Vol.3 No.12 | December 2014

EAA

EXPERIMENTER

The Spirit of Homebuilt Aviation | www.eaa.org

» **A Piel Beryl**
A vintage homebuilt

» **The *Determinator***
Klaus Savier's experimental test bed

Meet the Legal Eagle

Ultralight or homebuilt fun!

The Pelton family and their Cessna 195: Jack, Rose, Christine, Ryan, and Christy with grandsons Noah and little Owen.

Help Give the Gift of Flight

BY JACK J. PELTON

ALL RESEARCH SHOWS that a majority of us who fly have a family member who is also a pilot or is deeply involved in aviation in some other capacity. It could be a parent, grandparent, aunt or uncle, or even a more distant relative. But the link is solid. Families have been very successful at passing down the excitement and challenge of personal aviation.

But what about people who are not born into an aviation family? How can we best show them the great joy and feeling of accomplishment we all draw from personal aviation? EAA can be a big part of that solution.

EAA is, after all, one really big family made up of people from all walks of life who love aviation. Our Founder Paul Poberezny repeated countless times that "airplanes bring us together, but friends we make keep us together." Nothing could be truer.

Our biggest family event happens at Oshkosh every summer where we get to meet and greet old friends, and more importantly, make new friends. Oshkosh welcomes anyone with an interest in aviation into the EAA family and shows them up-close and hands-on what personal aviation is all about.

Our nearly 1,000 chapters certainly function as families throughout the year meeting to share experiences, dispense advice learned from building all sorts of airplanes, and promote the value of personal aviation to the community.

And the nearly 2 million youngsters who have gone flying in our Young Eagles program now know the freedom and excitement of personal flight firsthand. And they also have new family members—the pilots and chapter members who organized the Young Eagles rally—who can guide them to a future in aviation.

I think about our EAA family at this time of the year because Rose and I are finalizing plans to celebrate the joy of the season with our own children and grandchildren. And I bet you are doing the same.

We have done our best to pass on our values and passions and traditions to our kids and grandkids, and experiencing personal aviation is a big part of that. Actually going flying is an important part of that tradition, but so is telling aviation stories, reliving the experiences we have had over the years, and even passing on the tales from earlier generations. Shared experiences, shared traditions, and shared interests are what bond families and any other group of humans together.

To keep the EAA family and what it means to all of us going, we need your help.

Volunteers are essential for almost every EAA activity whether it be at a chapter event that welcomes the community or among the many thousands who make our annual convention at Oshkosh possible.

Young Eagles flights are possible only because so many thousands of you donate your time, your airplane, and pick up the costs. And I thank each of you.

But to continue our work of growing the aviation family EAA also needs donations. Your gift of any size will be very helpful. Many members are including EAA in their planned giving in the same way they plan for the future of their families. There are many opportunities to support EAA, and in every case your donation is tax-deductible to the full extent of the law.

Personal aviation faces many challenges, and EAA works every day to resolve threats to our freedom to fly. But in the joyous holiday season when we gather with family and friends to share, I ask you to please think of EAA as part of your family. Together we can be certain the excitement, challenge, and fun of personal aviation carries on to the new generation the same way all families celebrate the experiences and traditions they hold most dear.

Rose and I, the EAA board of directors, and everyone at our Oshkosh headquarters wish you and yours a very merry Christmas, a happy New Year, and a joyous holiday season with your family close and together. EAA

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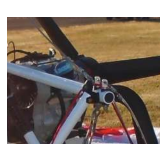

On the cover: Dennis Scott's Legal Eagle XL takes to the air. (Photography courtesy of Dennis Scott)

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2014 in Review

Homebuilding victories and challenges

BY CHARLIE BECKER

WITH WINTER SETTLING in here in Oshkosh, flying will be put on the shelf and my full attention will be back on my homebuilding projects. Given the weather we experience during a Wisconsin winter, I don't think it was a coincidence that Wisconsin became a hotbed for the homebuilding movement. The weather is particularly well suited to hunkering down and working on your project. The end of the year is always a good time to take stock of what you have accomplished during the year, so let's look at some of the highlights for EAA and the homebuilder in 2014.

After more than a year's work with the FAA, we were able to make a historic change in the way we flight test aircraft. For the first time ever, a homebuilder now has the option of having a second pilot onboard the aircraft during Phase 1 flight testing. We are hopeful that this new option will decrease the number of fatal accidents that occur during that time of greatest exposure. We implore all of our members who choose to use this option to do so with responsibility by understanding and following the guidance in Advisory Circular 90-116. We want to be able to show the FAA that this additional privilege will not be taken lightly or abused. It will help us pave the way for more options in the future if we are successful.

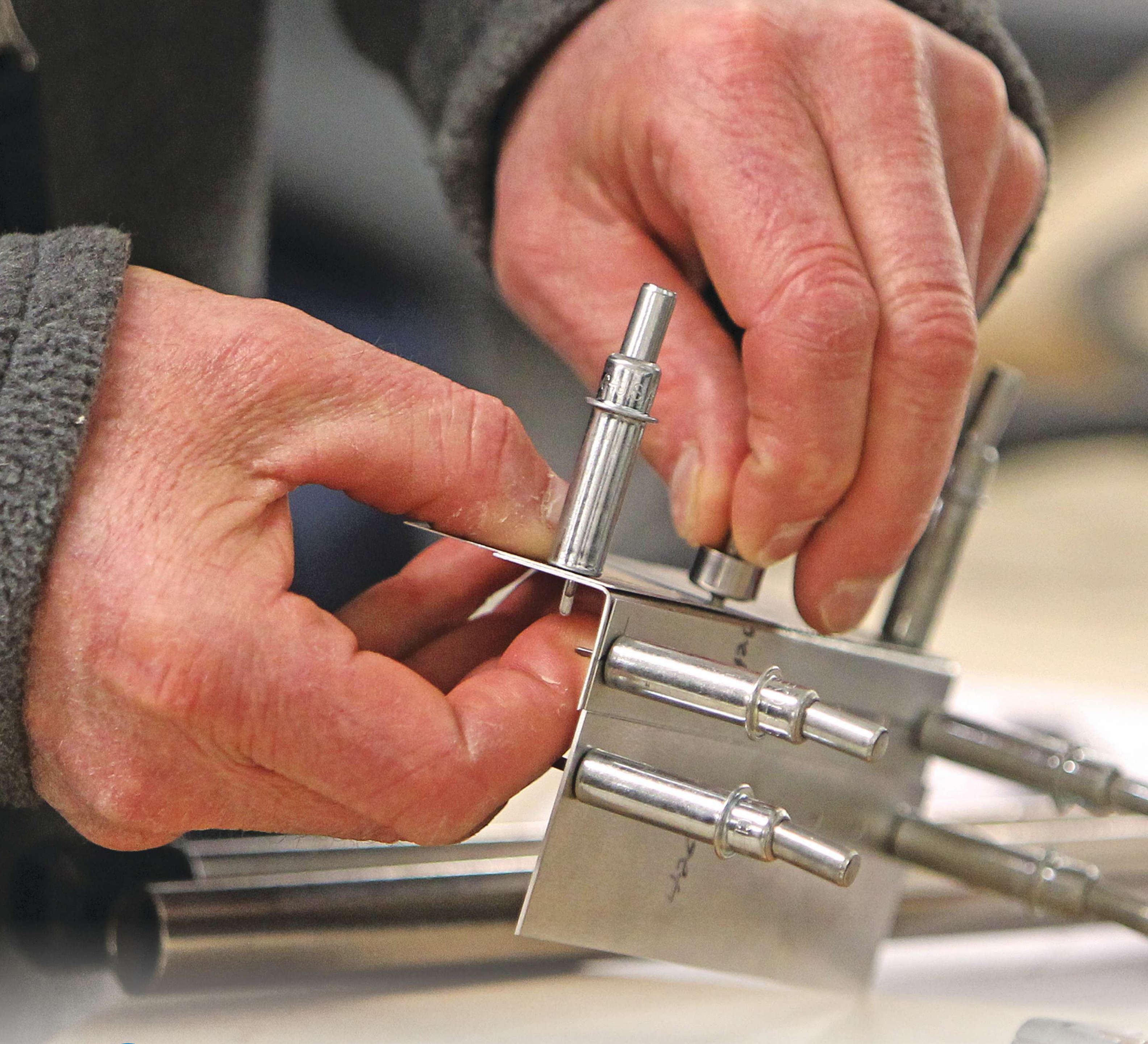
On a personal note, your EAA staff completed its Zenith CH 750 STOL project that was started back in September of 2012. I had announced in this column in January of this year that my goal was to lead this project to completion by AirVenture 2014. With a lot of hard work by a number of different EAA staff, the aircraft was signed off the day prior to the start of convention. Just made it! The aircraft is now finished with Phase 1 flight testing and has become our sport pilot-eligible aircraft in the EAA Employee Flying Club. It was a great way for a number of different staff here to learn about homebuilding.

Probably the biggest threat we faced this year was from the FAA's proposed modification of FAA Order 8130. The proposed update in this policy document would have seriously confused FAA inspectors in the field regarding the ability to fly homebuilts over "densely populated areas." Fortunately, we were able to make our case against this change with top FAA personnel and are confident that the crisis is over, but we are still waiting to see the revised draft of this document before we consider it a victory.

The other major policy issue we fought on behalf of homebuilders was the FAA Airports division's proposed revision of the definition of an "aeronautical activity." This definition is critical as things that fall outside of the definition can put FAA airport grant money at risk; something no airport wants to do. The good news is that for the first time ever, final assembly of a homebuilt was recognized as an aeronautical activity. The bad news is that leaves all the other construction phases of a homebuilt outside the definition. I really can't think of something more "aeronautical" than building an aircraft, regardless of what part of the process you are working on! We are still battling on this one, and the jury is still out.

Every year, our annual convention, EAA AirVenture Oshkosh, is a highlight. You never know exactly why going into it, but it never disappoints. This year, homebuilding took center stage with the construction of the One Week Wonder, a Zenith CH 750 Cruzer, right at show center. It was a huge success. Literally thousands of people participated in the construction, and many more were introduced to the opportunity to build your own aircraft. I'm hopeful that "build an aircraft" was added to lots of bucket lists because of the One Week Wonder and that this project inspires many people to build.

All in all, it was a very good year for homebuilding. Thank you for being an EAA member. I hope that you and your loved ones have a very merry holiday season and a prosperous new year! EAA



The Wright Stuff

Newly awarded Wright Master Pilots from EAA Chapter 983 include (from left, front row) Jerome McChristian, David Guinn, Bob Satterwhite, Bill Rose, Larry Hale, and Ed Brown. Row 2: Charlie Hamilton, FAA SW Region FAASTTeam, Robert Winegar, Mack Angel, Murray Sloan, Marv Jensen, Roe Walker, John Parks, and Joe Murphy, FAA DFW FAAST team supervisor. Missing is Ray Nasypany.

EAA CHAPTER 983, Granbury, Texas, presented the Wright Brothers Master Pilot Award to 13 members in November in what FAA officials claim to be the most ever presented at one ceremony. The FAA Safety Team (FAASTeam) confers the Master Pilot Award to pilots who have been certificated and flying for 50 consecutive years without an accident.

Chapter 983 also has six existing Master Pilots, and four more members who are thought to be eligible, giving the chapter a potential 23 Wright Brothers Master Pilots in its ranks. It is an honor and a testament to the pilot's skill, safety record, longevity, and continued health to qualify.

EAA Chapter 983 is based at The Landings Airpark, 65 miles southwest of the Dallas/Fort Worth International Airport with more than 150 aircraft, helicopters, and ultralights based there. The list of honorees November 8 includes Mack Angel, EAA 211971; David Guinn, EAA 441451; Larry Hale, EAA 107106; Marv Jensen, EAA 420767; Jerome McChristian, EAA 451902; Ray Nasypany, EAA 474678; John Parks, EAA 140293; Billy Rose, EAA 110449; Bob Satterwhite, EAA 420441; Murray Sloan, EAA 795562; Roe Walker, EAA 536104; Ed Brown; and Bob Winegar.

According to Tom Woodward, Chapter 983 newsletter editor, the chapter's previous Wright Brothers Master Pilots include Bruce Wilson, Sid Tucker, Tom Eanes, Terry Strange, Henry Erlich, and Jim Crain. Joe Murphy, local FAA Safety Team leader, along with other FAA dignitaries conducted the presentations.

They will each receive a certificate and lapel pin, and their names will be added to the Wright Brothers Master Pilot Award Roll of Honor, which lists close to 3,000 Master Pilots. EAA offers its congratulations to all the pilots!

'Sponsor a Classroom' to Help Students Discover Aviation

EAA'S NEW SPONSOR a Classroom initiative launched in October will provide opportunities for Wisconsin students to discover aviation. Individuals and groups are welcome to contribute to the effort to bring students to the EAA AirVenture Museum in Oshkosh, where they'll discover aviation as well as engage in science, technology, engineering, and math (STEM) activities.

Each $600 raised will cover the cost of transportation, museum admission, and activities for a class of up to 25 students.

Along with individual contributions, museum visitors through the remainder of 2014 are invited to participate through small donations when they visit the museum or make a purchase through its gift shop. Featured items at EAA's online store will also include opportunities to contribute.

Funds raised now through the end of 2014 will be used to welcome classes to EAA during the 2015-2016 school year. School groups can apply for the program scholarships beginning in early 2015.

The initial goal of the program is to serve as many as 40 classes from throughout Wisconsin during the initial year of the Sponsor a Classroom initiative.

Quad City Aircraft's Dave Goulet Passes

QUAD CITY ULTRALIGHT Aircraft Corporation's co-founder and president Dave Goulet passed away on November 13, 2014, following a brief illness. He was 68.

Goulet started Quad City Ultralight Aircraft Company in 1983 with the late Charles "Chuck" Hamilton, introducing the first Challenger ultralight kit. The company went on to design and market several models of ultralight and kit-built aircraft, with more than 4,000 kits delivered to date.

EAA extends its deepest sympathy to Dave's family, friends, and to the Quad City Aircraft family. EAA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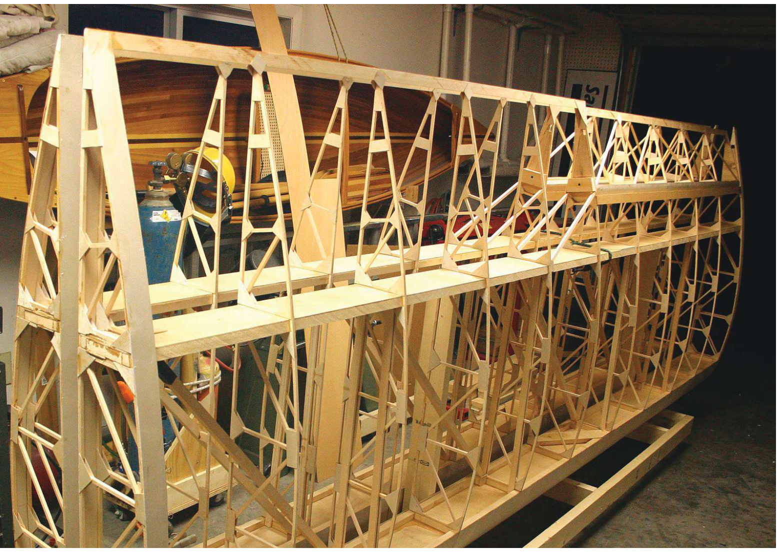
Leonard Milholland's Legal Eagle

A popular plans-built ultralight

BY DAN GRUNLOH

Photography courtesy of Dennis Scott


LE XL
XL-B-55



A pair of Legal Eagle wings ready for cover.

The cockpit of Les Homan's Legal Eagle XL reveals minimal instrumentation.

Leonard Milholland with his Double Eagle two-place.

LEONARD MILHOLLAND'S LEGAL EAGLE is a low-cost, plans-built ultralight with a conventional configuration that is designed to be powered with a ½ VW engine. With more than 2,500 sets of plans sold, hundreds of aircraft under construction, and at least 100 airplanes completed since the design was introduced 16 years ago, the Legal Eagle is on its way to becoming the most popular plans-built ultralight. Milholland, of Brookshire, Texas, accomplished several feats with this airplane.

First, Leonard showed it was possible to build a satisfactory three-axis, fixed-wing ultralight under the 254-pound legal weight limit for ultralights, something that other designers have found difficult. He produced a plans-built design that drastically lowered the cost of an ultralight. With good scrounging and ordinary building skills, a builder could complete a Legal Eagle and have it ready to fly for $5,000, including the engine and prop. The choice of a simple design using long-established construction methods combined with an undeniable cuteness has made the Legal Eagle a hit. Finally, Leonard did it with a four-cycle engine! Many of us had long believed that only a two-cycle engine provided the needed weight-to-power ratio for a successful (and legal) ultralight. Very close attention to weight savings in the airframe and the engine makes it possible with the Legal Eagle.

HISTORY AND ORIGINS

The ability to come up with a successful and popular plans-built ultralight didn't come out of nowhere. Leonard said he was "infected" with aviation even before he saw his first barnstormer at the age of 5 during the Depression. In an EAA Timeless Voices interview, he admits to sneaking into hangars as a boy to sit in airplanes. He was an avid model airplane builder and flier, a hobby he continued into his adult life. The Army Air Corps gave him intensive training in airplane engine mechanics in 1943, and he became a crew chief on BT-13s and B-24s.

In 1970 he and his wife took flight training and became pilots, and he discovered EAA in 1972. In 1998, after owning and building a number of airplanes, he became concerned about his third-class medical and decided to build an ultralight. The airplanes that seemed to have influenced his design were a Corben Junior Ace that he built, which he admired for its use of triangulation, and a Sorrell Guppy powered by a Cushman scooter engine. When the Cushman engine failed and he replaced it with a ½ VW engine built from plans, the seeds were born for the Legal Eagle.

The Legal Eagle ultralight draws heavily from other designs. Leonard would say he hasn't done anything that hasn't been previously tested. The wing structure was inspired by the well-proven Mini-Max ultralight designed by Wayne Ison. The ribs are ¼-inch spruce with plywood gussets, and the wooden wing spars are the built-up type with spruce caps and a plywood web. The fuselage is mostly welded 5/8-inch 4130 steel tubing. The pop-riveted aluminum tube

Photography courtesy of Sam Buchanon and www.BetterHalfVW.com and gusset tail weigh 4 pounds before covering. Because the Guppy flew well with the ½ VW engine, it was an obvious choice for the Legal Eagle. Leonard said he has been drawing airplanes all his life and decided to make one as simple and light as possible.

"MY LIFE CHANGED THE DAY THAT PICTURE CAME OUT"

In 1999 Leonard submitted a picture and a description of his 244-pound empty weight ½ VW-powered Legal Eagle ultralight to the "What Our Members Are Building" section of *EAA Sport Aviation* magazine. As he tells the story now, some 15 years later, "My life changed the day that picture came out because the phone started ringing, and it hasn't stopped." Everyone wanted plans. It could have been the cute bicycle wheels, the overall look, the four-cycle engine, or a combination of all these factors, but a lot of plans have gone all around the world. Leonard simply put pencil and square and triangles to standard office paper until all the parts had been described. Obviously it's a little harder after the airplane is built. He admits there is no money in selling plans because of the support required, but the reward is the people who are calling with questions. He still gets several calls every day and enjoys talking about the airplane.

The Legal Eagle is designed for pilots up to 220 pounds. A challenge to build a follow-up design for larger pilots evolved into the Double Eagle, a two-place experimental version powered by a full 4-cylinder VW engine. The original Legal Eagle ultralight used established construction methods, but the Double Eagle was something new. Thanks to good luck, an aeronautical engineer in need of work was hired to do a complete structural analysis on the Double Eagle for a reasonable fee.

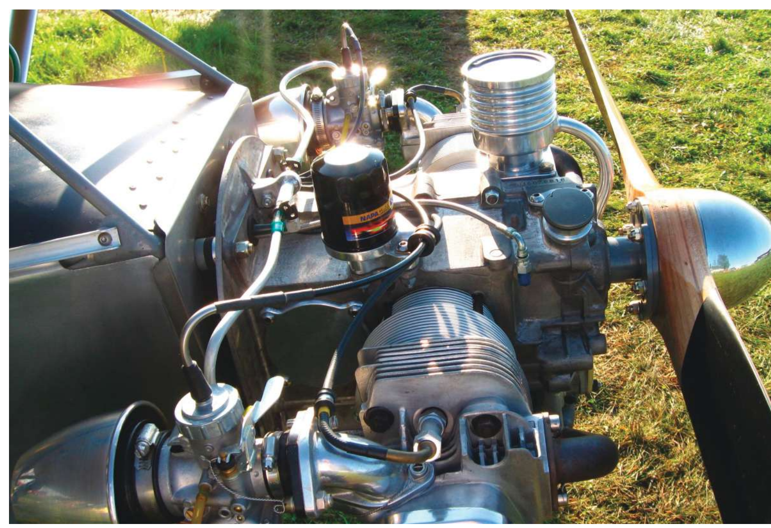
Leonard's next design, the Eagle XL (for extra large) is a true enlarged single-seat Legal Eagle with a wider fuselage and a longer wing intended for pilots up to 275 pounds. His engineer was no longer available, so the XL wing was static loaded to simulate a 4*g*-load. The witnessed test deflected the wing 5 inches with no permanent deformation.

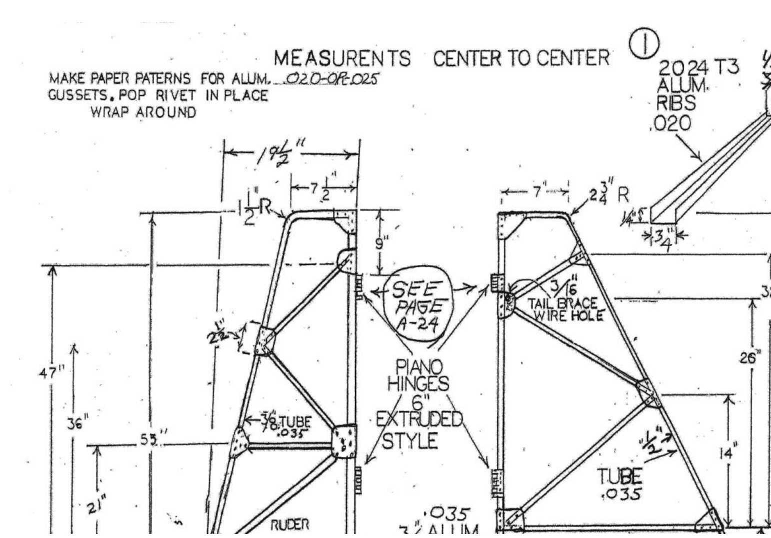
The Eagle XL has a larger cockpit and a larger wing, so it must have very minimal instruments and aluminum engine cylinders to meet the ultralight weight limit. The prototype XL weighed 246 pounds with no brakes. Leonard said he flies without brakes and has no problem. Very light bicycle brakes are possible. All the airplanes, including the two-place Double Eagle, have the same NACA 4414 airfoil for the wings. Construction of the Double is similar to the Legal Eagle, except the tail is welded steel tubing instead of aluminum. More than 500 sets of plans for the Double have been sold, with about 50 flying.

PLANS AND DVDS AVAILABLE

The Legal Eagle plans cost $50 and include about 45 pages of details and dimensions hand drawn with a pencil, T-square, and triangles. A construction text, materials list, and a few

A Legal Eagle built by Joe Engelman from Kansas at EAA AirVenture Oshkosh 2010.


A beautiful, jewel-like ½ VW engine built by machinist Joe Engelman.



A typical page of drawings from Legal Eagle plans.

Les Homan from California flying his Legal Eagle XL.

Scott Johnson of Oshkosh, Wisconsin, won the Reserve Grand Champion Lindy in 2007 with his Legal Eagle, the Silver Slug.

A Legal Eagle welded tube fuselage in the Ultralight Workshop tent at AirVenture.

pages of black and white photos bring the total to around 60 pages. The Legal Eagle XL airframe adds 32 inches to the wingspan and increases the wing area from 107 to 120 square feet. The XL plans are $80 but include more pages with 57 numbered drawings with more details than the original Legal Eagle plans, and a longer construction text. Leonard also sells a set of four instructional DVDs for each aircraft that cover various parts of the construction process. Some pre-manufactured parts are available from other vendors for the Legal Eagle, including metal fittings, wood parts, materials kits, and even a pre-welded fuselage. The plan sheets are printed on standard 8.5-by-11 copy paper to save on cost. Get all the details and learn more at www.BetterHalfVW.com.

WHICH LEGAL EAGLE TO BUILD?

The XL features one-man wing removal for storage, whereas the original Legal Eagle requires two people to remove the wings. The decision about which airplane to build depends on pilot weight and size and the importance of meeting the legal empty weight of 254 pounds. The original Legal Eagle will accommodate a 6-foot-tall pilot of 220 pounds and leave some margin for instruments and accessories.

The XL is a larger airplane and will come out heavier if similarly equipped. It is true that the FAA is not driving around with scales, looking for heavy ultralights and that some plans builders don't care that much about empty weight. At every forum he gives, Leonard admonishes builders to build for lightness. He does not approve or recommend modifications that make it overweight. Large pilots and those who care less about the legal weight limit are probably going to be looking at the XL.

BETTER HALF VW ENGINE

Leonard's first ½ VW engine was built by Dave Carr from plans that go all the way back to 1975. The 4-cylinder VW engine case and crankshaft are literally cut in half to make a 2-cylinder engine. Cutting off the unneeded portion of the case saves 4 pounds but requires building an engine mount and adding an oil cooler, because the half case doesn't hold enough oil to cool the engine adequately. Also, there is an air movement problem because both remaining cylinders move inward at the same time. A lot of air must move in and out rapidly without taking oil spray with it. A one-way reed valve or related device must be incorporated. A full case, however, provides an excellent engine mount for the Legal Eagle, and with half a crankshaft inside, it holds plenty of oil and reduces the air movement problem. The weight saved by cutting the case was replaced by the extra parts needed. Leonard's next engine would be a full-case ½ VW because it would save money and be simple to build.

Leaving the case intact makes it difficult to mount a magneto, a favored ignition solution, but magnetos are expensive and heavy, and other systems have a hotter spark. The Better Half uses a VW distributor with coil and condenser

Photography courtesy of Dan Grunloh

in a dead-loss battery system for a fraction of the cost of a magneto. The battery will supply a whole weekend of flying but must then be put on a charger. When walking through a hangar full of Legal Eagles, you have to watch out for all the extension cords.

Engine weight is 81 to 85 pounds, depending on how diligent you are about removing weight. Leonard originally flew with a single Zenith carburetor but switched to a pair of 28-millimeter Mikuni carbs. They are easy to mount, easy to adjust, and eliminate the need for carburetor heat. Leonard said when he switched to the pair of Mikuni carbs, it was like a different engine. The engine produces 30 hp at 3400 rpm with a 54-by-24 prop, and the fuel consumption is 2 gallons per hour or less. There are examples in service with nearly 1,000 hours on the engine. Only wood props can be used, as composite props cannot withstand the power pulses of the ½ VW. Leonard describes his full-case ½ VW engine in a set of plans comprised of 18 pages of drawings and text. Engine plans are included with the Legal Eagle plans but are also available separately for $20. Two videos on the construction of the heads and on final engine assembly are available. Order information is at www.BetterHalfVW.com.

REGULAR ENGINE MAINTENANCE IS CRITICAL

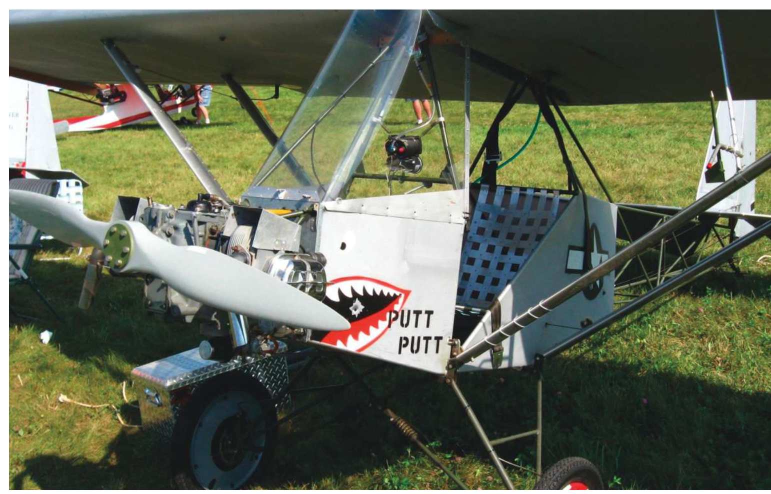
Half VW engines are very dependable and give excellent service, but regular maintenance is critical. As Leonard said, "You can't expect to bolt the engine on and forget about it." Every 25 hours the oil should be changed, valve covers removed, and the valve adjustment checked. Monitoring the valves will give advance warning of any problems. The propeller bolt torque should be checked every 25 hours. The cutting, machining, and balancing of the crankshaft require a well-equipped machine shop, and there are multiple sources for those services. Leonard's engine puts out 30 hp, but there are custom builders that make more powerful engines by using larger cylinders.

The most popular source of ½ VW engines is Scott Casler of Hummel Engineering at www.HummelEngines.com in Coolidge, Arizona. Scott builds full-case and cut-case ½ VW engines using aluminum billet cylinders. His engines range from 28 to 45 hp, and he offers electric starters, single or dual ignition, and battery systems. A lot of Legal Eagles are flying with Casler engines.

CELEBRATING LEONARD'S 90TH BIRTHDAY AT AIRVENTURE 2014

Leonard celebrated his 90th birthday during EAA AirVenture Oshkosh 2014 with about 70 friends and supporters at a local Oshkosh restaurant. The master of ceremonies was his son-in-law, Graeme Gibson, who has been involved with Leonard's projects since the first plans and instructions were typed and printed. He may have surprised a few when he announced that in addition to being an airplane designer, Leonard has a potential career as a stand-up comedian. When given the microphone, this gentleman, whose energy makes other men 20 years younger feel old and tired,

Les Homan brought his Legal Eagle XL to AirVenture 2014 from California and won the top award for ultralights.



Joe Spencer's PuttPutt showing the unique, one-pound seat made of woven metal strips.

Leonard Milholland at a Legal Eagle forum during AirVenture 2014.

LEGAL EAGLE XL SPECIFICATIONS

Empty weight: 246 pounds
Wingspan: 315 inches (26 feet 3 inches)
Wing chord: 55 inches
Wing area: 120.3 square feet
Gross weight: 575 pounds
Fuselage length: 193 inches (16 feet 1 inch)
Height: 75 inches (6 feet 3 inches)
Fuel capacity: 5 gallons
Propeller: Wood, 54-by-22
Engine: 30 hp Better Half VW
Stall speed: 27 mph
Takeoff distance: 250 feet

proceeded to deliver a string of standard jokes with a perfect sense of timing. He also talked about his age, saying he had promised his wife he would live to be at least 100. A check of his calculated life expectancy at this time came out to 104, so when they reach that point they will make new plans. It was a treat to be in the same room and feel the affection expressed by family, friends, and customers.

A successful plans-built airplane must have builder support, and that's where an organized builder community can help. The Eagler's Nest at www.EaglersNest.com/forum/ is an online community of builders and owners with 456 members and more than 3,000 posts covering more than 500 topics. The running slide show of completed Legal Eagle projects may make you want to build one. There is also a Yahoo discussion group for ½ VW engines. Sam Buchanan has a wonderful build site with detailed photos and text about every aspect of his Legal Eagle XL project. The photos and explanations add a lot to what is in the plans. Don't miss the link to his flying videos. Sam previously built a Van's RV-6.

Les Homan brought his Legal Eagle XL to AirVenture 2014 all the way from California and won the top ultralight award given by the judges in the Fun Fly Zone, as the Ultralight/Lightplane area is now called. He has a lot of great videos of Legal Eagle flying at www.YouTube.com/user/homanles/videos and also some snippets from Leonard's forums at AirVenture. Les flew a Super Starduster biplane for three years prior to the Legal Eagle.

Leonard and his builders have been bringing their airplanes to EAA AirVenture, and he has been giving forums in the Ultralight/Lightplane area for nearly 15 years. For some reason, there are few news and magazine articles about his airplanes. Leonard said the airplane doesn't get the recognition it deserves. Perhaps writers dismiss it as old-fashioned and instead focus on the "jazzier" airplanes. Check out the Legal Eagles in the Ultralight/Lightplane area next time you come to AirVenture, and watch for news of Leonard's next airplane, an enclosed cabin model with folding wings. Contact Leonard at Leonard@lemilholland.com. EAA

Dan Grunloh has logged 1,200 hours in trikes, and he won the 2002 and 2004 U.S. National Microlight Championships in a trike.

Leonard cutting his 90th birthday cake during EAA AirVenture Oshkosh 2014.

Photography courtesy of Dan Grunloh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Keeping Up a Family Tradition

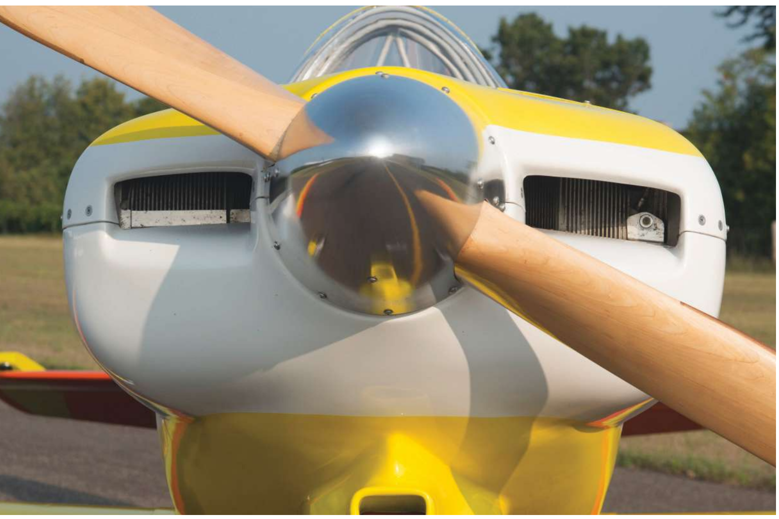
Randy Weselmann and his Piel Beryl

BY BUDD DAVISSON

Photography by Tyson V. Rininger


The wing and tail planforms of the Beryl are very recognizable as being shared with the Piel Emeraude and the certified Cap 10.

IT'S HARD TO BELIEVE that EAA is more than 60 years old and that we're seeing second- and third-generation homebuilders following in the footsteps of parents who built airplanes. To the average person on the street, building an airplane sounds preposterous, but to someone who grew up with an airplane in his family's garage, it sounds perfectly normal. Doesn't everyone have an airplane in his garage? Randy Weselmann of Bainbridge, Indiana, would say, "Yeah, we had an airplane in the garage, so why not build one myself?"



The cowling is a Randy Weselmann original, since the plans didn't address the cowling in detail.

Randy's dad was an aeronautical engineer who worked for General Electric and Boeing, among others. However, in the early 1960s he decided to set up his own airplane factory and bought the plans for a Thorp T-18. Being small, Randy was the official crawl-inside-the-fuselage-bucking-bar holder.

He said, "I don't know where the urge to work with my hands came from, but certainly watching and then helping my father take flat sheets of metal and turn them into an airplane had a lot to do with it. It must be in my DNA because the urge bit me early. I started on my A&P license while still in high school and eventually went to work with United Airlines in their sheet metal and machine shops. I wanted to build an airplane, but I wasn't making enough money to go the normal homebuilt route. So I built a Mitchell B-10 flying wing ultralight."

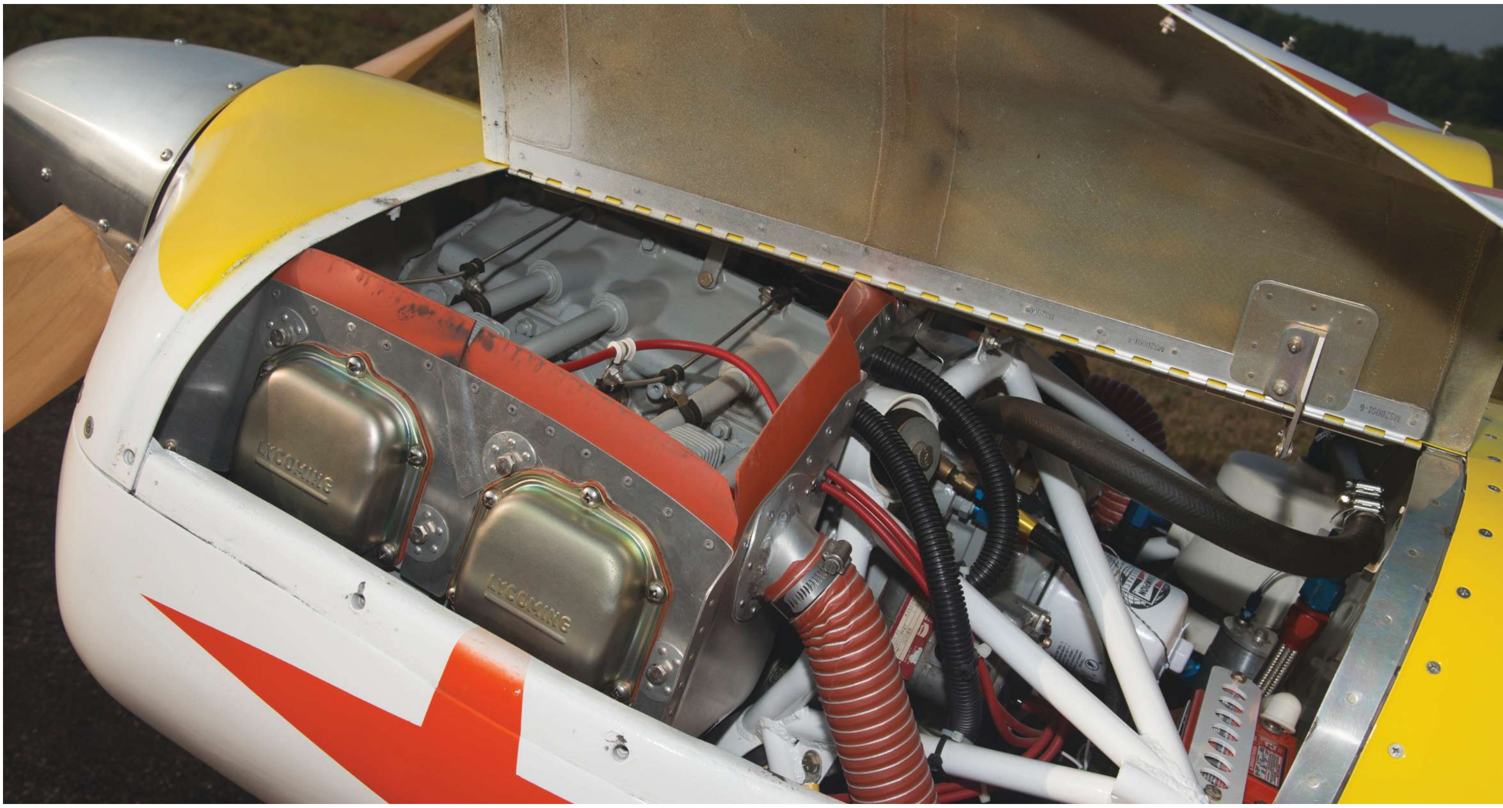
It would be easy for another homebuilder to look down on the concept of building an ultralight, but Randy has the last laugh.

"I have put over 400 hours on it and have gone through three engines. I still have it but haven't flown it for a while because of the Beryl."

The Piel Beryl caught his eye because he liked "the Spitfire look" that the wing had. Also, the advertisements for it said

The Beryl was Claude Piel's aerobatic version of his better known, side-by-side design, the Emeraude.

Photography by Tyson V. Rininger



The Lycoming 0-320E2D was a totally disassembled basket case that Randy found on Barnstormers.com. In the course of rebuilding the engine, Randy added a Silver Hawk fuel-injection unit and a Christen inverted oil system.

it was designed for aerobatics, and that really appealed to Randy. He said, "The wing is essentially the same as the two-place, side-by-side Emeraude that Claude Piel had designed earlier, except that it is a bit shorter and slightly beefed up. The fuselage, however, is totally different in every way."

What he's referring to is that, besides featuring tandem seating, the wood fuselage of the Emeraude was replaced by a conventional steel tubing truss unit in the Beryl like so many other aerobatic airplanes.

Randy said, "Claude Piel was a professional engineer and didn't give too much thought to the limited aircraft building experience the builders of the airplane would have. The Emeraude was designed in the early 1950s, the Beryl in the '60s, so the homebuilding movement was still quite young. Claude approached the airplane as he would any other professional airplane design, so some parts of it are—if not difficult for an amateur to do—at the very least challenging and/or time consuming.

"The fuselage, for instance, is not a conventional tubing box like a Pitts or Skybolt where you build the sides flat and then stand them up to put the crosstubes in. The firewall station is square, but from there back, the fuselage is trapezoidal and sweeps up. So you build the top of the fuselage first, then construct a three-dimensional jig that holds the bottom two longerons in the right place and start putting in the side tubing. The side trusses have few 90-degree crosspieces. It's a Warren truss, so most side pieces are running at angles in the shape of warped W's, and because the wing runs through the bottom of the fuselage, rather than attaching on either side, there is a big discontinuity in that area. Further complicating things is that the bottom truss is highly unusual and irregular plus the longerons aren't one piece. They are multiple pieces of different sizes getting smaller as they go back where the strength isn't needed.

The aileron balance weights hang out into the wind.

The fuselage of the Beryl is much more complicated than most tubing structures of the type because it isn't square, so the sides can't be laid out and then stood up. Plus, the longerons are made of numerous sizes.

Randy says wheelpants may be installed someday, but he's having too much fun flying to put them on.

"The truth is that I didn't get serious about the fuselage until I was about 15 years into the project. I started out building small pieces of both steel and wood because they looked so good hanging on the wall; and I was polishing my skills as I went. I learned to weld in A&P school but hadn't welded in years, so I practiced on the small pieces until I had the time, money, and space to attack the fuselage."

The project was further complicated because Randy said the plans only addressed about 75 percent of the airplane. A lot of things such as forming sheet metal and cosmetic details were left to the builder's imagination and creativity. Plus, there was no building manual, so there, too, the builder had to think far ahead while figuring out how to jig and build the different components.

He said, "One thing about the plans is that they were very professionally drawn. But there were a lot of them, and you had to do some head-scratching to figure out how things related to one another. Plus they were written in French with rough English translations. Also, they were all metric, which was actually no problem. In some ways, I like working with metric better. For the most part, I made no effort to convert measurements. I just used metric and had the right measuring equipment."

Randy constructed the big parts last due to space considerations, and that applied especially to the wing. Typical of wood construction, the parts count of the wing is extremely high, and to make matters worse, most of the parts are only repeated twice because of the shape of the wing. Randy explained, "You didn't get a rib template; the shape of the wing, with every rib being different, made it impractical for Claude to do templates. So he gave you the X/Y coordinates and you plotted the airfoil yourself, which is no problem and is probably more accurate than working with

 Photography by Tyson V. Rininger

something like a paper template. But like everything else, it takes time. Especially since you had to calculate the airfoil and draw it full size for every rib station.

"The ribs are built-up trusses, and only those between the spars in the center section are the same. So after you calculated the airfoil for each station, you had to build another rib jig that would only produce two ribs. Then you trashed that jig and made another one. I really like variety, but it gets tiresome after a while. However, it worked well for my situation at the time. I didn't have the time or money to really dive into the project, so every so often I'd make up a pair of ribs, then work on something else."

One of the major space hogs in the project was the wing because it is one piece. Also, it is complex, and because it's a cantilever wing, everything on the spar has to be perfect. This includes laminated spar caps that have to be jigged to match the airfoil change as it goes out the wing. To further complicate the life of a builder who is short on space, the spar (hence the wing) is more than 25 feet long.

Randy said building the worktable was a project in itself, not only because it was so big but also because it had to have a perfectly flat, true surface. "I built the spar lying flat as if it were a gigantic rib with a similar type of jig," he said. "This let me get all the angles exact. However, when I started actually building the wing, because of the dihedral, I was back to constructing another very stout three-dimensional jig. I had to be careful; because even though the spar was quite strong, being that long, it had a little flex and you had to be careful to keep it true. So it was jigged everywhere that I could attach the jig to it."

The original CP.30 Emeraude wing, on which the Beryl is based, continued to evolve until the Emeraude melded into the certified, French CAP 10 aerobatic trainer. As originally designed for the Beryl, the wing was plywood

The canopy was the biggest, most difficult single part of the airplane to build.

Randy's panel reflects the trend toward glass cockpits in almost any kind of airplane. And the iPad is becoming the most popular navigation add-on.

AIRCRAFT SPECIFICATIONS

Top speed (V_{NE}): 183 knots
Cruise speed: 120 knots at 2,300 rpm
Full throttle speed: 149 knots at 2,650 rpm
Landing speed: 60 knots
Takeoff roll: 1,000 feet
Rate of climb at gross: 800 fpm at 95 knots
Range at 65% estimated: 3.5 hours
Range at 50% estimated: 4 hours
Empty weight: 1,174 pounds
Gross weight: 1,700 pounds
Useful load: 526 pounds
Fuel capacity: 26 gallons
Wingspan: 26 feet, 6 inches
Wing area: 117 square feet
Length: 22 feet, 9 inches
Cabin width: 24 inches
Cabin length: 84 inches, rudder pedals to rear seat
Engine: Lycoming O-320-E2D
Prop: Sterba 70-by-68, wood

sheeted only forward of the main spar. This formed a torque box that carried all of the various loads the wing would experience. Behind that, it was fabric covered. When Randy did his wing, he went one step further and sheeted the entire wing, like the CAP 10. In fact, he copied a number of changes that were made in the CAP 10 wing.

He said, "I wanted the wing to be not only stiff but also smooth as well. So I continued 1/16-inch birch ply from the spar to the trailing edge. When I finished it, I used boat cloth over the ply, which is really thin fiberglass with resin. With very little filling and some sanding, you can get a nice, smooth surface.

"I also changed the wing incidence from four degrees to two degrees and took the dihedral from five degrees to three degrees and used electric actuators for the trim and flaps."

The tail is also wood and the structure mimics that of the wing but much smaller. Its trailing edge is laminated like a tip bow to provide the requisite curve. The one-piece skins are very gentle compound curves, which Randy accomplished by forming them in place when wet. As with the CAP 10, he also balanced the elevators and inset the elevator trim in the left elevator.

The basic structure had a few complexities, which Randy worked out with no problem, but as is often the case with airplanes, some of the lesser assemblies caused as much or more headaches. In this case, it was the canopy.

Being a tandem airplane, the canopy is a visual focal point of the design and one of the areas that took a lot of work to get right. The tubing structure itself was complicated enough, but the Plexiglas covering was a story unto itself.

Randy said, "I hadn't anticipated how tough doing the canopy and windshield was going to be. I would have actually preferred to buy the canopy, but by the time I got that far, I was looking at each new part as a challenge to see if I could do it. And the Plexi work definitely fell into that category. I didn't want to go with some sort of one-piece, flat-wrap canopy. It would be too angular and would conflict visually with the rest of the airplane's lines. I wanted something with just the right shape, and the only way I was going to do that was to do it myself.

"The first thing I did was study a section in [Ladislao] Pazmany's building book that addressed forming Plexiglas. Then I made a big wooden form and covered it with flannel. To heat the plastic, I built an oven, and the Plexi sheet was suspended from a telescoping, overhead rail that could be extended. I could bring the whole sheet up to temperature, then roll it out. I had five other guys over, each with gloves and welding vise grips. We grabbed the hot sheet and stretched it down over the mold.

"I'd be lying if I said it worked the first time. I ruined a few sheets of Plexi [while] learning, but it was something I wanted to try to do. The entire process covered a couple of years, but I'm glad I went that route. I'm proud of having done it."

We would be remiss if we didn't delve deeper into Randy's do-it-yourself oven; a lot of builders would benefit from his experience. He explained, "The oven is made from galvanized steel sheet and metal 2-by-4's, with fiberglass insulation. The heaters are eight electric resistance elements with switches on the outside for each element. Once I got it hot, I shut two or four of them off. There is a fan to circulate the air, also. I had a thermocouple in the center of the bottom edge of the sheet, and when the temp hit 320 degrees, we got it on the mold as quickly as possible. When the Plexiglas gets too hot, it bubbles and is ruined.

"The pieces of Plexiglas were different sizes, depending on which part of the canopy was being done; the canopies are 1/8 inch and the windshield is 3/16 inch. The back canopy was the largest but was quite a bit smaller than 4-by-8.

"I tried to get the room as warm as possible because, at the most, you might have a couple of minutes to work with the hot Plexiglas. When the first windshield worked out, it was a beautiful thing!"

When it came time to cover the airplane, Randy went with Ceconite with nitrate, then butyrate with Randothane over it.

"Painting was difficult," he said. "I had to do some parts twice because the yellow just didn't cover. Next time, if there is a next time, I'll know that, if I'm painting yellow or light colors, to put down a coat of white first. But then, that's what the building process is all about: learning stuff you didn't know before."

The engine was a Barnstormers.com find: an O-320 that was completely disassembled. He sent the case, cylinders, rods and crank out for inspection and reconditioning and assembled it himself with a new cam, lifters, oil pump, and pistons. Since the Beryl was to be his aerobatic mount, he added Silver Hawk fuel injection and a Christen inverted oil system. A T-18 spinner and nose bowl finished off the nose, and the prop is a Sterba 70-by-68.

He said, "With that combination, it gets off the ground quickly and climbs out at around 800 fpm at 100 knots. It'll cruise at 120 knots at 2,300 rpm and 7 gph, which is throttled well back.

"On landing, I shoot for around 80 to 85 knots on final and 75 knots over the threshold. It is sensitive to having too much speed and will float like crazy. If that happens, I usually just wheel it on. It is super stable on the runway, about like a Decathlon or Citabria, which is to say it's nice!"

In total, the project took 24 years, but Randy said, "I knew it was a big project when I started, but I never considered not finishing it, even when I wasn't able to work on it for long stretches. The lowest point of the project was toward the end. The wing fuel tanks on the plans were welded aluminum with two center ribs that were spot-welded. I didn't know where to get that done; so I made a test with welding over a rivet head and it worked great. So I riveted in the ribs and welded up the rest of the tanks—they were looking great. Then I went to weld over the rivet heads on the center ribs, and I hadn't considered that with everything else welded up, the heat on the skin in the middle buckled and broke the rivets. Three months work ruined! I briefly wished I'd never heard of a Piel Beryl, but it soon passed. I borrowed my brother's RV-4 plans and riveted and sealed the tanks the way the RV guys do, and they turned out better than welded ones would have."

Now that the airplane is finished and he has more than 300 hours logged in it, he said, "This was the perfect airplane for me in so many ways. I absolutely love building things, and with this airplane, I got to work with every conceivable type of material: wood, steel, fabric, fiberglass, Plexi, and aluminum. More than that, it flies exactly the way I hoped it would, so this has been a win-win project from the very beginning."

Another that's another happy homebuilder: Life is good!

Klaus Savier's *Determinator*

He makes speed mods look EZ

BY LYNNE WAINFAN, PH.D., EAA LIFETIME 50408

KLAUS SAVIER CALLS HIS Long-EZ the *Determinator*. The airplane's name seems to be a "quadruple entendre": Klaus is determined to terminate inefficiency, and he wanted to use the plane to determine what can be achieved in efficiency and performance. Or, the name could reference Klaus' German accent; he sounds a bit like Arnold Schwarzenegger's movie character the Terminator would, if he had ever been the poster boy for experimental aviation.

Klaus Savier and his Determinator*, a much-modified Long-EZ.*

Klaus, the stocky, serious, self-taught engineer, said, "I've made hundreds of improvements, mostly aimed at going faster." He started experimenting in 1983 with his VariEze. (He calls that the *Delaminator*.) Thirty-one years later, he still continues to improve his airplanes. Some of the VariEze improvements were in the propulsion system—more sophisticated intake tuning and a better fuel-injection system. Aerodynamic modifications were more numerous: changes to the canard elevator slot; upswept canard tips; and a new canard airfoil, among others.

The result of all those improvements? Klaus increased the VariEze's speed from 183 to an amazing 260 mph. His experimentation made him go—can you believe this—42 percent faster! Also, if he flies at 15 percent power, the VariEze can get 100 mpg.

Klaus considered buying a partially completed Long-EZ back in 1985, but he wasn't very optimistic about its performance over his modified VariEze. "At first glance, there was no chance that the Long-EZ could do any better," Klaus explained. "It could only burn more fuel." He ended up buying the Long-EZ at 10 cents on the dollar but continued to work on the VariEze for several more years. Eventually Klaus had so many parts left over from his VariEze modifications that he figured he should just incorporate them onto his Long-EZ project.

So what did Klaus do to his airplanes to make them go faster? Lots and lots of little things.

Before we get into specifics, some words of caution. "Do not try this at home," he warned. "Changing little things on an airplane, especially a canard, can have big effects, mostly negative." *EAA Sport Aviation* (November 2009) reported that bugs, paint stripes, or even rain near the leading edge of a canard can increase minimum flying speed and cause pitch changes.

Klaus' cautious approach is how he has developed an impressively methodical and exceptionally thorough process to make his planes go faster. For each improvement he contemplates, he goes through four phases:

1. Understand the situation.
2. Design a fix.
3. Test the fix.
4. Repeat until satisfied. (This would be "never satisfied" for Klaus.)

The improvements Klaus has made fall into three categories. The first is with the propulsion system: intake, ignition, exhaust, propeller, and fuel subsystems. The goal here is to improve efficiency and run the engine at lower rpm.

Photography by Lynne Wainfan

The second category includes aerodynamic improvements: reducing drag and improving flying qualities.

Then there is the eternal desire to reduce weight at every feasible opportunity.

Let's take a look at some of Klaus' modifications.

PROPULSION SYSTEM IMPROVEMENTS

Klaus' plans to improve his Long-EZ were thwarted a bit in the beginning when his engine wouldn't run right. "It acted like a fuel-injection issue, like excess fuel would get injected and cause a rich miss," he said. "It was hard to find and hard to fix. I struggled with it for almost two years."

The methodical Klaus admitted that he had been looking in the wrong place—fuel injection. Instead, it turned out to be poor intake design. He had finally accomplished step one of his four-step process: He had understood the situation.

Now that Klaus found the general source of the problem, he had to return to step one: Find out what exactly was happening inside the intake. Klaus outfitted the Long-EZ's intake with a pressure sensor for a portable oscilloscope and went flying.

But Klaus had to get good measurements. He advises that magnetos make it very difficult to understand what's going on with other parts of the engine. Klaus said, "Their weak and short-duration spark delivered at greatly fluctuating degrees causes so much scatter in exhaust and intake pressure waves as well as Lambda (mixture) values that they mask other problems."

A precisely timed, powerful electronic ignition removes a lot of variables in the pressure data and shows other issues such as fuel atomization more clearly.

Klaus is a recognized expert and advocate of electronic ignition for light airplanes. He is appalled that after three decades of automotive use, aircraft engines don't use electronic ignition as standard equipment. In addition to helping with clear measurements of what's going on in the engine, "electronic ignition provides an immediate 10 percent reduction in fuel consumption with 5 to 10 percent increase in power," he said. He uses Plasma III systems that are triggered directly at the crankshaft, reporting that "these systems have around 0.5 degree of timing accuracy and can be varied by 1/10 of a degree. Their spark energy is about three times that of any mag."

Klaus applied another automobile technology to improve his Long-EZ engine—a tuned intake. How do they work? Ambient air gathers speed as it rushes into the intake pipe during the intake stroke. At the end of the intake cycle when the inlet valve is closed, the high-velocity air hits the valve and compresses. This high-pressure air can't go into the engine, so it bounces back through the intake pipe. Then it hits the plenum on the other side and bounces back toward the engine. This pressure wave travels back and forth until the valve opens again. Figure 2 shows one of Klaus' oscilloscope readings for this pressure wave. Note that the big dip is the piston sucking.

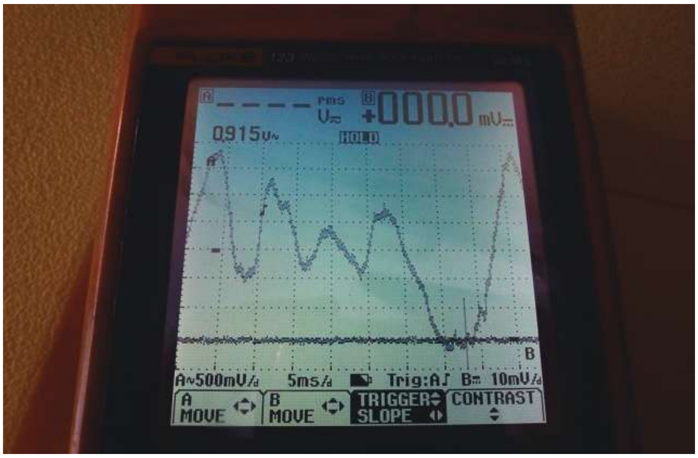


Figure 2: An example of an oscilliscope reading showing the effect of Klaus' tuned intake.

If the high-pressure wave happens to hit the valve at the exact moment that the valve is opening, then it acts like a supercharger!

In order to accomplish this feat, we need to tune the frequency of the pressure wave so that it hits the valve as it is opening. In cars, this frequency is affected by engine speed and manifold length. You pick an engine speed where you want the effect to peak, and then change the manifold length appropriately. A longer intake manifold gives the best tuning performance at low speeds; a shorter intake manifold gives the best effect at higher rpm.

Tuned intakes have been on cars and motorcycles for a long time, but they are relatively recent additions to light aircraft engines. Aircraft engine intakes are somewhat easier to tune than cars or motorcycles because their rpm range is smaller. On the other hand, the tuned intake must fit inside an aircraft cowling and works best over a limited altitude. The main variables that are considered in tuning an aircraft engine intake are altitude plus the length and the diameter of the intake tube.

Because car and motorcycle intakes do not have to be efficient at widely varying altitudes, the traditional way of designing a tuned system is to use a dynamometer—a workbench instrument that measures an engine's torque. Klaus explained, "When done on a dyno, you have to make different intake manifolds, which is a huge pain to do. But [air] density changes the resonance. So you can use the airplane as a dyno and fly to different densities and watch the resonances change." This is the best method to design a tuned intake because doing it on a dyno would take years building different tubes for different altitudes; and altitude is almost impossible to simulate on a dyno.

Klaus reported that understanding, fixing, and testing his tuned intake took two years.

Once the intake was tuned, Klaus turned next to the exhaust on the *Determinator*. Tuned exhausts have been used on a variety of engines: automobile, motorcycle, aircraft, and even model aircraft. An untuned exhaust sometimes has the problem that the exhaust gas from one cylinder can travel out and then *up* the exhaust manifold to a second cylinder's exhaust. When that second cylinder's exhaust valves open, its exhaust gas is met with high pressure from the original cylinder's exhaust. This means that the second cylinder's exhaust gas doesn't completely leave the cylinder. A tuned exhaust, on the other hand, reduces the exhaust pressure right before the port closes, using resonances like those occurring in the intake system. This lets spent gas out of the cylinder and fresh mixture into it, improving engine efficiency.

"I talked to all sorts of people who were knowledgeable about exhaust systems," Klaus said. "One let me use his shop. I spent six weekends and $2,000 worth of material. After all these modifications, the best I could do was 10 pounds *more* weight and 6 knots *less* speed. This was one of my bigger mistakes." Klaus urges caution when talking to experts, as it's easy to get bad advice. Because of that experience and because there is so little room for a longer exhaust on a pusher airplane, the Long-EZ's exhaust is still on his list of future improvements.

Next, Klaus decided on a timed-sequential, fuel-injection system. Traditional injectors fire all or two injectors as a group, regardless of whether the cylinder is ready or not. A timed-sequential system opens the injector during a specified period in the intake cycle. Because of cowling constraints, Klaus had to buy a smaller injector so he could put it in a better location.

A different kind of problem came when Klaus put a header tank behind the cockpit to replace the traditional external sump blisters. He installed a transfer pump to fill the header from the left main tank. A standpipe prevents accidental overfilling of the header tank. In flight, when the air hit the common vent, the dynamic pressure actually pushed fuel *into* the header tank, keeping it full. The solution? Reduce the area of the vent opening. Klaus made a new vent by wrapping carbon around the cap of a felt marker. Figure 3 shows Klaus' header tank—with visual fuel gauge—and carbon vent tube.

Figure 3: The header tank with a visual gauge.

What about the propeller—was there anything to be gained from modifications there? Klaus, through his company Light Speed Engineering, has designed, built, and tested more than 50 propellers for different aircraft. He knows how to optimize their shape.

"It's really hard to get speed out of a propeller," he said. "It's tough to increase the propeller efficiency of a good propeller. All you can do is increase the maximum rpm where the engine makes more hp." Propeller modifications let you set your optimal performance at lower rpm, saving wear and tear on the engine and reducing fuel costs. But again, he has made discoveries that go against the conventional wisdom. For the *Determinator*, he uses a carbon, fixed-pitch propeller that he designed and hand carved to an amazing 100-plus inches of pitch. It turns at 2,600 rpm.

Making real propeller improvements aerodynamically is also structurally challenging. Klaus cautions that metal props don't work on pusher airplanes. "The blades get excited by the wake of the wing and cowling, and the aluminum, with its characteristically poor fatigue life, will fail sooner or later," he warned. "All of the wood and most of the composite props are fairly thick in order to have adequate structure. Aerodynamic improvements come mainly from using a much thinner airfoil. But these thin blades are difficult to shape and require a vacuum-bagged laminate of very high strength. Thin airfoils are also very sensitive to angle of attack. This means that if the pitch distribution does not correspond to the inflow angles, the blade will stall." Klaus said that a racing propeller is also on his list of future changes.

Klaus has an unusual take on prop mounting. "In the 1930s, we stopped using wood propellers due to the increase in horsepower and the better performance of metal props," he said. "We went from eight [mounting] bolts used for wood props to six bolts, which are plenty for a metal hub." Wood is less stiff than metal, so the bolts see more bending load. On the Long-EZ project, he actually broke bolts at two different occasions before having a set of custom bolts made. "Very expensive," he said. For his 250-hp engine, he hopes that the industry standard for wood props lowers the bolt ending load, returning to eight bolts instead of six, and a crush plate that is splined to the shaft.

AERODYNAMIC IMPROVEMENTS

Klaus has made dozens of changes to the way air flows over his airplane. Recall that the first of our four-step process is to understand the situation. How does Klaus understand the air?

Readers of last month's *Experimenter* will recall from my article that we aeronautical engineers are obsessive about visualizing airflow. We look for it in smoke trails, coffee cream, Saturn's swirls, and movie stars' cigarette smoke. Klaus is widely recognized as the world's flow visualization guru. He uses whatever method he can find, but the main techniques are oil flow and impingement.

In the oil flow method, special dark-colored oil is put on the airplane before flight. After landing, the oil tracks show where the air was—or was not. Klaus has a finely tuned mixture for his oil: He starts with carbon black, the fine black powder that is added to paint base to make it black. Carbon black is available on the

Photography by Lynne Wainfan

Internet and in paint shops. To this, he adds motor oil which is viscous—a handy trait that helps it not fall off the airplane. Then Klaus reduces this mixture with diesel fuel or kerosene, but this combination has too much surface tension. To counteract that problem, he adds a lot of dish soap...One begins to understand exactly how obsessive engineers are about visualizing airflow. (I have found that dish soap makes carbon-black cleanup a breeze.)

Klaus sometimes uses tufts as well. Tufts are small pieces of string that are attached by tape to a surface. In flight, the tufts line up with the air that flows past them. Tufts that stay lined up with the direction of flight represent an aerodynamicist's dream. If they aim elsewhere or bounce around, they show that there is opportunity for airflow improvement. Figure 4 is a picture of Klaus' tufts (while the plane is on the ground) that he used to fine-tune the canard tip shape.

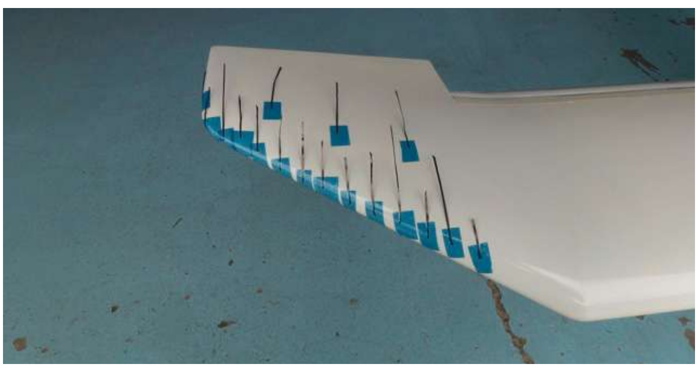


Figure 4: Tufting testing on the canard tip.

There are several reasons that oil flow visualization is more useful than tufts. First, the tufts sometimes fly up above the boundary layer into free-stream air. Second, the tufts can trip the flow from laminar to turbulent, which could affect the airplane's flying qualities and mess up your measurements. Third, tufts only show the air motion when the aircraft is in flight, unlike the oil which stays in place after landing. Finally, tufts are only helpful if you can actually see them during flight. Installing cameras to see the tuft movement in flight is often not feasible. Figure 5 shows the same shaped wing on the ground after a flight with the oil visualization method.

Figure 5: Using oil visualization to determine airflow.

The other method that Klaus uses for flow visualization is impingement. Things in the air can strike the flight surfaces and leave their mark. Most aerodynamicists know about the bug method—if bugs hit the airplane, most of them will slide right off. The ones that hit the plane perpendicularly—at the stagnation point—tend to stick. This bug splat method of flow visualization approach is not limited to wings. Figure 6 shows a duct where the air is supposed to flow smoothly from left to right. The bug splats tell the story: The air is hitting the duct perpendicularly and aerodynamic improvements can be made.

Figure 6: The bugs inside the cooling duct show that the airflow into the duct isn't smooth.

An unexpected impingement opportunity came when Klaus and his co-pilot Jenny Tackabury flew through smoke from a California wildfire. The particles in the smoke rubbed on the freshly waxed airplane. Where there was laminar flow on the forward part of the flight surfaces, the particles slid off cleanly. But the turbulent boundary layer embedded dust particles into the wax. This left the laminar region polished and made the turbulent area dull. As you may remember from my article on aerodynamic devices last month, this transition from laminar to turbulent flow is important to locate.

So Klaus' flow visualization methods let him accomplish step one of the process: Understand the situation. From here, Klaus identified several ways that the air was not flowing efficiently. The following shows some of his improvements which have been designed and tested.

Klaus worked on the cowling first, lowering its profile in order to reduce drag ("it pushes less air out of the way"), and to blank less of the pusher prop. Figure 6a shows Klaus' sleek cowling.

Figure 6a: The Determinator's sleek cowling.

Photography courtesy of Light Speed Engineering

He also made several changes to the Long-EZ's canard. He modified the canard's airfoil, sharpening the leading-edge radius from the standard Roncz airfoil. Klaus decided on the Dornier-style upswept tapered tips instead of the typical Hoerner tip he has on his VariEze, and he modified the elevator's deployment angle. The stock configuration deploys to 25 degrees; Klaus found that after some slot changes, flow stays attached to the elevator all the way to a surprising 45 degrees. "Obviously, making any changes on your airfoils can easily be disastrous," Klaus cautioned. "Increasing the lift capability of the canard—or your tail—can drive the main wing into a stall, and we all know how that plays out!"

He also changed the direction of the gap between the wing and the ailerons. The plans call for the gap to be lined up perpendicular to the wing's swept trailing edge. Instead, Klaus lined this gap up with the direction of flight. This reduced the small drag caused by the edge of the elevator being angled into the wind. He also added a foam insert to the gap to further reduce drag. These changes can be seen in Figure 7.

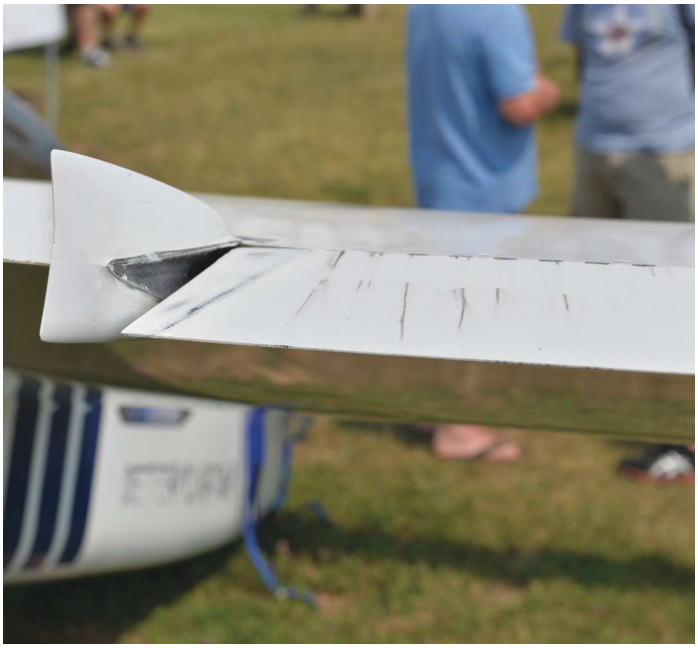


Figure 7: Aerodynamic improvements to the ailerons.

Note also the accidental flow visualization—some oil remained in the hinges and flowed out during flight. The lines that don't line up with the direction of flight show that there is some spanwise flow. More on that later.

To seal other gaps, Klaus uses a special blue flash breaker tape, as seen in Figure 8. What's so special about this tape? First, it doesn't leave a residue. Second, it doesn't fly off when Klaus races. Third, rain doesn't chisel under the edges, causing the tape to come off. Finally, it's available commercially at some airplane equipment supply shops.

Figure 8: Klaus uses this special blue "flash breaker" tape because it doesn't leave a residue and doesn't come off in flight.

Swept-wing aircraft typically experience flow from the wing root to the tip, especially at high angles of attack. Unless mitigated, this spanwise flow can cause poor stall characteristics: tip-stall; increased landing and takeoff speeds; and pitch-up at stall. Spanwise flow also can reduce control-surface effectiveness and can even blank the areas behind the wing.

To deal with this problem, fences are sometimes used. Fences are typically flat plates that stick out perpendicular to the wing, extending from the leading edge to the trailing edge. They dam up the spanwise flow and shed a vortex at high angles of attack. This can cause the boundary layer to stay attached longer, which can delay stall and improve control system effectiveness.

Vortilons are another tool to battle high angle-of-attack flight qualities. Like fences, vortilons are typically flat plates that stick out perpendicular to the wing. But vortilons extend from the lower surface past the leading edge. Compared to fences, vortilons have less drag in normal flight because of their smaller wetted area.

Here's where Klaus' innovative thinking paid off for him and hundreds of EZ pilots who have used his idea. He looked at fences that cover the entire chord of the wing and thought of a better way. Spanwise flow doesn't just travel along the wing; it flows behind the wing, too. So Klaus shrank the size of the fences and designed them to extend past the trailing

Photography by Lynne Wainfan

edge of the wing. Trailing-edge fences have many advantages over similar devices. They have less drag than vortilons because they affect less of the wing; they have less drag than regular fences for the same reason; they have less wetted area than regular fences; and they are mostly inside the boundary layer.

Figure 9 (and Figure 7) show Klaus' 4-inch-tall trailing-edge fences. Fences can be installed at various locations on a wing, but Klaus' are placed on the wing near each end of the ailerons to increase aileron effectiveness and to reduce spanwise flow, which is highest during aileron deflection. "On swept wings, fences should not be installed on aileron control surfaces since this loads them up to the point that roll authority is all but lost," he cautioned.

Figure 9: A trailing edge fence.

The trailing-edge fences' effect on low-speed performance was remarkable. Klaus' testing on the VariEze showed "it was immediately noticed that takeoff distance is reduced 10 to 15 percent; climb rate is improved 20 percent; and most noticeably, approaches can be flown at least 10 to 15 percent slower, resulting in a significantly shorter landing distance—nearly 30 percent less. There was a measurable increase in top speed above 10,000 feet."

Recall from my article "Vortilons, VGs, and Fences, Oh My" that it is sometimes helpful to trip the boundary layer from laminar to turbulent slightly forward of where it would naturally transition. Klaus used his flow visualization methods to find the transition zone and the ideal place to trip the flow to turbulent. Figure 10 shows the zigzag tape that Klaus sometimes uses to trip the boundary layer on his wing.

Figure 10: Klaus occasionally uses this zig-zag tape to trip the boundary layer on his wing.

When Klaus oiled up his airplane, he was surprised to find that the transition to turbulent flow was not where conventional wisdom predicted. "Surprise!" he reported. "The transition was at 62 percent of the chord, 5 percent aft of the predicted location of the GAW-2 airfoil. It was way farther back than expected." If he hadn't understood the situation by visualizing his flow, he would have put the zigzag tape too far forward, giving up those precious few inches of laminar flow.

So why did he find that his boundary layer transitioned later than experts predicted? Klaus believes that the turbulence in free air is much lower than in any wind tunnel. Readers are invited to send in thoughts on this potentially important theory.

Boundary layer trippers aren't just useful on wings. Figure 11 shows Klaus' landing gear, with zigzag tape on the strut and wheelpant.

Figure 11. More zig-zag tape on the wheelpant trips the boundary layer there as well.

Although Klaus' plane appears perfectly built, with absolutely no ripple on the wing, his flow visualization revealed another surprise. He said, "On a recent laminar flow test, I noticed that the extent of the laminar flow varied slightly between the two winglets. One has more laminar flow on top (inboard) and less on the bottom (outboard) than the other. This clearly indicates that the installed incident is slightly different."

One of Klaus' remarkable traits is that he is completely honest: He reports his failures as well as his successes; he shows photos of his instruments to prove his performance claims; and he doesn't talk about anything he hasn't done yet. He has an extremely high reputation in the industry for his integrity.

Perhaps the most innovative concept Klaus has come up with isn't even obvious to people looking at the *Determinator*. Other Long-EZs use a so-called NACA duct engine cooling air inlet on the bottom of the fuselage. The NACA duct was invented in 1945 by the National Advisory Committee for Aerodynamics (NACA), a precursor to NASA. It came up with a design for a standardized, low-drag submerged duct, as shown in Figure 12.

Figure 12: A standard NACA cooling air duct.

The reason the duct starts out narrow and then widens is to increase the area slowly to avoid flow separation. The vertical sides of the duct produce two counter-rotating vortices that roll off the sides and into the duct. These vortices cause more air to move into the duct than normally would.

Klaus looked at NACA ducts that had been in use for 70 years and wondered something: "How do the two vortices created by the duct shape fit into the rectangular opening?" So Klaus played with the shape of the edges of the inlet. Figure 13 shows the duct he flies on the *Determinator*.

Figure 13: The duct Klaus designed for the Determinator.

The result? Klaus got a two-fer. "I saw an improvement; both a reduction in drag and an increase in cooling," he said.

Aerodynamicists have been known to say that they would sell their grandmother for 15 counts of drag. If that is the case, then Klaus can measure his aerodynamic improvements in deca-grannies!

WEIGHT

Extra aircraft weight costs performance in a number of areas. For instance, the wing needs to develop more lift, which increases the drag. The need for more lift means that the heavier airplane will stall at higher speed than the lighter one. It takes more control authority to get the same angular rates with more weight, especially if that weight is toward the front/back or left/right of the aircraft. Extra weight means more load on structural members, meaning they might have to be sturdier and heavier. More weight might mean a shift in the airplane's center of gravity.

On the other hand, reducing weight arbitrarily could get you into trouble, too. Of course, cutting back on structural elements is a problem, but even cutting back on that wing skin thickness or heavy counterweight could increase the risk of flutter. On the Facetmobile, the two counterweights on the elevons weighed 7 pounds, and they affected the CG of its light, long airplane. It goes without saying (although some should have been told) that you need to know what you're doing if you plan to increase or decrease your airplane's weight.

Klaus naturally applied his methodical, persistent approach to cutting weight on the *Determinator*. For example, when he was changing the injector location, he made an all-carbon-fiber intake plenum. He also built a 9-quart oil sump that weighs 2.1 pounds. The sump alone saved 11 pounds.

Klaus again warns that such engine parts require a specific process. "They should be vacuumed for reduced porosity and only use cured epoxy from an oven at least 300°F," he warned.

Some of Klaus' other weight-saving changes include replacing the plywood and glass firewall with a high-temper-

Photography by Lynne Wainfan

ature foam, carbon-sandwich structure, which saved several pounds. He innovatively combined weight savings and aerodynamic improvements with his wheelpants. "The new wheelpants have the split line at the laminar transition so no zigzag tape is required," he said. "They weigh only 21 ounces with paint and hardware."

Smaller weight-savings opportunities that Klaus took on are too numerous to list. "I put in a great deal of effort to make things light," he said. "But the result was the lightest Long-EZ with a Lycoming IO-360 engine. Most such airplanes weigh in at over 1,100 pounds. Mine is 900 pounds."

THE *DETERMINATOR*'S PERFORMANCE

The *Determinator*, with its propulsion, aerodynamic, and weight improvements, has transitioned beyond what could be considered a Long-EZ. "No engineer would ever design a plane with too much power and too much wing and too little weight," Klaus explained. "It turns out for a cross-country machine, there's nothing better. At high altitude—17,500 feet—it loses only 5 or 6 knots over sea level speeds." Klaus explained that the airplane "plows" less than others; its wing loading is only 13 pounds/square foot so the nose stays down when the air is thin. The *Determinator* wing doesn't present as much area to the wind and has less drag at these lower angles of attack. "Some popular planes with much heavier six-cylinder engines can't even go that high because they just need too much angle of attack at these altitudes," he said.

Klaus says that the *Determinator* is a fast cross-country machine. "A 900-pound airplane with 250 hp does really well at altitude," he said. "It puts out about 250 hp at sea level. Air at 17,500 feet has half the density, so you still have 125 hp at altitude. But at 17,500 feet the drag is halved also. Given the already low-drag airframe, that helps the airplane to go very fast." This speed at altitude gets him to Oshkosh from California quickly. "I've never seen a piston airplane that loses so little speed at altitude."

How fast does the *Determinator* fly? At this year's Bronze Race at Reno, Klaus averaged 263 mph—and that is going around in circles, an inefficient flight pattern. Klaus' average speed documented for the AirVenture Cup was 270 mph. "A few Long-EZs with high-compression piston O-360 engines may top out at 240 mph," he said. The next fastest Long-EZ in the AirVenture Cup averaged 229 mph. Klaus is getting almost 20 percent speed improvement over the next best speed-improved Long-EZ at Oshkosh!

Speed isn't the only performance improvement that Klaus was after. The efficiency-obsessed engineer notes the *Determinator*'s fuel mileage is more than 41 mpg at 250 mph true airspeed above 15,000 feet. This, plus his 49-gallon fuel capacity, allows him to fly almost anywhere in the United States nonstop. Of course, the mileage improves further with reduction of speed, all the way to around 100 mpg at best glide speed. (VBG is where all airplanes get their best fuel mileage.) It is interesting to note that VBG refers to indicated airspeed. Flying at VBG at 17,500 feet adds about 50 mph to your true airspeed! A more stock Long-EZ with an O-360 engine at 220 mph would achieve only 25 to 30 mpg, compared to Klaus' 41 mpg—Klaus burns 64 percent less fuel while cruising 14 percent faster!

The fuel efficiency of Klaus' airplanes surprises most experienced pilots. In 2003, he flew his O-200-powered VariEze in the Reno National Championship Air Races. At the end of the week of racing, as pilots stood in line at the cashier to pay their fuel bill, the other race pilots' jaws dropped with shock and envy: Klaus' bill for the week of flying came to only 17 gallons—and that included the fuel to fly home!

ADVICE

When asked for words of wisdom for other aircraft experimenters, Klaus contemplated for a while. Referencing the time and money he spent making his exhaust heavier, he advised, "It's really important that you don't get too attached to your wonderful ideas. You have to be man enough to take it back out." (An alternate phrase used at Boeing was "You have to be able to admit that your baby is ugly.")

All people who successfully modify their airplanes know that the improvement process—to understand the situation, design a fix, and test the fix—takes some time to master. To understand the situation, you not only have to pinpoint the problem element on the airplane, but you have to understand the *system*—how that one element affects the rest of the airplane in different flight conditions. To design a fix, you have to be knowledgeable about what and how to build and install the improvement. To test the fix, you have to have a well-planned test program, implemented methodically by someone competent to flight-test the airplane. As Klaus' *Determinator* demonstrates, it is possible to modify an airplane to get amazing results. However, it is also possible to inadvertently mess up an important part of the system.

Klaus' final words of wisdom for aspiring aircraft efficiency experts: "Use an abundance of caution."

The cautious Klaus reflected back on his hundreds of ideas to improve his airplane's propulsion, aerodynamic configuration, and weight and said, "I make the changes even though the increment of gain might be so small you might never measure it." Klaus does not have sophisticated instruments or a wind tunnel. But he has the intuition, the expertise, the persistence—plus the determination—to undertake a 31-year improvement effort that gives him unparalleled efficiency and speed. If slow and steady wins the race, then Klaus will win many, many races. EAA

Lynne Wainfan has been a private pilot for more than 30 years. Originally an aerospace engineer, then a manager at Boeing Space, Lynne now consults and teaches at California State University, Long Beach. Readers may remember the Facetmobile experimental airplane, which was built by Barnaby and Lynne Wainfan and Rick Dean.

2014 Perseverance Awards

Celebrating more builders' success

BY JOHN MANGOLD

THIS MONTH WE WILL wrap up our recognition of homebuilders who brought their aircraft to EAA AirVenture Oshkosh for the first time since completing it. Each year, those builders are recognized with a Perseverance Award to acknowledge the work and investment they made to complete their projects.

The Perseverance Award was founded by Doc and Buddy Brokaw (now deceased) who built and flew a Brokaw Bullet for many years. The award continues in their honor and to fulfill their wish that homebuilders be recognized for their perseverance.

Over the next few months, we will share photos of several aircraft that made their first appearance at Oshkosh 2014.
— Mary Jones

RV-7A, N787KV

Peter Richmond flew his RV-7A to EAA AirVenture Oshkosh 2014 from Annapolis, Maryland, where he lives on a boat and bases his plane at Easton/Newnam Field (KESN). The airplane was certificated and first flown in February 2014, after five years of build time. Peter was inspired to build a plane by his brother, who also flew his RV to AirVenture 2014 from Glenwood Springs, Colorado, and parked and camped next to Peter and his airplane.

ZENITH 601XLB, N678AK

Pavlou Kanellos built this Zenith 601XLB over seven years, having to rebuild it after receiving the upgrade kit for the spar and wing improvements. The airplane was certificated in April 2014, and he made the first flight that month. It has an all-glass panel and is equipped with an autopilot. Pavlou flew the airplane to Oshkosh from the Groton–New London Airport (KGON) in Connecticut.

BEARHAWK, N805TD

Jared Yates purchased this four-place Bearhawk from another builder. Altogether, it took four years and 2,500 hours to complete the project. It was certificated and first flown in December 2013. The aircraft is powered by a Lycoming O-360 engine. Jared is based in Hickory, North Carolina. At AirVenture 2014, he displayed his plane in the Bearhawk exhibit in the Homebuilder's North Aircraft Display Area.

SUPER BREEZY, N149X

This Super Breezy was flown to Oshkosh 2014 from Yakima, Washington, by Paul Breed and Ian Kluft. It's powered by a Lycoming TIO-360-C1A engine. This year marked the 50th anniversary of the Breezy, and a number of Breezys flew to Oshkosh to celebrate the event.

RV-10, N779DS

Dana Saucier flew the second RV-10 in that flight of three airplanes from Ohio. His airplane received its airworthiness certificate in November 2013 after four years of construction. It's powered by an IO-540-C4B5 engine. He also flies from the Delaware Municipal Airport (KLDZ) in Ohio.

SUPER CUB, N7836W

Ted Waltman bases his Super Cub, a Backcountry Cub kit, at Platte Valley Airpark (18V) in Colorado. The aircraft took 16 months and 1,800 hours to complete. It was certificated and first flown in June 2014. It is powered by an IO-375 engine producing 205 hp and swinging a constant-speed propeller. The airplane has a 38.5-foot wingspan and leading edge slats and cruises at 85 mph with a 6-gph fuel burn. It lands at 22 mph.

RV-9A, N987J

Brice Johnson is the owner and builder of this RV-9A. The airplane received its airworthiness certificate in December 2013, and its first flight occurred in February 2014. The airplane took nine years to complete. Brice said it was challenging to learn about the electronics to complete the airplane, but it was a rewarding project. He flew to Oshkosh from Federal Way, Washington, which also took more than three days because of bad weather.

RV-10, N410BL

Bob Leffler flew his RV-10 to AirVenture 2014 from Delaware, Ohio, in a flight of three with another RV-10 and a Cozy. Bob completed his -10 after six years of building; it was certificated in July 2013, and the first flight was made in November 2013. The aircraft is powered by a Lycoming IO-540-D4A5 engine. While he was building his -10, two other RVs were being constructed on his residential block—another RV-10 and an RV-7. Bob and his neighbors are laying claim to the title of most RVs per capita in the United States.

RV-6A, N9806A

Steve Allison's RV-6A was certificated in December 2013 and first flown in March 2014. The airplane took 20 years to build, and he spent three days en route to AirVenture 2014 from San Jose, California, because of weather delays. One of Steve's goals at AirVenture was to get ideas for the paint scheme for his airplane, which is powered by a Lycoming O-360-A1A rated at 180 hp. Steve's father, a retired Air Force fighter pilot, attended AirVenture for the first time, flying in with Steve's brother. EAA

Above: Sean's Destiny 2000 powered parachute. Below: The replaced U-brackets.

That's Not Normal

Check your brackets!

BY SEAN CURRY

Editor's Note: This month we're deviating slightly from offering a hint for homebuilders to share this important safety hint for powered parachute pilots. The machine this problem occurred on is a Destiny 2000 powered parachute, but it might behoove owners of other machines to check their machines out thoroughly as well. As you put your machines away for winter, give them a thorough inspection.

A COUPLE OF WEEKS ago, my wife and I were at a local fly-in. One evening the weather was great, so we decided to go for a flight. Kite-up and takeoff seemed normal, but as we started to climb, I noticed that the machine, a Destiny 2000 powered parachute, started turning left at a good rate. I had trees and power lines to clear, so I continued to climb until I reached a safe altitude before trying to check out what was going on. I thought the torque of the engine or maybe the wind was affecting the machine.

I leveled out at 400 feet and began my review of the situation. This machine has flown straight as an arrow since the day I got it, but I had to pull in about a foot of steering line on the right to get it to go straight. I started checking out the chute and everything looked normal. I made a couple of turns to make sure the wind wasn't affecting the machine. We landed so I could check out the machine to see what the problem might be.

After landing, I looked over the chute lines and risers, and again, everything seemed fine. The next day, a couple of other pilots helped me check out the machine and chute. We even turned the chute over so we could check out the top. Nothing appeared wrong with the chute. We checked out the cart, grabbed and shook each tube like I do when I preflight, and could find nothing wrong. Since the winds were up the next couple of days, I decided not to test-fly it again until I got it home and had time to look over the machine one more time.

When we got back home, and while I was unstrapping my machine in the trailer, I noticed a small piece of metal sitting on the floor under my machine. My wife and I started looking to see where the metal could have come from, and she noticed a cracked U-bracket on one of the diagonal tubes. We checked the other side and found that the metal piece had come from that U-bracket. When not under load, the bracket was around the bolt and didn't move. When under load in flight, the bracket moved away from the bolt and allowed the machine to flex enough to make the engine thrust to cause the turn. After checking over every bracket on the machine, I found two more brackets that were cracked. They were all the aluminum ones that came with the machine originally. After finding this, I called a friend who owns another Destiny 2000 of similar age. He found that the same brackets were cracked on his machine, and he also found others that were deformed or cracked.

I recommend anyone who owns a similar Destiny machine to take a close look at all of the brackets on his machine. After 15 years, vibration and stresses of flight can and will take a toll on parts. As in my case, a normal preflight might not catch this problem. If something doesn't seem normal, there is a reason. Don't stop looking until you find the problem! EAA

The fatigued brackets.

HINTS FOR HOMEBUILDERS VIDEOS

HERE'S SOME OF THE MORE RECENT VIDEOS ADDED TO EAA'S CADRE OF MORE THAN 400 HOMEBUILDER HINTS VIDEOS:

Rod End Bearing Installation
Brian Carpenter from Rainbow Aviation Services provides tips on the installation of rod end bearings.

Cutting Dacron sailcloth
Brian also shows how to cut dacron sailcloth by modifying a soldering iron into a hot knife.

Cable End treatment
Next, Brian demonstrates a way to permanently eliminate frayed cable ends.

Balancing Your Propeller
Here's a hint that everyone can use…Brian shows us an easy and effective way to balance a propeller.

The D-motor in the B.O.T. SC07 aircraft, imported into the U.S. by Renegade Aircraft, www.renegadelightsport.com.

Introducing the D-motor

Belgian engine manufacturer throttles up

BY MARINO BORIC

THE ENGINE CHOICES AVAILABLE for the ultralight, light-sport, and experimental markets were, in the recent past, fairly limited, with the default industry standard Rotax 912 engine leading the way. That situation changed in the last several years with the introduction of several interesting engines designed solely for light aviation use, including the Jabiru, ULPower, and others, along with several auto conversion engines, such as the VW and Corvair, that gained increased popularity in the experimental market.

Among those newcomers is the Belgian D-motor. The D-motor was first presented in Europe in 2010 as the four-cylinder LF26 engine with 80 hp. In 2013, D-motor followed that with the 125-hp, direct-drive LF39 engine. In 2013 the LF26 (the numbers behind the "LF" stand for engine displacement in liters) reached the final development stage and went into serial production at 92 hp. Now the Belgian manufacturer is working on production of a new, six-cylinder LF39 engine, which recently began test flights.

Although D-motor's engines look pretty conventional, they have characteristics that can't be found in almost any other current engine. Despite the fact that the D-motor engines were designed in the last decade, some of their design features originated from the past. Side valves or the "flathead" design used in postwar times and an ECU electronic ignition don't seem to fit together at first glance. This unusual mix made me curious. And it's one of the main reasons why I decided to visit the D-motor plant in Deerlijk, Belgium, and get the design features explained by one of the company owners, Alain Dejager.

When I arrived in Deerlijk in the southwestern part of Belgium, I was looking for an aircraft engine manufacturer, but at the address listed I found only a car body shop. Nevertheless, I rang the bell and Alain Dejager received me personally. Alain explained that this automotive business, M & M Cars, provides the financial base for the aviation engine development.

Photography by Marino Boric

The actual engine production facility is located within a stone's-throw distance of the car company. When we got there, I found a completely different world; a modern factory with computer-aided lathes and an engine assembly line with an engine test bench.

SIDE-VALVE, 'FLATHEAD' ENGINE

Both engines—the four-cylinder LF26 and the six-cylinder LF39—look similar, although the new LF39 six-cylinder looks much more "intimidating" with its longer engine block. All D-motor engines are liquid-cooled, fuel-injected, four-stroke, flat-opposite engines with direct drive to the propeller.

On each cylinder head, pairs of spark plugs protrude, sitting halfway between the pistons and the laterally located valves. Typically, spark plugs are not located here, but these cylinder heads and the "flathead" location of the intake and exhaust valves beside the cylinders is the unique feature of D-motor engines. Currently, D-motor is the only aviation engine manufacturer using the side-valve, "flathead" design. The pistons and cylinders are conventionally built with a bore/stroke of 103.6/80 mm.

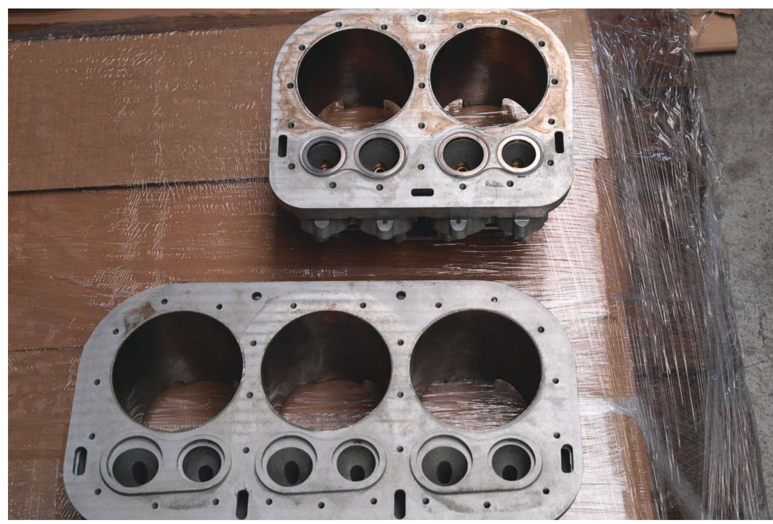
The side valves dictate the unusual design of the combustion chambers and the position of the intake and exhaust valves. The valves of the LF26/39 engines are not located above the pistons in the cylinder head; rather they are beside and below the cylinder. The stems of the valves are parallel to the cylinder walls, and the valve tops are facing toward the engine center and toward the single camshaft.

The camshaft that actuates the intake and exhaust valves is located below the crankshaft so short pushrods are used. In normal engines where the valves are located above the pistons, we can find pushrods that are more than 10 inches long. If you take off the cylinder head of a conventional engine, you will see a round, hemispheric combustion chamber directly above the piston. Because the valves of the side-valve D-motor engine are located beside the cylinder, the combustion chamber is unusually laterally developed. A part of the combustion chamber, about two-thirds of it, is above the piston and the rest of it is alongside the cylinder—above the valves. Thus instead of the usual circular-shaped combustion chamber, we find a kidney-shaped combustion chamber protruding alongside of the cylinder perimeter. The result of this flathead design is a very slender and narrow engine.

This combustion chamber/valve design was in regular street use almost 50 years ago. In the United States, the most common and most famous side-valve engine was the Ford side-valve V-8 or flathead used in automobiles from 1932 to 1953. A similar design was used in Moto Guzzi motorcycles in Europe in the pre- and postwar period.

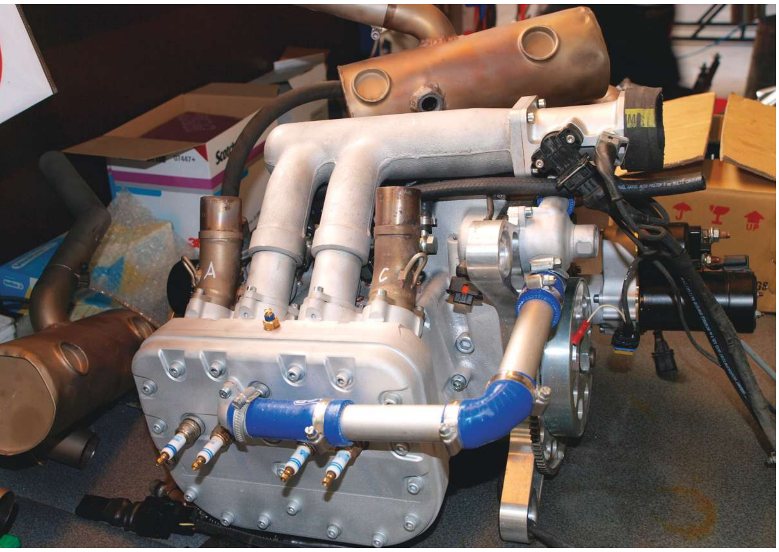
The disadvantage of the side-valve engine is that the airflow characteristics of the design are far from optimal. On

The D-motor assembly line in Belgium.

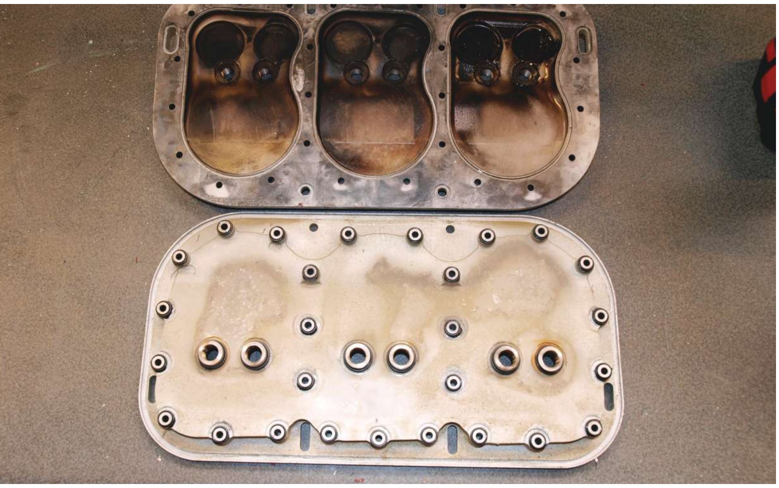


The cylinders of the four-cylinder engine LF26 (top) and the six-cylinder engine LF39 (bottom).

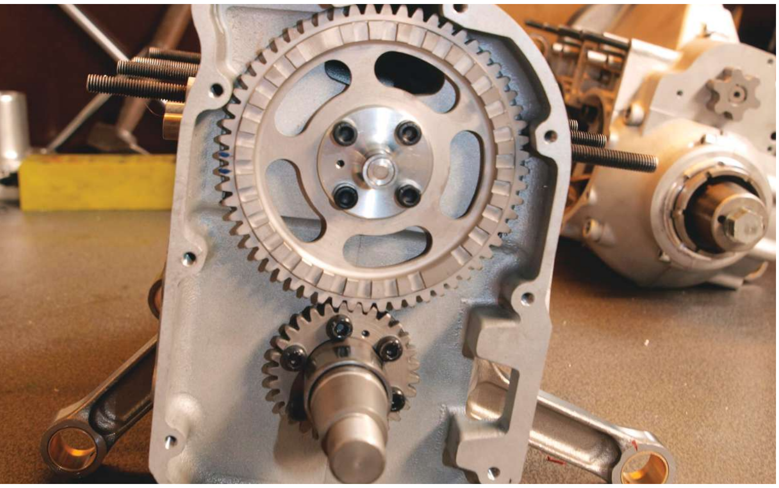
Alain Dejager showcased the six-cylinder engine, the LF39, at the French Blois Fly-In this fall. The scale was indicating 175 pounds.



This image of the upside-down engine shows the flat cylinder head cover...



...and below it the extraordinary flat cylinder head. For a better explanation, two cylinder-heads are pictured--one from inside (above) and the other from outside (below).



Close-up of the "real" cylinder head; because of the engine's flathead design, the valves are not located in the cylinder head. Instead, they are located below it parallel to the cylinder barrel.

the intake stroke, the intake valve will open, and the suction caused by the downward movement of the piston will draw the air/fuel mixture into the cylinder and cylinder head. The intake air/fuel mixture flow path is not smooth. The flat surfaces and internal corners are not conducive to good airflow. Usually there are too many obstructions that cause turbulence and airflow eddies that impede efficient air movement. The same thing happens during the exhaust stroke.

When I asked the D-motor designers about this suboptimal side-valve engine characteristic, I got the following answer: "That is true and we can't deny these facts. We have tested countless cylinder heads solutions with different combustion-chamber shapes until we reached the present optimal shape. Because our engine is directly driving a propeller (low rpm engine), those nonoptimal engine characteristics don't affect our engines." That is pretty correct because this airflow inefficiency is not a problem for low revolving engines, and the LF26/39 engines turn at 3,000 rpm. At D-motor they are particularly proud of the safety aspect of their engines. They said, "When a valve of a conventional overhead engine does not close, the engine stops and is likely to be ruined. When a valve of a side-valve engine does not close, the engine develops less power but it will not stop running and there won't be expensive repair cost."

The engine block is divided in two halves vertically. The crankshaft protrudes out of the front part of the engine block with a prop-flange attachment (different length prop flanges can be ordered); on the rear, the crankshaft ends with a toothed gear that drives the single camshaft. The camshaft ends on the engine front with an oil pump. Neither of the four-stroke engines has cooling liquid or oil thermostats, but they can be fitted if required.

ENGINE PRODUCTION

The D-motor factory has its own molds for the engines, and most of its aluminum engine parts are machined in-house, making them less dependent on outside suppliers. Another interesting engine detail is that the cylinders and cylinder heads are not screwed to the engine block by long steel studs, such as with the Rotax 912 engines. Instead the cylinders are bolted to the engine block with short screws, as with Lycoming engines. The cylinder heads are screwed by even shorter screws to the cylinder bodies. Nonmoving engine parts are aluminum, while the crankshaft, camshaft, and connecting rods are steel, of course. The cylinder walls are Nikasil coated. Because of these material choices and because the engines have a relatively low number of parts, they don't weigh much. The 92-hp, four-cylinder engine weighs only 126 pounds (58 kilograms). The 135-hp six-cylinder engine weighs 170 pounds (78 kilograms). Those numbers are for dry weight and include the exhaust, intake, fluid coolant, and the oil tank. Wet weight with

Photography by Marino Boric

liquids for the LF26/39 engines are 137/185 pounds (63/85 kilograms), respectively.

CLEAN ENGINE TOP

The upper portion of the D-motor engine is unusually "clean" for a liquid-cooled engine. There are only two hoses on the four-cylinder engine and four cooling hoses on the six-cylinder engine that lead to the coolant collector, and the intake and exhaust are located below the engine, which allows for a very flat engine cowling.

UNCOMMON FIRING ORDER

The firing order of the D-motor engines is different. Normally, the firing order in four-cylinder engines is 1-3-4-2. The four-cylinder D-motor firing order is 3-1-4-2. This sequence was chosen a few years ago because the vibrations of the engine featuring the modified firing order was significantly lower than in those with a conventional firing order. Even if this seems to be an easy conversion, in reality it wasn't. D-motor has solved all related problems, and the engine now runs smoothly.

PROPRIETARY ECU AND FUEL INJECTION

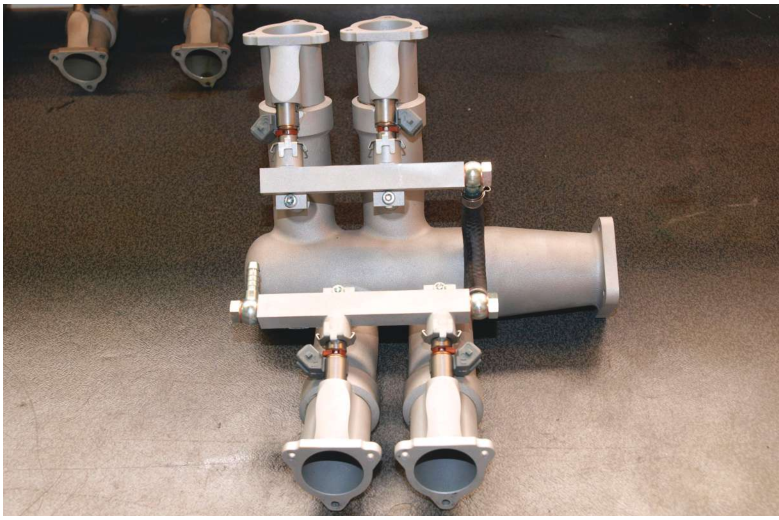
As is common for a modern engine, a computerized engine control unit (ECU) is responsible for ignition and fuel injection. This ECU comes from the company called Optimax. A single-channel unit (with an emergency backup mode) is delivered with the LF26 four-cylinder, and a twin, independent-channel unit will be delivered with the LF39 six-cylinder engine. Two spark plugs per cylinder are standard on both engines. On request, the newest, redundant dual-channel unit also can be ordered for the four-cylinder engine—a $1,300 (1,000 euros) option.

D-motor's proprietary engine pickup sensor detects 4,096 pulses per crankshaft turn. This allows D-motor technicians not only to monitor the engine but also to sense acceleration pulses from each mixture ignition in the engine and address possible problems in each cylinder. This sensor/pickup is a D-motor product.

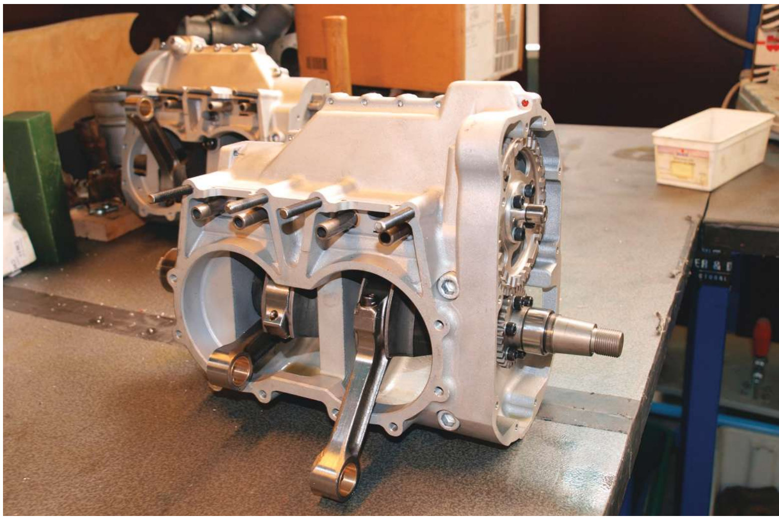
The LF39 six-cylinder engine is running. During my factory visit in May, the six-cylinder engine was already running (more than 30 hours) on the D-motor proprietary test bench, so I could see and feel the smooth-running engine properties. I was allowed to see some (uncorrected) engine performance numbers on the dyno. I saw that the LF39 delivered 60 kilowatts and 275 Nm of torque at 2,000 engine rpm. In the meantime, this engine is being flown in a German helicopter and in D-motor test aircraft.

After the factory tour, I was able to test-fly the LF26 engine on board the company's B.O.T. SC07 airplane. The flight was pretty short. But the engine was powerful and its vibration level is one of the lowest on the market today.

The start sequence of the four-cylinder is very simple. Turn the fuel pumps on and select both channels of the



The intake manifold is located below the engine; note the two short high-pressure fuel rails and four injectors.



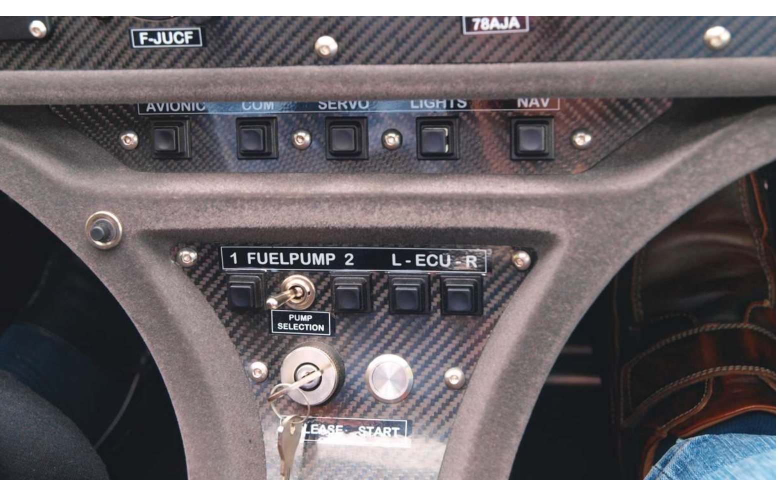
This is the compact engine block (above), with the cylinders removed (below).

ECU. After a short turn of the ignition key, with the OAT at 30°C, the engine went alive almost instantly. ECU checks take place at 2200 rpm; that consists of switching between the two independent channels and basically comparing the engine numbers. This ECU check is only doable if the optional two-channel ECU is installed. In flight, both channels of the ECU are active, each controlling separate ignition coils and spark plugs.

After the engine start, the engine stabilized at just under 800 rpm at idle, and after barely five minutes, coolant and oil temperatures were in green.

During taxi to the runway, I was impressed by the quiet, smooth-running engine and pleasant exhaust sound. At start, as well as in flight, the engine responded very quickly to different throttle settings, without the engine showing any uncertainties or inertia (delay) after the throttle change. At full-throttle (WOT) straight and level flight, the noise level increased considerably, and I could hardly distinguish the noise from that of a Rotax engine. I liked the engine most at a speed of 100 mph (160 kilometers/hour), where the engine rotated at 2,400 rpm with a MAP of 24 inches Hg. The display indicated a consumption of 2.9 gph (11 liters) at that power setting. The average of the previous flights was indicated with 2.84 gallons/hour (13 liters). At low throttle settings below 2000 rpm, the engine sound was pleasantly unobtrusive and not annoying. At these speeds, you could clearly hear the sound of the slowly revolving, direct-drive engine. While taxiing on the ground after landing with open doors, I loved the engine sound. Even without a special absorbing silencer, the engine was quiet. For me, the engine was almost too quiet. Alain Dejager laughed, saying, "So far we were able to solve all engine problems; we are going to fix even this one for you."

This is the all new double ECU used on the LF39 engine (standard on LF39, optional on LF26); the "B" channel is in use.



When the two-channel ECU is installed, the engine panel will look like this; note the two (left and right) ECU channel selector buttons.

D-MOTOR'S HISTORY

The history of D-motor engines crosses at its beginning with another Belgian engine manufacturer, ULPower. Both engines originated with the Belgian Masquito M80 helicopter project that was originally powered by a two-stroke Rotax 582 and later by the Jabiru 2200. Since those engines were not strong enough, in 2004, D-motor and ULPower developed their own engines for that project. A few shareholders of Masquito Aircraft founded ULPower Aero Engines.

Other Masquito technicians founded Mascotte, the company that developed the Masschi 105 engine. In 2006 that company took over the Masquito project and continued with it until 2008. Later, D-motor was established and the project was resumed. The LF26 debuted in 2010 in Brussels, Belgium, and at AERO Friedrichshafen in Germany. That same year the engine had its maiden flight in an X-Air microlight.

D-motor plans to raise the company's registered capital to $4 million through an agreement signed in April 2014 with a Chinese investor and distributor of the D-engine products in Asia.

Currently, the six-cylinder engine is flying on the company's own test aircraft in Belgium, and since June, on board of the German EDM Aerotec CoAX 2D/2R helicopter where it has logged 100 flying hours. As of September 2014, the temporary retail price of the LF39 is $19,900, according to the U.S. importer, Doc Bailey. According to Doc, the price includes the muffler, mounting hardware, coolant lines, and dual ECU—basically everything but the battery, prop, and radiator. The first six-cylinder engines are now on the way to European aircraft manufacturers.

For more information, visit www.D-motor.eu. EAA

Marino Boric, EAA 1069644, is an aeronautical engineer and holds a private pilot license in Germany with commercial and instrument ratings (CPL/IFR). He also flew as a military pilot.

Photography by Marino Boric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The Six-Chuter P3 Lite single-seat powered parachute.

Six Chuter International Powered Parachutes Announces New Ultralight P3 Lite

Go flying for less than $10,000!

REPRINTED FROM THE SIX CHUTER INTERNATIONAL NEWSLETTER

SIX CHUTER INTERNATIONAL LLC recently announced the production of its all-new ultralight powered parachute (PPC) model called the P3 Lite. The P3 Lite is a single-seat PPC that meets the strict requirements of FAR 103 for ultralight aircraft.

The model is equipped with a Kawasaki 440A engine, an Ultra-Prop, simple instrumentation, and a Performance Designs (PD) Barnstormer 360 canopy. The model is being offered for $9,995 in kit form, and the company includes a $500 coupon for training at that price.

The P3 Lite is built on a strong but light airframe made of aluminum and chromoly steel components. The Kawasaki engine is rated by the engine manufacturer at 750 hours between overhaul.

The Barnstormer 360 canopy is easy to fly and offers great performance. The seat is an oversized molded plastic seat with optional padded upholstery. The seatbelt is a heavy-duty, "racing"-style belt with shoulder straps.

The P3 Lite is offered in two standard colors, black or white. The molded seats are available in a variety of colors, and the optional upholstery is likewise available in various colors. The PD 360 canopy has several stock colors or can be custom designed at no extra cost.

Doug Maas, president of Six Chuter and director of marketing, outlined the objectives of the design. These included making a true, legal ultralight PPC that could be more easily manufactured and easily and quickly built from kit form. The price objective was to hit the market with a retail price under $10,000. The design also is intended to make a slightly smaller footprint for ease of transport while increasing the comfort and fit for even taller and larger pilots.

These were quite formidable goals given the cost of materials and the existing competition in the market.

Maas explained that the primary driver for the project was when Rotax announced the discontinuation of its popular 503 engine series. That engine had been used on Six Chuters and

Photography courtesy of Six Chuter International many other PPCs for more than 20 years. Once that engine was no longer available, the search for a reliable, well-supported, good-performing, and cost-effective replacement began. The Kawasaki 440A engine has been in the field for more than 20 years and was predominantly used on fixed-wing ultralight airplanes and weight-shift trikes, so it is well proven.

Once the engine was chosen, Dan Bailey, founder of Six Chuter Incorporated, began to design an airframe around that engine. His design took into account the company objectives of easy manufacturing and strict price control. Ultimately the design hit the mark with an airframe that is not only lighter than previous Six Chuter single-seat models but also stronger.

Maas said that the project has taken nearly two years to complete. That might surprise many, given the machine's simple design. But the desire not to just roll out another ultralight in an already crowded market, but rather to do so within the company's objectives for price control, quality, and performance, required a lot of teamwork and a lot of time to do right.

The engine testing and the production test flights proved that the team had achieved the design objectives. Test pilots Mark Martin and Paul Beam found that it is easy to kite the canopy; the PPC is very light and responsive on controls; and it has performance that is well suited for entry-level powered parachute pilots. They added, however, that experienced PPC pilots will also enjoy the "sportiness" of the Barnstormer 360 canopy. And everyone should enjoy the ease of learning to fly and the ability to enjoy ongoing legal flying that avoids the higher costs and complications of earning a pilot certificate to operate two-place powered parachutes.

Tom Connelly, operations manager and co-owner of Six Chuter International, reported that the average builder should be able to fully assemble and prepare this aircraft for flight in about a week's time. Connelly and Bailey have developed an easy-to-follow builder's manual. And Six Chuter International will provide builder support consultation at no extra charge. The company will also fully assemble the P3 Lite at an extra charge, for buyers whose only objective is to learn to fly safely and quickly and avoid the process of building.

Maas praised his team for its perseverance and hard work, including: Dan Bailey, designer; Rolando and Ramon Santiago, assembly and engine testing; Tom Connelly, P3 Lite fabrication; and Mark Martin and Paul Beam, flight testing. Maas said, "The P3 Lite in many ways takes us back to the beginning of Six Chuter powered parachutes. The early start for the company, founded in 1991, was all with simple, kit-built, ultralight-legal powered parachutes."

The P3 Lite joins Six Chuter's already successful line of light-sport experimental kits, amateur-built kits, and special light-sport models. Six Chuter continues to offer ongoing support and services to every customer and has nearly 2,200 aircraft operating around the world today. Connelly said that buyers of the P3 Lite will enjoy the same high level of personal support that other Six Chuter owners have come to appreciate.

To learn more about the Six Chuter P3 Lite, visit www.SixChuter.com, or visit the company's YouTube channel.