200	175	62		●		$25-35k
	V6 STOL	4	135	120	48		●		$25-35k
	Wichawk	3	140	127	56		●		$20-40k
Blue Yonder Aviation, Inc. *www.ezflyer.com*	E-Z Harvard	1	120	90	32	●		●	$21-35k
	E-Z King Cobra	1	120	90	32	●		●	$21-35k
	EZ Flyer	2	100	75	38	●		●	$25-30k
	EZ Fun Flyer	1		50	17	●			$14k
	Merlin EZ	2	110	85	30	●			$48-65k
	Twin Engine E-Z Flyer	2	100	70	38	●			$36-75k
Boeve Aircraft Inc.	MJ-7	2	265	230	69	●	●		–
Bonner Aircraft *www.cafes.net/bonneraircraft*	Scout	1	70	60	35		●		–
Bowers (Bowers, David R.) *www.bowersflybaby.com*	Bowers Fly Baby	1	110	87	45		●	●	$10-12k
Bradley Aerospace *www.vortechonline.com/bradley*	Aerobat	1	180	150	43	●			–
Breezer Aircraft USA, LLC *www.breezeraircraftusa.com*	Breezer II	2	135	120	43	●		●	$46k
Buethe Enterprises, Inc. *www.flybarracuda.com*	Barracuda	2	220	200	61		●		–
BushCaddy International Inc. *www.bushcaddy.com*	BushCaddy L160	3	125	115	42	●			$60-110k
	BushCaddy L162 Max	4	140	125	42	●			$60-110k
	BushCaddy L164	4	140	125	42	●			$80-120k
	BushCaddy R120	2	120	110	34	●			$60-90k
	BushCaddy R80 UL/Sport	2	120	110	32	●		●	$50-65k
BX-Aviation	Cherry BX-2	2	155	128	52		●	●	$20-50k
C-N-C Aviation	Supercat	1	100	80	32		●	●	$7-12k
Cadcor *www.cadcor.com*	Chanute	2	265	240	67	●			–

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Blue Yonder EZ Fun Flyer


BushCaddy L162 Max


Classic Sport Aircraft S18


Comp Air 9


Composite Aircraft Technologies Express 2000 RG

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Cameron & Sons Aircraft *www.cameronaircraft.com*	P51 Mustang	2	500	420	87	●			$150-450k
Canadian Museum of Flight	SE5A Replica	1	110	85	40		●	●	$5-15k
Carlson Aircraft, Inc. *www.sky-tek.com*	Carlson Skycycle	1	139	100	55	●			–
	Criquet	2	135	95	16	●			–
	Sparrow II	2	130	95	36	●		●	–
	Sparrow II XTC	2	115	110	39	●		●	$40-45k
	Sparrow Sport Special	1	100	85	31	●		●	$28-32k
	Sparrow Ultralight	1	63	58	27		●	●	$8-12k
Cassagneres, Ev	Ryan ST-R (replica)	2	140	120	45		●		$10-20k
CFM Aircraft Ltd.	Shadow-DD	2	124	90	38	●			–
	Star Streak	2	144	115	45	●			–
	Streak Shadow SA	2	140	110	40	●			–
CinCo Enterprises, Inc. *www.northwestartists.com/russiakits*	Russia AC4-KC	1	130		42	●			–
Circa Reproductions *www.nieuports.com*	7/8 Nieuport 11/17	1	85	75	30		●	●	–
	Nieuport 11 EXP (87%)	1	80	70	32		●	●	–
	Nieuport 12 EXP (87%)	2	94	75	33		●		–
Classic Aero Enterprises *www.members.cox.net/classic-aero*	H-2 Honey Bee	1	70	65	35		●	●	$7-15k
	H-3 Pegasus	1	85	70	30		●	●	$7-14k
Classic Sport Aircraft *www.classicsportaircraft.com*	S-18 & S-18T	2	215	180	63	●			$30-45k
Clifford Aeroworks *www.cliffordaeroworks.com*	Spad XIII	1	90	80	45	●	●		–
Clutton, Eric	Fred	1	80	75	40		●	●	$5-12k
Collins Aero	Dipper Amphibian	2	124	120	48				–
Comp Air Inc. *www.compairinc.com*	Comp Air 10	10	200	180	56	●			$250-425k
	Comp Air 12	10	356	340	84	●			$750k-2.4M
	Comp Air 3	3	175	145	45	●			$33-43k
	Comp Air 4	4	175	155	39	●			$56-90k
	Comp Air 6	6	175	165	39	●			$66-100k
	Comp Air 7	6	250	230	53	●			$87-325k
	Comp Air 7SLX	6	250	210	54	●			$98-375k
	Comp Air 8	8	227	210	48	●			$187-425k
	Comp Air 9	8	288	253	71	●			$770k-1.2M
	Comp Air Jet	10	400	375	71	●			–
	Merlin GT-582/912	2	120	85	35	●		●	–
	Merlin GT-912	2	120	93	38	●			–
Composite Aircraft Technologies *www.compairtechllc.com*	Express 2000 FT	4	230	207	55	●			$200-250k
	Express 2000 RG	4	290	200	50	●			$200-250k
	S300 RG	4	320	300	60	●			–
	Series 2000 FT	4	230	190	53	●			–

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


CubCrafter Carbon Cub EX-2


Custom Flight Lite Star

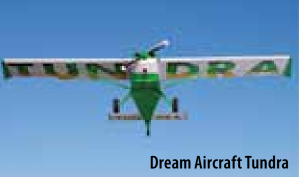

Dakota Cub Super 18-LT

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Corivi Aviation *www.magini.it/coriviaviation.htm*	Pegaso	2	155	142	45	●			–
CSN	Corby Starlet CJ-1	1	160	130	35		●	●	$15-27k
CubCrafters, Inc. *www.cubcrafters.com*	Carbon Cub EX-2	2	138	115	32	●		●	$100-150k
	Top Cub	2	140	115	43	●			–
Culp's Specialties *www.culpsspecialties.com*	Culp's Special	2	240	170	72	●	●		$70-250k
	Sopwith Pup	2	220	170	72	●	●		$90-240k
Custom Flight Ltd. *www.customflightltd.com*	Lite Star	2	120	100	45	●		●	$35-60k
	North Star	2	120	115	25	●			$80-100k
D & E Aircraft, Inc. *www.de-aircraft.com*	Kodiak Cruiser 2400/3200	2	150	130	25	●			–
Dakota Cub *www.dakotacub.com*	Super 18-160	2	125	100	49	●			$100-125k
	Super 18-180	2	148	100	51	●			$100-130k
	Super 18-LT	2	110	90	44	●		●	$90-110k
DCS, Inc. *www.teenietwo.com*	Mini Coupe	1	110	100	48		●	●	$8-20k
	Teenie Two	1	120	110	48		●	●	$7-20k
	Tinni Three	2	180	160	50		●		$15-35k
Design Resources	J. D. Special	1	170	140	38		●		$11-40k
DFE Ultralights, Inc.	Ascender 3A	1	55	40	25	●		●	$7-8k
	Ascender 3B	1	55	40	28	●		●	$8-10k
	Ascender 3C	1	55	40	28	●		●	$8-10k
Dova Aircraft *www.dovaaircraft.com*	Skylark	2	130	120	42	●		●	–
Dream Aircraft Inc. *www.dreamaircraft.com*	Tundra	4	132	118	52	●			$110-160k
Duccini *www.campavia.com*	Morin M85	2	100	90	37		●	●	$10-25k
Dyke Aircraft	Dyke Delta JD II	4	210	180	60		●		$9-30k
Early Bird Aircraft Co.	Jenny, 2/3 scale	2	70	60	35		●	●	$8-13k
Earthstar Aircraft *www.thundergull.com*	eGull Electric	1	63	63	24	●		●	$30-35k
	Gull 2000	1	63	63	27	●		●	$17-22k
	Odyssey	2	108	87	37	●		●	$22-35k
	Soaring Gull	1	63	63	26	●		●	$18-23k
	Thunder Gull J	1	63	63	25	●			–
	Thunder Gull JT2	2	87	87	34	●			–
Ed Marquart	Marquart MA-5 Charger	2	125	116	48		●		–
EDRA Aeronßutica Ltda *www.edraaeronautica.com.br/pt*	Super Petrel	2	110	85	32	●			–
Eklund Engineering, Inc. *www.thorpt18.com*	Thorp T-18	2	205	200	59		●		$20-45k
Elmwood Aviation	Christavia MK 1	2	118	105	40		●		–
Esqual North America, LLC	Esqual Retractable	2	230	210	50	●			–
	Esqual Sport	2	132	132	34	●		●	–
	VM-1 Esqual	2	195	175	43	●			–

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Dream Aircraft Tundra


Earthstar Gull 2000


Europa XS Trigear


Excalibur


Excalibur Four Stroke

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
EU-WISH Aircraft *www.groups.yahoo.com/group/Sidewinder2/*	Sidewinder S & GA	2	210	167	60		●		$22-85k
Europa Aircraft *www.customflightcreations.com*	Europa XS Monowheel	2	161	150	51	●			$75-125k
	Europa XS Motor Glider	2	155	143	52	●			$95-125k
	Europa XS Trigear	2	161	150	51	●			$75-125k
	Europa XS Trigear Light Sport	2	138	135	51	●		●	$75-150k
Evans Aircraft *www.evansair.com*	Volksplane 1 (VP-1)	1	95	75	45		●	●	–
Excalibur Aircraft *www.excaliburaircraft.com*	Excalibur	2	100	90	32	●		●	$24-25k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.

Different Strokes for Different Folks

From simple to complex, there's an Experimental aircraft for almost everyone.

Once upon a time, airplanes were simple. Made mostly of wood and fabric, with a few metal parts to connect the cables and struts, they were conceived and constructed by men familiar with farm implements and simple tools. The wingtips on the very first airplane were, in fact, hoops from a buggy canopy—resourcefulness and ingenuity being one of the strong aspects of the Wright brothers' character. Homebuilt aircraft of the '50s and '60s were similarly simple, with the use of available materials and engines (sometimes from an old car) that could be found by the average person with limited resources.

Pilots being what they are, such simple airplanes immediately became the subject of upgrades. Everyone always wants to go a little faster, fly a little higher, travel a little farther. It would be nice to be able to talk to someone else on a radio, and maybe even navigate with some other sort of electronics. And then someone takes the step of flying their homemade airplane in the clouds, leading to the never-ending arms race in complex electronics that today allow us to fly in just about any conditions, with "George" handling the controls while we plot our next business deal or flip through Internet pages to find our next project.

The truth, of course, is that people are building airplanes of all levels all of the time. Some are going for light and simple, while others are working on that high-Mach suborbital business rocket they hope will bring them nonstop across the Atlantic in just 25 minutes. And that's OK, for variety is the spice of life, and people should build the airplane they want—not the one that others think they should build.

Building on a Budget

A builder needs to know their own limitations when choosing a project. Most builders can learn just about anything, but financial considerations (among many other factors) always drive the projects that we choose. Many builders start with a set of plans and buy materials along the way to produce frames for a fabric-covered fun machine. The tail comes along one year, the fuselage frame the next, and wings are formed in yet another winter or summer. Builders find good deals on an engine and store it away for the time when they have an airframe on which to mount it. Many collect instruments at various fly markets and from online ads, readying them for the time when they have an instrument panel to fill out. Airplanes like these are often works of art because the builder has more time than money—and time is an important element of craftsmanship.

Building in tube, fabric, and wood is a wonderful way to connect to your inner craftsman. Running one's hands over a piece of spruce or a sheet of plywood that will become a major element of your flying machine is a sensual experience that can rival the joy of flight. Such projects can be completed quickly, but in doing so, the builder often misses the joy of savoring the process. Doping and sanding, doping and sanding—finishing a fabric airplane takes time (and generates a certain amount of mess), but simple planes bring around visitors who might otherwise never have been met. Open hangar doors invite the curious—and sometimes the visitors stay to become helpers—even partners. Building this way is indeed a way to become so deeply involved in aviation that one can feel the history seeping into their very core.

Complex Projects

Of course, for every simple airplane under construction in hangars across the globe, there are many more complex airplanes taking shape. Made of metal and fiberglass, machines of all speed ranges and purposes grow from plans and kits to fulfill their creators' desire for speed and complex

The RV-10 is a four-seat traveling machine that rivals the most complex certified singles on the market—for far less money.


Falcomposite Furio LN 27 RG


Falconar Cubmajor


Falconar F11E Sporty

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Excalibur Aircraft *www.excaliburaircraft.com*	Excalibur Four Stroke	2	100	90	33	●		●	$28-29k
	Excalibur Stretch	2	100	90	32	●		●	$24-25k
Extra Flugzeugproduktions GmbH *www.extraaircraft.com*	Xtra 200	2	265	172	61	●			$240-300k
Falcomposite Ltd *www.falcomposite.com*	Furio LN 27 RG	3	219	201	54	●			$200-250k
Falconar Avia Inc. *www.falconaravia.com*	AMF-14H	2	115	92	36	●	●	●	$19-40k
	AMF-Super 14D Maranda	2	130	120	39	●	●		$28-40k
	ARV-1K Golden Hawk	2	130	100	40	●			–
	Cubmajor	2	120	100	40		●	●	$10-33k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory.*

capabilities. Where the simple plane builder might have only a few wires to install to control the magnetos, the complex aircraft builder contends with multiple power buses, dozens of serial computer channels, and antennas for the variety of transmitters and receivers needed for flight in the clouds.

Complex homebuilts include aircraft with turbine engines and pressurization. The list includes multi-engine machines and those with hybrid powerplants. Wings can fold and unfold, with high lift devices sprouting from leading and trailing edges—and sometimes the fuselage itself. Wheels retract, cowl and radiator flaps open and close, and if you don't like the mechanical nature of actuating such devices, electronic servos are available to do the job for you. Many builders are computer-savvy and have designed control systems to manage nearly everything in the airplane—including in-flight coffee service. Complex avionics systems rival what is available in all but the latest transport-category aircraft that are winging paying passengers across the oceans of the globe.

Construction methods for these complex machines range from metal forming and riveting, to autoclaving composite materials to achieve shapes conceived in computers and transferred electronically to machines capable of carving smooth contours in foam and plastic. Builders learn a variety of construction techniques while creating these complex machines—none of them better or worse than their counterparts slaving away with dope and fabric—just different.

And that is what we have to recognize when we see the many different types of airplanes listed in these pages. They are all different—but none is inherently better or worse than another. Just different. Go to the average active EAA chapter and you'll see and talk with people building all across the board. I have walked through many an airport and seen a Cub-like aircraft taking shape next door to a Lancair IV-P, a pressurized go-fast machine that can whisk its passengers across the country, while the Cub pilot is still making his first fuel stop 150 miles from home.

Open cockpit designs take us back to the early days of aviation and allow us to simply enjoy the sky.

Pre-Punched Kits

Many, many builders are sharing the common experience of building modern metal airplanes from pre-punched kits. They share information on common avionics and engines, fuel systems that have become safer by standardization, and systems layouts that have been well-proven by those who have gone before. These airplanes are quickly becoming the bread and butter of general aviation; many airports now have more operations in a week from Experimental aircraft than they do from the aging certified general aviation fleet in a month. Fast or slow, Experimental aircraft are the fastest growing segment of aviation—and equipment manufacturers are beginning to take notice.

Build What You Want

Fast or slow, high or low, take your pick and build what works best for you. Wander the airport, peek into hangars, and revel in the choices we have, as evidenced by the choices of others. Take joy in your neighbor's Legal Eagle while you prepare fiberglass layups for your Cozy. Stop in and have a look at the RV-3 being built down the way, and see the smile of the guy that just figured out a way to make his bulkheads fit. Listen to the woman running up the brand new IO-540 on the RV-10 she has built to carry her growing family around the country to visit the relatives. And don't forget that fellow out in the distant hangar working on that helicopter—for not all homebuilts have fixed wings.

The truth is, Experimental aviation is more than a tale of two airplanes—it is a tale of as many planes as have been built. No two are alike, no two built for exactly the same purpose. None are equipped identically, and none have the exact same capability. But all of their builders have shared a common experience: the joy of bringing raw materials together in a way that creates flight. And flight, in all its forms, binds us together as homebuilders. Pick the airplane or project that is right for you—the aircraft that you want to build—not the one that others want you to build.

—Paul Dye


Falconar Turbi D5


Fisher Flying Products Celebrity


Fisher Flying Products Youngster


Flight Addiction Daisy Mae


Glasair Sportsman

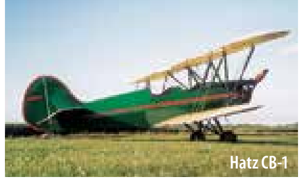
Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Falconar Avia Inc. *www.falconaravia.com*	F11A Sporty	2	140	123	38	●	●	●	$20-40k
	F11E	2	140	100	42		●	●	$10-37k
	F11E Sporty	2	130	110	41	●	●	●	$20-40k
	F12A Cruiser	2	175	150	51	●	●		$22-45k
	Falconar F10A	1	140	120	35		●	●	$9-30k
	Falconar F11E	2		100	42		●	●	$10-37k
	Falconar F9A	1	116	100	43	●	●		–
	Fauvel AV36/361/AV362	1	137	60	30		●	●	$9-20k
	HM 290/293	1		90	28		●	●	$5-26k
	HM 360	1	120	95	28		●	●	$7-34k
	HM 380	2	120	95	28		●	●	$7-34k
	Ladybug 380L	2	124	113	28	●	●		–
	Mignet Flying Flea 290E/293E	1	110	90	28	●	●	●	$11-20k
	SAL Mustang (2/3)	2	200	176	60	●	●		$40-80k
	Turbi D5	2	108	81	34	●	●	●	$20-35k
Fighter Escort Wings *www.fighterescortwings.com*	FEW P51	2	250	210	62	●			–
	P51D	2	240	210	65	●			–
	TF51	2	240	210	65	●			–
Fisher Flying Products *www.fisherflying.com*	Avenger	1	63	60	28	●	●	●	$9-11k
	Avenger V	1	100	85	31	●	●	●	$10-12k
	Celebrity	2	95	85	40	●	●	●	$20-25k
	Classic	2	100	85	39	●	●	●	$15-17k
	Dakota Hawk	2	100	100	35	●	●	●	$25-35k
	FP-202 Koala	1	75	55	26	●	●	●	$10-12k
	FP-303	1	70	60	25	●	●	●	$8-10k
	FP-404	1	80	72	30	●	●	●	$11-13k
	FP-505 Skeeter	1	63	60	26	●	●	●	$10-12k
	FP-606 Skybaby	1	63	60	26	●	●	●	$10-12k
	Horizon 1	2	100	95	40	●	●	●	$17-20k
	Horizon 2	2	110	100	38	●	●	●	$22-25k
	R-80 Tiger Moth	2	100	80	35	●	●	●	$25-30k
	RS-80 Tiger Moth	2	100	80	40		●	●	–
	Super Koala	2	95	75	32	●	●	●	$17-20k
	Youngster	1	110	85	32	●	●	●	$13-15k
	Youngster V	1	110	85	32	●	●	●	$13-15k
Flight Addictions LLC (Alarie, Russell) *www.daisymae-biplane.com*	Daisy Mae	2	100	80	40		●	●	$17-30k
Flightstar, Inc. *www.flyflightstar.com*	eSpyder	1	80	50	24	●		●	$15-18k
	Flightstar Loadstar	1	95	70	36	●			–
	IISC	2	83	65	36	●		●	$30-35k
	IISL	2	80	65	36	●		●	$23-29k
	Spyder	1	80	65	36	●		●	$16-18k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Glasair III


Great Plains Sonerai II


Hatz CB-1

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Flying Flea Archive USA *www.valkyrie.net/~flyingflea*	Flying Flea HM-14	1	70	55	25		●	●	–
	Flying Flea HM-160/1/2	1	80	65	20		●	●	–
	Flying Flea HM-290/1FB	1	85	75	26		●	●	–
Four Winds *www.fourwindsaircraft.com*	Four Winds 192	4	255	200	51	●			–
	Four Winds FX210/FX250	6	287	215	66	●			$196-248k
Free Bird Innovations, Inc. *www.flyfbi.com*	LiteSport Classic	2	85	80	32	●		●	$15-19k
	LiteSport II	2	80	75	32	●	●	●	$10-15k
	LiteSport Ultra	2	62	55	22	●	●	●	$9-15k
Freedom Aviation *www.freedom-aviation.com*	Freedom Aviation	4	230	215	75	●			$230-350k
Glasair Aviation *www.glasairaviation.com*	Glasair III	2	300	278	78	●			$125-300k
	Glasair Super II FT	2	228	210	73	●			$80-200k
	Glasair Super II RG	2	238	221	73	●			$80-200k
	GlaStar	2	167	161	49	●			–
	Sportsman	4	186	172	48	●			$80-200k
	Two Weeks to Taxi Sportsman	4	186	172	48	●			$189-250k
	Two Weeks to Taxi Sportsman Carbon	4	186	172	50	●			$204-250k
Golden Circle Air, Inc. *www.goldencircleair.com*	T-Bird Cargo	3	88	65	39	●		●	–
	T-Bird I	1	78	60	26	●		●	–
	T-Bird II	2	90	70	38	●		●	–
	T-Bird Side-by-Side	2	95	70	36	●			–
Great Plains Aircraft Supply Co., Inc. *www.gpasc.com*	Easy Eagle I Bi-Plane	1	110	100	45		●	●	$8-12k
	Sonerai I	1	200	150	45		●		$10-20k
	Sonerai II Original, LT, L	2	200	140	45		●	●	$10-20k
	Sonerai II Stretch	2	200	140	50		●		$10-20k
Green Sky Adventures, Inc. *www.greenskyadventures.com*	Micro Mong	1	100	80	35	●	●	●	$14-30k
	Zippy Sport	1	120	110	45		●	●	$10-25k
Griffon Aerospace *www.griffon-aerospace.com*	Lionheart	6	232	213	56	●			–
Groppo Avio *www.groppo.it*	Trail	2		115	35	●		●	$55k
Grosso Aircraft Inc.	Easy Eagle	1	110	100	45		●		–
	Easy Eagle II	2	110	100	45		●		–
Hansen Aero *www.tecnam.com*	Tecnam P92 Super Echo	2	140	123	39	●			–
Harper Aircraft *www.harperaircraft.com*	Fascination D4-BK	2	172	160	38	●			–
	Lil' Breezy	2	75	65	28	●		●	–
	Sky Scooter	1	62	55	28	●			–
	Ultrasport	1	60	60	30	●			–
Hatz Biplane Association *www.hatzbiplane.com*	Hatz CB-1	2	105	90	38		●		$12-80k
	Kelly-D	2	105	90	40		●		$12-80k
Hensley Aircraft *www.hensleyaircraft.com*	H-1 Wolf/Wolf	4	225	210	55	●			–

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Hummel H5


ICP Savannah VG


Indy Aircraft T-Bird I


Jabiru J170


Jim Kimball Pitts Model 12

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Hevle Aviation LLC *www.hevleaviation.com*	Hevle Classic	2	135	105	45		●	●	$19-40k
Higher Class Aviation *www.sporthornet.com*	Hornet	2	115	109	40	●		●	$32-52k
Hinz	BL1-KEA	2	168	155	53		●		–
Hipp's Superbirds, Inc. *www.geocities.com/Paris/LeftBank/7993/plane.html*	J-3 Kitten/Super Kitten	1	63	59	24	●	●	●	$10-30k
	J-4 Sportster/Super Sportster	1	63	59	24	●	●	●	$10-30k
	Reliant SX	1	100	75	31	●		●	–
	Reliant/Reliant SX	1	63	60	24	●	●	●	$10-31k
HP Aircraft, LLC *www.hpaircraft.com*	HP-24 Sailplane	1	150		45	●		●	$36-45k
Hummel Aviation *www.flyhummel.com*	CA-2	1	63	50	26		●	●	$4-11k
	H-5	1	130	120	42	●	●	●	$17-32k
	Hummelbird	1	125	115	38	●	●	●	$8-15k
	UltraCruiser	1	95	75	28	●	●	●	$9-28k
	UltraCruiser Plus	1	135	125	36	●	●	●	$20-30k
ICP Srl *www.icpaviazione.it*	Bingo 4S	2	84	75	28	●		●	$35-45k
	Savannah	2	110	85	30	●		●	$45-50k
	Savannah ADV	2	125	115	34	●		●	$55-60k
	Savannah VG	2	110	95	30	●		●	$45-50k
	Savannah VGW	2	110	95	30	●		●	$45-50k
Indy Aircraft, Ltd. *www.indyaircraftltd.net*	T-Bird I	1	78	60	26	●		●	$15-30k
	T-Bird II	2	90	66	36	●		●	$17-55k
Ion Aircraft *www.ionaircraft.com*	Ion 100	2	138	138	52	●		●	$47-75k
Jabiru USA Sport Aircraft , LLC *www.usjabiru.com* **Jabiru Aircraft Australia** *www.jabiru.net.au*	Calypso	2	143	120	44	●		●	$35-55k
	J450	2	155	138	52	●			$65-100k
	Jabiru J170	2	132	115	52	●		●	$45-60k
	Jabiru J200	2	159	138	55	●			$60-90k
	Jabiru J230	2	138	138	52	●		●	$65-100k
	Jabiru J250	2	138	138	52	●		●	$60-90k
	Jabiru J400	4	152	138	55	●			$65-95k
	Jabiru J430	4	138	138	57	●			$65-100k
	Jabiru SP	2	154	130	50	●			–
	Jabiru UL	2	139	115	40	●		●	–
Jim Kimball Enterprises Inc. *www.pittsmodel12.com*	Pitts Model 12	2	239	170	64	●	●		$115-140k
Jim Maupin, Ltd. *www.jcpress.com/JMaupinLtd*	Carbon Dragon	1	70		20		●		–
	Windrose II	1	132	75	52		●		–
	Woodstock	1	100		35		●		–
Johnston Aviation *www.tigercubaircraft.com*	Tiger Cub II	2	125	105	35	●		●	$34-61k
	Tiger Cub UL	1	90	65	25	●	●	●	$16-21k
Junqua-Diffusion *www.junqua-aircraft.com*	Ibis RJ.03	2	158	126	57		●		–

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Just Aircraft Highlander


Kitfox Super Sport


Lancair Evolution

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Jurca Plans, c/o Ken Heit	MJ-10 Spitfire (75%)	1	230	180	65		●		–
	MJ-100 Spitfire (100%)	1	355	300	62		●		–
	MJ-12 P-40 (75%)	1	275	225	65		●		–
	MJ-2 Tempete	1	120	102	62		●		–
	MJ-5 Sirocco	2	225	200	64		●		–
	MJ-77 Mustang (75%)	2	330	230	65		●		–
	MJ-8 FW-190 (75%)	1	240	200			●		–
Just Aircraft *www.justaircraft.com*	Escapade	2	132	110	42	●		●	$55-85k
	Highlander	2	132	105	39	●		●	$58-85k
	SuperSTOL	2	132	100		●		●	$55-85k
Kitfox Aircraft LLC *www.kitfoxaircraft.com*	Kitfox Lite	1	63	55	27	●		●	–
	Kitfox Model (Classic) IV	2	115	110	37	●		●	$32-55k
	Kitfox S7 Super Sport Tailwheel	2	140	123	41	●		●	$35-60k
	Kitfox S7 Super Sport Tri-gear	2	140	123	41	●		●	$30-60k
Kitplanes for Africa *www.web.penta-net.co.za/kitplanes*	Bushbaby	2	120	90	35	●			–
Kolb Aircraft Co LLC (The New Kolb Aircraft Co) *www.kolbaircraft.com*	FireStar II SS	2	90	68	34	●		●	$15-40k
	FireFly	1	63	63	28	●	●	●	$15-18k
	FireStar	2	90	80	27	●	●	●	$22-28k
	Kolb Flyer	2	50	30		●		●	–
	Kolbra	2	110	75	45	●		●	$26-39k
	Kolbra Ultralight Trainer	2	100	75	35	●			–
	Mark III Classic	2	100	80	41	●		●	$28-42k
	Mark III Xtra	2	100	90	27	●		●	$32-45k
	Pelican Sport	2	145	132	44	●			–
	Slingshot	2	115	85	41	●	●	●	$21-37k
Lancair International Inc. *www.lancair.com*	Evolution	4	345	325	61	●			$1.4-1.5M
	Lancair ES/Super ES	4	230	215	70	●			$250-350k
	Lancair IV	4	300	285	75	●			$300-400k
	Lancair IV-P	4	330	300	73	●			$400-500k
	Lancair Legacy FGC-550	2	250	240	65	●			$200-295k
	Lancair Legacy RG-550	2	276	270	65	●			$250-300k
	Lancair Propjet	4		370	74	●			$375-550k
	Lancair Sentry	4		380	74	●			–
	Lancair Turbine IV-P	4		370	75	●	●		–
	Legacy FG-390	2	215	200	65	●			$180-225k
Legend Aircraft, Inc. *www.turbinelegend.com*	Turbine Legend	2	356	333	66	●			$180-500k
Legend Lite Inc. *www.airsport.com/kits/skywtch.htm*	Skywatch SS-11	2	90	80	29	●			–
Legendary Aircraft *www.legendaryaircraft.com*	P51	2	290	225	59	●			$125-200k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory.*


Littner Jewel


Littner Junior VI


Lockwood Air Cam


Loehle 5151RG Mustang


Loehle Sport Parasol

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Leichtflugzeuge, B & F GmbH - FK-Lightplanes *www.fk-lightplanes.com*	FK 12 Comet	2	131	118	42	●			–
	FK 14-B Polaris	2	170	155	42	●			–
	FK 9 Mark IV	2	140	120	42	●			–
Light Miniature Aircraft *www.lightminiatureaircraft.com*	LM-1A-W (85% J-3)	1	85	75	32		●	●	$10-20k
	LM-1X (75% J-3)	1	75	65	26	●	●	●	$7-9k
	LM-2X-2P-W (75% Taylorcraft)	2	85	75	38		●	●	$7-14k
	LM-2X-2P-W (87% Taylorcraft)	2	100	85	40	●	●		–
	LM-3X-W Aeronca Champ Replica	1	75	65	26		●	●	$7-12k
	LM-5X-W Super Cub Replica	2	90	80	42	●	●	●	$16-24k
	LM-J3-W Piper Cub Replica	2	85	70	38	●	●	●	$16-24k
	LM-TC-W Taylorcraft Replica	2	95	85	42	●	●	●	$16-24k
Light Wing Sport Aircraft	Savannah	2	110	100	28	●		●	–
	X-Air	2	75	65	30	●		●	–
	X-Air F	2	87	68	27	●		●	–
	X-Air H	2	105	93	33	●		●	–
Liteflite Pty Ltd *www.liteflite.com.au*	Connie	1	90	65	35	●			–
	Dragonfly 582	2	66	54	28	●		●	–
	Dragonfly 912ULS	2	66	54	28	●		●	–
	Dragonfly C-Model	2	65	55	22	●		●	$35-44k
	Tempest	1	80		26	●			–
Littner, S. *www.slittneraircraftplans.com*	C.P. 1320-Saphire	4	200	167	53		●		–
	C.P. 150 Onyx	1	62	50	22		●	●	–
	C.P. 328 Super Emeraude	2	150	142	56		●		–
	C.P. 60 Super Diamant	4	160	155	55		●		–
	C.P. 750 Beryl	2	185	160	56		●		–
	C.P. 80 Zephyr	1	200	175	50		●		–
	C.P. 90 Pinocchio	1	150	140	45		●		–
	Champion V	2	155	143	47		●		–
	Jewel	2	186	177	40		●		–
	Junior VI	2	125	100	38		●	●	–
	Supercab	2	162	143	35		●		–
	Vega	2	150	120	52		●		–
	Whisky IV	2	183	130	37		●		–
Lockwood Aircraft, Inc. *www.lockwoodaircraft.com*	Air Cam	2	110	85	39	●			$115-135k
	Super Drifter	2	85	75	34	●		●	$47-55k
Loehle Aircraft Corp. *www.loehle.com*	5151 Mustang	1	90	80	30	●		●	$22-59k
	5151 RG Mustang	1	95	85	30	●			$24-61k
	Fokker D-VII	1	70	65	20	●		●	$19-41k
	Jenny (67% Curtiss Jenny)	2	70	60	35	●			–
	KW-909	1	95	85	30	●			$21-61k
	Loehle Spitfire	1	140	105	38	●			$70-90k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


M-Squared Breese 2


Makelan Hatz Classic


Roger Mann RW16

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Loehle Aircraft Corp. *www.loehle.com*	P-40	1	90	85	30	●			$21-61k
	SE5A	1	70	65	20	●		●	$22-41k
	Spad XIII	1	70	65	20	●		●	$22-41k
	Sport Parasol	1	70	65	22	●		●	$13-21k
Lucas, Emile *www.emile-lucas.com*	L 11	2	125	103	42		●	●	–
	L 12	2	125	103	42		●	●	–
	L 5	2	165	145	54		●		–
	L 6	2	143	125	50		●		–
	L 7	3	142	125	56		●		–
	L 8	2	192	165	60		●		–
Luceair *www.luceair.com*	Wittman Buttercup	2	155	125	45	●	●	●	$15-23k
M-Squared, Inc. *www.msquaredaircraft.com*	Breese 2 DS	2	93	75	32	●		●	$25-60k
	Breese 2 SS	2	87	55	28	●		●	$26-60k
	Breese DS	1	93	65	26	●		●	$26-35k
	Breese SS	1	82	46	24	●		●	$25-35k
	Sport 1000	2	103	74	39	●		●	$36-60k
	Sprint 1000	2	94	58	27	●		●	$35-60k
Main Planes *www.alltrade.ws*	Beach Boy ST-II	2	85	75	22		●	●	–
Makelan Corporation *www.hatzclassic.com*	Hatz Classic	2	150	100	43	●	●		$45-60k
Mann, Roger *www.rogermann.org*	RW1 Ultra-Piet Pete	1	85	55	28		●	●	$5-10k
	RW11 Rag-A-Bond	2	105	78	38		●	●	$8-25k
	RW16 Aerial	1	90	60	28		●	●	$5-10k
	RW19 Stork	2	105	75	22		●	●	$15-30k
	RW2 Special I	1	125	70	30		●	●	$8-18k
	RW20 Stork Side-By-Side	2	105	75	22		●	●	$10-25k
	RW22 Tiger Moth	2	110	80	35		●	●	$10-25k
	RW26 Special II	2	135	85	38		●	●	$10-20k
	RW4 Midwing Sport	1	95	70	28		●	●	$5-10k
	RW5 Heath Replica	1	85	60	28		●	●	$5-10k
	RW6 RagWing Parasol	1	85	66	28		●	●	$5-10k
	RW7 Duster	1	95	65	28		●	●	$5-10k
	RW8 RagWing Pt2S	2	95	75	36		●	●	$10-25k
	RW9 Motor Bipe	1	95	60	36		●	●	$5-10k
Maverick Air, Inc. *www.twinjet.com*	Twinjet-1500	6	405	380	86	●			–
Meyer Aircraft *www.littletootbiplane.com*	Meyer's Little Toot	1	138	125	51		●	●	$20-45k
Microleve Com. Ind. LTDA *www.microleve.com.br*	Corsario MK-5	2	95	85	30	●			–
	ML500	2	95	80	20	●			–
Mini-IMP Aircraft Co. *www.mini-imp.com*	Mini-IMP	1	200	180	45	●	●		$15-27k

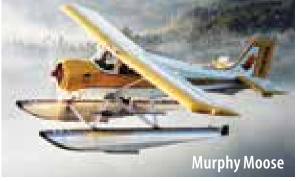
Information based on manufacturer-supplied data. All speeds are in mph.

**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.

Mini IMP

Mirage Celerity



Murphy Moose

Murphy Rebel Sport

Mustang Aeronautics Midget Mustang

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Mirage Aircraft, Inc. *www.mirage-aircraft.com*	Celerity	2	225	205	60		●		$27-59k
	Marathon	2	205	190	60		●		$23-42k
Montagne Aircraft LLC	Mountain Goat	2	165	159	27	●			–
Morrison Aircraft *www.morrisonaircraft.com*	Morrison 6	6	240	240	62	●			$170-332k
Murphy Aircraft Mfg. Ltd. *www.PattersonAeroSales.com*	Elite	2	145	132	42	●			$75-85k
	Maverick	2	110	80	32	●		●	$30-40k
	Moose	6	165	140	52	●			$100-130k
	Rebel	3	140	120	40	●			$55-70k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory.*

How Complete?

Different manufacturers have different ideas about what makes a kit complete.

Before the 1970s there really weren't any kit aircraft. There were lots of homebuilts constructed from plans, and Aircraft Spruce (among others) was turning out materials packages for popular designs—but they were just that—packages of raw materials that approximated what you needed to fabricate parts for a particular set of drawings. Hardware was rarely (if ever) included, and while there were custom houses producing a few engine mounts and the like, you were just as likely to receive a few lengths of the appropriate sized 4130 steel tubing as you were something that looked like you could hang an engine on it.

I have seen numerous claims as to who produced the first complete aircraft kit, and I am not going to try and adjudicate as to who actually deserves the honors, but in the early 1970s a few such kits began to appear. Even then, the word "complete" had different meanings to different people. At least one manufacturer taped a razor blade to the outside of the box, so that the new owner had the appropriate tool at hand with which to open the boxes—now *that* is complete. Except… things that might sit awhile, like paint or primer, still needed to be purchased. Very few kits include all of the fluids you'll need, and there is significant debate over the inclusion of assembly lubricants—are they a "tool" or part of the airplane?

The kit for the Zenith STOL CH 750 includes virtually everything you need to build the airframe. *(Photo: Courtesy of Zenith Aircraft Company)*

All kidding aside, builders today have a wide variety of kits to choose from, and it pays to look into the particular company's definition of completeness. You can still purchase plans and raw materials—many such offerings can be found in the back pages of this magazine, produced by small companies and offered with little more than moral support, experience on the end of a phone, and (honest) best wishes for your build. If you choose to go this way, and this is your first build, we'd suggest that you find an experienced builder nearby, and add them to your circle of friends. Airplane construction is full of specialized techniques and methods that, while not always difficult, aren't always intuitive.

Finding all of the necessary materials to go along with your plans can also be a struggle. It is important to realize that very, very few airplanes can be built safely using hardware store materials and parts. You'll want to quickly bulk up your catalog collection with names like Aircraft Spruce, Wicks, B&B Aircraft Supplies, and others too numerous to mention. Haunt the fly markets at Sun 'n Fun and Oshkosh, of course—but beware of parts that have been around since the Great War. There might be some degradation of insulation or flexibility.

A Closer Look at Kits

Let's take a step up from plans and look at kits. Yes, there are kits that really require very little fabrication—and the instructions are very much a matter of inserting Tab A into Slot A—or at least they seem like that to someone who has built from scratch. Late-model designs from the big names are often like this, and the instructions will hold your hand from start to finish. Not long ago, the kits from Van's Aircraft started out in excruciating detail when it came to building the tail pieces (the first part of the job). They almost told you which hand to use to pick up the part before attaching it to another part.

But as the process of building the airplane went along, Van's assumed that you had learned the various methods of construction, and before


Mustang Aeronautics Mustang II


National Aeronautics Cassutt 111M


Norman Aviation Mini Explorer

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Murphy Aircraft Mfg. Ltd. *www.PattersonAeroSales.com*	Rebel Sport	2	160	105	40	●		●	$50-60k
	Renegade Spirit	2	105	90	36	●	●	●	$48-55k
	Super Rebel TD	4	160	150	46	●			–
Mustang Aeronautics *www.mustangaero.com*	Midget Mustang	1	202	175	57	●	●		$25-40k
	Mustang II	2	225	220	58	●	●		$40-75k
National Aeronautics Co. *www.cassutt.lornet.com*	Cassutt IIIM	1	225	190	65	●	●		$25-40k
Norman Aviation Int'l Inc. *www.normanaviation.ca*	Mini Explorer Nordic 8	2	110	90	35	●	●	●	$60k
	Norman VI-912	2	110	103	34	●	●		–

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


The Cassutt wing and tail kit includes these welded structures, but not much else. You'll need covering material and other items to convert these frames into usable parts. *(Photo: Paul Dye)*

you knew it, you were in final assembly, and the step says, "Install the wing." Well, not literally—but indeed, there was much less detail as you went along. The latest offerings from the same company, however, maintain a level of detail throughout, from start to finish. There are builders who have completed fine aircraft who, before they started, had barely changed the oil in their cars. Remember—this is about education—and it shows.

Many of the companies that you find listed in these pages offer very complete kits. But most still require you to buy your own paint, fluids, battery, and upholstery. Frankly, this is good for the builder because paint dries out—and many have their own ideas on what they want for the interior. There are kits that come with complete avionics packages, and builder forums are full of comments that indicate that builders would rather have this, or that, instead—so it's a no-win problem for the kit company.

Some kit companies have chosen an interesting middle-of-the-road stance on completeness. Sonex, for instance, offers complete kits with pre-punched parts and matched-hole construction, yet they leave out most of the standard hardware you need to complete the project. They provide plenty of rivets, but no nuts or bolts. Why? Because of financial efficiency. Instead of keeping a huge variety of aircraft-grade hardware in stock (an expensive prospect for any small business), they provide a complete list of hardware needed for each kit to companies that do have a complete inventory of such hardware—like Aircraft Spruce or Wicks. The builder goes to these suppliers who can provide a complete hardware package based on Sonex's list. Since Sonex tells the customer up front in their cost estimator how much the hardware will cost, there is no misrepresentation here. It is efficient for everyone involved, since a large company can use their economies of scale to provide the hardware at a lower cost than the smaller company can.

What's Not Included?

Many plans and kits have traditionally stopped at the firewall, with little more than a suggestion to "Hang the engine here, and build a cowl around it." Take a look at a complete set of plans and what the kit offers in the way of firewall-forward instructions and materials. If you have been working on airplanes much of your life, you can probably gin up what you need pretty easily. If the extent of your experience with aircraft powerplants is to check the dipstick to see that there's oil, you might want to reconsider certain kits—or at least find a buddy that knows their way around a Lycoming or Continental to help out when it comes time.

Regardless of the level of completeness, expect that you, as a builder, will be doing some purchasing. Even if that kit company provides the oil for the engine, you'll be finding things that you want to change or upgrade. Buying avionics when you open the first big boxes is probably not a great idea anyway. The radios could easily be obsolete before you plug them in for the first time, and warranties often are based on purchase date—not the date the equipment is put into use.

The best thing you can do when shopping for an airplane is to research the level of completeness. Ask those who are already building how many times they order extra parts each month—or week. Get an idea what you are in for. There is no right or wrong here—just differences in philosophy (and capability) between manufacturers as to what will work best for them and their customers. Remember, it's important to be comfortable with your kit company's style of business because you are going to be married to them for as long as you are building and flying their aircraft. Get confortable with whatever you choose—and then build on!

—Paul Dye


Osprey 2


Pazmany PL-9 Stork


Phoenix Hawk Sport


Pietenpol


Pipistrel Virus

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Norman Aviation Int'l Inc. *www.normanaviation.ca*	Norman VI-912-SW	2	140	103	34	●	●	●	$45k
	Norman VI-914	2	135	115	34	●		●	$55k
Northbrook International	SportStar	2	129	121	45	●			–
NuVenture Aircraft *www.nuventureaircraft.com*	Questair Venture	2	305	276	70	●			$130-250k
nV Aerospace *(was Rand-Robinson Engineering, Inc.)* *www.nvaero.com*	KR-1	1	200	165	52		●		$9-15k
	KR-2	2	200	165	52	●	●		$12-24k
	KR-2S	2	200	170	52	●	●		$21-28k
Orion Aviation *www.orionaviation.cc*	Orion-TS	6	325	300	70	●			–
Orlando/Sanford Aircraft *www.airplane4sale.com*	Pioneer 200	2	108	100	34	●			–
Osprey Aircraft *www.ospreyaircraft.com*	GP-4	2	250	240	65	●	●		$50-68k
	Osprey 2	2	140	130	58	●	●		$25-35k
Pacific Aerosystem, Inc. *www.skyarrowusa.com*	P92-2000 RG	2	155	142	38	●			–
	P92-S Echo Super	2	146	130	37	●			–
	P96-Golf	2	149	133	38	●			–
	Sky Arrow 1450L	2	110	98	40	●			–
Partenair Design Inc.	S45 Mark II	2	180	160	55	●			–
	S45 Mystere	2	175	160	55	●			–
PAW	Free Spirit MkII	3	285	250	52	●			–
Paxman's Northern Lite Aerocraft	Viper	2	130	115	38	●			–
Pazmany Aircraft Corp. *www.pazmany.com*	Pazmany PL-1	2	120	115	54		●		$28-40k
	Pazmany PL-2	2	138	119	52		●		$29-45k
	Pazmany PL-4A	1	120	97	39		●	●	$18-25k
	Pazmany PL-9 Stork	2	116	104	33		●		$28-45k
Phantom Aeronautics LLC *www.phantomaeronautics.com*	Phantom X1	1	65	57	26	●		●	–
	X-1e (enclosed cockpit)	1	80	65	30	●		●	–
Phoenix Manufacturing, LLC *(was CGS Aviation)* *www.cgsaviation.com*	Hawk Arrow	1	90	75	35	●		●	$21-28k
	Hawk Arrow II	2	100	80	45	●		●	$24-28k
	Hawk Classic	1	80	65	35	●		●	$18-26k
	Hawk Plus	1	100	85	40	●		●	$21-28k
	Hawk Sport	1	90	75	35	●		●	$19-26k
	Hawk Ultra	1	63	55	27	●		●	$17-19k
Pietenpol Aircraft Company *www.pietenpolaircraftcompany.com*	Pietenpol Air Camper	2	100	80	40		●	●	$6-16k
	Sky Scout	1	70	55	35		●	●	$4-16k
Pipistrel-USA *www.pipistrel-usa.com*	Apis Bee	1	138	52	36	●		●	$67-76k
	Apis Bee Electro	1	138	52	36	●			$67-76k
	Sinus	2	149	136	39	●		●	$82-100k
	Taurus	2	138	84	39	●		●	$82-100k
	Taurus Electro	2	138	84	39	●			$82-100k
	Virus	2	155	140	40	●		●	$82-100k
	Virus SW (Short Wing)	2	138	138	39	●		●	$80-100k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Piuma Twin Evolution


Pro-Composites Personal Cruiser


Quad City Ultralights Challenger II

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Piuma Project (Tiziano Danieli) *www.piumaproject.com*	Piuma Evolution	1	72	62	35		●	●	$4-5k
	Piuma Motorglider	1	59	50	30		●	●	$4-5k
	Piuma Tourer	1	93	84	39		●	●	$4-5k
	Piuma Twin Evolution	2	103	92	44		●	●	$6-7k
Plane Perfection BRM *www.planeperfection.com*	LA582	2		90	25	●		●	$40-55k
	LA912	2		96	25	●		●	$46-60k
Pop's Props	Cloudster	1	60	50	22	●	●		–
	Pinocchio	1	70	60	27	●	●		–
	Zing	1	70	55	26	●	●		–
Preceptor Aircraft Company *www.preceptorair.com*	N-3 Pup	1	63	60	27	●	●	●	$18-19k
	Stinger	1	90	80	35		●	●	$22-26k
	STOL King	2	115	90	15	●	●	●	$38-45k
	Super Pup	1	90	80	35	●	●	●	$25-27k
	Ultra Pup	2	105	80	35	●	●	●	$32-33k
Precision Aero Engineering, LLC *www.precisionaeroeng.com*	S-51D Mustang	2	360	300	70	●			–
PrecisionTech Aircraft *www.fergy.net*	Fergy F-II B	2	90	80	28	●			–
PRIMAC ind. e com. ltda	Moskitto M-10	1	73	61	30	●			–
Pro-Composites Inc. *www.pro-composites.com*	Personal Cruiser	1	168	140	58	●			$19-29k
	Vision	2	207	155	55		●		$30-50k
	Vision EX	2	207	157	54		●	●	$30-40k
Produits Aviatech Inc. *www.produitsaviatech.com*	Super Cyclone	4	175	165	38	●			$150-200k
Progressive Aerodyne, Inc. *www.searey.com*	Searey	2	120	95	38	●		●	$60-90k
Prowler Aviation, Inc.	Prowler Jaguar	2	300	250	65	●			–
Pulsar Aircraft Corporation *www.pulsaraircraft.com*	Pulsar 150	2	190	175	55	●			$80-110k
	Pulsar III	2	175	150	50	●			$75-110k
	Sport 150 Taildragger	2	200	185	55	●			–
	Super Cruiser	4	190	175	55	●			$100-140k
	Super Pulsar 100	2	190	165	63	●			$85-110k
Quad City Ultralights Aircraft Corp. *www.quadcitychallenger.com*	Challenger II	2	90	75	30	●		●	$16-23k
	Challenger II CW LSS	2	110	95	37	●		●	$22-27k
	Challenger II LSS XL-65	2	100	90	32	●		●	$32-32k
	Challenger II Special	2	100	85	37	●		●	$19-23k
	Challenger Light Sport XS-50	2	120	95	32	●		●	$22-28k
	Challenger Special	1	105	90	28	●		●	$16-22k
	Challenger UL-103	1	90	75	25	●		●	$14-16k
Quicksilver Manufacturing Inc. *www.quicksilveraircraft.com*	GT 400	1	61	58	27	●		●	$19-22k
	GT 500	2	97	83	42	●		●	$30-55k
	MX II Sprint	2	55	51	27	●		●	$20-29k
	MX Sport	1	59	49	27	●		●	$16-18k

Information based on manufacturer-supplied data. All speeds are in mph.

**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Quicksilver GT400


RANS S-7S Courier


Raven 2XS


Ravin 500RG


Richard Steeves Coot Amphibian

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Quicksilver Manufacturing Inc. *www.quicksilveraircraft.com*	MX Sprint	1	54	54	24	●		●	$15-17k
	MXL II Sport	2	61	59	32	●		●	$21-29k
	Sport 2S	2	69	59	35	●		●	$24-40k
Quikkit Div. of Rainbow Flyers, Inc.	Glass Goose	2	140	140	42	●			$55-80k
R & B Aircraft *www.bearhawkaircraft.com*	Bearhawk (plans)	4	142	130	42		●		$24-40k
	Bearhawk LSA	2	140	125	30		●	●	$60-75k
	Bearhawk Patrol	2	156	140	35		●		$22-40k
R. J. Grega Enterprises LLC *www.gregagn-1.com*	GN-1 Aircamper	2	115	87	25		●		–
R&D Aerosports LLC *www.rdaerosports.com*	Legallight	1	63	50	25	●		●	–
R&D Aircraft	Keleher JK-1 Lark	1	145	135	57		●		–
Raceair Designs	Mong Sport	1	125	105	58		●	●	$7-16k
	Skylite	1	60	47	27		●	●	$6-18k
	Zipster	1	60	52	27		●	●	$6-12k
Rainbow SkyReach (Pty) Ltd. *www.fly-skyreach.com*	BushCat	2	125	100	35	●		●	$55-58k
RANS Designs, Inc. *www.rans.com*	RANS S-10 Sakota	2	130	125	48	●		●	$34-44k
	RANS S-12XL Airaile	2	100	90	35	●		●	$25-45k
	RANS S-12XL Super Airaile	2	103	90	35	●		●	$27-48k
	RANS S-14 Airaile	1	90	85	36	●		●	–
	RANS S-16 Shekari	2	172	160	58	●			–
	RANS S-17 Stinger	1	78	60	28	●		●	–
	RANS S-18 Stinger II	2	90	85	43	●		●	–
	RANS S-19 Venterra	2	150	136	45	●		●	$50-55k
	RANS S-20 Raven	2		112	33	●		●	–
	RANS S-4/5 Coyote	1	80	70	27	●		●	–
	RANS S-6ES Sport Wing Coyote II	2	130	110	36	●		●	$43-46k
	RANS S-6S Coyote II Sport Wing	2	130	115	36	●		●	$43-46k
	RANS S-6S Super Coyote II	2	130	115	36	●			–
	RANS S-7 Courier	2	130	118	41	●			–
	RANS S-7S Courier	2	130	110	33	●		●	$47-52k
	RANS S-9 Chaos	1	130	120	43	●		●	$30-40k
	RANS S-9 Chaos	1	106	100	41	●		●	–
Raven Aircraft Corp. *www.ravenaircraft.com*	Raven 2XS	2	200	188	60	●	●		$70-150k
Ravin Aircraft USA, Inc. *www.ravinaircraftusa.com*	Ravin 500 RG	4	242	220	62	●			$150-250k
Redfern Plans	Redfern Fokker DR1	1	120	100	40		●		$70-100k
	Redfern Nieuport 17 or 24	1	120	100	45		●	●	$70-100k
Refly, Inc.	Pelican	3	98	86	40	●			–
Replica Plans	SE5A Replica	1	110	85	40		●	●	$5-15k
Richard Steeves *www.coot-builders.com*	Coot Amphibian	2	140	110	50		●		$25-50k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Rocky Mountain Wings Ridge Runner III


SAM LS


Sky Classic Smith Miniplane 2000

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Rihn Aircraft Corp. *www.members.aol.com/danrihn*	Rihn DR-109	2	225	168	66	●			–
Robbins Wings *www.robbins-wing.com*	R-7	1	63	60	30	●		●	–
	R-8	1	63	60	30	●		●	–
	R-9	1	130	100	30	●		●	–
Rocky Mountain Wings, LLC *www.realflying.com*	Ridge Runner Model II	1	110	90	29	●		●	$17-19k
	Ridge Runner Model III	2	100	80	28	●		●	$18-28k
	Ridge Runner Model IV	2	110	100	35	●			$26-38k
	Ridge Runner Ultralight	1	62	58	24	●		●	$17-18k
Rogue Air Parts *www.flysquirrel.net*	M-19 Flying Squirrel	1	80	75	38		●	●	$4-10k
Ron Sands Replicas *www.ronsandsreplicas.com*	Fokker DR1	1	120	110	42		●	●	–
	Primary Glider, 1929	1	45	38	30		●	●	–
Rutan Aircraft Factory (RAF) *www.scaled.com*	Defiant	4	216				●		–
	Long EZ	2	185	144			●		–
	Quickie	2	180	140			●		–
	Vari EZ	2	195	165	55		●		–
	VariViggen	2	165	150	48		●		–
S.G. Aviation America Inc. *www.sgaviation.com*	Rally 105	2	149	134	34	●			–
	Sea Storm Z4	4	165	144	46	●			–
	Storm 300	2	163	148	32	●			–
	Storm 400	4	180	170	44	●			–
	Storm 500	4	180	172	48	●			–
	Storm Century	2	178	173	34	●			–
	Storm RG	2	178	173	34	●			–
SAM Aircraft *www.sam-aircraft.com*	SAM LS	2	155	125	42	●		●	$50-65k
Sapphire Aircraft Australia Pty Ltd *www.users.bigpond.com/stevendumesny*	Sapphire	1	112	98	42	●			–
Sauser Aircraft Inc.	P6E Replica (82%)	2	145	130	50		●		–
Seaflight (NZ) Ltd. *www.seaflight.co.nz*	Shearwater	4	165	155	57	●			–
SeaStar Aircraft Inc. *www.seastaraircraft.com*	SeaStar	7	275	260	59	●			–
Seawind/SNA, Inc. *www.seawind.net*	Seawind 2500	4	187	178	59	●			–
	Seawind 3000	5	200	191	59	●			–
Sequoia Aircraft Corp. *www.seqair.com*	F.8L Falco	2	212	190	62	●	●		$130-170k
Sherpa Aircraft *www.sherpaaircraft.com*	K650T	8	235	197	37	●			$995k-1.1M
Shirl Dickey Enterprises	E-Racer MK-I	2	240	220		●	●		–
Siers Flight Systems, Inc	Barracuda	2	205	200	62		●		$45-120k
Silence Aircraft GmbH *www.silence-aircraft.de*	Twister	1	146	145	47	●			$65-90k
Sky Classic Aircraft *www.skyclassic.net*	Smith Miniplane 2000	1	135	125	60		●		$7-25k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Sky Raider Frontier


SlipStream Revelation


Sonex Onex


Sport Performance Panther


Steen Skybolt

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Sky Raider LLC *www.skyraiderllc.com*	Frontier	2	75	105	38	●		●	$35-45k
	Sky Raider II	1	85	80	32	●		●	$22-30k
	Super Sky Raider	2	95	80	32	●		●	$24-32k
Sky Ranger Aircraft Company, Inc. *www.skyrangeraircraft.com*	SkyRanger II	2	116	105	36	●		●	$25-50k
	SkyRanger SS	2	116	100	33	●		●	$25-50k
SkyCraft International Inc. *www.arv-super2.com*	ARV Super2	2	137	115	58	●			–
Skyline Technologies	Sparrow II	2	130	95	36	●		●	–
	Sparrow II XTC	2	115	110	39	●		●	$40-45k
	Sparrow Sport Special	1	100	85	31	●		●	$28-32k
	Sparrow Ultralight	1	63	58	27		●	●	$8-12k
Skypaths Inc. *www.skypaths.net*	Pathmaker JK-05	2	128	110	42	●			–
SlipStream International **(Slip Stream International LLC)** *www.slipstream.bz*	Genesis	2	100	75	40	●		●	$28-32k
	Revelation	2	90	66	37	●		●	$22-32k
	Scepter	1	85	60	27	●		●	–
	Ultra Sport	2	100	70	40	●		●	$28-32k
SLO Air Inc. *www.sloair.com*	NXT	2	375	345	88	●			$250-450k
Sonex Aircraft, LLC *www.sonexaircraft.com*	Onex	1	155	135	45	●		●	$27-40k
	Sonex	2	150	130	40	●	●	●	$29-40k
	SubSonex Personal Jet	1	240	220	58	●			$135-150k
	Waiex	2	130	130	40	●		●	$30-40k
	Xenos Sport Motorglider	2	120	100	44	●		●	$35-50k
Specter Aircraft, Inc.	Specter II	2	170	140	54	●			–
Spencer Aircar	Spencer Air Car	4	155	140	53		●		–
Sport Aircraft Works LLC *www.sportaircraftworks.com*	Dynamic WT9	2	155	150	37	●			$85-95k
	Dynamic WT9 RG	2	178	168	37	●			$95-110k
	Mermaid	2	132	115	40	●			$80-95k
	Parrot	2	138	132	28	●		●	$70-90k
	Sport Cruiser	2	160	133	34	●			$55-70k
Sport Performance Aviation LLC *www.flywithspa.com*	Panther	1	170	138	51	●		●	$28-50k
Sportair Aviation, Inc. *www.sportairaviation.com*	Corsario MK-5	2	100	85	42	●		●	$45-60k
	ML500	2	80	65		●			–
SportairUSA, LC *www.sportair.aero*	Sting Carbon	2	190		43	●			–
Sportflight Aviation *www.sport-flight.com*	Talon Magnum	1	105	80	38	●		●	$22-31k
	Talon XP	2	95	72	41	●		●	$23-35k
St-Just Aviation International Inc. *www.supercyclone.com*	Super Cyclone	4	175	165	38	●			–
St. Croix Aircraft *www.stcroix.50webs.com*	Pietenpol Aerial	2	110	85	40		●		–
	Pietenpol Aircamper	2	90	75	40		●		–
	Sopwith Triplane (1916)	1	120	100	40		●		–

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Supermarine MK26B Spitfire


Tapanee Levitation 2


Team Mini-Max Aeromax

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Starflight Industria Aeronßutica LTDA *www.starflight.com.br*	Fox V5 Advanced/ V5 Super	2	84	75	35	●			–
	Fox V5 Tandem	2	80	75	34	●			–
	Fox Vector V6	2	90	78	35	●			–
Steen Aero Lab, Inc. *www.steenaero.com*	Firebolt	2	214	170	61		●		$40-105k
	Great Lakes Sport Trainer	2	138	125	40		●		$50-120k
	Knight Twister	2	180	145	56		●		$25-90k
	Pitts S1-C	1	200	154	64		●		$25-75k
	Skybolt	2	210	170	68		●		$35-100k
Stewart Aircraft Co. *www.stewartaircraft.com*	265/275	2	130	90	43	●		●	–
	FooFighter	1	120	115	48		●	●	–
	Headwind B	1	90	85	40		●	●	$10-35k
Storch Aviation Australia Pty Ltd *www.storch.com.au*	Slepcev Microlight Storch	2	85	78	27	●			–
	Slepcev Storch	2	85	78	25	●			–
	Slepcev Storch Moose	4	118	100	35	●			–
	Slepcev Super Storch	2	100	90	29	●			–
Sunshine Aero Composites *www.saci.us*	Dart	2	200	160	65		●		$15-30k
Super-Chipmunk Inc. *www.super-chipmunk.com*	Super Chipmunk	2	180	160	60	●			–
Supermarine Aircraft LLC *www.supermarineaircraft.com*	Mark 26B Spitfire	2	253	187	51	●			$230-260k
	Mk 26 Spitfire (80% or 90% Scale)	2	220	180	48	●			$130-145k
Swick Aircraft	Swick T	2	140	130	42		●		–
Tapanee Aviation Inc. *www.tapanee.com*	Levitation 2	2	125	115	35	●			$60-170k
	Levitation 4	4	130	120	38	●			$65-180k
	Pegazair 100	2	115	105	28	●	●		$45-125k
	Pegazair 80	2	110	95	15	●			–
Taylor, T. *www.taylortitch.co.uk*	Taylor Monoplane	1	115	100	40		●	●	$9-11k
	Taylor Titch	1	200	160	52		●		$11-15k
Team Mini-Max LLC ***(was JDT Mini-Max LLC)*** *www.teammini-max.com*	1030R MAX 103 Ultralight	1	62	55	26	●	●	●	$8-10k
	AeroMax	1	100	75	33	●	●	●	$12-14k
	Enclosed Cockpit, 1300Z	1	100	75	31	●	●		–
	Enclosed Cockpit, 1600R	1	75	72	28	●	●	●	$7-9k
	Enclosed Cockpit, 1650R Eros	1	80	75	33	●	●	●	$10-12k
	Hi-MAX, 1700R	1	75	70	31	●	●	●	$7-10k
	MAX-103 1030H	1	90	55	27	●	●		–
	Mini-MAX, 1100R	1	75	65	31	●	●	●	$8-10k
	Open Cockpit, 1200Z	1	100	65	31	●	●		–
	Open Cockpit, 1500R	1	75	65	31	●	●	●	$8-10k
	V-MAX, 1550V	1	85	75	38	●	●	●	$8-10k
Team Rocket Aircraft *www.teamrocketaircraft.com*	F-1 Evo	2	265	235	50	●			$90-175k
	F-1 Rocket	2	257	230	56	●			$70-175k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

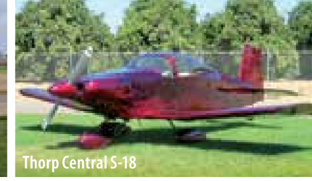
For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.

Team Tango Tango XR

Thatcher CX4

The Airplane Factory Sling 4

The Light Aircraft Company Sherwood Ranger ST



Thorp Central S-18

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
TEAM Tango *www.teamtangoaircraft.com*	Foxtrot 4	4	260	220	62	●			$100-180k
	Tango	2	276	207	70	●			$57-150k
	Tango XR	2	276	207	70	●			$60-150k
Thatcher Aircraft Inc. *www.thatchercx4.com*	Thatcher CX4	1	130	125	40		●	●	$12-18k
The Airplane Factory *www.airplanefactory.com*	Sling 2	2	155	132	45	●		●	$65-80k
	Sling 4	4	161	138	54	●			$80-100k
The Butterfly Aircraft L.L.C. ***(The Butterfly LLC)***	Banty	1	60	50	27				–
The Light Aircraft Company Ltd. (TLAC) *www.g-tlac.com*	Sherwood KUB	1	99	64	25	●		●	–
	Sherwood Ranger ST	2	90	70	38	●		●	$45-69k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.

Shopping for a Second-Hand Project

Bargains are out there, but do your homework before writing a big check.

Buying a new kit from the factory is easy, but the convenience comes at a price. Bargain shoppers can save some cash by looking for an orphaned kit or one that's been started and abandoned. It's not unusual for a kit to change hands several times before the project is completed. Life gets in the way, mission requirements change, or people realize they've bitten off more than they can chew.

Sadly, the labor invested into an unfinished project rarely adds value. Projects are typically sold for the parts value (or less), and poor workmanship will reduce the price further. A patient buyer with time to inspect and research before purchasing can get a good deal.

As with any kit purchase, define the mission first. If you only have access to a 1000-foot grass strip next to the house, a canard-pusher that requires 2500 feet of paved runway will not be a good buy unless it comes with an engine or instruments that can be used, and you can resell the remainder of the project. However, ancient instruments may not be worth anything, and engines that have been sitting for a long time may need an expensive teardown.

Once you've identified the models that fit your mission, scour the classifieds. Bookmark the web sites for Barnstormers, Trade-a-Plane, EAA chapters, KITPLANES®, and builders' associations and visit them daily. Put the word out you're looking for a project, and you may get someone from "thinking about it" to actually offering their kit for sale.

Kits still being marketed by the manufacturer will command a higher price than discontinued ones or those from companies that have gone out of business. Even though a model may no longer be available from the factory, the manufacturer may still be offering parts and support. This is where your diligent research comes in. As you're looking at classified ads, look at manufacturers' web sites, builders' associations, and online forums dedicated to the particular model you want—there you will quickly learn how good the support is and whether parts are still available. These things change and suppliers go out of business without notice, so be sure the information you're getting is current.

With plansbuilt projects there is less worry about parts availability, but support from the designer, other builders, and sub-assembly

Transporting the kit home by yourself is not rocket science, but be sure to understand your limits and your insurance policy.

Try to inventory all parts before the purchase. It may save you headaches and money if you bring the kit home and discover it is missing a box of parts.


Thunder Mustang


Thunderbird Hiperlight SNS-9


Titan T-51 Mustang LSA

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
The Light Aircraft Company Ltd. (TLAC) *www.g-tlac.com*	Sherwood Ranger XP Aero	2	90	70	40	●		●	$40-60k
	Sherwood Scout	2	132	92	39	●		●	$37-58k
Thorp Central ***(Classic Sport Aircraft)*** *www.thorpcentral.com*	S-18	2	215	180	63	●	●		$30-45k
Thunder Mustang LLC ***(Gut Works, LLC)*** *www.thundermustang.com*	Thunder Mustang	2	375	345	68	●			$350k
Thunderbird Aviation, Inc. *www.hiperlightaircraft.com*	Hiperlight SNS-8	1	93	58	27	●		●	$19-30k
	Hiperlight SNS-9	2	113	85	39	●		●	$30-50k
Titan Aircraft *www.titanaircraft.com*	T-51 Mustang	2	170	150	42	●			$80-100k
	T-51 Mustang - V6	2	197	175	48	●			$80-150k
	T-51 Mustang LSA	2	170	140	42	●		●	$80-100k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Most projects start with the tail, and this is where many end, once the first-time builder realizes it's beyond his or her skills and offers the kit for sale.


Peek inside the wings and control surfaces to assess the workmanship and determine if good construction practices were followed.

suppliers can make the difference between a project that languishes under layers of dust and one that gets completed.

Support from a builders' group is one of the most valuable elements in your project's life—during construction and after. An active community of builders and owners will help you get through the steps that leave you scratching your head. You will learn about maintenance issues and solutions that never made it into the construction manual. Being part of a builders' association is almost like having an extended support team.

Solicit the advice of those who have built the model you've set your eyes on, and bring an expert with you to help with the pre-purchase inspection. Ideally, you should make a parts inventory and determine if what's missing can still be obtained or if you'll have to fabricate it. Check out the workmanship and find out who did the work. Logs and notes can be tremendously helpful later, so be sure to review and get them if they're available. Having an expert with you will be especially helpful if the original builder is no longer around, and the family member selling the kit can't offer much guidance.

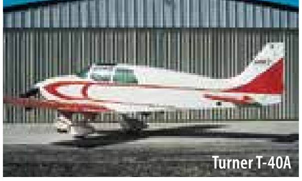
You will be applying for a repairman's certificate, so learn as much as possible about the already completed sections. In his regular KITPLANES® column, "Ask the DAR," Mel Asberry has explained the process and legalities of registering a homebuilt when more than one person performed the work. You'll be happy to know that it's generally easy to do.

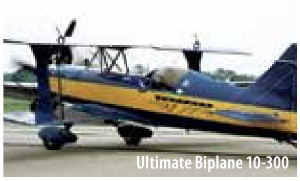
Depending on the project's stage of completion, getting it home could prove challenging. Check with companies that specialize in aircraft transport, freight companies, and services like *UShip.com*. If you don't mind driving a truck or pulling a trailer, doing it yourself is an option. You can rent a truck or a trailer with a box big enough for most projects. You can also purchase a trailer and sell it after you're done. Be sure to check with your insurance company about coverage while in transport.

When your new (to you) project is safely in your shop, start from the beginning of the plans or construction manual and understand and retrace the steps the previous builder(s) took to get it to its current state. You will be responsible for obtaining the airworthiness certificate and for maintenance, so it will be in your interest to know the aircraft inside out regardless of your starting point.

—Omar Filipovic


Titan Tornado S Model


Turner T-40A


Ultimate Biplane 10-300


Van's RV-4


Velocity V-Twin

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Titan Aircraft *www.titanaircraft.com*	Tornado I Sport	1	113	95	30	●		●	$20-35k
	Tornado II FP	2	120	100	40	●		●	–
	Tornado II Trainer	2	150	110	35	●		●	$35-45k
	Tornado MG	1	130	100	35	●		●	$16-25k
	Tornado MG II	2	150	120	35	●			–
	Tornado S Model	2	150	125	35	●		●	$35-50k
	Tornado SS	2	150	125	40	●		●	$38-60k
Toxo Aircraft North America *www.mytoxo.com*	Toxo Sportster	2	180	175	40	●			–
Turbine Design	TD-2	2	400	330	65	●			–
Turner Aircraft, Inc. *www.turnert-40airplanes.com*	T-40	1	170	145	45		●		$8-20k
	T-40A	2	160	147	56		●		$12-30k
	T-40A Super	2	175	155	62		●		$20-35k
U.S. Aviation *www.ultralight-soaring-aviation.com*	Cumulus	1	90	75	32	●		●	$12-19k
Ullmann Aircraft Company *www.ullmannaircraft.com*	Panther	4	200	200	67	●			$100k
Ultimate Biplane Corp. *www.ultimatebiplane.com*	10-100	1	190	140	55	●	●		–
	10-200	1	190	170	60	●	●		$60-90k
	10-300	1	195	190	60	●	●		$95-190k
	20-300	2	200	190	58	●	●		$108-213k
Ultravia Aero Int'l Inc. *www.ultravia.ca*	Pelican PL	2	155	145	49	●			–
	Pelican PL/912S	2	140	130	50	●			–
	Pelican Sport	2	132	126	44	●			–
Unger, Carl H	Breezy R.L.U.-1	3	105	80	28		●		$8-12k
Van's Aircraft, Inc. *www.vansaircraft.com*	RV-10	4	208	197	63	●			$95-121k
	RV-12	2	135	131	52	●		●	$65-70k
	RV-14	2	205	195	53	●			$75-95k
	RV-3	1	207	196	51	●			$35-63k
	RV-4	2	204	192	51	●			$37-73k
	RV-6/6A	2	210	199	49	●			–
	RV-7/7A	2	216	206	51	●			$41-97k
	RV-8/8A	2	222	212	51	●			$41-98k
	RV-9/9A	2	196	188	50	●			$44-82k
Velocity, Inc. *www.velocityaircraft.com*	Velocity Elite RG	4	230	210	70	●			–
	Velocity SE-FG	4	175	184	70	●			$70-140k
	Velocity SE-RG	4	190	200	72	●			$75-150k
	Velocity SUV	4	183	175	65	●			–
	Velocity TXL-RG-5	4	290	288	72	●			$175-250k
	Velocity V-Twin	4	230	207	82	●			$235-400k
	Velocity XL-FG	4	207	213	75	●			$110-180k
	Velocity XL-FG-5	5	190	200	75	●			$110-185k

Information based on manufacturer-supplied data. All speeds are in mph.

**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Vintage UltraLight J3-JR


Wag Aero Sport Trainer


WAR Aircraft F-4U Corsair

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Velocity, Inc. *www.velocityaircraft.com*	Velocity XL-RG	4	210	219	75	●			$125-195k
	Velocity XL-RG-5	5	215	230	75	●			$125-195k
Velox Aviation Inc. *www.veloxrev.com*	Rev1, Rev2	2	230	200	63	●			–
Viking Aircraft *www.vikingaircraft.com*	Cygnet SF2-A	2	110	100	48		●	●	$14-16k
Vintage UltraLight Association *www.vula2.org*	Betabird	1	80	80	45		●	●	$2-5k
	Gypsy	1	55	45	22		●	●	$2-5k
	J3-JR	1	55	45	25		●	●	$2-4k
	Mr. Easy	1	63	50	28		●		–
	MW-7	1	85	55	35		●	●	$2-5k
	Skypup	1	69	50	26		●	●	–
	Whing Ding	1	45	35	24		●	●	$2-5k
	Woodhopper	1	40	30	18		●	●	$2-5k
Viper Aircraft Corp. *www.viper-aircraft.com*	ViperJet Mk II	2	538	400	88	●			$650-795k
VSR *www.snoshoo.com*	SR-1 Snoshoo	1	260	200	65		●		$15-30k
VSTOL Aircraft Corporation *www.vstolaircraft.com*	SS2000	2	67	50	20	●			–
	SST2000	2	100	60	22	●			$85-105k
VX Aerospace Corporation *www.vxaerospace.com*	FX 300	4				●			–
W.A.C.O. Aircraft Company Ohio, Inc.	WACO M-F	3	140	120	48	●			$120-150k
Wag-Aero Group, The *www.wagaero.com*	Sport Trainer	2	94	85	38	●	●	●	$35-45k
	Sportsman 2+2	4	128	124	38	●	●		$45-60k
	Wag-A-Bond	2	126	124	43	●	●	●	$29-40k
WAR Aircraft Replicas *www.waraircraftreplicas.com*	A6M2-Zero	1	155	135	55		●		$18-24k
	F-4U Corsair	1	155	135	55		●		$18-28k
	F8F Bearcat	1	155	135	55		●		$17-26k
	Focke Wolf 190	1	155	135	55		●		$16-26k
	Hawker Sea Fury	1	155	135	55		●		$16-26k
	Hurricane	1	155	135	55		●		$17-26k
	Messerschmidt BF-109	1	155	135	55		●		$18-24k
	P-40 Warhawk	1	155	135	55		●		–
	P-47 Thunderbolt	1	145	135	55		●		$14-26k
	P-51 Mustang	1	155	135	55		●		$17-26k
Warner Aerocraft, Inc. *www.warnerair.com*	Revolution I/Spacewalker I	1	140	120	38		●		–
	Revolution II/Spacewalker II	2	125	120	42		●		–
	Sportster	2	125	110	43	●		●	$45-55k
Weedhopper, Inc. *www.weedhopperusa.net*	Weedhopper 40	1	60	55	20	●		●	$9-11k
	Weedhopper Standard	1	55	50	25	●		●	$4-10k
	Weedhopper Super	1	65	60	25	●		●	$12-12k
	Weedhopper Two Place	2	65	55	28	●		●	$14k

Information based on manufacturer-supplied data. All speeds are in mph.

**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Wings of Freedom Phoenix 103


World Aircraft Vision


Zenair Zodiac CH 650


Zenith CH 750 Cruzer


Air Command Elite EJ22 Tandem

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Western Aircraft Supplies Ltd.	PGK-1 Hirondelle	2	157	145	55		●		–
Williams, Lynn *www.flitzerbiplane.com*	Flitzer Z-21	1	105	93	42		●	●	$10-25k
Wings of Freedom LLC *www.wingsoffreedomaviation.com*	Flitplane	1	70	63	28	●	●	●	$7-12k
	Phoenix 103	1	75	63	28	●		●	$12-15k
	Spirit	2	143	115	35	●		●	$55-65k
World Aircraft Company *www.worldaircraftco.com*	Spirit	2	125	110	35	●		●	$60-75k
	Vision	2	125	105	27	●		●	$60-75k
World War I Aeroplanes	Fokker D.VII	1	117				●		–
	SE5A	1	136				●		–
York Enterprises *www.yorkaircraft.com*	Laser Z-200	1	180	165	64		●		$30-50k
	Laser Z-2300	2	250	195	60		●		$30-50k
	Ultimate Series	1	220	170	60		●		–
Zenair Ltd. *www.zenair.com*	CH 750 Cruzer	2	118	115	39	●		●	$20-55k
	STOL CH 750	2	105	100	35	●	●	●	$38-65k
	STOL CH 801-HD	4	110	105	39	●			$60-100k
	Zodiac CH 640	4	160	150	47	●	●		$45-100k
	Zodiac CH 650	2	138	138	44	●	●	●	$35-65k
Zenith Aircraft Co. *www.zenithair.com*	CH 750 Cruzer	2	118	118	39	●	●	●	$21-50k
	STOL CH 701	2	100	90	30	●	●	●	$30-50k
	STOL CH 701 Amphib	2	90	74	32		●	●	$38-64k
	STOL CH 750	2	110	100	35	●	●	●	$38-65k
	STOL CH 801	4	125	105	39	●			$40-80k
	Zodiac CH 601 HD	2	135	115	44		●	●	$8-46k
	Zodiac CH 601 UL	2	135	115	44		●	●	$8-45k
	Zodiac CH 650	2	138	138	44	●	●	●	$35-65k
	Zodiac XL	2	138	134	44	●	●	●	$29-60k

Rotorcraft

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
A-B Helicopters	A/W 95	1	65	65			●	●	–
Aero-Works, Inc. *www.aerolite103.com*	Microlight	1		60		●		●	$18k
	Single Place-High Performance	1		65		●		●	$25k
	Two Place Tandem	2		70		●		●	$34k
	Ultralight	1		55		●		●	$16k
Air Command International, Inc. *www.aircommand.com*	Commander Elite 3202	1	75	55		●		●	–
	Commander Elite 447	1	63	50		●		●	–
	Commander Elite 503	1	75	55		●		●	$18-20k
	Commander Elite 582	1	95	65		●		●	$20-23k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Auto Gyro Cavalon


Composite Helicopter KC 518 Adventourer


FD-Composites ArrowCopter AC-20

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Air Command International, Inc. *www.aircommand.com*	Commander Elite 912 Tandem	2	110	75		●		●	$60-75k
	Commander Elite EJ22 Tandem	2	110	75		●		●	$40-60k
	Commander Elite Mazda	2	120	70					–
	Commander Elite S/S F-30	2	84	65		●			–
	Commander Elite Single-Place EJ22	1	95	65		●		●	$30-40k
Aircraft Designs, Inc. *www.aircraftdesigns.com*	Bumble Bee	1	65	40			●	●	$2-5k
	Sportster	2	90	75			●	●	$6-25k
American Sportscopter, Int'l. Inc. *www.ultrasport.rotor.com*	UltraSport 254	1	63	63		●		●	$35k
	UltraSport 331H	1	104	65		●		●	$38k
	Ultrasport 496 RT	2	104	69		●			–
	UltraSport 496H Hornet	2	104	70		●		●	$68k
Auto Gyro USA *www.autogyrousa.com*	Calidus	2	120	100		●		●	$75-78k
	Cavalon	2	120	90		●		●	$96-99k
	MTO Sport	2	120	100		●		●	$60-63k
Aviomania Aircraft *www.aviomania.com*	G1sa Genesis Solo	1	105	80		●		●	$19-27k
	G2sa Genesis Duo	2	120	90		●		●	$35-50k
Barnett Rotorcraft *www.barnettrotorcraft.com*	Barnett J4B	1	120	97		●	●	●	–
	Barnett J4B-2	2	112	93		●	●	●	$19-38k
	BRC540 Coupe	2	138	110		●	●	●	$44-58k
CH-7 Helicopters Heli-Sport S.r.l. *www.ch-7helicopter.com*	CH-7 Angel	1	100	80					–
	CH-7 Kompress	2	129	100					–
Chayair Manufacturing & Aviation *www.limpopo.co.za/chayair.htm*	Sycamore Mk1	2	90	80		●			–
Composite Helicopter International Ltd. *www.compositehelicopter.com*	KC 518 Adventourer	6		155		●			$395k
Eagle R&D, LTD *www.helicycle.com*	Helicycle	1	110	95		●			$40-45k
Eagle's Perch, Inc.	Eagle's Perch	1	113	85		●			–
Engineering System Co., Ltd, Aviation Division	GEN H-4	1	100	60		●			–
FD-Composites GmbH *www.arrow-copter.com*	ArrowCopter AC-20	2	121	90		●	●		$150k
Groen Bros. American Autogyro *www.americanautogyro.com*	SparrowHawk Gyroplane	2	100	75		●		●	$45-60k
Gyro-Kopp-Ters *www.gyro-kopp-ters.com*	Midnight Hawk	1	90	60		●		●	$14-16k
	Mosquito Hawk	1	80	55		●		●	–
	Twin Eagle	2	90	60		●		●	$18-23k
Helo Werks, Inc. *www.helowerks.com*	HX-2 Wasp	2	107	81		●			$125-130k

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


HoneyBee G2 Two-Place Tandem


Innovator Mosquito XE


Little Wing LW-5


Magni M-16


RotorWay A600 Talon

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Hillberg Helicopters	RotorMouse EH 1-01	1	180	160		●	●		–
	Shark Mouse EH 1-02	2	185	145		●	●		–
	Two Place EH 1-02	2	170	130		●	●		–
Hinchman Aircraft Co.	H-1 Racer	1	85	65			●		–
HoneyBee G2, LLC *www.honeybeeg2.com*	HoneyBee G2 High Performance Single	1	75	60		●		●	$25k
	HoneyBee G2 Microlight	1		60		●		●	$18-19k
	HoneyBee G2 Two-Place Tandem	2	85	60		●		●	$34k
	HoneyBee G2 Ultralight	1	63	55		●			$16-17k
I'm Fly'N Mfg. LLC *www.imflyn.com*	SnoBird Charger	1	100	70		●			–
Innovator Technologies *www.innovatortech.ca*	Mosquito Air	1	70	60		●			$30-37k
	Mosquito XE	1	85	70		●			$34-42k
	Mosquito XE3	1	100	80		●			$39-47k
	Mosquito XEL	1	75	65		●			$35-43k
	Mosquito XET	1	100	80		●			$51-58k
JAG Helicopter Group, LLC *www.jaghelicopter.com*	JAG	2	178	145		●			–
Joe Souza Gyroplanes *www.rotorcraft.com/bandit/index.htm*	Bandit Two Place	2	70	40		●			–
	Bandit Ultralight	1	63	55		●			–
	Super Bandit	1	85	65		●			–
Ken Brock Mfg. *www.kenbrockmfg.com*	KB-2 Gyroplane	1	95	70		●	●	●	–
	KB-3 Gyroplane	1	63	60		●	●	●	–
Little Wing Autogyros, Inc. *www.littlewingautogyro.com*	LW 3+2	2	100	75		●	●		–
	LW-3	1	100	75			●	●	$10-40k
	LW-4	2	100	75			●	●	$20-75k
	LW-5	2	100	75			●	●	$20-75k
Magni USA, L.L.C. *www.magnigyro.com*	M-14	2	115	90		●		●	$68-78k
	M-16	2	115	90		●		●	$74-84k
	M-18	1	105	70		●		●	$39k
	M-22	2	115	95		●		●	$85-86k
	M-24 Side by Side	2	105	90		●		●	$97-99k
Neico Aviation Inc.	CH-7 Kompress	2	130	100		●			–
North American Rotorwerks	Pitbull UL	1	63	58		●			–
	Pitbull II	2	88	70		●			–
	Pitbull SS	1	85	70		●			–
PAM Group *www.flying-platform.com*	PAM 100B	1	60	45		●			–

Information based on manufacturer-supplied data. All speeds are in mph.
**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Sport Copter Vortex


The Butterfly Monarch Butterfly


Vortech Hot Rod Helicopter

Homebuilt Aircraft DIRECTORY 2016

Manufacturer/Web Site	Model	Seats	Max Speed	Cruise Speed	Stall Speed	Kit	Plans	LSA Legal	Price
Raven RotorCraft Inc. *www.raven-rotor.com*	Raven Lite	1	65	60		●		●	$16-19k
Rotary Air Force SA Pty Ltd **(Rotary Air Force Marketing, Inc.)** *www.rafsa.co.za*	RAF 2000	2	140	85		●			$70k
	RAF 2000 GTX SE 2.2 FI Gyroplane	2	120	70		●			$27k
	RAF 2000 GTX SE 2.5 FI Gyroplane	2	140	85		●			$31k
Rotor Flight Dynamics *www.rotorflightdynamicsinc.com*	Dominator	1	114	65		●	●		–
	Dominator Tandem	2	95	70		●			$41-45k
RotorWay International *www.rotorway.com*	A600 Talon	2	120	95		●			$105-110k
	Exec 162F	2	115	95		●			$70-75k
Safari Helicopters **(CHR International, Inc)** *www.SafariHelicopter.com*	Safari	2	100	85		●	●		$90-135k
	Safari 400	2	100	85		●	●		$133-185k
Showers Aero	Skytwister	1	80	65			●		–
Sport Copter, Inc. *www.sportcopter.com*	Lightning	1	65	50		●		●	$23-29k
	Sportcopter II	2	120	100		●			$185-218k
	Super Sport	2	120	100		●			$82-105k
	Super Sport Tandem (SST)	2				●			–
	Vortex	1	80	75		●		●	$30-34k
	Vortex M912	1	110	95		●		●	$35-65k
Star Bee Gyros *www.starbeegyros.com*	Star Bee Light	1	65	55		●		●	$15-16k
The Butterfly Aircraft L.L.C. ***(The Butterfly LLC)*** *www.thebutterflyllc.com*	Aurora Butterfly	1	90	70		●		●	$51-58k
	Emperor Butterfly	1	63	55		●		●	$19-26k
	Golden Butterfly	2	95	70		●			$60-70k
	Monarch Butterfly	1	70	60		●		●	$23-31k
	Super Sky Cycle	1	90	70		●		●	$80-87k
	The Ultralight Butterfly	1	63	55		●			–
	Turbo Golden Butterfly	2	95	70		●			$70-86k
	Ultralight Butterfly	1	63	50		●		●	$18-22k
Vertical Aviation Technologies *www.vertical-aviation.com*	Hummingbird 260L	4	120	100		●			$207-215k
	Hummingbird 300LS	4	120	100		●	●		$207-215k
Vortech, Inc. *www.prismz.com/helio*	A/W 95 Helicopter	1	75	60		●	●		$26-32k
	G-1	1	63	50		●	●	●	$17-18k
	Hot Rod Helicopter	1	103	90		●	●		$20-30k
	Kestrel Jet Helicopter	1	63	55		●	●		$18-20k
	New Choppy Helicopter	1	80	65		●	●		$33-36k
	New Choppy Ultralight	1	63	55		●	●		$27-30k
	Shadow Gyroplane	2	100	70		●		●	$28-33k
	Skylark Helicopter	1	95	70		●	●		$34-36k
	The Sparrow	1	63	60		●		●	$9-11k
Zeus Helicopter Inc.	Zeus	2	110	95					–

Information based on manufacturer-supplied data. All speeds are in mph.

**For reference only—not currently available.*

For a side-by-side comparison of models, visit *www.kitplanes.com/aircraftdirectory*.


Aircraft Spruce Cozy Mark IV


Kolb Mark III Xtra


Lancair Legacy


Legend Turbo Legend


Pipistrel Taurus Electro

Buying Your First Homebuilt Aircraft

Building isn't the only path to owning an Experimental aircraft.

Some people dive right into their first homebuilt project. I've known a couple of folks who didn't even have a pilot's license when they started their first build, then went on to complete the project and took their checkride in the plane they built. Other friends of mine started assembling model airplanes in elementary school, graduated to U-control and radio-control kits, and didn't think twice about building the full-scale airplane of their dreams. I'm not one of those people. I slowly crept into the homebuilt world by buying a flying Experimental years before I considered building a plane myself.

There are many good arguments for buying your first homebuilt, especially if you love flying but don't have a passion for building. If the plane you seek is common (à la Van's RV, Sonex, Zenith, etc.), you will be up in the air much sooner, probably spend quite a bit less money than building it yourself, and will not have to sweat the potential headaches of Phase 1. The plane should already be proven airworthy with known characteristics. Most experienced folks in the homebuilt community agree that if you have to ask the question about whether you should buy or build a readily available homebuilt, you should buy. Building requires a passion to successfully complete. For me, there was no question; in 2005, I didn't feel I had the skills, time, or support system available to build my RV. I would buy one—or continue plugging along in the club Cherokee 180.

Research

Just like your high school history teacher told you about writing your big term paper, research is the first step toward a successful project. And, just like that high school project, incomplete, shoddy, or poorly sourced research will likely result in an unsatisfactory conclusion. You will want to find the best sources (the KITPLANES® archive is a great place to start!), investigate all the pertinent issues, and check your emotional preconceptions at the door during this phase of your journey. Once you know the facts, emotions can come back to the forefront as you make a decision.

What are the issues to investigate? Certainly, the type of aircraft you seek will determine the pertinent topics to probe. Some common, generic ones are:

- Will you and the aircraft qualify for insurance coverage? If so, how much will it cost? If not, what will you need to do to qualify for coverage?
- Is formal transition training available for the aircraft? Will your insurance company require such training? Where does it happen? How much will the training cost?
- What is the safety record for the aircraft under consideration? What are the issues causing accidents?
- What engine is recommended and well tested for the aircraft? What is the safety record, maintenance schedule, and maintenance cost of the engine you are considering?
- Is factory/designer support readily available? While you may not be building the aircraft yourself, you are still likely to want to give an occasional call to the factory for help with a problem or to purchase replacement parts.
- What safety bulletins and/or airworthiness directives have been issued by the airframe and engine factories?
- What sort of community support is available to help you? Internet forums? Chat groups? Local builder and/or pilot groups? Are there folks in the local EAA chapter who have useful expertise to help with problems that might come up?
- Unless you are an A&P or you are considering an Experimental Light Sport Aircraft (ELSA), you will want to know if there is a readily available A&P willing to perform annual condition inspections on the Experimental/Amateur Built aircraft that you are considering. (Some A&Ps will not work on Experimentals.) If you are considering an ELSA, learn about the required course that you will need to take to perform your own annual inspections.

Networking

It is never too early to start networking. Find owners and builders of the plane you are considering. Oshkosh, of course, provides a wonderful opportunity to meet the factory folks of the major kit manufacturers and pick their brains. You might be able to arrange an introductory flight in the model you are considering. You'll also meet current owners hanging around the booths and have a chance to talk with them. Then, walk the lines of Homebuilt Camping and Homebuilt Parking, where you'll likely meet more owners and builders of the planes you are pondering. If you are considering one of the less common homebuilts, the folks in Homebuilder Headquarters or, often better, the parking attendants in the homebuilt area (the guys with orange vests racing around on scooters parking homebuilts) can often tell you where to find particular models of homebuilts.

Most of the popular homebuilts have type gatherings. Zenith and SeaRey, for example, bring their tribes into their factories once a year. Information appears on their web sites. The Van's community has several big gatherings throughout the country, generally advertised on *www.vansairforce.net*. Before I bought my first RV, I attended such a gathering and walked the lines of scores of RVs with a knowledgeable friend, learning the different models and some of what differentiated a good build from a shady build.

A&P mechanic Randy Richmond performs a pre-buy inspection. He has had hundreds of RVs pass through his shop, and his eye for finding problems and providing solutions is legendary.


(Left) The original panel in the author's RV-6. While a modern panel or stunning paint job may add the greatest sex appeal to a flying homebuilt, neither is likely to impact flight safety, at least while flown VFR. (Right) The author's updated panel. Panels and paint schemes can be easily changed when funds become available.

Most types, even the more obscure models like the Dream Tundra that we are currently building, have on-line support and chat groups. Many groups assemble on Yahoo or Google. Some use more robust forum software. Vansairforce.net is the granddaddy of such groups, with dozens of postings each day by tens of thousands of subscribers from around the planet.

Many providers of kits and plans offer newsletters, and copies can usually be obtained by prospective builders. A long list of newsletters can be found at the KITPLANES® web site: *www.kitplanes.com/homebuilders-portal/supportgroups.html*.

Of course, you'll also want to check out the local expertise. EAA chapters generally provide a good starting point for finding the folks who know about the model you are considering. In some metropolitan areas, when a critical mass of local builders work on kits from the same manufacturer, independent builder groups form. Look for such groups if you live in a densely populated area.

How to Find the Perfect Plane for You

Before seriously shopping for a plane, identify your mission—your must-haves—and ensure any partners agree to the list. The list might change as you proceed, but start with a list. I initially thought I had to have a nosewheel but, when I couldn't find a good tricycle model in my price range, I re-evaluated and decided a conventional-gear airplane was my future.

In addition to the usual suspects (e.g., Trade-A-Plane, *www.barnstormers.com*, FBO bulletin boards), you can shop for your ideal flying homebuilt through the network you developed in the previous step. Let your new contacts know what you are trying to find, and sellers will likely seek you out. Forum sites and discussion groups often allow free postings of aircraft for sale. The KITPLANES® web site classified page *(www.kitplanes2.com/classifieds)* also provides a free place to advertise flying homebuilts. You can generally post a request to purchase on these sites, too.

Once you've identified an airplane that might fit your needs, the process is nearly identical to purchasing a certified aircraft, and there is abundant information on that process on sites like *www.aopa.org*. One difference with homebuilts is the pre-purchase assessment of the plane. Many successful homebuilt purchasers take an experienced builder of the model (or similar aircraft) with them for the initial look at a plane. A good builder will be able to make an initial assessment of the build quality. Where do you find your builder/helper? Once again, the importance of networking proves itself. But having an experienced builder look at a plane is not a substitute for a pre-purchase inspection by an A&P who is familiar with homebuilt aircraft, unless your builder/helper is also an A&P.

Many, probably most, A&Ps are not experienced with homebuilt aircraft. They may have never worked with fabric or composite materials. You want someone who knows the common pitfalls and issues of the model of plane you are considering. . .or is at least familiar with similar homebuilts. I was very lucky that the RV-6 I wanted to buy was at 52F in Roanoke, Texas, and so was one of the most experienced RV mechanics in the world. Randy Richmond has had hundreds of RVs pass through his shop, and his eye for finding problems and providing solutions is legendary. Randy thoroughly inspected my pending purchase, identified the immediate "must-address" issues, corrected them, and sent me off with a list of issues that wouldn't cause me to fall out of the sky, but should be worked on over the next few years. I knew exactly what I was buying and what future expenses would be coming down the road. I wouldn't purchase another flying homebuilt without a "Randy" making a pre-purchase inspection, even if I had to pay the expenses of flying the person in from another state.

Bringing the Plane Home

Formal transition training is the key to safe flying in your new homebuilt, whether a pre-owned plane or a new build. If you are lucky, as I was, there might be a factory-approved CFI in the area of your purchase to prepare you for the flight home. Or, you might travel to the CFI's base and transition in his plane before bringing the plane home. You might be able to arrange for the seller to fly the plane to an appropriate CFI's base (or your base) for the final sale. Commonly, new owners bring their purchased homebuilt back home with a pilot experienced with the model. A long cross-country after only a few or no hours of experience in a new plane is probably not prudent. I can recite too many terrible accidents that have happened under such circumstances.

Once you have your adopted airplane home and transition training completed, be sure to fly it as often as possible in the first few months to develop experience. If you're like me, you may also start working right away on the list of deferred maintenance items that came out of the pre-purchase inspection. Soon, it will feel like your own plane, and you will feel like a member of the homebuilt community. ✈

—Louise Hose

POLE TO POLE!

Around the world over both poles (part 2).

BY BILL HARRELSON

Visiting the monument honoring Ferdinand Magellan in the main square of Punta Arenas.

These islands, which are part of the Kingdom of Tonga, were the only land the author saw between New Zealand and Hawaii.

There are certainly worse places to be stuck than Punta Arenas. It's quite a pleasant city with friendly folks, good food, and lots to see. After the requisite 72 hours and a lot of work on the part of the ground crew, the permit to fly to Tahiti is in hand. The weather is now somewhat less than desirable, but forecast to get worse and stay bad for an extended period. The key is to get north into warmer air and out of the very strong headwinds that exist in the south.

Another full-weight takeoff—the last I hope to ever make—is required for the 4828 nautical mile, 28-hour northwest bound leg to Tahiti. Headwinds are fierce in the several hours after takeoff—50 to 60 knots right on the nose. This not only slows progress but, over the mountainous terrain northwest of Punta Arenas, creates turbulence. At this weight the autopilot cannot be used. In this turbulence it is not even a consideration. Things just couldn't get worse…unless…yep…ice. Once again, the only choice is a descent into warmer temperatures. This requires circumnavigating the mountainous islands off the western South American coast. I am able to stay over open water with the help of the Garmin 496 with its excellent terrain depiction. Once I reach 500 miles northwest of Punta Arenas, the weather and winds gradually improve. The rest of the night is mostly flown in smooth, above-freezing air. Shortly after sunrise the next morning, the flight is entering the intertropical convergence zone with the expected thunderstorms. Tahiti ATC contacts the ground crew about a SIGMET along my route. The ground crew negotiates a re-route around the worst of the weather and relays that to me via satellite text.

January is the rainy season in Tahiti. Landing there this afternoon requires flying the ILS approach, not exactly what I want to do after a 25½-hour leg, but you do what you have to do. Three barrels of fuel are pumped into 6ZQ, plenty to make New Zealand with large reserves. After a few hours of sleep at the Tahiti Airport Motel, it is time to continue. Although early in the morning and not nearly at full fuel, the hot temperature in Tahiti still makes for a rather unenthusiastic takeoff. No serious weather is encountered from Tahiti to Auckland, where I am able to quickly clear customs and

Adding CamGuard in New Zealand.

Crossing the equator northbound.

Photos: Bill Harrelson and Bigstock

While waiting out the weather, the author visited Dillingham Airport on Oahu.

continue to Hamilton. Total time in Auckland from touchdown to liftoff is 30 minutes. I arrive in Hamilton with plenty of daylight left, about 14 hours after departing Tahiti.

New Zealand to Honolulu

Hamilton Aero Maintenance is a great place to go for general aviation work in New Zealand. Tim O'Neill and Dave Stewart are enormously helpful and competent. We do an oil and filter change, clean spark plugs, replace a broken shear pin in the autopilot pitch servo, repair a broken amperage sensor in the #1 electrical system, and give the airplane a thorough going over. New Zealand is #1 on the places that I want to return to when not on a world record quest. Thanks Tim and Dave for your hospitality and good work.

I depart Hamilton for the 23-minute flight to Auckland, where I clear customs outbound and fuel for the 3825 nautical mile, 21½-hour leg to Honolulu. This is another lethargic takeoff in the warm summer temperatures. A rather severe cluster of thunderstorms is forming over Tonga. The ground crew has an excellent handle on this from satellite and lightning data, and suggest a westward deviation. This works out well and other than an hour or two of moderate turbulence, I am able to proceed without serious problem. That night I cross the equator northbound at 166 degrees 57 minutes west, giving me almost 123 degrees of separation from my southbound crossing. The minimum separation required for the record is 120 degrees. Dawn is just breaking when I begin my descent into Honolulu.

The plan has been to continue from Honolulu directly to Fairbanks, Alaska. I know that this will be a challenging leg weather-wise. While the arctic weather that is expected in Fairbanks will probably be too cold and dry for airframe icing and the weather near Hawaii too warm, the transition from tropical to arctic will likely prove interesting. Making matters worse, a huge low has parked itself in the Gulf of Alaska, pumping large quantities of warm, wet air into Alaska. Fairbanks is reporting the warmest winter in its history. This will produce almost certain serious icing, something that I very much prefer to avoid.

Waiting for Better Weather

After waiting several days for better weather in the north Pacific and Alaska, I decide to fly to the U.S. West Coast and wait out the weather there. Working my way up the coast will provide more options if I need to land. An early evening departure from Honolulu at a relatively light weight into good weather with a bit of a tailwind and no icing

The route flown: 31,118 nautical miles, 24 days, 174.9 hours—lots and lots of ocean with some ice here and there.

Weather off the coast of Alaska.

makes the leg to San Louis Obispo the easiest of the long legs (2145 nautical miles and $11\frac{1}{2}$ hours). I land at KSBP just before dawn and catch an hour of sleep in the pilot's lounge, while I wait for the maintenance shop to open for another oil change.

Two nights in the pleasant town of San Louis Obispo leave me well rested for the flight to Alaska. A pre-dawn departure helps assure a daylight landing in Fairbanks. As expected, ice is the big concern on this leg. The takeoff is made with just 155 gallons on board, well under half capacity. My plan is to climb high early and find temperatures below -4° F (-20° C). The plan works, and even though I am in clouds from northern California through coastal Alaska, I encounter no ice. Plenty of pilot reports of ice are received at the lower altitudes though.

When the route leaves the coast and proceeds inland to the Yukon Territory, the clouds dissipate and leave me with more spectacular views of some very impressive mountains in the Yukon and eastern Alaska. I land at sunset, around 3:30 p.m. in Fairbanks, where I am met by Art Mortvedt. Art is a long-time Alaskan bush pilot and has flown his orange Cessna 185, the *Polar Pumpkin*, to both poles. Art has been very generous in sharing his knowledge of polar flying and weather with me in phone calls that I have made to him. Now he has driven four hours to Fairbanks so he can take me to his favorite Fairbanks restaurant. Thanks Art!

The next morning I'm back at the best FBO in the north, Alaska Aerofuel, ready to go. The weather is good everywhere except right over Fairbanks

Polar Pumpkin pilot Art Mortvedt (left) and the author in Fairbanks.

airport. A layer with tops only to 3000 feet is producing light snow and many reports of icing from everything from a Navajo to a DC-9. Since this will be yet another heavy takeoff with slow climb rates, I cannot take the chance of even a little ice. I need to climb to 10,000 feet within 130 miles of Fairbanks in order to clear the Brooks Range. This will not likely be possible with any ice on the wings. So, after waiting several hours for the weather to improve, I return to the hotel, planning to try again the following morning.

Over the North Pole

The next morning is clear and cold, exactly the weather I have been counting on for Fairbanks. After fueling to 300 gallons, 61 gallons short of full tanks, I depart Fairbanks on the last leg—non-stop to Kinston,

Who is ZQGC?

Any extreme flight needs a ground crew and N6ZQ had a great one, made up of five very busy pilots with international flying experience. Three have airline and general aviation backgrounds, one is a three-time earthrounder, and another is a radio/avionics expert. ZQ Ground Control was ready for the challenge.

For greatest flight coverage and efficiency, several methods were used by ZQGC to communicate. With members located in three states, Skype instant text messaging was the best way for the ground crew to chat amongst themselves during flight monitoring. Real time communication was essential for each leg, particularly when things weren't going smoothly. Sleep and rest schedules were quickly set up, with overlapping coverage by at least two ground crew members, especially at night. The thread could easily be picked up by each person returning from a rest period, and everyone would be up to date at all times. But no one got much sleep.

Bill was unable to retrieve his webmail during the trip, so a Gmail account was set up for him to communicate with ZQGC. This was vital, since it allowed him to email a new flight plan to ZQGC. Bill could plan a flight using Jeppesen FliteStar on his laptop computer, then email the RPK file to home base. There it was loaded into the same Jeppesen flight planning program, printed out, and scanned into a PDF file, then emailed to the rest of the ground crew with updated winds and temperatures.

In addition to four onboard flight recorders, there was also a Spidertracks unit (*www.spidertracks.com*), which allowed flight enthusiasts anywhere to follow Bill everywhere he went. There is a great feature on Spidertracks that was tremendous help to ZQGC: the ability to upload a KMZ file depicting each of Bill's planned routes on a Google Earth image. This really helped the ground crew keep track of estimated versus actual time and fuel at each waypoint on every leg.

ZQGC communicated with Bill using Iridium Go! via text through satellites. It was easy to cut and paste a weather report and send it. Bill would acknowledge by replying with a text or simply sending a "mark" on Spidertracks. If Bill was unable to send a position report via HF radio, he sent the ground crew the information and it was relayed to Oceanic ATC by phone. Bill sent hourly engine readings, indoor/outside temperatures, and oximeter O2/pulse numbers. Using the Go! was the best method for air-to-ground communication with ZQGC.

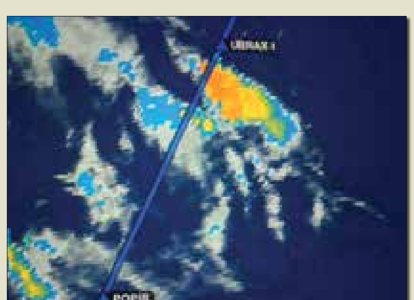
The ground crew was constantly studying weather using the live weather feature on the Jeppesen flight planning program, on satellite images, and especially on ForeFlight. Both FliteStar and ForeFlight depict color satellite images as well as lightning. All of these tools were central in the decision to turn back from the South Pole, to deviate around heavy storms in Polynesia, and to avoid icing over the North Pacific by flying to California instead of directly to Alaska.

One of the ground crew had the brilliant idea to set up and maintain a Facebook page. Even though Bill didn't see it until returning, the updates kept flight followers informed of the latest goings on. It also greatly reduced phone calls and emails to home base, allowing the ground crew there to rest uninterrupted. The home base ground crew was very grateful to the friends and neighbors who appeared at the front door with many trays of prepared meals. Thank you.

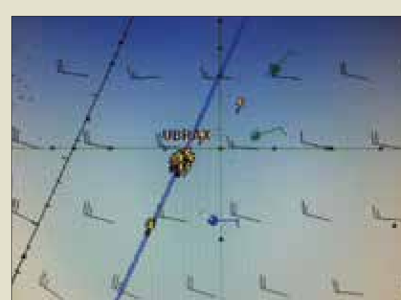
There were bound to be unexpected challenges during this record attempt, and ZQGC had to scramble several times to make alternate plans, search for avgas, get landing permits, arrange customs, and take care of many other things. Nobody got much rest during the 3½ week adventure. There were some very exciting times and other very tense ones lasting hours and hours. Kudos to Bill for having the guts to persevere and succeed!

—Sue Harrelson

KMZ overlay on Google Earth showing N6ZQ at the North Pole.



ForeFlight with route overlay showing the area storms near Tonga. Clearly visible waypoints allowed the ground crew to guide N6ZQ around storms.



Jeppesen FlightStar depicting lightning near Tonga, Flight Information Region (FIR) boundary, and winds at 10,000 feet.

North Carolina via the North Pole. The Brooks Range is a beautiful sight in the early morning light. Once past the Brooks Range, I am able to spot the Alaska pipeline and follow it to Deadhorse. Now, little more than two hours after my sunrise takeoff, I watch the sunset as I pass off the north coast of Alaska into the Arctic Ocean.

There's still enough light for a while for me to see the broken pack ice riddled with leads. I reflect on the possibility of making a landing out here, not very likely to be successful. Perhaps it's best not to put too much thought into that. Eight hours after takeoff, I pass over the North Pole. Now, I just need to finish this flight, only another 3290 nautical miles to Kinston, North Carolina.

With the oil sump temperature still alarmingly low, I'm wondering if I'll ever see increasing temperatures. I'm wondering if I'll ever see daylight. I'm wondering if this record attempt is worth it. After crossing Baffin Island in hour 14, I finally see a little upward movement of the OAT. The temperature has gone from -36° F (-38° C) to -27° F (-33° C). The oil sump temp starts creeping up a little to 80° F (27° C). If this trend continues, I just might make it. The hour 15 readings show yet another degree of oil temp increase and hour 16 a positively tropical 84° F (29° C). Hour 17 finds me over Hudson Bay with just a hint of an orange glow on the southeastern horizon and 87° F (31° C) in the sump. My mood brightens considerably as dawn breaks. I might actually make it through this long, cold night.

START FUEL: 300   END FUEL: 17.0

Date: 20 JAN 2015   Dep: PAFA @ 1909 Z   Arr: K1S0 @ Z

HR	ALT	OAT	TAS	GS	MPG	MP	RPM	IND FF	OP	OT	CHT	FUEL USD	FUEL REM	HR BRN	AOA	O2/HB	SLP
1	110	-16	187	184	15.5	19.6	2410	11.8	47	129	220	16.0	283.8	16.0	3.1	92/78	CT 45
2	110	-18	188	188	16.6	19.7	2290	11.4	51	115	209	27.4	272.2	11.6	3.0	94/72	CT 42
3	120	-22	184	176	16.0	19.1	2260	11.0	53	110	205	38.6	—	–	3.1	93/71	CT 40
4	120	-23	188	173	15.4	19.1	2260	11.2	54	106	205	49.6	250.6	–	2.9	93/74	CT 38
5	120	-27	193	180	15.8	19.1	2270	11.5	56	99	197	61.1	239.2	11.4	2.8	92/67	CT 42
6	120	-30	193	187	15.8	19.2	2260	11.6	59	93	191	72.5	227.7	11.5	2.8	97/73	CT 28
7	120	-30	197	201	17.3	19.2	2270	11.7	59	90	190	84.3	215.9	11.8	2.6	94/76	CT 28
8	120	-28	200	203	17.5	19.2	2270	11.7	59	90	190	95.8	204.3	11.6	2.2	95/67	CT 44
9	120	-27	192	181	15.8	19.2	2270	11.5	58	102	197	107.5	192.5	11.8	2.4	76/61	CT 48
10	120	-28	193	182	16.4	19.2	2270	11.2	59	90	183	118.7	181.4	11.1	2.2	95/62	CT 50
11	120	-33	211	197	14.9	19.3	2270	13.3	62	81	217	130.4	169.6	11.8	1.6	96/62	CT 47
12	120	-38	205	196	16.0	19.3	2270	12.7	63	76	181	142.	156.8	12.8	1.6	96/65	CT 14
13	120	-37	211	214	17.1	19.3	2270	12.6	63	76	193	156.4	143.6	13.2	1.5	96/70	CT 04
14	120	-33	209	227	18.7	19.3	2270	12.2	63	80	183	168.8	131.0	13.6	1.5	96/69	CT 19
15	120	-30	205	221	18.7	19.2	2270	11.7	65	81	174	180.4	119.7	11.3	1.6	96/67	CT 34
16	120	-27	193	196	18.3	19.2	2200	10.7	64	84	169	191.6	108.3	11.4	1.8	96/71	CT 28
17	120	-27	198	200	18.2	19.2	2200	11.0	62	87	183	202.6	97.3	11.0	1.6	97/71	CT 40
18																	
19																	

Hourly log of the North Pole leg of the trip.

Almost Home

The ground crew is now starting to brief me on possible weather problems farther south. My destination, Kinston, is reporting a 100-foot ceiling and 1/2-mile visibility with temperature slightly above freezing. A large snowstorm is blanketing the northern U.S. from Ohio to New York state. All of Pennsylvania is reporting low visibility in snow. I could duck into Buffalo or Syracuse, but I'd probably be stuck there. Flying west around the backside would add a lot of distance, and I'd have to stop for fuel. It seems to be moving a little too fast to beat the storm around the east side, and I could get pushed to the Atlantic if I tried that.

There are a few things going in my favor though. I'm working Toronto Center on VHF, infinitely easier than HF. Around North Bay I'm in radar contact. I'm starting to receive XM weather on the Garmin 496 and am able to build a good picture of the weather situation. Best of all, I'm light. I can climb. I ask Toronto Center for FL180 and they approve.

Crossing the U.S. border at Buffalo, New York, I can clearly see the weather. It looks like FL180 will keep me on top. I ask Cleveland Center for tops and icing reports. Tops are around 180 and no ice reported at that altitude or above. I know that I can now climb to the low 20s if I need to but FL180 seems to be working well with only very thin, poorly defined tops. I'm mostly in the clear and air temperature is still cold enough to preclude icing. I decide to continue on course. In a few hours I'm over central Virginia and am clearly past the worst of the weather. Kinston weather is now VFR and rapidly improving. The situation is looking quite good. At FL180 I'm only burning 8.5 gallons per hour. My wing and bladder tanks are empty. All of my remaining fuel is in fuselage tanks with well-calibrated sight gauges so I can actually see the fuel. I am quite confident in my quantity readings. I've got 23 gallons left and I'm about an hour out...should land with 17 or so, about 2 hours worth. This is actually going to work! 25.6 hours after takeoff from Fairbanks, I touch down at Kinston.

Sunrise (and sunset) over the Brooks Range, Alaska.

It's hard to describe the feeling of landing back at Kinston. The years of work and planning have finally paid off. Taxiing in, I see several Lancairs parked on the ramp. I am overwhelmed to see lots of friends who flew in. Thanks. That meant a lot to me.

Success!

Several months after this last landing the FAI (Fédération Aéronautique Internationale), keeper of aviation records since 1905, ratified our flight as a new World Record for Speed Around the World over Both of the Earth's Poles. Here are a few of the statistics: ✢

Total flight time:	174.9 hours.
Total elapsed time:	24 days, 8 hours, 11 minutes, 5 seconds (584.18 hours)
Great Circle distance between declared points (total credited distance):	22,172 nautical miles (41,062 kilometers)
Official Speed Record:	37.9 knots (70.3 kilometers per hour)
Previous Record set in June 1987 by Richard Norton and Calin Roseti:	7.6 knots (14.04 kilometers per hour)
Distance actually flown:	31,118 nautical miles (57,630 kilometers)
FAI record class:	C1d. C = Landplane (as opposed to seaplane or amphibian). 1 = internal combustion engine(s) any number of engines, piston or turboprop. d = weight 1750–3000 kg (3858–6614 pounds)

Ground Team

Sue Harrelson
Lancair pilot, airplane builder, retired airline pilot.

Ken Harrelson
GA pilot, retired airline pilot.

Glenn Oxford
Lancair pilot, current airline pilot.

Wes Whitley
GA pilot, airplane builder, avionics expert extraordinaire.

CarolAnn Garratt
World record holder (Speed around the World Westbound). Three times around the world in her Mooney. Airplane builder.

Now, a wireless sync is easier than you'd think. With Garmin G3X™ Touch.

The newest G3X™ Touch displays now feature built-in Connext™ wireless link capability that lets you stream information to/from your Apple iPad® (or other compatible mobile devices) via Bluetooth®. This means you can use your Garmin Pilot™ app to do advance flight planning on your iPad – and then quickly upload the waypoints into your G3X integrated flight deck system once you're at the airport. On the flip side, you can also use the link to stream subscription-free weather and traffic from an ADS-B datalink* – as well as G3X-based backup attitude and rock-solid GPS input – onto your iPad for added situational awareness in flight. You can even use the link to view and wirelessly control Garmin's VIRB® Elite action camera*. So you can record, upload and relive your aerial adventures in awesome HD video.

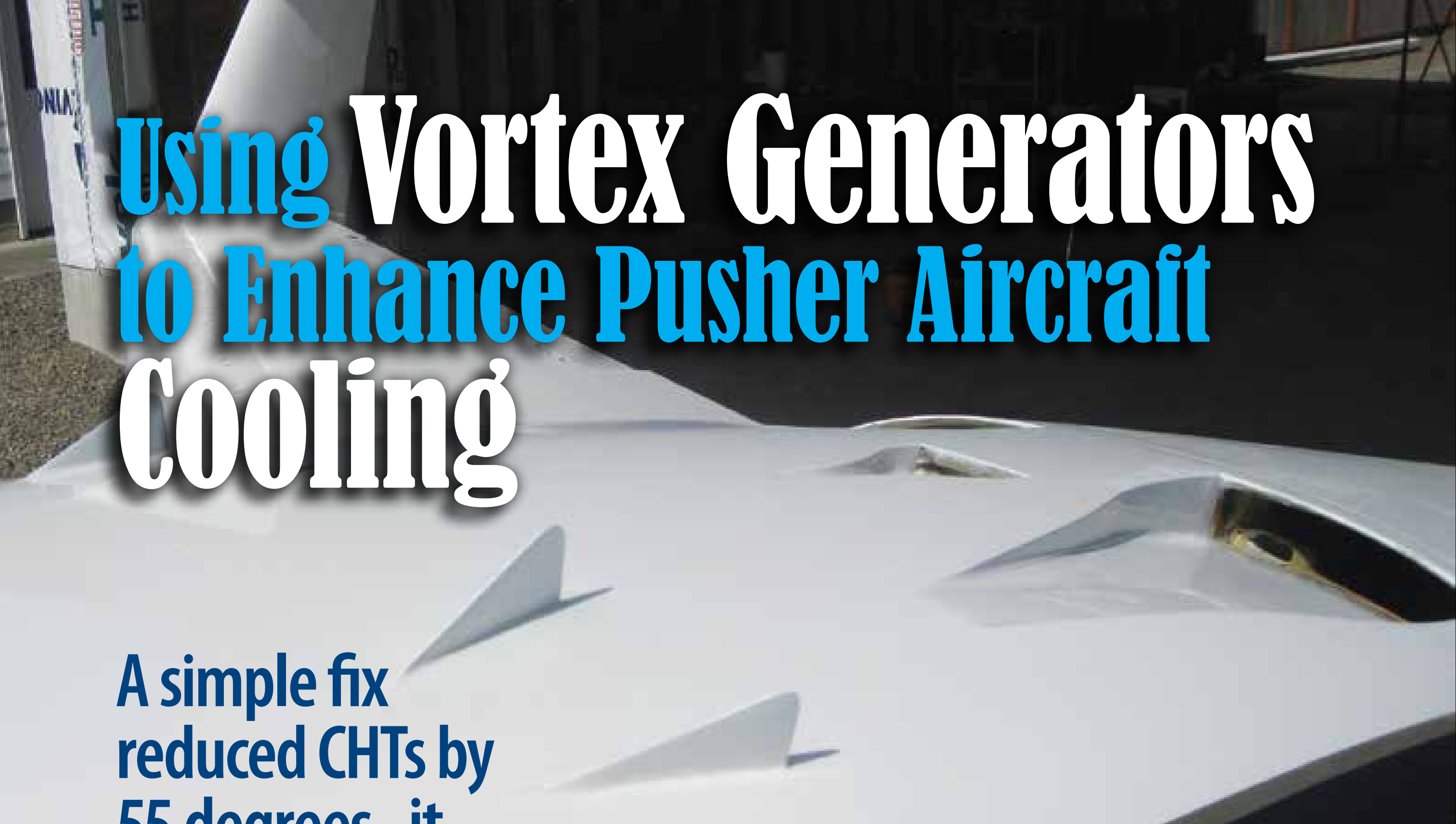
To learn more, visit our website: **Garmin.com/experimental**

connext™ TeamX

GARMIN®

G3X TOUCH

*Sold separately. NOTE: Weather displays in photo above are simulated and enhanced to illustrate wireless streaming capability.



Using Vortex Generators to Enhance Pusher Aircraft Cooling

A simple fix reduced CHTs by 55 degrees–it just took a while to find it.

BY DAVID G. ULLMAN

The cooling air for the IO-360 engine in my Velocity SEFG comes through two NACA style ducts in the top of the fuselage. The air then downflows through the cylinders and is exhausted out the rear of the fuselage about 2 inches in front of the propeller. I have flown the plane for about three years, and it has always run hot.

I added external scoops on the rear edge of the NACA ducts and that helped, but looked crude and not very elegant as the NACA ducts were supposed to be low-drag, internal scoops. When I painted the airplane, after three years in primer (a color I called "blotch white"), I took the scoops off. The combination of no external scoops and a smooth paint surface made the NACA ducts very ineffective. On climb-out and in cruise, my engine was overheating with cylinder head temperatures (CHTs) above 425° F.

This led me to study different methods to get more air through the engine. First, I tried to see how much air was going through the NACA ducts by putting smoke oil on the top and flying around the pattern. Traces showed that air was indeed flowing into the ducts, but this gave no indication of how much.

Early efforts to make the engine run cooler were based on suggestions from flying colleagues; latter efforts were based on studying literature to find a good engineering solution. I call these the "hacking" phase and the "engineering" phase, respectively. I will document what I tried and also detail the engineering solution. To give away the ending, I knocked 55° F off the CHTs with a simple fix. It just took a while to find it.

Understanding the Problem

One check to learn more about the airflow through the engine was to measure the pressure drop across the cylinders. Lycoming specifications state that there should be a drop of 6 inches H_2O for adequate cooling. To measure this, and to better understand the pressures created by the NACA ducts and the changes, two manometers were used. These were made of long lengths of clear

Table 1: Takeoff pressure drop across cylinders.

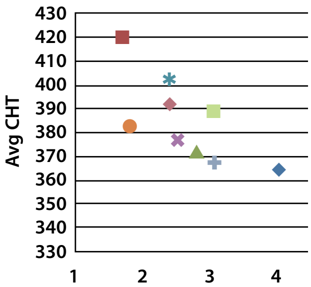


Table 2: High-cruise pressure drop across cylinders.

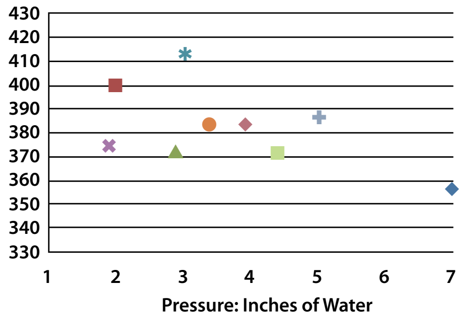
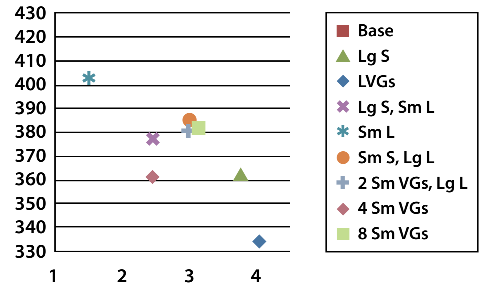


Table 3: Low-cruise pressure drop across cylinders.



tubing and some water with red dye and a drop of dish soap in it (Figure 1).

The first manometer measured the pressure difference between the static pressure and the plenum above the cylinders labeled 3 and 4 in the photo. One end was plumbed directly into the static system in the airplane. The other end was secured to the fuel injection spider in the plenum above the cylinders. The end of that tube was blocked off and holes were drilled around the periphery of the last inch of the tube so that it was clearly sensing static pressure.

The second manometer measured the difference in pressure across the cylinders labeled 1 and 2 in the photo. One end was mounted in the upper plenum next to the tube from the first manometer. It too was plugged and drilled. The other end was mounted just below the cylinders under the engine and was plugged and drilled.

The manometers themselves were mounted on a board in the cockpit so that a copilot could photograph them for later data reduction. The example shown is from late in the experiments and at high velocity. It shows 4.6 inches of H_2O across the cylinders and 7.2 inches of static pressure in the plenum above the cylinders. Initially, before any additions, the pressures were 2.0 inches H_2O and 3.0 inches H_2O.

The Hacking Phase

There were two schools of thought on what to do: Push more air into the NACA ducts or pull more air out the back of the fuselage. Most of the advice came from builders with front-engine experience, where often the problem is that not enough air is being pulled.

A variety of hacks were tried: Scoops were used to push more air into the NACA ducts. Louvers were added to the bottom of the cowl to pull more air out. Small vortex generators (.43 inches high) left over from the wing installation were placed in front of the NACA ducts to force more air in. Sometimes a variety of ideas were used in combination.

The results of testing can be seen in Tables 1, 2, and 3. Three test conditions were used:

Climb	115 kts (104 ft/sec). Note that VX is 95 knots, but I generally climb out at this higher speed.
Low Cruise	125 kts (114 ft/sec)
High Cruise	170 kts (155 ft/sec)

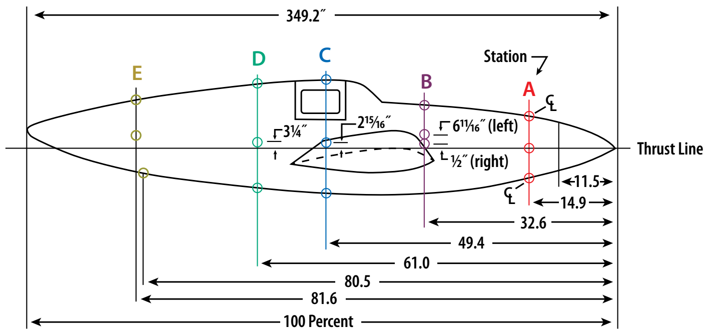
Data was taken from the manometers and the average cylinder head temperature. The engine was run full rich for all test points to be consistent. All temperatures were corrected for the outside air temperature (OAT) by normalizing them to a 60° F day. The results are plotted in Tables 1, 2 and 3. The points are for:

Lg S	Large Scoop—stuck up 3 inches above the fuselage surface.
Sm S	Small Scoop—stuck up 1.5 inch above the fuselage surface.
Sm L	Small Louvers
Lg L	Large Louvers
Sm VGs	Small Vortex Generators—these were the same vortex generators used on the wings and canard. They are 0.43 inch tall
L VGs	Large Vortex Generators—these worked! They are 2 inches tall.

The results are shown for each of the three conditions. Data for the base condition, just the NACA scoops as built, is in the upper left corner of the takeoff and high-speed cruise plots. No base data was taken at the low-speed cruise condition. These points are all worse than they appear as the temperature was still climbing when I throttled back. Note that besides high temperatures, the pressure drop across the cylinders was only 2 inches or less—no wonder the engine was overheating!

The results in the lower right corner are for the final configuration with large vortex generators. Here the temperatures are acceptable and pressure drops 4–7 inches, much closer to the Lycoming 6-inch spec.

Figure 1: Two manometers were used for testing. One measured the pressure difference between the static pressure and the plenum above cylinders 3 and 4. The other measured the difference in pressure across cylinders 1 and 2.



(a) Locations of pressure rakes on the fuselage of the model.

Figure 2: Details of pressure-rake locations and fuselage contours.
(Courtesy of National Advisory Committee for Aeronautics [NACA])

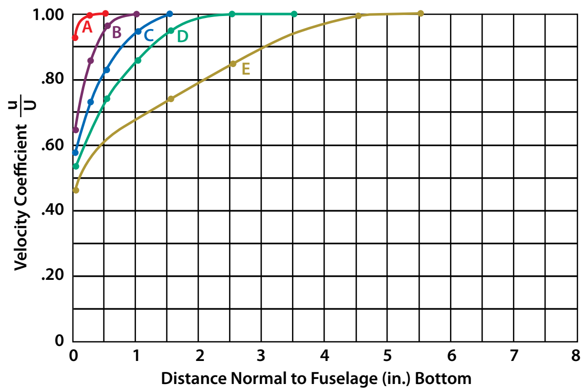


Figure 3: Boundary layer thickness at various locations on the fuselage shown in Figure 2.

The other configurations are scattered between these two extremes. Some key points that can be taken away from these are listed below.

- The Large Scoop (Lg S) helped on takeoff and high-speed cruise, but not as well on low-speed cruise. But this scoop was both ugly and increased the drag (no firm data on this).
- The louvers on the bottom did not make significant difference.
- Small VGs helped some, but it was unclear how many to use and where to put them.

Note that not all combinations were tested, as that would have been too many runs. This was also trial and error, so not all options were known beforehand.

The Engineering Solution

Parallel to the hacking phase, I worked to understand the physics of what was happening. It became clear that even though air was flowing into the NACA duct as shown with the oil traces, there was not enough. The boundary layer, which increases in thickness on the fuselage, was keeping air out of the NACA ducts.

To explain what the boundary layer was doing and why it is important, here are some basics. These are all worded from the viewpoint of the surface, with the air moving past it, as it makes easier reading.

The boundary layer is the region of air near the surface. At the surface it's not moving at all, and at some distance out, it's moving at the speed of the air flowing over the body. We usually think of the boundary layer as quite thin. It isn't!

The actual thickness of the boundary layer can be seen from the results of an experiment described in a NACA Technical Note[1]. In this note, the authors measured the velocity of the air near the fuselage of an unidentified fighter (Figure 2). They had removed the propeller, antennas and other protuberances, and sealed all ducts. They measured the velocities in the boundary layer on the top, bottom, and sides at various angles of attack.

Typical of what they found is shown in Figure 3. Here the vertical axis is the ratio of the speed of the air in the boundary layer divided by the speed of the air in the free stream (u/U) for the various stations along the fuselage bottom. This bottom image is the clearest in the report, so it is used here. It is typical of the airflow on the top and sides. The edge of the boundary layer is generally defined as when u/U = .99 (air moving at 99% of the free stream velocity). So here the boundary layer on the bottom, at station E (81.6% the length of the fuselage), is about 5 inches thick!

Note further that the air near the surface is moving at only 50% of the free stream velocity; the NACA engineers could not get all the way to the surface with their pitot tube where the velocity actually goes to zero.

What is important here is that on top of the test plane, behind the cockpit, the boundary layer thickness (d) was measured at 3.0 inches with the airplane in a dive, 4.0 inches in cruise, and 5.5 inches in a climb. No wonder my NACA ducts didn't work as they should on the Velocity.

To make sure that these results make sense, consider a simple explanation of the boundary layer theory. Theoretically, boundary layers start off laminar and, after a distance, become turbulent. Think of smoke coming off a match that has just been blown out. The smoke leaves the match as a smooth column and then, after a few inches, becomes a turbulent jumble. The first part is called laminar and the second, turbulent. On

Small scoops protruded 1.5 inches above the fuselage surface. Large scoops (not shown) were 3 inches high.

Small louvers on the bottom rear of the cowl helped draw air out.

a fuselage, with its long distance, most of the boundary layer is turbulent. For a turbulent boundary layer, the thickness over a flat plate is:

$$d = x * .16 /(Re)^{1/7}$$

where:

x = the distance from the front in feet

Re = Reynolds number which for standard conditions is = 6350 * U * x (U is in ft/sec).

The Reynolds number is a non-dimensional number that can be used to determine if the flow is laminar or turbulent. If below about 1×10^6, the flow is laminar and above this value, turbulent.

The formula above is for a smooth, flat plate. The shape of the fuselage and the surface smoothness affects this in complex and second-order ways. Assuming this is adequate, then for the fighter in the NACA report, x = 23.7 feet (81.6%), and the tests were run with U = 63 mph or 92 feet per second. Thus,

$$d = 23.7 * .16 / (6350 * 92 * 23.7)^{1/7} = .36' (4.34")$$

This result is close enough to that measured at the cruise condition to give comfort that it is OK to use on the Velocity.

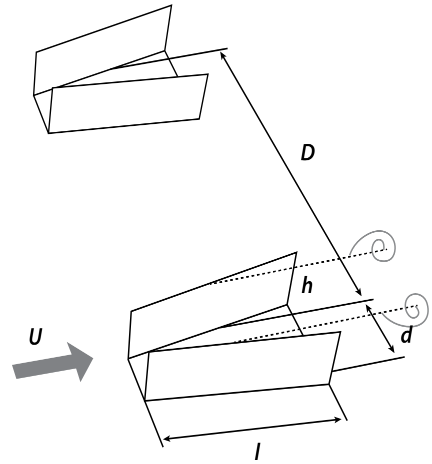
Then, for the Velocity, the NACA ducts are about 11 feet from the nose and thus:

$$d = 11 * .16 / (6350 * U * 11)^{1/7} = .36 / U^{1/7}$$

	U	d
Climb	115 kts (104 ft/sec)	.185' (2.2")
Low Cruise	125 kts (114 ft/sec)	.183' (2.2")
High Cruise	170 kts (155 ft/sec)	.175' (2.1")

As can be seen, the speed has little effect, and the boundary layer is about 2 inches for all conditions. It is then no surprise that the small vortex generators tried earlier (.43 inches tall) had so little impact. They were only

Large louvers placed over the same holes as the small louvers, but with much more projection into the slipstream.



Left: Two small VGs, .43 inch tall, were tried first in front of each NACA duct. They helped, but not enough. The small VGs in the foreground were added later to help bring flow in when at a high angle of attack. Center and Right: Large VGs that are 2 inches tall and 5 inches long solved the problem. They are placed in pairs 15 inches in front of the start of each NACA scoop.

stirring the bottom layers of air, those with low velocity.

Adding Vortex Generators

I put vortex generators on the wings and canard of my Velocity from the beginning. My test pilot strongly encouraged this, as I was a low-time pilot. They make the handling very docile. I know this because just before I painted my plane, I took off the inner ¼ of the VGs on both the wing and canard. The plane was much looser at low speed. After painting I put all of them back on, but I did not really understand what they did to the airflow.

The VGs I used on the lifting surfaces were .43-inch tall and at about 22% of the chord. Since the airfoils on the Velocity have the maximum thickness at 35%, the boundary layer is still laminar (Re < 1 x10^6).

A really good article on vortex generators on certificated airplanes is on AvWeb ("Vortex Generators: Band-Aids or Magic?" *http://tinyurl.com/plt6rkh*). This gives a good overview of the basics for use on wings and tails.

A well-designed VG stirs the free stream into the boundary layer. This brings higher energy air (more velocity) into the boundary layer at the cost of a slight increase in drag. There are two design variables: the height of the VG relative to the height of the boundary layer, and orientation of the VG to the free-steam air and adjacent VGs.

To be effective the VG must reach into the free-stream air or near to it. For the Velocity cooling problem, the boundary layer is a little over 2 inches thick. Thus, the VGs need to be nearly that high to stir in free-stream air. The VGs tried during hacking were only .43-inch tall and, even at that height, they did some good, but there was more to be had. Note that some literature claims that VGs that reach 20% into the boundary layer are just as effective as those reaching into the free stream. It will be shown that this was not the case here.

The position and orientation of the VGs is also important. Typically VGs are oriented at 15–20 degrees from the flow direction. Thus they are like little wings at high angle of attack with a vortex rolling off of them.

Counterrotating VGs

There are a variety of styles of Vortex generators available. After researching the various options, I decided to try counterrotating vanes, which also happen to be the most common. Counterrotating vanes reinforce each other by driving air from the free stream down into the area between the VGs.

The design rules for counterrotating VGs are generally accepted to be:

- h = .95 * boundary layer height
- D = 10 * h (Distance between set of VGs)
- d = D / 4 (Center distance between a pair of VGs)
- l = 2.5 * h

Thus I designed the VGs for cooling to be:

- h = 2 inches
- l = 5 inches
- D = 20 inches
- d = 5 inches

I put them about 15 inches in front of the start of the scoop and at 15 degrees from the centerline. I would have liked them farther forward, but wanted to stay away from the door opening.

	Delta P across cylinders, inches H_2O			Plenum static pressure relative to static port, inches H_2O			CHT corrected to an OAT of 60° F		
	Base	Final	Difference	Base	Final	Difference	Base	Final	Difference
Takeoff	1.6	4.0	2.2	2.1	4.4	2.3	420+	365	55
High Cruise	2.0	7.0	5.0	3.0	9.2	6.2	400	357	43
Low Cruise	1.6	4.0	2.4	2.0	5.2	3.2	403	334	69

Table 4: Final results with large, 2-inch VGs placed in front of the NACA scoops.

At first I bent some aluminum VGs and pop-riveted them on for testing. When the data showed them effective, I replaced them with fiberglass. Table 4 shows the results. The values in the table are the same as in the earlier plots with two exceptions. First, data is also shown for the change in the static pressure in the plenum. Second, I did not take data for low cruise in the base condition. Thus I have used the small louver data instead, as it was near (actually slightly better than) base for the other conditions.

The plenum static pressure is an indication of how well the NACA ducts are working. As can be seen, the addition of the VGs increased the pressure there dramatically (between 2.3 and 6.2 inches). Even the large scoop only increased the plenum static pressure to values about 70% as high as did the VGs.

Note that all data was taken with a payload of 480–520 pounds (pilot, copilot and 10–15 gallons of fuel).

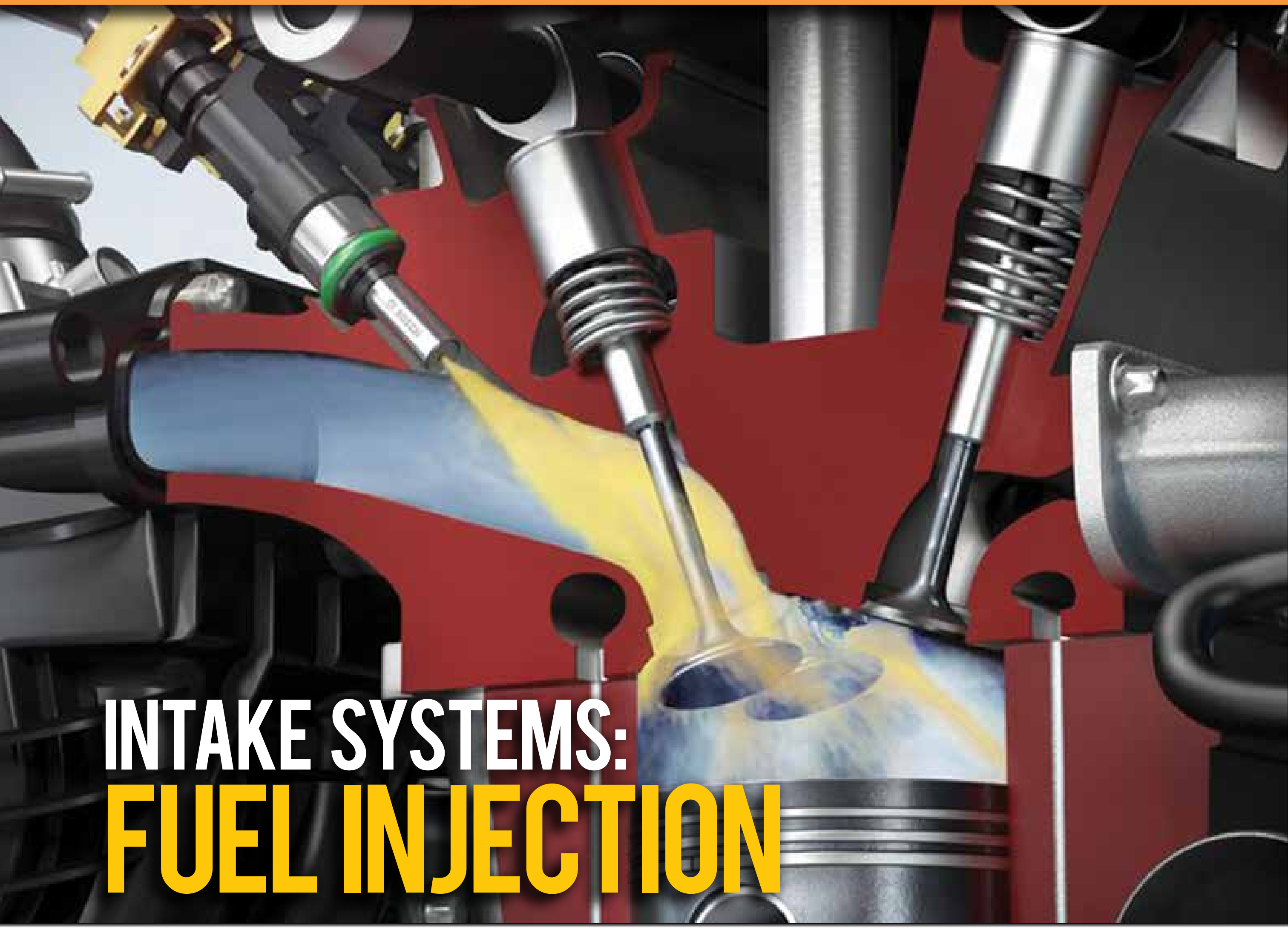
Conclusion

The VGs work well. The 6 inches of H_2O across the cylinders is only achieved at high cruise, but the 4 inches at takeoff and low cruise is more than double the base values. Most importantly, the average CHT is down an average of 55° F, just by the addition of four VGs. The data in the table above is even better than I hoped for. I probably could improve on this further by moving the VGs to another location, but this is good enough.

I like this solution. It is elegant, simple, and effective. Other Velocity builders have had similar results, and the factory is adding them on some aircraft. There's no reason large VGs won't work on similar types of airplanes, too.

I don't know for certain, but as best I can measure, there is no speed penalty. Another plus is that it gives yet another area for people to ask questions about. Now it's off to the next thing I want to improve. ✢

[1]*TN 1087, Langley Full-Scale-Tunnel Investigation of the Fuselage Boundary Layer on a Typical Fighter Airplane with a Single Liquid Cooled Engine, June 1946).*



INTAKE SYSTEMS: FUEL INJECTION

Putting pressure into fuel delivery.

BY TOM WILSON

Fuel injection is a catch-all term for any number of mechanical or electronic fuel delivery systems. Detail differences abound, so a bit of precision helps when addressing the subject. For example, when we hear "fuel injection" today, we mentally default to "multi-point sequential-fire electronic-port fuel injection," or simply "EFI," because that's what cars have used for the last quarter century. But that's not what we have in aviation (except for newer aftermarket systems).

The Bendix Baseline

At the start of WW-II the Germans were ahead of everybody with Bosch direct-cylinder mechanical fuel injection (a result of diesel engine development). Attempts at multi-port fuel injecting Allied airplane engines were mostly unsuccessful or not developed in time (your first clue fuel injection is not your average technical accomplishment). Post-war, Bendix developed their wartime single-point

Port fuel injection places the fuel injector just above the intake valve in the cylinder head's intake port. This has been the automotive standard since the 1980s, and the architecture most adaptable to legacy aviation engines by EFII, SDS, Precision Airmotive, and others. *(Image: Courtesy of Robert Bosch Corp.)*

pressure carburetor system into the RS multi-point fuel injection, and by the late 1950s that was detail improved into the RSA system that's still with us, both

(Left) An EFII electronic fuel injector displays its well-atomized spray pattern on the EFII test bench. (Above) Both the Bendix fuel servo at left and the smaller EFII unit at right are throttle bodies. But the Bendix unit also meters fuel, hence its fuel servo name; the EFII electronic throttle body simply throttles the air supply and reports the throttle position to the computer.

in original form and updated by several aftermarket sources, notably Airflow Performance and Precision Airmotive.

Bendix's RSA is constant-flow, mechanical fuel injection. An engine-driven diaphragm pump supplies fuel to the fuel servo; this is a throttle body and fuel metering assembly that typically mounts in the same place as a carburetor. The servo senses air pressure and employs a series of diaphragms to meter the fuel flow for the mass of air passing through the throttle body portion of the servo. But unlike carburetion, the fuel is not administered to the air stream at the fuel servo; instead it is routed to the flow divider. Like a railroad roundhouse the flow divider parses the fuel to small lines running to each cylinder's intake port. There fuel passes through a precision nozzle, spraying in a constant stream into the intake port, just upstream of the intake valve.

Note there is no pulsing of the fuel; it flows in a steady stream. Fuel pressure as delivered to the fuel servo varies with demand, and is often around 20 psi, but can rise to approximately 45 psi. Fuel pressure is the energy operating what could be called an analog fuel computer (the fuel servo), and so fuel pressure is, by design, consumed operating the various diaphragm springs, overcoming line losses, and pushing fuel through the main jet. Therefore fuel pressure is much lower at the fuel nozzles than at the fuel servo. Nozzle pressure can well be under 1 psi at idle and around 7 psi at full throttle.

Clearly the big advantage is the fuel is administered individually to each cylinder rather than a single point as with carburetion. Mixture variations are limited to intake manifold design, something the engine manufacturer can easily get close, plus you can fine-tune mixture variations by substituting different size nozzles. Each cylinder can be more closely maximized for power, economy, and aggressive lean-of-peak operation; greater maximum engine power is thus possible compared to rudimentary carbureted systems, and more economy is possible when leaned, too. The RSA system features a standard fuel mixture control knob in the cockpit, plus an automatic altitude compensation circuit so the pilot need not readjust the mixture because of subsequent climbs or descents.

Unlike a carburetor no fuel is administered at the venturi inside the fuel servo (there's still a venturi to generate an airflow signal), so icing is eliminated. Instead, an alternate air source is provided in case the main engine air inlet gets clogged from toilet paper when you're cutting up that roll you flung overboard—it only takes one square...

Disadvantages are cost, complexity, and therefore an increased number of failure points. That said, the simple Bendix system is tough to fail. The diaphragms have proven bulletproof, a backup boost pump saves the day should the engine-driven diaphragm pump fail (rare), leaving debris the only real-world worry. Even then, grit clogging the fuel servo causes the system to run dripping rich. Merely pulling the mixture knob to nearly idle cutoff typically restores a workable mixture and thus power.

Bendix's flow divider determines fuel flow among cylinders at low fuel flow (idle, very low power settings), provides a positive flow shutoff during engine shut down, and functions as a simple distribution block at normal cruise and takeoff power settings. Under those conditions, fuel flow is determined by injector nozzle size.

Photos: Tom Wilson; Illustrations: Courtesy of Robert Bosch Corp.

More annoyingly, the small injection nozzles are easy to plug by minute bits. Typically this causes rough running until the nozzles are removed and the trash back-flushed. Obviously, fuel filtration and system cleanliness are required.

With no float bowl, a fuel injection system needs a non-engine-driven pump for priming. In practice an electric pump serves as the priming pump and as emergency backup to the engine driven pump. Otherwise the Bendix system is purely mechanical, needs no electrical system, thereby segregating the electrical system as a failure point to the fuel system in flight.

A rarely encountered limitation of the standard Bendix system is its fuel-metering window can be slightly narrower than needed, so fuel metering on a large displacement, hot-rodded engine can grow increasingly inaccurate when heavily leaned. This isn't a normal issue on mainstream engines, but with high-power Experimental engines, the system fuels precisely at WOT and rich-of-peak high-power cruise settings, but cylinder-to-cylinder variations show up when lean-of-peak at low power (manifold pressure) settings. Think of an RV-10 leaned to near strangulation at 12,000 feet. Careful matching of nozzle diameters, fuel pressure, and diaphragm spring pressures in the flow divider can address this issue.

EFII's 60 pounds-per-hour electronic fuel injector is definitely larger than the brass Bendix fuel nozzle at right. The EFII injector is a solenoid operated fuel valve that fires in discrete bursts. The Bendix piece is a metered orifice that flows continuously.

Electronic Fuel Injection

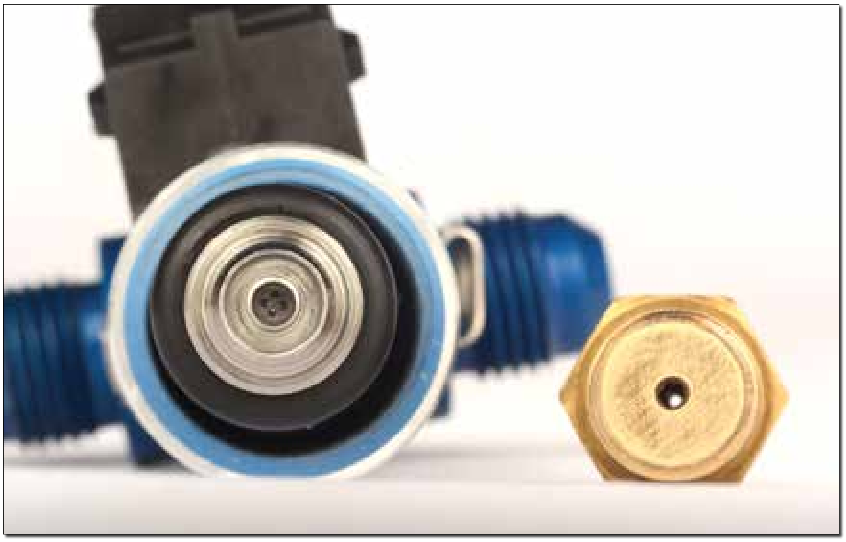
Sharing little more than the label "fuel injection," EFI as we know it from automotives is completely different from aviation's constant-flow, mechanical fuel injection standard bearer. But automotive EFI is where Experimental aviation seems headed, so it begs description here.

In now traditional automotive EFI, the action begins with an electric fuel pump supplying fuel at a metered pressure—typically around 40 psi—to the fuel rails. These are simple galleries fitted atop and linking the individual fuel injectors. The injectors are electrically powered, computer-controlled solenoid valves; when open they spray fuel into the intake port.

Of course there are filters and fuel regulators, and the fuel can either run in a constant loop from the fuel tank, through the fuel rails, and back to the fuel tank (old school, less fuel heating at the injector during hot starts), or be a one-way returnless design (newer emissions-driven design with less fuel heating and vapor-inducing agitation of the in-tank fuel).

The EFI advantage is computer control. A small army of sensors measures many things including engine speed, crankshaft, camshaft and throttle positions, plus intake air mass is measured directly by a hot-wire style mass air sensor. About ten times per second the computer uses all this information to compute when and how long to fire the injectors, thus controlling the air/fuel ratio by the amount of fuel delivered.

Bendix fuel nozzles have been two-piece assemblies for many years, making nozzle inspection, cleaning, and swapping easy. The lower brass portion contains an internal chamber vented to the atmosphere via a perforated screen. The air sucked through the screen at low manifold pressures mixes with the fuel to aid atomization. The small "A" on the hex should be installed facing down; that keeps a vent hole facing up so fuel will not leak out at engine shutdown.



While electronic injectors employ a single pintle valve, they shoot their 35+ psi fuel stream through a multi-hole outlet to break the stream into droplets. By comparison the Bendix nozzle squirts a steady stream through a single large hole at between 1 to 7 psi.

Automotive computer strategies vary greatly among manufacturers, and the computations are more complex than sensing rpm and airflow, then looking up spark and fuel values in a table. And yes, the computer also controls the ignition timing and camshaft timing (sometimes that's four camshafts all moving independently of each other) and is programmed to trim the fuel (and spark and cam) computations as required by possibly 30 different parameters. These include engine coolant temperature, rate of engine acceleration, knock sensor input, what gear the transmission is in, emission requirements such as EGR function and carbon canister purging, WOT enrichment, accessory loads from the air conditioning and possibly the alternator, engine de-tuning during automatic transmission shifting, emergency engine air cooling (via cylinder deactivation) in the case of coolant

At equal operating conditions on EFII's test bench, the Bendix nozzle (left) shoots a steady, thick, 3-psi stream of gasoline, while the EFII injector fires 35-psi pulses of fuel droplets. EFI's better atomization makes power at part throttle and lower rpm; at WOT the implosive pressure change when the intake valve opens shreds even a puddle of fuel into an atomized cloud.

loss, and seemingly if the dome light is on. These systems even adapt mildly to the driver's historical driving style and are sometimes also adjusted for traction conditions (snow, rain, mud, dry) as the driver selects from a dial. Adjusting the software code to a particular engine and car application, called mapping, is a long, laborious process for the manufacturer; four technicians with access to every tool, climate control lab, and a host of worldwide proving grounds (Abu Dhabi in summer and Fairbanks in winter) can take three years to fully map a new engine's management software. Things such as setting the cold start strategy can take weeks to map simply because you only get one cold start per overnight heat soak. You get the idea.

In the 1980s such systems fired all the fuel injectors at once (batch fire), or one cylinder bank in a vee engine at a time (bank fire). But with advances in computing, sequential firing has long been the norm, where the injector triggering is synchronized with the cylinder's firing order. The efficiencies in batch vs. bank vs. sequential firing are small and mainly driven by emission and transient response (changes in engine rpm) concerns.

EFI on the Fly

Today companies such as EFII—there are several others besides the EFII system detailed here—are offering aftermarket electronic port fuel injection systems for Lycomings. Like the auto systems just described, these are actually engine management systems incorporating the ignition along with the fuel. Unlike auto systems, the aviation systems (including Continental and Lycoming efforts that haven't reached the market) are much simpler in that they concern themselves strictly with the engine and don't bother with interacting with the rest of the airplane (responding to propeller pitch or flap position, lets say). Also, airplane engines run a far narrower rpm range and change rpm much less often and more slowly than auto engines, no knock sensors are used because our loose-tolerance air-cooled engines are mechanically too noisy, and 100LL is universal. EFII's system is also batch fire, eliminating the need for a camshaft sensor.

Furthermore, unlike *mass air* auto systems, aviation EFI systems are *speed density*. They don't directly measure air mass, but infer it from the air temperature, barometric pressure and engine rpm. This is notably less expensive, but requires mapping the software to each engine, and if something meaningful is changed (cam timing), it has to be remapped. Thankfully the mapping requirements for our aviation applications are hugely simplified from automotive needs. Heck, your lawn tractor might require more mapping if it were EFI.

Such aftermarket aviation systems are a big step forward and provide experimenters new opportunities. Ultimately outfits such as EFII, SDS, Precision Airmotive, and others are showing the way to reduced pilot workload and more easily-gained fuel economy among other things. But they are aftermarket items from tiny development budgets and also require modern thinking and are absolutely electrically dependent. If that electric fuel pump quits, it's going to get very quiet, so an airplane running EFI must be electrically robust. Professional wiring standards, dual alternators, batteries, buses or some combination of these are mandatory. In short, EFI needs integration into the entire airframe and the builder's thinking.

Gasoline direct injection is the new norm in automotives. Conceptually similar to diesel practice, very high pressure fuel is sprayed directly into the combustion chamber, gaining a useful quenching effect. Incorporating 2500 psi GDI to legacy aviation engines would most practically require a complete engine redesign in addition to the expensive high-pressure fuel pump and robust injectors.

Hot and Cold Manifolds

One last thing: hot intake manifolds. In the flat-engine beginning (1940s), carb icing was a big fear, and an easy answer was to preheat the intake air. An easy solution on a horizontally-opposed engine is to package the intake runners through the oil pan. This reduces intake icing, but also air density and thus power.

In response, the aviation aftermarket offers cold air intakes for use with fuel injection, and they are a must if maximum power or fuel efficiency is the goal. While these cold air intakes absolutely make power, recent tests suggest the majority of their gains are from something besides cooler intake air. Optimized runner length and shape, plus plenum volume and other tuning are likely their largest benefits.

Lycoming intake tubes are the obvious, convenient place to add an electronic fuel injector as this EFII assembly shows. It takes a second to realize the injector blows into the airstream, done in order to keep the fuel lines above the injector, so air bubbles formed at engine shutdown self-purge, and not complicate hot starts.

Unfortunately, these systems are too costly at aftermarket economies of scale to pencil out in fuel budget savings, so they remain a hot rod trick for aerobatic and racing types. But they are available if you're experimenting for maximum efficiency or have a need for speed.

The Future

Going forward, electronic engine management (fuel injection and ignition commanded by the same computer) seem obvious as new aircraft become electronically intensive and robust. Reduced pilot workload (no mixture knob), easier starting, smoother operation, better fuel economy, more power at altitude (fewer misfires and adjustable ignition timing), no-hassle lean-of-peak cruising, and reduced spark plug fouling (lean ground operation) are all benefits. Still, such systems are more expensive and relatively untested in aircraft. In the short term, financial reality shows there's plenty of life left in legacy aviation intake systems when it comes to aspirating our simple, steady-state rpm engines. In the long term, the march of progress will continue. ✢

Electrical Trim and Flaps for Experimental Aircraft.

BY MARC AUSMAN

This month we'll discuss electric trim and flaps as utilized in Experimental aircraft. Most aircraft kits are designed around either manual or electric control of trim and flaps. If your preference is electric control, this article shows you how to wire the motor control system. It does not cover the actual installation of the control surfaces, motor, or control linkage.

Electric Trim

Electric trim systems have become more popular in recent years. Pilot concerns about unreliable relays, runaway trim, and overly sensitive feel are now mitigated with solid-state trim control systems. When adding electric trim there are three methods you can choose from:

1. Traditional wiring with a relay deck and pushbuttons on the stick, or momentary rocker switches on the instrument panel. Ray Allen Company makes a relay deck for this purpose.
2. Stand-alone, solid-state trim control system like that sold by TCW Technologies.
3. Integrated, solid-state trim control system like that made by Vertical Power. The trim control system is integrated with many other electrical functions in order to simplify wiring.

Adding an electric trim system is often lighter than a conventional cable and crank system, especially in the pitch axis.

Trim control systems can automatically adjust the speed of the pitch trim motor so that it moves more slowly while in cruise and moves at normal speed while in the pattern. This is controlled by either airspeed or flap position, depending on the system.

Most Experimental aircraft use trim servos from the Ray Allen Company, and we'll focus this article on the assumption you're using Ray Allen servos. These servos are self-contained units that include the trim motor as well as a position sensor.

The Ray Allen trim servo (models T2-7A-TS, T2-10A-TS, or T3-12A-TS) has five 26 AWG wires, as shown in Figure 1.

Two white wires power the trim motor. Reversing the positive and negative connections to the trim motor controls the direction of motor travel. This is done conventionally using switches or relays, and it is done in the Vertical Power system with solid-state circuitry. Each trim motor should be protected with a 1-amp circuit breaker.

The position sensor connects with three wires—white/green, white/orange, and white/blue. The three wires are wired directly to the position display, which is typically an EFIS, VP-X, or LED indicator bar. As the control arm on the trim motor moves in and out, the voltage on the position feedback line (white/green) varies between 0 volts and the reference voltage (typically +5 or +10 volts). This variable voltage is read by the display and converted into a format that can be displayed for the pilot.

Ray Allen makes a nice 5-conductor wire with matching wire colors, and I recommend using it to wire the trim motors.

Electric trim can be installed on the pitch, roll, and yaw trim axes of the airplane. Each type of aircraft is the same electrically, but the physical installations are different and not addressed herein. If you are installing trim on all three axes, be aware that most EFIS displays only support two axes. Knowing the pitch trim setting prior to takeoff is essential, so that requires an indicator. You can then decide if yaw (rudder) or roll (aileron) is the best to show on the display, leaving the remaining axis without an indicator.

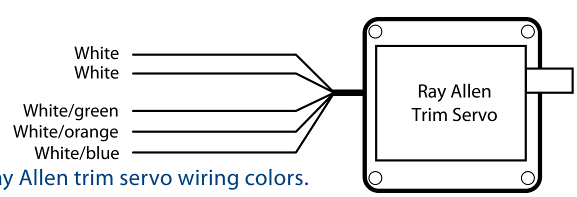


Figure 1: Ray Allen trim servo wiring colors.

Ray Allen Trim Servo Wire Functions

Function	Wire	Notes
Motor power	White	Motor is powered by positive and ground on each white wire.
Reference voltage	White/Blue	Wire to regulated power source per EFIS instructions. This needs to be a fixed voltage provided by the EFIS or VP-X. Do not wire it to the aircraft electrical bus.
Ground	White/Orange	Wire to ground.
Position feedback	White/Green	Goes to input on device that displays position.

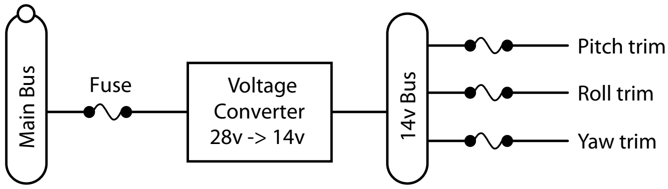


Figure 2: Use a voltage converter with 14-volt trim motors in a 28-volt aircraft.

My recommendation is to forgo the aileron indicator, as aileron position can usually be felt in the stick or you can view the trim tab on the aileron from the cockpit. And it's easy to overcome once in flight if set incorrectly. The rudder trim setting cannot be verified easily prior to takeoff without a cockpit display indicator. Another option is to use the two indicators on the EFIS, and add an LED bar indicator in the instrument panel.

Auto-trim modules are now available with many autopilots. While the autopilot is engaged, the auto-trim module takes control of the pitch-trim servo and automatically relieves pressure on the autopilot pitch servo as needed.

Ray Allen servos are designed to run at 14 volts, and the VP-X system provides regulated 14-volt power to the trim motors so they can operate safely in 14-volt or 28-volt systems. If you're running a 28-volt system without using Vertical Power, you'll need to install a voltage converter module (Figure 2) and power all of the trim circuits from it.

There are several ways you can wire the trim motor, and we'll show three of them here. The first way requires a double-pole, double-throw (DPDT) momentary toggle switch that is off when in the middle default position. Moving the switch to either off-center position reverses the polarity of the motor and drives it in one direction or the other. The position sensor wires are connected to the EFIS display to show the trim position. This configuration is used with a switch on the instrument panel and not with pushbuttons on the control stick. Figure 3 shows the wiring and back side of the switch.

The configuration shown in Figure 4 is typically used with control sticks that have pushbuttons on them. The trim control module can be a relay deck or a solid-state trim control module (preferred).

The Vertical Power Electronic Circuit Breaker System is shown in Figure 5. It controls the motor with solid-state circuitry and sends the trim position information directly to the EFIS via a data line.

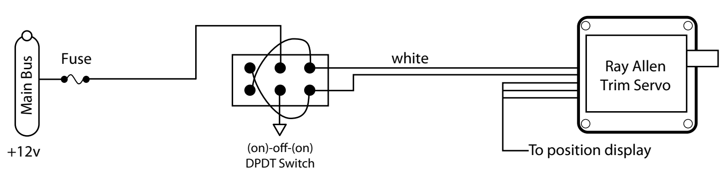


Figure 3: Single axis trim using a simple DPDT momentary switch.

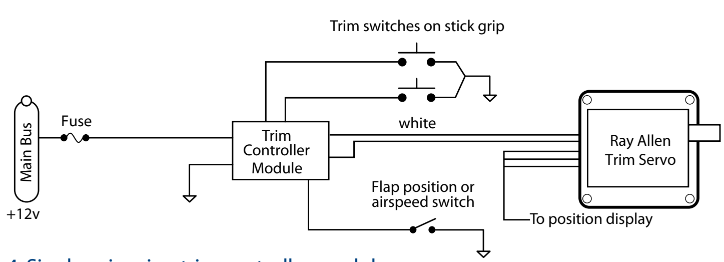


Figure 4: Single axis using trim controller module.

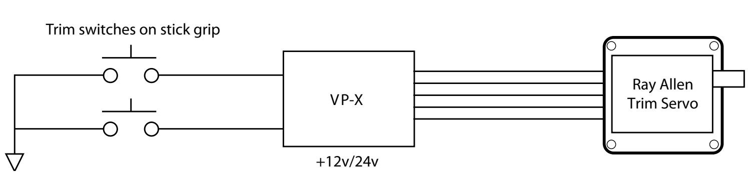


Figure 5: Vertical Power trim control system showing only one axis.

Illustrations: Marc Ausman

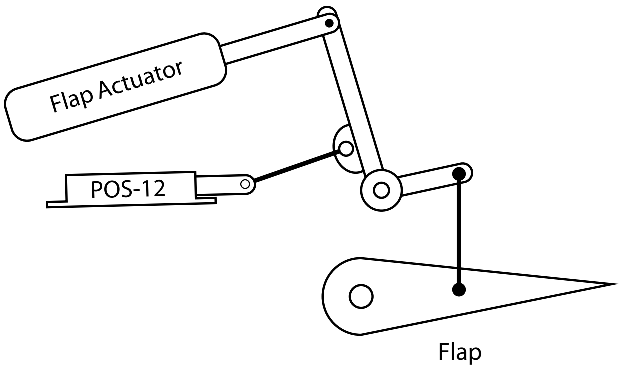


Figure 6: Relative mounting of flap actuator and POS-12 sensor.

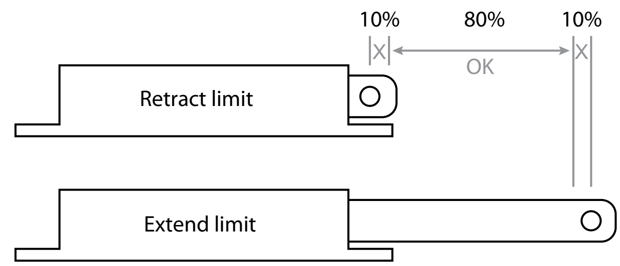


Figure 7: POS-12 sweet spot in the middle 80% of travel.

Electric Flaps

Electric flap systems have become popular in recent years, and kit plane manufacturers are designing them in as standard equipment. At a high level, the flap system is similar to the trim system. You have a motor that reverses direction by flipping the motor polarity, and an optional position sensor that reads the flap position and shows it on the EFIS.

The simplest way to control the flap motor is to install a momentary DPDT flap switch that changes the motor polarity. It is very simple and inexpensive, but you have to hold the switch in order for the flaps to move. Also commonly installed is a switch that stays in the *Up* position. Van's Aircraft customers especially should not use such a system, as the flap motor can run continuously if the flap switch is left in the wrong position. The pilot has no way of knowing that the flap motor is running and wonders why the expensive flap motor needs to be replaced often.

The next level of functionality comes from using a stand-alone flap controller. While the features vary, a flap controller typically allows you to raise the flaps with one motion, limit the flap motor run time, and manage conflicts if more than one flap switch is installed. TCW Technologies manufactures such a flap controller.

More advanced functionality comes from the Vertical Power system, and includes the above-mentioned features plus intermediate flap stops, slow retract at go-around, and others as part of an integrated system.

The position sensor is optional, and most EFIS displays show the flap position. The most common flap position sensor is the Ray Allen POS-12.

Install the position sensor on the flap motor bellcrank or nearby. Figure 6 shows a conceptual drawing of how the electric flap actuator travel is much longer than the 1.2 inches of travel for the POS-12. Mechanically, this all works out because the POS-12 is located lower on the bellcrank where there is less linear travel.

The POS-12 should have some extra slop at the extreme ends of the flap actuator travel (Figure 7). As a rule of thumb, allow an extra 10% (about 0.1 inch) of extra slop at each end of travel so that the position sensor does not bind. If it binds it cannot measure travel, and therefore the readings will be inaccurate. Additionally, the POS-12 is not accurate at the extreme 10% ends of its travel.

There are several ways you can wire the flap motor, and we'll show three of them

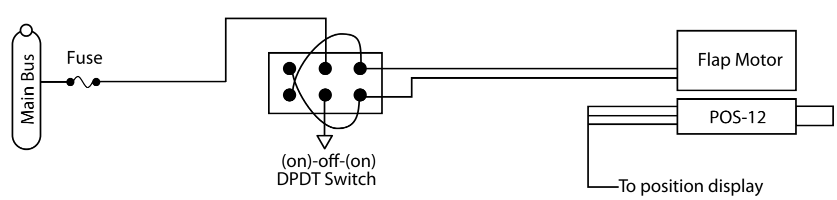


Figure 8: Simple electric flap switch.

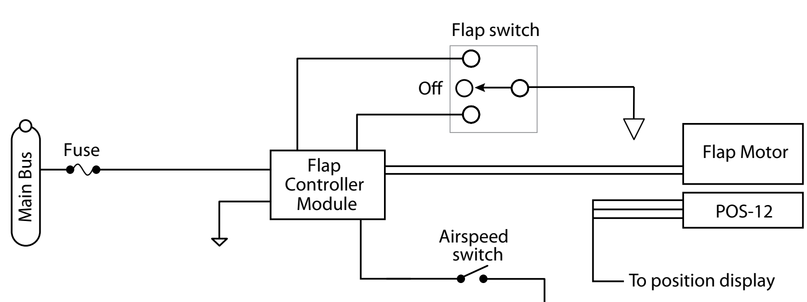


Figure 9: Stand-alone flap controller.

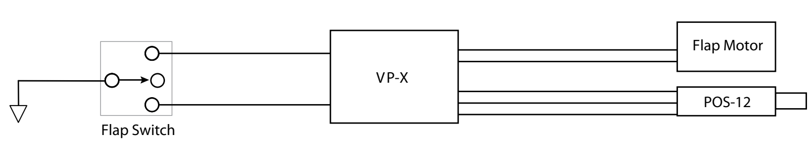


Figure 10: Vertical Power flap control system.

here. The first way requires a double-pole, double-throw (DPDT) momentary toggle switch that is off when in the middle default position. Moving the switch to either off-center position reverses the polarity of the motor and drives it in one direction or the other. The optional position sensor wires are connected to the EFIS display to show the trim position. Figure 8 shows the wiring and back side of the switch.

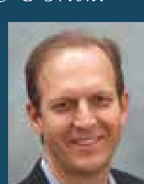
The next flap configuration (Figure 9) uses a flap control module. The advantage of such a system is that the flap switch does not have to carry the full current of the flap motor, and therefore you can use one of the switches on the control stick for flap functions. Another advantage is that the controller can raise and lower the flaps with a simple momentary press of the flap switch.

The Vertical Power electronic circuit breaker system is shown in Figure 10. In addition to the advantages mentioned above, it controls the motor with solid-state circuitry and sends the optional flap position information directly to the EFIS via a data line. ✈

Read the Book
Hopefully this article has helped you understand electric trim and flaps in Experimental aircraft. It is an excerpt from my new book entitled Aircraft Wiring Guide. *For more information, or to order a copy, visit* www.aircraftwiringguide.com.

MARC AUSMAN

Marc currently flies an RV-7 that he finished building in 2006. He was founder and president of Vertical Power and has served as an EAA Director since 2011. He flew with the U.S. Navy as a Naval Flight Officer on board the P3-C Orion. He lives in California with his wife and three children.



Amateurs and Experimental aircraft.

I don't believe I've introduced you to Paul "Bugsy" Gardetto. Bugsy and I served as colonels together in the Air Force, and we both built RV-7As. Back at Langley, he let me share his T-hangar space and cost during his last long deployment to the sandbox. We're both married to beautiful blond goddesses, and we're both students of aviation safety and human factors.

One day, Bugsy and I were at the hangar leading other builder/pilots in a hard-hitting Experimental aviation risk management symposium. Over some cold micro (brew, that is), I remarked at how building an aircraft, and preparing myself to safely fly that aircraft, is far more of a mind-switch than I had ever anticipated. It's more than just a great mental workout: For me, it's a total change in how I've ever gone about training and preparing for flight in a new aircraft.

Bugsy was several months ahead of me in his build (he was completing his Phase 1 fly-off, which I just started). He had noticed exactly the same juxtaposition, and had already been considering its reasons. This was just the sort of philosophical hangar talk we needed, so we primed the conversation pump with a second round.

Here's the difference: As military aviators, we were handed tech and ops manuals (that somebody else wrote) and keys to an aircraft (that somebody else built). We learned all the operational procedures and limits (that somebody else determined through flight test). Military flight training is an entirely organized and structured endeavor: Our job was to learn and perform. It took three of my four years as a lieutenant to finally arrive in Germany qualified in the F-4G Phantom Wild Weasel.

Now, today, we were building our own airplanes, writing our own POHs, devising our own test plans, and ultimately training ourselves. We were constructing our own aircraft logs, publishing our own airplanes' weight-and-balance and operational flight limits. "Formal" training came in the form of two to four hours of dual instruction from a CFI in an A-model RV. This development as an Experimental aircraft pilot/builder may not have been as rigorous as the military checkout, but it is a wholly different way of doing things. I'm not saying it's bad. Not bad at all. Just different.

We then reflected on how Experimental aviation allows a builder to get creative with solutions to some of the design and construction challenges. There is more than one approach to design, construct, or install systems or components onto our E/A-Bs.

That's one reason why I, like so many of you, love Experimental aviation. For instance: The Van's stable of airplane designs use piano hinges to adjoin the top and bottom cowl halves and attach the cowlings to the airframe. However, MilSpec and Skybolt fasteners offer another solution, equally effective and, for some, more attractive and timesaving. Not better or worse, just different.

Another great example: Whereas the RV-7's design has a builder attach the canopy bubble to the frame with

The author (right) leads another hard-hitting Experimental aviation risk management symposium, this time with Doug Reeves of *VansAirForce.net*.

Sidney Mayeux

Sid "Scroll" Mayeux has over 25 years of experience in aviation training, safety, and risk management in the military, civilian, airline, and general aviation sectors. He currently trains Boeing 777 pilots. Sid has recently completed Phase I flight testing on his newly built Van's RV-7A.

You'll never find one of these on a certified aircraft. Oh, the joys of Experimental aviation.

flat-head screws, nuts, and/or rivets, Bugsy and I employed a more experimental method. We both affixed our canopies to the frames with Sikaflex, a nautical adhesive system used to adhere windowpanes to boat window frames. In our RVs, the Sika protects the Plexi from flex-stress cracking and leaves a much cleaner-appearing install.

As Bugsy and I considered our experimental deviations from the designer's intended approach to a completed RV-7A, we concluded we have actually improved on the design: Through our own efforts, we have over-engineered aircraft that are already quite well engineered. That, in turn, reduces risk.

"Still," I said as we paused for reflection and another sip, "what new risks do Experimental aircraft builders introduce to their aircraft?"

A Well-Worn Path Less Traveled

A few years ago, an RV-6A pilot successfully executed a forced landing after his engine lost power during a day VMC cross-country flight. This pilot did not build the aircraft; he had just purchased the airplane and was flying it back to his home airfield. During climb-out after a fuel stop, the engine suddenly quit. Switching on an auxiliary fuel and ignition system did not heal the engine. The pilot set it down in a pasture; he and his CFI passenger survived with minor injuries.

Photos: Sid Mayeux

Corvair engine modified for Experimental aviation. Auto engine conversions are great options for aircraft, but they require close attention to technical details to mitigate risks and ensure reliable power. *(Photo: Paul Dye)*

The FAA inspector noted that the aircraft had a Chevy 4.6L automotive engine converted for aviation use, and that the carburetor air filter was dirty and clogged. More importantly, the wire connecting the ignition coil to the distributor was disconnected from the coil terminal. Both were automotive-style components with traditional terminal male/female plugs, but no additional locking feature. The NTSB said that, most likely, the coil-distributor wire loosened in flight, rendering the ignition system inop, which prompted an unrecoverable loss of engine power.

In another accident, the NTSB cited the installation of a firewall-mounted automotive racing oil filter assembly in a Northman 2+2 that lost power and crash-landed in trees. The builder had installed the specialty filter assembly for ease of servicing. However, the filter housing cracked under vibration, dumping the IO-320's oil which seized the engine.

Auto engine conversions are manna to the Experimental aircraft builder, and why not? Car engines are plentiful, come with mated-by-design ignition and induction systems, and cost loads less than aircraft engines. Parts are cheap. Best of all, the FAA *allows it,* as long as the DAR isn't uncomfortable or unconvinced of its airworthiness.

For these reasons, I conditionally support an automotive engine application to an aircraft. Shoot, I've eyeballed the rotary engine approach for some time: Light weight, fewer moving parts, smoother power line…what's not to like? However, I have neither the expertise nor the talent to prove the reliability of any given automotive engine in an aircraft built by my hand. I'm an amateur, remember? I leave that up to the professionals…and I'm reassured to see how *seriously* they have taken the *serious* business of properly configuring automotive engines for Experimental aviation.

Take Titan Aircraft, for example. The T-51 Mustang ¾-scale aircraft features six engine choices from the company web site. Three of those are V6 car engines, each listing for just under $10,000.

However, to complete the auto engine's conversion, you must also purchase and install a $16,500 firewall forward kit to properly prepare it for aviation use. The FWF kit includes pretty vital stuff like a more reliable ignition system and, most importantly, a very robust and reliable prop speed reduction unit. Without it, the Mustang won't fly. With it, you have a reasonably safe, reliable, risk-tolerant, and awesome-sounding mini-Merlin powerplant for your Mustang. Just remember: It's still Experimental.

Crashing the Perfectly Airworthy Airplane

Bugsy then remarked, "OK, so we built good Experimental airplanes, but now, in Phase 1, are we flying them smartly? Are we taking unnecessary chances in our test plans?" I knew what he was talking about. For instance, I'm about to buy sandbags to conduct heavyweight, forward-, and aft-CG test flights. I cringe at the thought of not battening them down effectively.

Access panels are common additions to builders' finished aircraft, and often fall outside the original design. Do your research! Be sure you haven't compromised key structural designs or introduced some new risk for the sake of convenience.

Not long ago, another RV-6A pilot launched on a Phase 1 flight to determine the unusable fuel quantity in his right wing tank. He purposefully fed fuel from that tank until the engine ran out of fuel, then he planned to immediately switch to the left tank, a method he had successfully used in the past on other airplanes. However, on this flight, in a turning climb after takeoff, the engine quit and the aircraft stalled. He landed straight ahead in a field with a half-full left tank, but only about two gallons in the right.

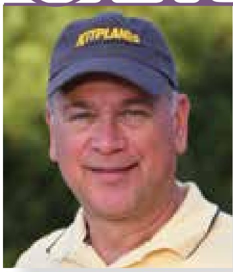
There are often many ways to attain data on a given test point. Some of those ways may yield more accurate data than others, but not without risk. To determine unusable fuel in my RV-7A, I pumped fuel from the boost pump into a jerry can at 0 knots/1 G in my hangar until each tank could yield no more fuel. What remains in the tank? About 1.5 gallons of unusable fuel on each side. Might not be the most accurate figure but, to me, it was the least-risk approach.

At this time in our conversation, my bride Kelli walked in, saw the micro (brews), and asked us what world problem we were solving this day. Bugsy described the essence of our conversation on Experimental aircraft risk, which got me a little concerned; I hoped his words wouldn't make her think I was worried about our newly-airworthy RV-7A.

"Kelli, love," I said, "I sure can't wait to take you up in Zero Kilo Mike."

"Shoot, Sid, I'm ready now!" My bride really knows how to warm my heart…only 32 more hours of Phase I testing to go. ✈

Note: All references to actual crashes are based on official final publically-released NTSB and Air Force Accident Investigation Board reports of the accidents, and are intended to draw applicable aviation safety lessons from details, analysis, and conclusions contained in those reports. It is not our intent to deliberate the causes, judge or reach any definitive conclusions about the ability or capacity of any person, living or dead, or any aircraft or accessory.



Skills transference, part 2.

So far over the course of my flying career, I've been managing to fill the experience bucket faster than the luck bucket is emptying. And I believe most pilots are able to do that, especially if we stay away from doing the stupid things like low-level show-off aerobatics, running out of fuel, or continued VFR into IMC. During our initial flight training we do practice for the obvious, such as engine failures, inoperative radios, and weather scenarios, and discuss others, such as inoperative or stuck trim. In some cases we learned to react by rote learning. Many other failures are few and far between and can be somewhat insidious and slow to present themselves, even with the simpler, mostly mechanical airplanes of yesterday. With today's completely glass cockpits, I am a strong proponent of really understanding the systems and how they all work together. I want to share a couple of examples I've experienced, from the simple to the complex.

Small Problem, Easy Solution

On one of those trips to Cleveland, Ohio, it rained for three days while our Bonanza was parked outside. The temps then proceeded to drop below freezing on the day of our departure. I thoroughly preflighted the aircraft, preheated the engine, and drained the fuel sumps multiple times, even though I never found any signs of water. Startup, taxi, and runup were normal. I know what you're already thinking: frozen fuel lines. Nope. I was departing IMC into an 800-foot overcast that was clear above 3000. Takeoff roll was normal, and once airborne and pitched to the correct angle, I immediately transitioned to instruments to prepare for the immersion in the overcast. A quick scan revealed all was normal with the engine, but as I came back to the flight instruments I noticed the VSI and altimeter were showing a descent and the airspeed was decreasing. The attitude indicator looked normal, and a quick glance outside showed I still had the right pitch angle. I had enough experience in the Bonanza to know that at these temps and with two adults and two small kids in the back, climb should not be a problem. The outside visual picture matched the normal climb I was used to seeing. I believe in the old adage of not reacting quickly and looking at your watch.

A normal reaction here would have been to push the nose over, as we were clearly approaching an impending stall if I were to believe the airspeed indicator. It happened a little faster than I can write it, but I quickly recognized it as a blocked static system. Upon activating the alternate static source, everything immediately came back to normal. We continued the flight back to Atlanta, and once on the ground and in warmer conditions, we managed to blow a lot of water out of the static system, disconnected of course.

With a modern glass panel and all of the bells and whistles, I am sure I would have heard something like "Speed! Speed! Push! Push!" Good input. Bad output. And I managed to see it actually happen while flying a regional jet.

WOW!

It was the start of a four-day trip, and I was flying the first two legs, one from Atlanta to Newark and then from Newark to Columbia, South Carolina. It was during cruise on the first leg that I noticed the first anomaly. We had a wind shear alert message flash across both PFDs for a split second. The captain didn't notice it because he was busy playing his Game Boy. But upon discussion, we both agreed it should not happen at 35,000 feet. It happened again, and this time the captain saw it, too. The remainder of the leg was normal, but it happened again on the leg to Columbia. Our trip that day called for a leg to Atlanta after Columbia before we headed out again, and I mentioned that I thought we should have maintenance take a look at the airplane, as I thought something might be failing in the air data computer. We traded roles departing Columbia, and I was now the non-flying pilot. On the departure roll, and just as I called V_1, we hit a bump in the runway. Subsequently, it seemed like every warning light and horn went off in the cockpit.

For those readers who aren't multi-engine rated, V_1 is the speed at which an abort on the remaining runway is not in the cards. We were committed. I silenced the horns and then tried to make sense out of the EICAS (Electronic Instruments and Crew Alerting System) readout. At the top of the list was WOW (Weight on Wheels) failure. I kind of chuckled as there was no way a WOW failure should present itself right now, as we certainly

Vic Syracuse

Vic is a Commercial Pilot and CFII with ASMEL/ASES ratings, an A&P, DAR, and EAA Technical Advisor and Flight Counselor. Passionately involved in aviation for over 36 years, he has built 10 award-winning aircraft and has logged over 7800 hours in 69 different kinds of aircraft. Vic had a career in technology as a senior-level executive and volunteers as a Young Eagle pilot and Angel Flight pilot. He also has his own sport aviation business called Base Leg Aviation.

This Bombardier regional jet is similar to the ones flown by Vic when he worked as a first officer for Atlantic Southeast Airlines.

weren't configured for landing and the spoilers weren't armed. Remember my motto to understand the systems?

By the way, I was flying with a very young 2700-hour Embry-Riddle captain, and I was a little concerned about how he might react, which was justified as the flight continued. I told the captain we were OK, continue, and I will explain above 10,000 feet. Earlier he wasn't so agreeable that we should have maintenance look at the airplane when we arrived in Atlanta. I now made it clear that we really needed to ground the airplane, and he agreed.

From Bad to Worse

The computer still had a few tricks in store for us. It was the middle of August, and that time of the year is prone to afternoon thunderstorms. Sure enough, as we approached Atlanta, we were put into a holding pattern due to a thunderstorm parked right over the airport. We didn't exactly have enough fuel for a lot of holding, so the captain transferred the controls to me while he worked with dispatch to find an alternate. So there I was going around in circles at 225 KIAS and 7000 feet watching the thunderstorms build around me. It was a nice view, but things weren't looking real friendly, so I keyed the mic and told Approach that we couldn't hold here much longer. Approach acknowledged and gave me a heading that would be pretty much direct to the airport. Yes! I turned to the new heading just as the captain came back on and said we were going to our alternate. I briefed the controls change and just as the captain assumed the controls, we poked into a puffy cumulus cloud. Well at 225 KIAS it was a pretty good bump, and whatever was loose in the ADC (Air Data Computer) reared its ugly head. We immediately got a "Stall! Stall! Stall!" audio warning along with stick shaker activation and a whole bunch of warning lights. Now I knew we were *not* stalled. We were in fact almost 90 knots above the stalling speed at our current weight. However, before I could say anything, the captain reacted to his rote-learned behavior for a stall (most likely in a C-172). He immediately shoved the yoke *and* the throttles full forward. I yelled, "Captain we are *not* stalled—look at the EFIS airspeed and the standby airspeed," and I proceeded to pull the yoke and throttles back, as well as declare an emergency. We were now at 335 KIAS and in a pretty good dive.

I'm sure I looked like a one-armed paper hanger! Just as we rounded out, we came out the bottom of the cloud into smooth air, and everything went quiet again. The captain was frozen on the standby instruments, and I was explaining to Approach that we had a computer and flight control problem and needed immediate vectors to the airport. Before I could finish we hit another bump and the scenario started all over again, not the least of which was the captain wanting to push the yoke forward as if we were in a stall. As respectful as I could be at the time, I explained we had nothing more than a computer problem, and we needed to turn the stall protection off. I was overruled by someone who didn't understand how the stall protection worked. The scenario repeated itself about five more times on the way to the FAF (Final Approach Fix), and I politely told the captain that I was turning stall protection off at the outer marker. I was not going to participate in a landing with the stick shaker potentially going off. I knew that the stick shaker first activates and then at the 30-second mark will push the nose over if you don't take corrective action. So far, our problems had lasted less than 30 seconds.

As luck would have it, it seems none of the passengers had noticed our earlier nosedive as we were in the clouds and were fairly level when we came out. I did my usual standing in the door and thanked them for flying with us!

The captain and I spent a good amount of time with maintenance, and we all agreed to ground the aircraft. I have ridden in that same aircraft as a passenger since then, and it always gives me the willies.

I'm out of space for this month, but in a future column, I will share one other lesson learned regarding systems knowledge and situational awareness. In the meantime, keep the fun factor alive, whether you are building or flying! ✈

Photo: Lord of the Wings, Toronto, Canada [CC BY-SA 2.0 (http://creativecommons.org/licenses/by-sa/2.0)], via Wikimedia Commons

Basic mold making.

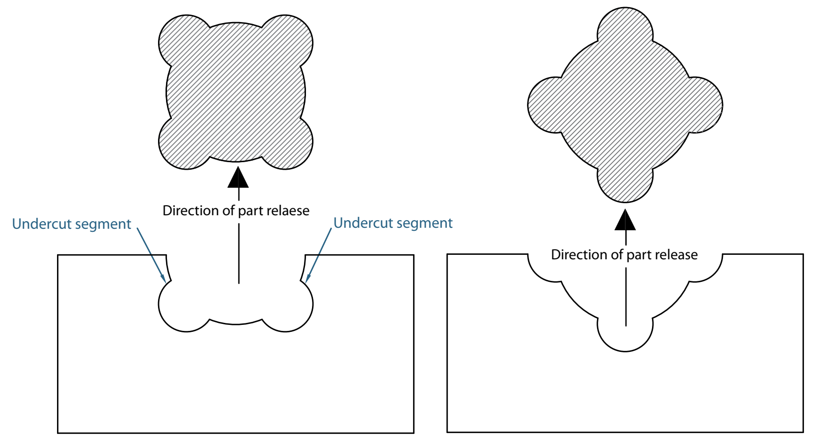
Casting is an ancient technique that can come in handy a number of interesting ways. Using simple techniques to make aluminum or wood molds, one can cast a variety of custom parts into shapes, or use materials, that can't be machined.

Traditional gravity casting involves pressing a negative impression into sand and then pouring molten metal into the impression. After the metal solidifies, you break away the sand and, voilà, you've replicated the pattern in metal. Sand casting is an inexpensive way to make a small run of production parts for a low cost. Among the obvious issues, at least for the home shop, is you need an accurate casting form to make an impression and a furnace to melt metal. All in all, it's a bit complicated for a first-time casting project.

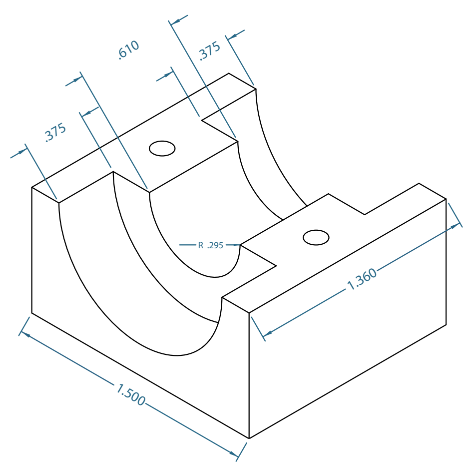
For this project, we'll trade hot metal for RTV (room temperature vulcanization) silicone rubber, which makes first-time casting both fun and safe. Instead of using a sand impression for the mold we will use regular metalworking tools to machine a reusable mold out of a tight-grained maple hardwood.

The part is a custom rubber grommet for neighbor Phil Hooper's Velocity RG. He needs two of them, plus a few spares for down the road while we're at it. The grommets go on 3/8-inch fuel lines (one from each wing tank) where they pass through the bulkhead to the header tank. The grommets prevent the aluminum lines from chafing against the fiberglass bulkhead.

Any molded part starts with an idea of how the finished piece should look. A simple part generally makes for a simple mold, but sometimes not. There are a few basic rules to mold-making that have to do with being sure the molded part will come out of the mold ("release" in mold-maker speak). A good example is "draft angle," or simply "draft," which is adding a slight taper to the sides of the mold to help prevent the part from binding in place. Another tip is to avoid



The example on the left shows an undercut segment of the mold cavity. The same part on the right, but oriented to eliminate the undercut and allow for a clean release from the mold.



The dimensions were determined by the hole in the bulkhead (5/8-inch diameter x 0.61-inch width). The flange diameter (1 1/8 inch) and thickness (1/4 inch) can be whatever you want, but if it's too bulky, you won't be able to squeeze it into place.

Bob Hadley

Bob Hadley is the R&D manager for a California-based consumer products company. He holds a Sport Pilot certificate and a Light-Sport Repairman certificate with inspection authorization for his Jabiru J250-SP.

undercuts or protuberances in the part that might cause the molded part to get locked into the mold. Most of the time you can work around these problems by paying attention to how the part is designed or adjusting the orientation of the part in the mold.

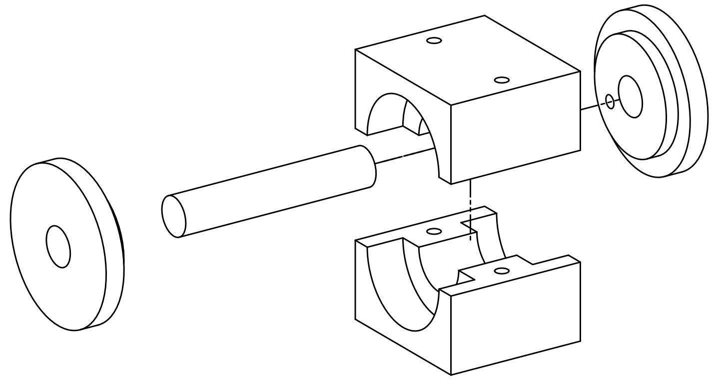
Small undercuts are usually not a problem when molding rubber. The material is flexible enough to be peeled out of the mold without harming the part. But if you're using a hard plastic or epoxy resin, any undercut will cause the part to break trying to get it out of the mold.

The grommet mold consists of a two-piece base, two end caps, and a center core. All the parts can be made using basic drilling, boring, and facing techniques. You can make the mold base on a lathe, a milling machine, or even a drill press using Forstner-style bits. The end caps are made on the lathe. The center core is a simple 3/8-inch bar or tube cut to length.

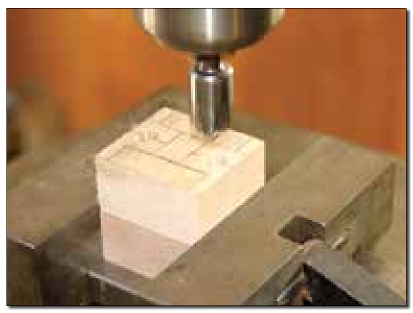
The rubber I selected to cast the grommets was a 1:1 two-part silicone called Rebound 25. It cures in six hours. The number 25 refers to the Shore hardness scale of the cured rubber. If you prefer somewhat stiffer material, the same company offers two-part silicone kits with a hardness of 40 (also a 1:1 mix) and 60 (a 10:1 mix). Mixing the 10:1 in small batches requires a scale with at least a 1-gram resolution.

The mold uses less than an ounce of material to fill so, using a postal scale, I metered out about ¾-ounce each of part A and part B. The mixed-up goop is pretty viscous. The manufacturer suggests to be careful not to over-stir, which can create air bubbles. By doing the minimal amount of mixing and then tapping the mixture on the bench vigorously for two minutes, most of the air will rise up and escape. The rest of the air should escape when you pour it into the mold.

The manufacturer suggests pouring from "high up" and filling the mold as slowly as possible to reduce air bubbles. Our mold is pretty small, so it can be messy to hit the bull's-eye—spread out a newspaper and wear gloves.



The top and bottom halves are identical. The cavities are machined with the two parts screwed together. The 3/8-inch rod forms the hollow center of the grommet. The 1/8-inch lip on each end cap centers the rod and seals the mold. The small hole in the cap on the right allows excess rubber to escape when sealing off the mold.



With the mold halves clamped together and the clamping holes marked, drill, countersink, and screw the two parts together as a matched pair.

Using the four-jaw chuck, clamp the screwed-together block in the lathe, center it, and drill or bore the 5/8-inch center hole.

Using the boring tool, face the block flat and counterbore the flange cavity. Flip the block and repeat the facing and counterbore operations on the opposite side. When done, remove any stray wood fibers with 180-grit sandpaper. A coat of acrylic clear coat and some mold release wax will seal the wood and prevent the rubber from sticking.

Photos and Illustrations: Bob Hadley

The end caps are lathe-turned from Delrin-type nylon, but any machinable plastic or aluminum will work. Drill an overflow hole into the top cap.

Rebound 25 two-part silicone. According to the manufacturer, it's non-flammable. That's a good thing on an airplane!

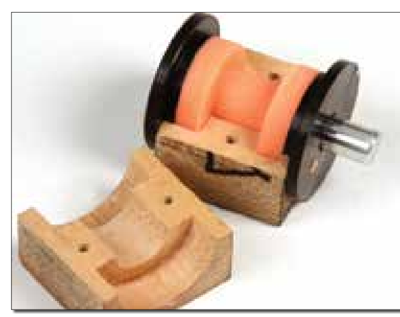
I found that it was a little easier to fill the bottom part of the mold cavity with the center post retracted (see photo). Once the mold was about 85 to 90% full, I pushed the center post up and capped the top. Overfilling the mold was not a problem because the excess came out the overflow hole.

Of the dozen or so parts I cast for this project, most of them had a few pinhead size air bubbles cured into the top surface. A few ended up with larger air pockets. Tapping the mixture for at least two minutes to help the air escape is important. If you have access to a vacuum pump and chamber, you can de-air the mixture 100 percent in about 2 minutes. The pot life is only 10 minutes, so you don't want to wait much longer than 5 minutes to start pouring.

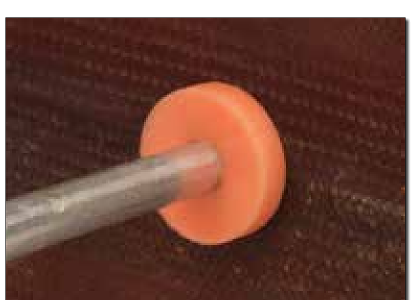
Final thoughts: Tear strength, UV resistance, heat, and flammability attributes are factors to consider for any material not specifically recommended by the designer of your kit or plans. These particular grommets are installed in the fuselage/cabin area of the Velocity and therefore not subject to direct UV degradation. Even so, they probably won't last forever. We molded a supply of extras and labeled and bagged them for future use. A check of the fuel system is part of the annual inspection, so their durability will be under continual scrutiny throughout the life of the aircraft.

Molded parts are something you most definitely should point out to your friends when showing off your airplane. It's way up on the "that's cool" scale. +

(Left) Using the manufacturer's recommended "high pour" method, fill the mold as slowly as possible. (Right) Push the cap into position and the excess will ooze out the overflow.

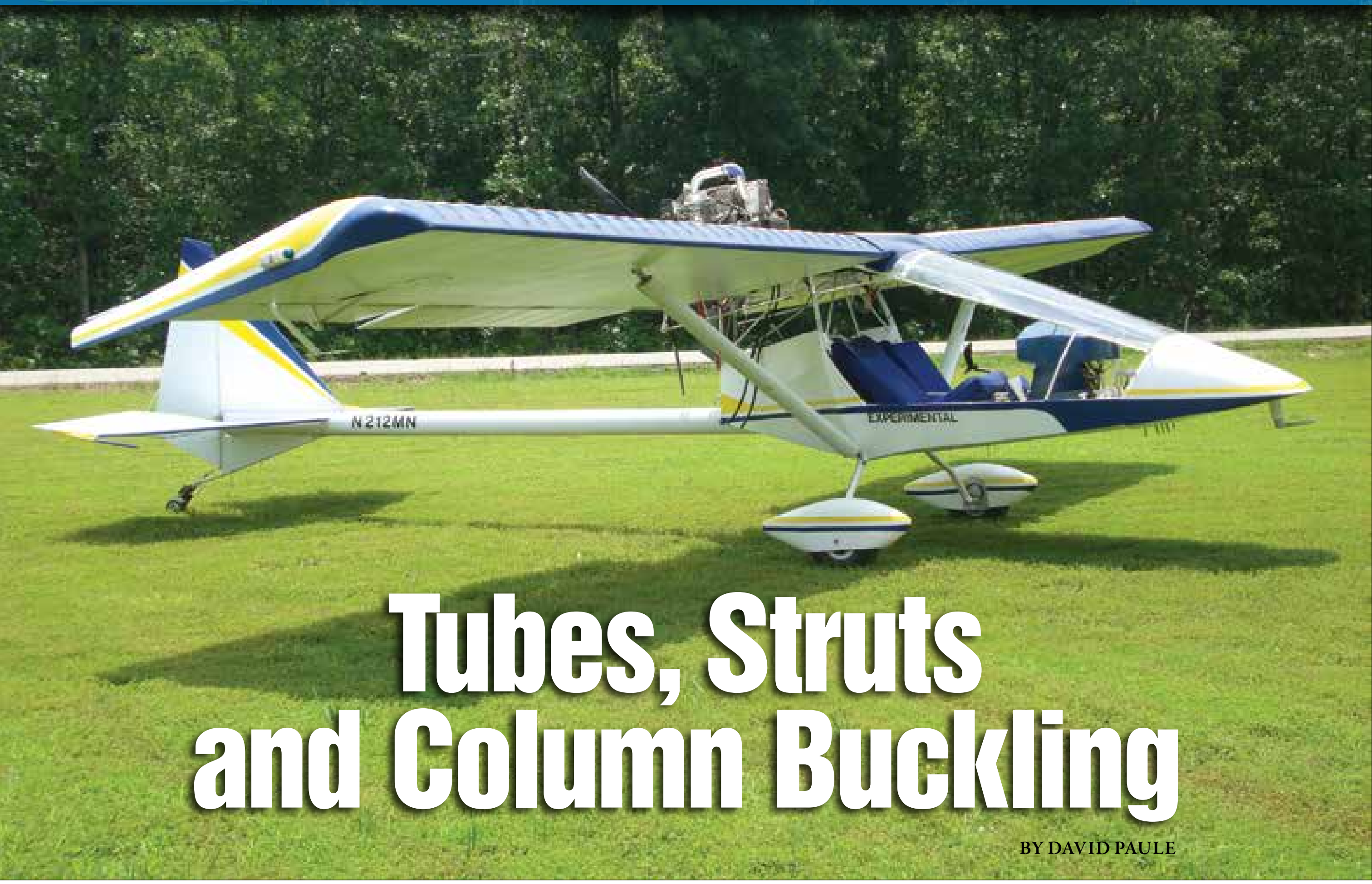


After curing at least six hours, slice off the cured rubber from the overflow and de-mold the part. As long as the mold is handled carefully, you can reuse it to make dozens of identical parts.



Some soapy water helps to fit the grommet in the bulkhead opening.

STRESSING STRUCTURE



Tubes, Struts and Column Buckling

BY DAVID PAULE

Most of our aircraft have some parts that carry mostly axial forces. These are often things like wingstruts, pushrods, and nearly all of the pieces of welded steel tube trusses. When they carry compressive loads, their designer needs to figure out how to make them carry that load without buckling. Since aircraft must be designed for both positive and negative flight loads, there's probably at least one load case that puts almost any part on the plane into compression. Usually that load condition is the critical one for the part, and being critical, that particular load governs that aspect of the design.

Imagine a long, skinny tube in compression. It might be a wingstrut without jury struts, like the ones on the Kolb Mark III Xtra shown in Figure 1. Our generic strut has some sort of single-fastener connection at each end, so that the strut is free to rotate about the fastener. While the fastener acts like a hinge in one direction, in the other direction it's not especially stiff and, in fact, it practically acts like a hinge in that direction too. These ends can rotate in any direction except perhaps in torsion. A strut or column with this type of end is a "pin-ended column," and if the compression load is too high, it'll buckle. Instability is another term for buckling. Buckling and instability are interchangeable terms, so if you're looking up one and you can't find what you're looking for, try the other. Either way, when it comes to struts, we don't want it to happen.

The load that these columns carry depends on a lot of things. Let's assume that the column or strut:

Figure 1: The fun Kolb Mark III Xtra has wing struts with no jury struts.

- Has a constant cross section except at the end fittings. That is, it's not tapered.
- It's all the same material, except at the short end fittings.
- Its cross section has at least one axis of symmetry.
- The cross section is closed, like a tube. In fact, tubes are what we'll be discussing here.
- It's straight.
- Any side loads are tiny.
- The load is concentric or coaxial with the long axis—that is, the ends aren't eccentric.

It's still possible to find out the strength of a strut or column that fails

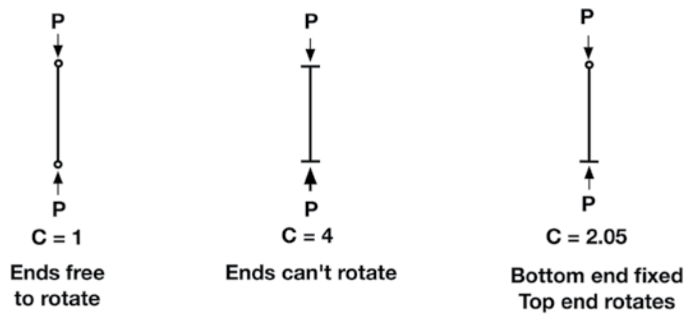


Figure 2: End fixity conditions and the associated column stability constants.

one or more of these assumptions, but we can't do it in this article.

Before we can get very far with this, we need to introduce some new terms: the end fixity and radius of gyration.

The end fixity describes how rigid the ends are. There are really only three possible cases that don't require considerable analysis complexity: free, pin-ended, and fixed. In aircraft, a column with a free end has negligible structural utility, so we won't discuss it. We've already talked about a pin-ended condition, where the column is able to rotate but not move laterally. If it has a fixed end, that end prevents rotation as well as lateral movement.

Figure 2 shows a few of the more common end fixities and the numeric value of C (sometimes the lower-case c is used), the symbol for fixity in column analysis. There's an important gotcha buried in these, though, and that's the question of how rigid is the actual fixed end? Will it maintain its rigidity as the load increases? Is it part of a larger structure, such as a welded truss, in which all the elements might be loaded, and in which the whole joint is rotating because of that? That's a particularly sneaky way for what looks like a fixed end to actually be a pin end. In structural analysis, we have to be certain that we don't error on the side of weakness or possible failure. Therefore, if we haven't made certain that the fixed ends are actually rigid, we should assume that they are pinned.

The next concept is the radius of gyration. It's the radius about which, were the whole area concentrated there, the element would behave the same as it actually does. However, I've never found that definition to be as helpful as the mathematical definition of it:

$$\rho = (I/A)^{1/2} \qquad \text{Equation 1}$$

Where

- ρ is the radius of gyration, inches
- I is the area moment of inertia, inches^4
- A is the cross sectional area, inches^2

Although what we're discussing today isn't limited to round tubes, often that's what we use. For a round tube,

$R = D/2$ Outside radius, inches

$r = R - t$ Inside radius, inches

$$I = (R^4 - r^4) * \frac{\pi}{4} \qquad \text{Equation 2}$$

Area moment of inertia, inches^4

And

$$A = (R^2 - r^2) * \pi$$

Area, inches^2 Equation 3

Where

- D is the outside diameter, inches
- t is the wall thickness, inches

This gives you enough to solve for ρ. For streamline sections, download the file *Streamline-Tube-Data.xls* at *www.kitplanes.com/includes/structure_stress.html.*

We'll also need:

$$D/t \qquad \text{Equation 4}$$

It's just called "D over t," nothing fancy here.

Another term:

$$L' = L / \sqrt{C}$$

Where

- L is the length of the strut, pin center to pin center, inches
- C is the fixity from Figure 2, no units

STATEMENT OF OWNERSHIP, MANAGEMENT, AND CIRCULATION

(Required by 39 U.S.C. 3685)

1. Publication Title: KITPLANES. 2. Publication Number: 0891-1851. 3. Filing Date: 9/4/15. 4. Issue Frequency: 12 issues per year. 5. No. of Issues Published Annually:12. 6. Annual Subscription Price: $29.95. 7. Complete Mailing Address of Known Office of Publication: Aviation Publishing Group, LLC, an affiliate of Belvoir Media Group LLC, 535 Connecticut Ave, Norwalk CT 06854. Contact Person: Greg King, Phone: 203-857-3119. 8. Complete Mailing Address of Headquarters or General Business Office of Publisher: Aviation Publishing Group, LLC, an affiliate of Belvoir Media Group LLC, 535 Connecticut Ave, Norwalk CT 06854. 9. Publisher: Phil Penny, 535 Connecticut Ave, Norwalk CT 06854. Editor-in-Chief: Paul Dye, 535 Connecticut Ave, Norwalk CT 06854. Managing Editor: Mark Schrimmer, 535 Connecticut Ave, Norwalk CT 06854. 10. Owner: Aviation Publishing Group, LLC, an affiliate of Belvoir Media Group, LLC, 535 Connecticut Ave, Norwalk CT 06854. 11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages or Other Securities: None. 12. Tax Status: Has Not Changed During Preceding 12 Months. 13. Publication Title: KITPLANES. 14. Issue Date for Circulation Data Below: October '15. 15. Extent and Nature of Circulation (Average No. Copies Each Issue During Preceding 12 Months/No. Copies of Single Issue Published Nearest to Filing Date): a. Total Number of Copies (Net press run): (40,573/41,950) b. 1. Paid/Requested Outside-County Mail Subscriptions Stated on Form 3541: (22,388/22,369). 2. Paid In-County Subscriptions Stated on Form 3541 (0/0). 3. Sales Through Dealers and Carriers, Street Vendors, Counter Sales, and Other Non-USPS Paid Distribution: (4,252/3,947) 4. Other Classes Mailed Through the USPS: (0/0) c. Total Paid and/or Requested Circulation: (26,640/26,316) d. Free Distribution by Mail: 1. Free or Nominal Rate Outside-County Copies included on PS Form 3541: (34/33). 2. Free or Nominal Rate In-County Copies as Stated on PS Form 3541: (0/0). 3. Other Classes Mailed Through the USPS: (0/0). 4. Free or Nominal Rate Distribution Outside the Mail: (777/442). e. Total Free or Nominal Rate Distribution: (811/475). f. Total Distribution: (27,451/26,791). g. Copies not Distributed: (13,122/15,159). h. Total: (40,573/41,950) j. Percent Paid and/or Requested Circulation: (97.0%/98.2%).16. Publication of Statement of Ownership: Dec.15 17. I certify that all information furnished on this form is true and complete: Greg King, VP, Circulation.

Photo: Mike Welch, Kolb Mark III Xtra owner/builder

With all these, calculate L′/ρ. This is a number we'll use a lot. We pronounce L′ "L prime," by the way.

Look at Figure 3. You'll see that it has two graphs. The inset graph shows the upper limit for the allowable crushing stress as a function of the D/t ratio. You can see that as the tube gets thinner (that is, the D/t number gets bigger), the allowable crushing stress goes down. Crushing stress is a bit of a misnomer; what's occurring is local buckling of the tube's wall. The overall column buckling of the tube is different from the local crippling, which is why these charts include both the effect of length and the effect of the wall thickness. For a particular part, one or the other might dominate and control the design, so you'll need to check both and use the lower value.

Some graphs have tick marks on the main curve to show where the D/t ratio starts to dominate, but not all of them.

When tubes are welded, the weld strength can be a cutoff stress; no matter the tube's geometry, even if it doesn't buckle, its weld can still fail. For steels, that's often shown on the graph. Typically for 4130 that's normalized, the maximum stress in weld-affected places is shown as a cutoff limiting the curve.

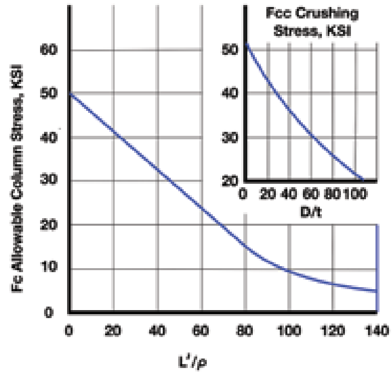


Figure 3: Example of column strength data. (Don't use this graph in an actual design—it's just for illustration.)

For other shapes than round or streamline tubing, and other materials than 2024-T3 or 6061-T6 aluminum and 4130 normalized (that is, sold as condition N) round tubing, you'll have to analyze it the hard way. Still, even there, if you have a long pin-ended column and you know its major inertia (the smaller number of the two moments of inertia), Euler's column buckling equation will be handy ("Euler" is pronounced "Oiler," just so you know):

$$Pe = \frac{\pi^2 * Ec * I}{L^2} \qquad \text{Equation 5}$$

Where

- Ec is the modulus of elasticity for compression, psi
- Pe is the compression force, pounds, that will buckle the strut
- L is the pin-to-pin length, inches
- I is the smaller of the moments of inertia inches^4

(C = 1 for pin-ended columns, so we didn't need to put it in this equation.)

Euler's equation is a fundamental structural analysis equation. I use this equation a lot to estimate what the moment of inertia ought to be. It might not be the final value, but it's a place to start. Unfortunately it's limited to large values of L′/ρ, such as over 80 or 100, so in most cases you'll also need to check local crippling. One thing about local crippling is that it often causes some local yielding and the strut will never straighten out again. If that happens, its strength is ruined, and therefore it's an ultimate condition.

You'll have to get the minimum area moment of inertia for a particular cross section from the vendor or calculate it yourself.

You've probably noticed by now that if you can only reduce the term L′/ρ, that the strength improves considerably. One way to do that is simply to reduce the length of the column by adding jury struts. These small struts intersect the main strut in the middle and brace it to prevent buckling. They are usually effectively pin-ended, even if they're clamped to the main strut. This is because they offer no bending rigidity to the main strut. Since the main strut has a point of inflection at the jury strut connection, the main strut's rotation there means that the jury strut is pin-ended. If they're in the middle of the main strut, that reduces the length of the main strut by two. That's a big improvement since the length squared is in the denominator.

If you want the lightest-weight strut, make it of aluminum. Because its modulus of elasticity is lower than steel's, that forces the size to be larger for the same

Referencing Graphs

The illustrative graph I made for this article is not real data. You'll have to go to the sources for that. Here are some references. For years, the main structural analysis strength reference for metals was MIL-HDBK-5H. It was preceded by ANC-5 and superseded by MMPDS; for the metals we're likely to use, the data remains substantially the same. KITPLANES® has them online at *www.kitplanes.com/includes/structure_stress.html*.

In the older ANC-5, the material call-outs are a little different. 24ST is now 2024-T3 or -T4, and 61S is now 6061-T6.

1. **Round 4130 steel tubing: See ANC-5, page 28, table 2.21 for some equations, or page 29, Figure 2.23(c) for the graph.**
2. **Streamline 4130 steel tube: See ANC-5, page 28, figure 2.23(b).**
3. **2024 and 6061 round tubing: See ANC-5, page 80, figure 3.23(A) or MMPDS, page 3-520, figure 3.10.2.3.**
4. **2024 streamline tubing: See ANC-5, page 80, figure 3-23(B). I couldn't find curves for 6061 streamlined tube.**

A spreadsheet called *Streamline-Tube-Data.xls* is available at the link above. It has the section properties of streamlined tubing for commonly available sizes. It's only applicable to tube formed from round tube that has constant wall thickness all the way around.

Some aluminum streamlined tube is available that's been extruded. It has flat sections on the inside. This facilitates mounting fittings and increases the moment of inertia, both good things. But the tables don't cover these shapes, so you'll need to contact the vendor for data for these.

—D.P.

column buckling strength. Since its density is lower than steel's, the weight is lower. But if you want the lightest-drag strut, make it from steel. The higher modulus of elasticity pays off here in smaller size.

What happens when a strut or column buckles? That depends a lot on what's happening with the strut. If there's local crippling and the wall is distorting, it'll probably carry some load, but not much more than the load at the onset of buckling. It's limited because the cross section is changing and that will probably adversely affect its stiffness in that area; that is, it's on the verge of collapse. If it's yielding, even locally, then that also causes some reduced stiffness—and local crippling nearly always means that there's some local yielding. Both of these lower the strength, and if either is present, you can't count on any load available beyond the onset of buckling.

But if the strut is a long strut, with L'/ρ greater than 100, it doesn't have any local crippling, and if the stresses are still wholly in the elastic range, it can carry additional load after it buckles. The cost for that will be much, much higher deflections and a lot of bending. A yardstick is a good example. Compress it lengthwise, and until it buckles it'll have low deflections. When it does buckle, it will deflect a lot as it bends. An estimate of the post-buckling axial deflection is:

$$e = 2 * L * \Delta P / Pe \qquad \text{Equation 6}$$

Where

- e — is the axial deflection, inches, after buckling
- L — is the unbuckled initial length of the strut, inches
- ΔP — is the post-buckling increase in load (just the increase), pounds force
- Pe — is the Euler buckling load, pounds force

This suggests that if the load increases by 10% past the buckling load, the additional axial deflection will be about 20% of the original length of the strut—that's huge. Nevertheless, this probably won't matter.

Column Buckling Strength of an Elevator Pushrod

Let's look at an elevator pushrod that goes from a bellcrank to the elevator horn. It has rod ends, so we know it's pin-ended. Let's check it for column buckling. The pushrod material is a 6061-T6 tube.

$D = 1.5$ in — Outside diameter of the tube

$t = .035$ in — Wall thickness of the tube

$L = 53$ in — Length, pin to pin, since $C = 1$, pin-ended, $L = L'$

$R = \frac{D}{2}$ — Outside radius of the tube — $R = 0.75$ in

$r = R - t$ — Inside radius: $r = 0.75$ in $- 0.035$ in — $r = 0.715$ in

$I = \frac{\pi}{4} * (R^4 - r^4)$ — Area moment of inertia — $I = \frac{\pi}{4} * [(.75 \text{ in})^4 - (.715 \text{ in})^4]$

$I = 0.04324 \text{ in}^4$

$A = \pi * (R^2 - r^2)$ — Cross-sectional area — $A = \pi * [(.75 \text{ in})^2 - (.715 \text{ in})^2]$

$A = 0.1611 \text{ in}^2$

$\rho = \sqrt{\frac{I}{A}}$ — Radius of gyration — $\rho = (0.04324 \text{ in}^4 / 0.1611 \text{ in}^2)^{1/2}$

$\rho = 0.518$ in

We'll need these two parameters next:

$$\frac{L'}{\rho} = \frac{53 \text{ in}}{0.518 \text{ in}} = 102.3 \quad \text{and} \quad \frac{D}{t} = \frac{1.5 \text{ in}}{0.035 \text{ in}} = 42.9$$

The material is 6061-T6 round tube. Look into ANC-5, page 80, figure 3.23(A), and we immediately see that D/t crippling will not be an issue because the L′/ρ is large. This tells us that since crippling isn't an issue, and the L′/ρ is definitely in the elastic column buckling region, we can use Equation 5, Euler's column buckling equation:

$Ec = 10.1 * 10^6$ psi — Compression modulus of elasticity for 6061-T6 tubes

$Pe = \frac{\pi^2 * Ec * I}{L^2}$ — Euler's equation for column buckling

$$Pe = \frac{\pi^2 * 10.1 * 10^6 \text{ psi} * 0.04324 \text{ in}^4}{(53 \text{ in})^2} = 1534 \text{ pound force}$$

So the column buckling strength of this pushrod is Pe = 1534 pound force, and that's an ultimate criterion.

If we needed the allowable compressive stress, it's

$$Fc = \frac{Pe}{A} \qquad Fc = \frac{1534 \text{ lbf}}{0.1611 \text{ in}^2} \qquad Fc = 9523 \text{ psi ultimate}$$

All this did was find the strength of the tube itself. We need to analyze the end fittings as well, but that's beyond the scope of this article.

—D.P.

If it buckles, it'll be bending and that, combined with the compression load, could fail the strut. And even if it doesn't fail, it'll be deflecting so much that other issues will arise, such as control system interference or even flutter. I recommend that you treat column buckling as an ultimate failure and not rely on any post-buckling load capability. ✢

References

1. Analysis & Design of Flight Vehicle Structures, *E. F. Bruhn, 1973, has an excellent discussion of the whole matter, including lots of tables and graphs, that can take you well beyond round and streamline tubes. Although thorough, it can be difficult to find what you need.*

The following references can be downloaded at www.kitplanes.com/includes/structure_stress.html.

2. Metallic Materials and Elements for Aerospace Vehicle Structures, *MIL-HDBK-5H, 1998, is an excellent source for data and includes other materials than the ones I discussed here.*

3. Metallic Materials Properties Development and Standardization (MMPDS) *is an FAA document that supersedes MIL-HDBK-5. Both are largely the same, especially for the metals and fasteners we're most likely to use.*

4. Strength of Metal Aircraft Elements, *ANC-5, 1951, is a precursor to MIL-HDBK-5 and contains some useful data that was later removed. That data is still valid, and this is a good source.*

5. Astronautics Structures Manual, *NASA MSFC (Marshall Space Flight Center), 1975, is very good for general structures. Since our round and streamline tubes are easier than some more complicated shapes, we don't need this unless things are getting complicated. Then it's very helpful. But just remember to check your structure for crippling as well as column buckling.*

6. Design of Wood Aircraft Structures, *ANC-18, June 1951, covers wood in detail. But it goes beyond that to include structural analysis methods that are applicable to aircraft in general. Even if you're not designing with wood, you should find a copy of this.*

7. *Another good general-purpose reference is Bell's clear* Structural Design Manual.

List of Advertisers

Please tell them you saw their ad in KITPLANES® Magazine.

KITPLANES® *interactive makes it quick and easy for you to receive instant information about products or services directly from our advertisers' web sites.*

➥ Go to: *www.kitplanes.com/links* for a virtual shopping tour via links to their web sites.

➥ Call the phone numbers listed below and be sure to tell them you saw their ad in KITPLANES® Magazine.

Advertiser	page #	telephone
Aero Sport Power	63	877-376-0861
Aircraft Spruce & Specialty	CV4	877-4SPRUCE
Aircraft Tool Supply Co.	89	800-248-0638
Avemco Insurance Company	71	888-241-7890
Avidyne	15	800-AVIDYNE
Bearhawk Aircraft	75	877-528-4776
Belite Aircraft	87	316-253-6746
Beringer	89	708-667-7890
Better Aircraft Fabric	79	907-229-6792
California Power Systems	73	800-AIRWOLF
CubCrafters	11	509-248-9491
Dynon Avionics	CV2	425-402-0433
Garmin International	5	913-397-8200
Garmin International	59	913-397-8200
Grand Rapids Technologies	65	616-245-7700
Grand Rapids Technologies	77	616-245-7700
Ivoprop	81	800-FOR PROP
Kitfox Aircraft	71	208-337-5111
KITPLANES® Bookstore	77	800-780-4115
Levil Technology	75	407-542-3971
MGL Avionics	79	877-835-9464
Quad City Ultralights	69	309-764-3515
Sonex Aircraft, LLC	55	920-231-8297
Stewart Systems	89	888-356-3490
Titan	3	210-820-8140
U.S. Sport Aviation Expo	9	See Advertisement
Van's Aircraft	57	503-678-6545
Vertical Power	55	See Advertisement
Wag Aero	73	800-558-6868
Wicks Aircraft Supply	65	800-221-9425
Zenith Aircraft Co.	CV3	573-581-9000

Advertiser	page #	telephone
BUILDERS' MARKETPLACE		
Aerotrek Aircraft	93	812-384-4972
Airflow Performance	93	864-576-4512
Alturair	92	619-449-1570
Arion Aircraft	92	931-680-1781
Bede Corp.	95	See Advertisement
Better Half VW	92	281-383-0113
Falconar Avia Inc	93	780-465-2024
Flight Data Systems	94	831-325-3131
Flight Grip	93	800-204-7625
Glen-L	93	888-700-5007
Grove Aircraft	95	619-562-1268
Homebuilt Help	94	See Advertisement
INFINITY Aerospace	94	See Advertisement
Kuntzleman Electronics Inc.	92	610-326-9068
Matco Manufacturing	95	801-335-0582
Mountain High Equipment	92	800-468-8185
Mustang Aeronautics	93	248-649-6818
Osprey Aircraft	92	See Advertisement
Recreational Power Engineering	92	800-583-3306
Sky Ox	94	800-253-0800
Sportsman's Market	93	800-SPORTYS
TCW Technologies	93	See Advertisement
Tormach LLC	92	See Advertisement
Tosten Manufacturing	95	See Advertisement
UMA Instruments	94	800-842-5578
VAL Avionics	95	800-255-1511
WhirlWind Propellers	94	619-562-3725
Zenair Ltd.	95	705-526-2871

BUILDERS' MARKETPLACE

I DESIGNED IT MYSELF FOR 'TAILGATING'!


This Little Battery Brings Big Peace of Mind
Back-Up Battery
Backup power for your EFIS, GPS, Auto Pilot and Electronic Ignition Systems. Order yours today at www.tcwtech.com
TCW technologies
ENGINEERED FOR FLIGHT


All-Metal Construction
Quickbuild Kits Available
MUSTANG II
- Two Seat
- Full IFR Capability
- Tapered Wing
- Folding Wing Option
- 215mph Cruise
- Aerobatic
- 400+ built
MIDGET MUSTANG
- Single Seat Hotrod
- Tapered Wing
- 215mph Cruise
- Aerobatic
- 400+ Built
Mustang Aeronautics
1990 Heide Dr - Troy, MI 48084
Phone: (248) 649-6818
www.MustangAero.com

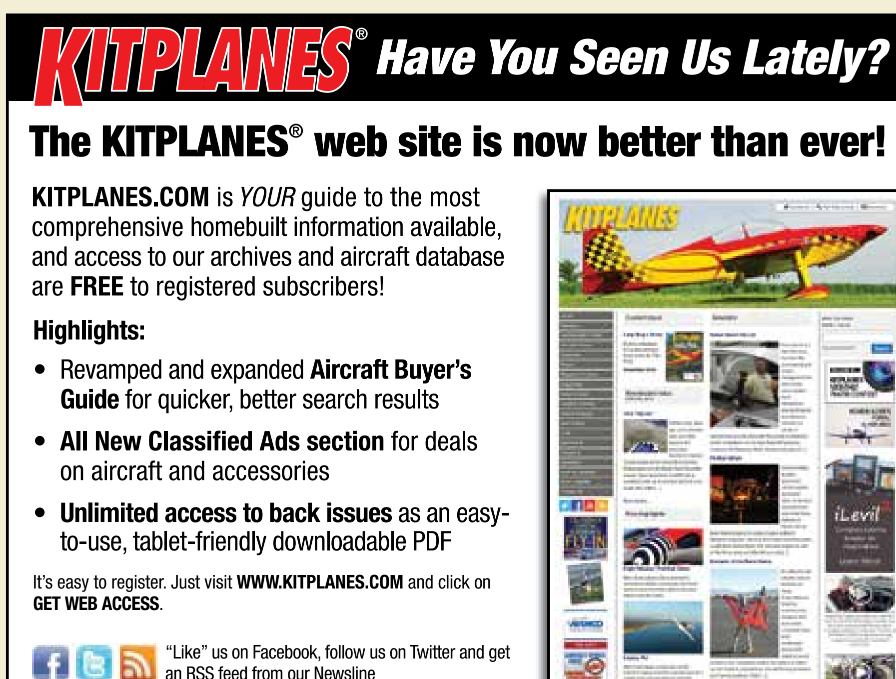

STRATUS SECOND GENERATION
• Subscription-free weather
• Dual band ADS-B traffic
• WAAS-enabled GPS
• Built-in AHRS for attitude
• Remote GPS and ADS-B antenna options
$899.00 8217A
sporty's pilot shop
1.800.SPORTYS
SPORTYS.COM/STRATUS

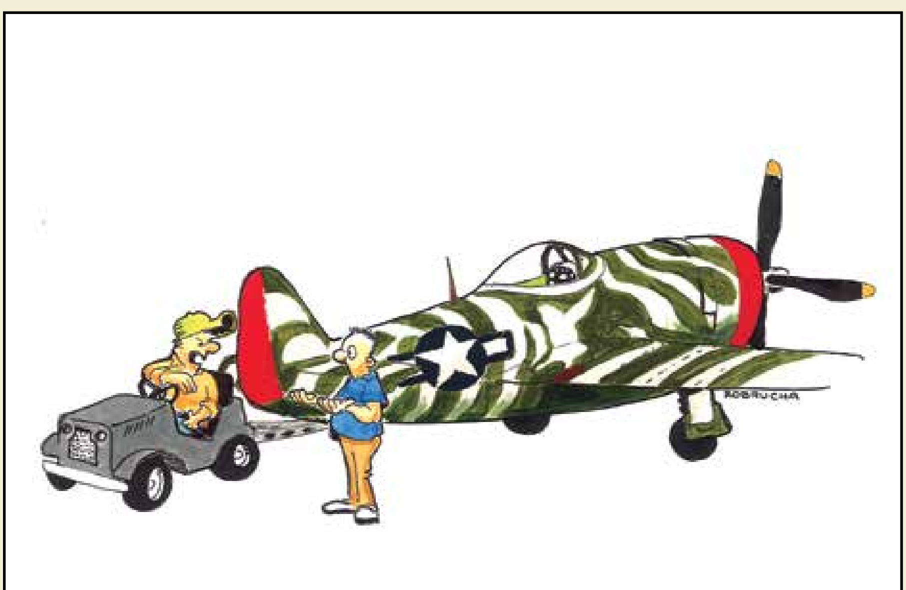

CUSTOMIZE OUR GRIP FOR YOUR AIRCRAFT
Easy Installation
Comfortable
Rocker (shown) or push button trigger style
Thumb Switches: Push Button, Toggle and/or 4-Way Trim
Fit to 5/8" thru 1-1/8" sticks
Next day shipping for virtually any configuration you desire.
Flight Grip, LLC
812 Jacquelyn St. • Milton-Freewater, Oregon 97862
800-204-7625 • 541-938-0533 • Fax: 541-938-7242


A220 taildragger
A240 tricycle gear
one-person quick-folding wings
factory-built and S-LSA certified
distributor-direct for only $88,950!
Aerotrek
812-384-4972
www.aerotrek.aero


PLANS - KITS - PARTS
2/3 Mustang
F12 Cruiser
and 10 other all wood designs
Info Packs $10/ea + $3 Postage
HIPEC Covering System - no ribstitching, no taping.
Lo cost — Lo labor — proven
www.falconaravia.com
Email: sales@falconaravia.com
FALCONAR AVIA INC. Ph: 780-465-2024


BE ORIGINAL
AIRFLOW PERFORMANCE
THE TRUE BLACK AND GOLD
Aircraft Multi-point Fuel Injection
• Operates all engines from 65 to 800 HP
• Applications for V6/V8 engines
• Manual Mixture Control
• Bolt on Kits for Lycoming Engines
• No Carburetor heat required
• Instant throttle response
• All Mechanical, No Electronics
• Increases mid-range HP
• Approved for Aerobatic use
• Compatible with all Fuels
• Precise Fuel Metering under all conditions
111 Airflow Drive
Spartanburg, SC 29306
(864) 576-4512
(864) 576-0201 (Fax)
www.airflowperformance.com
Email: airflow2@bellsouth.net


KITPLANES® Have You Seen Us Lately?
The KITPLANES® web site is now better than ever!
KITPLANES.COM is YOUR guide to the most comprehensive homebuilt information available, and access to our archives and aircraft database are FREE to registered subscribers!
Highlights:
• Revamped and expanded Aircraft Buyer's Guide for quicker, better search results
• All New Classified Ads section for deals on aircraft and accessories
• Unlimited access to back issues as an easy-to-use, tablet-friendly downloadable PDF
It's easy to register. Just visit WWW.KITPLANES.COM and click on GET WEB ACCESS.
"Like" us on Facebook, follow us on Twitter and get an RSS feed from our Newsline


ISN'T IT OBVIOUS?! I'M PULLING A JUG!

KITPLANES®

YOUR HOMEBUILT AIRCRAFT AUTHORITY

The Builders' Marketplace offers several advertising opportunities designed to enhance response for your precious advertising dollars. This section offers 1-, 2- or 3-inch ads designed by us or provided by you. Here are samples of the three different sizes, acceptable formats and the rates to submit your own Builders' Marketplace ad or have us create one using your photo/logo and text.

As you know, advertising isn't just reaching people...it's reaching those who are most likely to buy your product and producing results. The kit manufacturers and our regular advertisers who sell via mail order and track their response tell us that KITPLANES® regularly outperforms other media on a cost-per-sale basis. This no-waste circulation delivers greater efficiency for your valuable ad dollars. In advertising, consistency pays off. Your ability to sustain a long-term advertising program shows customers that you're a successful, reliable brand.

KITPLANES® Marketplace Rates – GROSS *effective 10/9/2013*

Size	1x	6x	12x
1" 4-color	180	160	130
2" 4-color	400	360	300
3" 4-color	560	510	440

Gross rates include a new ad design with photo and copy to be provided by the advertiser. **A 15% discount is allowed for providing the ad to meet our specifications below.**

Required File Formats:

PDF/X-1a: PDF version 1.3 (Acrobat 4); output resolution 2400 dpi; composite CMYK; high-quality JPEG or lossless Zip compression; resolution for color and gray scale images is 300 dpi; resolution for monochrome images is 1200 dpi; and fonts are embedded and subsetted 100% as well as other characteristics. This format is acceptable for spread, full or partial pages. Trapping is the responsibility of the file provider. Total density should not exceed 300%.

Unacceptable file formats:

Other file types, such as Postscript, TIFF, TIFF/IT, EPS or native applications such as Quark, InDesign, Illustrator, Photoshop, etc.

Ink Specifications:

4/C process.

Please visit www.kitplanes.com/advertising to peruse our 2015 Editorial Planner with deadlines to formulate your advertising schedule now, or call Chuck Preston at (805) 382-3363.

***Sample 1" Ad**– 2.25" wide x 1" high*

***Sample 2" Ad**– 2.25" wide x 2" high*

***Sample 3" Ad**– 2.25" wide x 3" high*

Ask the DAR

RV-7A converted to RV-7, importing a Canadian ultralight to the U.S. and registering as an LSA.

BY MEL ASBERRY

Question: I am considering buying an RV that was originally built and signed off as an RV-7A. It suffered fuel starvation, and the off-field landing resulted in significant damage. During repairs, it was converted to an RV-7. Do the new repairs have to be signed off by a DAR since it was a major structural change, with a new 25-hour flight testing requirement?

Answer: Your operating limitations is the controlling document on these matters. There should be a paragraph within your op lims describing just how to handle major changes. You will need to place the aircraft back into Phase I for a minimum of 5 hours. A new airworthiness inspection is not required.

Now, if you want to change the model, that gets more difficult. To do that would require a new inspection and new data plate in addition to the original one. That's right, two data plates. According to FARs, if the model is changed, a new data plate must be installed next to the original one. Fortunately for us, an Experimental/Amateur-Built aircraft can be whatever model the builder wants, so changing the model is not required.

Question: Can a Canadian-registered Basic Ultra-Light Aeroplane (BULA) or Advanced Ultra-Light Aeroplane (AULA) be bought in Canada, brought into the U.S., and registered as an LSA (assuming the AULA/BULA fits the U.S. LSA category)? Conversely, can a "fat ultralight" that never received an N-number be purchased by a Canadian, certified AULA/BULA, and then be sold and brought back into the U.S. and registered as an LSA?

Answer: In both cases, the answer is no. In the U.S. there are only three ways to register an aircraft as an LSA.

One is for a manufacturer to build an LSA and have it certificated as a Special Light Sport Aircraft (SLSA).

The second way is for an individual to build the aircraft from a certified Light Sport Aircraft kit. To offer an LSA kit, the kit manufacturer must first build and certificate at least one example of a Special Light Sport Aircraft. That aircraft may then be cloned in kit form. The kit manufacturer must certify that all components contained in the kit are the exact same parts as used in the original SLSA. The "builder" must then certify that he/she built the kit in accordance with all instructions and components supplied by the kit manufacturer without any modifications.

The third way would be to re-certificate an SLSA as an ELSA (Experimental Light Sport Aircraft). After doing this, the aircraft is no longer restricted to the original operating limitations, thereby allowing the owner to perform modifications, as long as the modification does not take the aircraft outside of LSA parameters. The negative side of this is that the aircraft may no longer be used for commercial operations.

The only practical solution to what you are proposing would be to certificate the aircraft as Experimental/Amateur-Built. To do this, you must be able to prove that the aircraft was more than 50% amateur-built. This is done by submitting the builder's log, an eligibility statement (FAA Form 8130-12), etc., and must meet the same requirements as if the aircraft were built in the U.S. If the aircraft meets U.S. LSA parameters, then it may be flown by a Sport Pilot, but it will never be registered as an LSA. ✢

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

Photo: Mel Asberry

A blast from the past.

One of the really frustrating things about the teaching profession is that you really have no way of telling if and when your efforts will ever bear fruit. And then you have Oshkosh '15. I was sitting in the KITPLANES® booth chatting with some readers when this fellow told me he'd been reading my stuff "for a while." When I asked him how long that had been, he started quoting chapter and verse from the very first airplane article I ever had published, "The TSO'd Pencil," from the AOPA magazine, August 1977. 1977—that's nearly 40 years ago, and he's quoting me verbatim stuff that I'd written and forgotten about a long time ago.

So I get home and start answering my email and here is a letter from a fellow thanking me for writing an article on how to make a COM antenna for his RV-3B, and how he'd just made one, and that it turned out really well. I looked that one up and it was from the KITPLANES®, November 1999 issue, over 16 years ago! Now, how's *that* for a Weir two-fer coincidence within a week of each other?

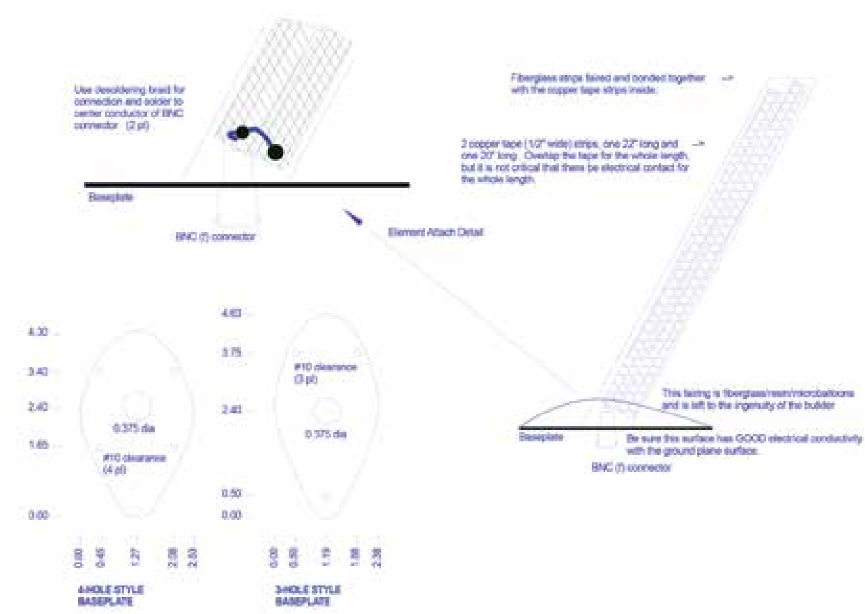
That got me thinking: Perhaps it might be informative to show you what I wrote and how I configured the project in 1999 and how Robin McKee, based at New Ulm Municipal Airport in Minnesota, took that article and manufactured his antenna for the RV last year. In addition, I'm going to include a brief report of recent test results, along with my test results from '99.

How We Did It In '99

The basic plan was to show how the copper tape antenna so widely used on composite ("plastic") aircraft could be used on metal ships as well. To effect this plan, I proposed that we procure a long, narrow strip of fiberglass, cover it with a couple of strips of copper tape, and use it much as you would use any of the white com antennas sold at preposterous prices for metal aircraft.

The drawing shows the theoretical realization of this plan, in that it provided the fiberglass strip in conjunction with a metal mounting plate to which was affixed a standard BNC connector. The BNC connector center pin was soldered to the bottom end of the copper strips, and the strips were held to the plate with RTV caulking material.

To simulate a metal aircraft "ground plane," four copper wires were covered



The original drawing from 1999 for a com antenna that is made from $2 in parts, yet performs as well as commercial antennas costing hundreds of dollars more.

Close-up shot from 1999 shows the BNC connector soldered to the center of two ½-inch-wide strips of copper tape.

Jim Weir *is the chief avioniker at RST Engineering. He answers avionics questions in the Internet newsgroup www.pilotsofamerica.com–Maintenance. His technical advisor, Cyndi Weir, got her Masters degree in English and Journalism and keeps Jim on the straight and narrow. Check out their web site at www.rst-engr.com/kitplanes for previous articles and supplements.*

Copper foil applied to balsa wood.

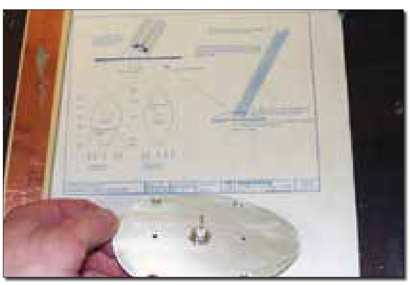
Putting balsa wood halves together.

Top view of antenna shows its airfoil shape.

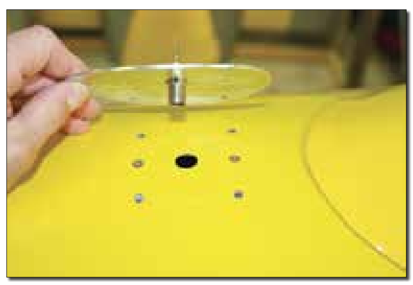
Com antenna with a coat of fiberglass.

Com antenna covered with filler.

The finished antenna, ready for mounting.



Making an antenna from plans.



Mounting holes with inside plate attached.

Fitting antenna base plate to fuselage.

with copper tape and strung out horizontally from the metal mounting plate. While it is true that we all believe that none of our children are ugly, this particular baby of mine was not in the running for cute child of the year.

Be that as it may, the tests we ran on the antenna showed it to be head and shoulders ahead of any of the commercial com antennas on the market *and* had been built for less than $2 (2015 prices) in parts.

How Robin Did It In 2012

Robin is evidently quite a craftsman, and a quick look at his aircraft should bolster that opinion. He took that ugly duckling of mine and transformed it into an absolutely beautiful white swan of an antenna. Not only that, but his tests exactly paralleled my tests and showed that what I had envisioned he had been able to construct.

He made a couple of very clever changes. In the first place, instead of using a piece of layed-up and resined fiberglass for the basic structure, Robin chose a couple of pieces of balsa wood for the structure. This allowed him to form the balsa into an aerodynamic shape that reduced the drag of the antenna significantly. Note on the left corner of the balsa that he carved out a notch for the connector to fit into. He then put the two copper strips that I showed on the drawing onto the surface of one of the balsa pieces and then sandwiched the copper tape into the balsa assembly.

He also formed the base plate to conform to the shape of his fuselage attach point. This also reduced drag from the flat plate that I used for my tests. Since it made not a whit of difference in the performance of the antenna, this was a mod that made the antenna truly unique to his particular airframe.

Finished antenna mounted on the RV-3.

Photos: Jim Weir

Once the baseplate was formed, with the connector installed and bolted down, the balsa-copper tape was soldered to the center pin of the BNC connector and then the whole assembly was fiberglassed together.

The rest is artistry. The antenna would have worked perfectly well at this point, but the craftsman always takes steps to make it pretty. Between fiberglass filler, sanding, painting, and generally cleaning the assembly up, Robin made a very handsome antenna that, from my eye, rivals anything you can find in any aircraft parts catalog.

The proof, as they say, is in the pudding. VSWR "goodness" tests of this antenna in the aircraft are *exactly* what I measured over 16 years ago. And, his comment was that 90-mile range was not at all uncommon when he test-flew the antenna.

Robin and Barb McKee and the completed RV-3.

Conclusions

My only conclusion is that Robin could have ordered an antenna from any one of a dozen vendors, spent on the order of $200 to $400 on the product, and not had as good a result as he got for $2 in parts.

Given this conclusion, I make this offer to KITPLANES® readers: Tell me about the antenna or other fairly simple product you want for your homebuilt, show me a commercial example, and if I think I can do it for less than half of what you would spend, I'll feature it in a KITPLANES® article. The caveat is that if I design it, you must build it and report your results back—along with photos showing your craftsmanship and your results. Until then, stay tuned.

Offset hinge lines.

Until the advent of fully powered control systems shortly after WW-II, airplanes had manual flight control systems. The control surfaces were linked to the cockpit controls by mechanical linkages, and all of the force to deflect the controls was provided by the pilot's muscles acting on the stick and rudder pedals. As airplanes got larger, so did the control surfaces.

The combination of larger control surfaces and greater aerodynamic loads resulting from higher flight speeds presented designers with a problem: The moments required to deflect the controls got so large that a single pilot was not strong enough to move a simple flap-type control enough to fly the airplane. In order to solve this problem, it was necessary to learn how to shape and hinge control surfaces so that the hinge moments needed to deflect them remained within the capacity of an average human pilot.

In today's world, large and high-speed airplanes use fully powered control systems, so the problem is solved with brute hydraulic or electrical force. General aviation airplanes, however, still use mechanical controls, and some of the aerodynamic balancing concepts originally developed for WW-II military airplanes can be quite useful to tailor the flying qualities of the airplanes private pilots build and fly.

The simplest form of aerodynamic balance is the offset hinge line. Instead of being placed at the leading edge of the moveable surface, the hinge axis is moved aft. When the control surface is deflected, the force acting on the portion of the control surface ahead of the hinge line will produce a moment that is opposite to that produced by the force acting behind the hinge line. By adjusting the position of the hinge line, the designer can control the restoring tendency of the surface. The position of the hinge line will also affect the floating tendency. As the hinge line moves aft, both the floating tendency and the restoring tendency decrease. In addition, the moments that oppose the control deflection when it is moved become smaller, and the surface has less tendency to rotate parallel to the airstream as angle of attack changes. In most cases, both of these effects are desirable, provided they are not so extreme that control surface instability results.

Offset hinges disappeared almost entirely from the scene with the advent of powered controls on large airplanes. In recent years, they have reappeared on the ailerons of aerobatic airplanes.

Disadvantages

Offset hinge line balancing does have some disadvantages that must be addressed. The first is that the hinge system becomes more complex. The hinges must be cantilevered back from the fixed portion of the flying surface, and the

The aileron of this Giles 200 shows the set-back hinge axis and an intermediate nose shape. Note how far the aileron hinges are cantilevered aft of the wingspar.

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.*

hinges themselves and the structure they are anchored to must be strong enough to withstand the moment caused by this aft cantilever.

The second disadvantage is that, in order to work properly, the control surface nose must be able to move up and down relative to the fixed surface the control is attached to. This necessitates some gap at the control surface leading edge and means that gap sealing is not possible. There will be some aerodynamic penalty for this.

One characteristic of the offset hinge line type of balance is that it can introduce significant nonlinearity into the control-surface hinge moments. The hinge moments on a plain flap control surface change smoothly as the surface deflection changes. If the hinge line is offset, the moments may change suddenly at some deflection, or the rate of increase of moment with increasing deflection may change over the control surface's range of deflection.

This nonlinearity is not always undesirable. On an aerobatic airplane, it can be used to tailor the aileron forces so that the initial stick force for the first few degrees of deflection is heavy enough to allow precise control and for the airplane not to feel "twitchy," while at the same time keeping the force required to make a large aileron movement for rapid rolls light enough to allow the pilot to maneuver aggressively.

If done wrong, however, the nonlinearity in stick force can become a problem if it causes the pilot to feel control forces which do not vary smoothly with changes in control position and flight condition of the airplane. Such nonlinearity can make the airplane difficult to control or unpleasant to fly. Sudden changes in stick force or stick force reversal that cause the control to try to deflect itself are never good.

The nonlinearity arises from the fact that the nose of the control surface is shielded by the fixed surface ahead of it when the angle of deflection is small. As the deflection increases, the nose of the control surface moves out into the free stream and new aerodynamic forces start to be generated by the increased airspeed over the nose.

The B-29 rudder has a sharp nose shape and an offset hinge. The large amount of offset was needed so this very large surface could be moved by the legs of a single pilot, with no power assist. The included angle of the rudder leading edge is chosen so the sharp leading edge of the rudder does not unport at maximum rudder deflection.

The rudder of the Consolidated PB4Y-2 Privateer (Naval patrol version of the B-24 Liberator) has a mix of nose shapes. The lower half has a more rounded shape, while the upper portion is sharp edged. The combination of the two allowed the rudder hinge moment to be tailored by varying the span of the sharp and rounded segments of the leading edge.

If the control surface nose is rounded, the air flowing over the curve of the nose will produce a low pressure area, and this lift will produce a moment which tends to increase the control surface deflection. This moment is opposed by the moment produced by the lift on the portion of the surface aft of the hinge line. The lift on the aft portion of the surface changes relatively linearly with changing deflection, but the lift on the nose of the surface can change suddenly both when the nose first protrudes into the airflow and at higher deflections when the nose of the surface stalls.

Over the years, designers have developed a number of control surface nose shapes that are used on balanced controls.

Blunt Nose Balance

Blunt nose balance gives the largest reduction of restoring tendency and hence the largest reduction in stick force. Unfortunately it also produces the most nonlinear variation of hinge moment with control deflection.

As the nose of the control surface moves out from behind the back of the fixed surface, the air begins to flow over the highly curved leading edge of the surface. This produces a low-pressure area on the nose of the control surface, which develops as the deflection increases. This lift on the control surface leading edge helps reduce the surface's hinge moment, but it varies greatly as the deflection changes. In the region of small deflections, the nose of the surface is shielded behind the fixed portion of the wing or elevator and there is very little nose lift. When the nose of the surface unports or comes out from behind the fixed surface, the nose lift will begin to develop. This will be felt by the pilot as a reduction in the stick force required to deflect the surface. A fully blunt nosed surface unports at very low deflections, so the nonlinearity is felt almost immediately as the surface deflects.

At some larger deflection the nose of the control surface will stall. This will cause an abrupt change in both the hinge moment and effectiveness of the control surface. Stall of offset-hinge control surfaces is dangerous, and can lead to loss of control of the airplane. The deflection of the surface should be limited to prevent this stall from happening, even with the controls against the stops.

Sharp Nose Balance

The second type of balance nose shape is the sharp nose balance. A good example of this type of balance is the rudder of the WW-II B-29 bomber. The sharp nose balance provides less balancing effect than the blunt nose balance, but has the advantage that its variation of hinge moment with deflection is quite linear over the range of deflections available before the nose unports. This range of deflections is determined by the wedge angle of the balance nose.

The disadvantage of the sharp nose balance is that the control surface will stall abruptly when the nose of the surface does emerge from behind the back of the fixed surface. A surface employing a sharp nose balance should be limited in deflection so that the nose will never unport and cause the surface to stall.

Intermediate Nose Balance

The third type of nose shape is a compromise between the blunt nose and the fully sharpened nose. As one might expect, its characteristics are somewhere between the characteristics of the two other shapes. The compromise nose provides more hinge moment relief than the sharp nose, but less than the full blunt nose. It has more linear hinge moment characteristics than the full blunt nose and is less prone to sudden stalling than the sharp nose surface. As a result, this compromise nose shape is a good choice for control surfaces using offset hinge line balance.

All of these nose shapes have been successfully used on flying airplanes to alleviate hinge moment and floating tendency. Which is the best choice depends on three factors:

1. How much hinge moment alleviation is required.
2. How much hinge moment nonlinearity with deflection can be tolerated, and
3. How much control power is required.

The fully blunt shape provides more hinge moment relief than the other two shapes, but has the most nonlinear hinge moment characteristics.

The sharp nose provides the most linear variation of hinge moment, but reduces hinge moments less than the blunt shaped nose. The sharp nose also has the lowest total control power for a given control surface area due to its sharp stall when the nose unports.

The intermediate nose shape offers a compromise between these two sets of characteristics. ✈


IT'S THAT TIME AGAIN!
REINDEER ONLY
UROLOGY
@4#! I HATE THESE ANNUAL OVERHAULS!
ROBRUCHA

Zenith CH 750

Sport Pilot Ready
Awesome Visibility
Wide & Roomy Cabin
Fun to Fly / Great Performance
Many Engine Choices

Two Models To Choose:
STOL or CRUZER

The Complete Kit with extensive CNC-cut match-drilled parts.
Assemble the all-metal airframe kit in about 350 hours with simple hand tools.
Build your own Zenith from a complete kit, component kits, or from blueprints.

Download our free 48-page magazine for an excellent introduction to the world of recreational flying and kit aviation: http://j.mp/zenith-magazine

Zenith CH 750
Cruzer

Build It and Fly It... Faster!
***STOL**: Take-off in just 100 feet!*
***CRUZER**: 118 mph cross-country performance*

Check our website for complete specifications, pricing, and builder resources

ZENITH AIRCRAFT COMPANY
Quality Kit Aircraft Since 1992

Zenith Aircraft Company
1881 Airport Road, Mexico, Missouri 65265 USA
Telephone 573-581-9000

Exclusive online builder community:
www.zenith.aero

www.zenithair.com

Follow us on **facebook.com/zenithair**


AIRCRAFT SPRUCE
AIRCRAFT SPRUCE IS YOUR ONE STOP SHOP
FOR PARTS & PILOT SUPPLIES - SINCE 1965
AVIONICS & INSTRUMENTS
PILOT SUPPLIES
AIRCRAFT PARTS
BUILDING MATERIALS & KITS
Aircraft Spruce & Specialty Co.
FREE CATALOG
Aircraft Spruce
SINCE 1965
& Specialty Co.
CELEBRATING 50 YEARS IN AVIATION
50th
1965 - 2015
PROUD SPONSOR OF:
EAA
THE SPIRIT OF AVIATION
AOPA
Strategic Partner
www.aircraftspruce.com
CALL 1-877-4-SPRUCE
777823