
Sport Aviation
OCTOBER 1991

## BOB AND GINNY GREIDER'S
## G★R★A★N★D C★H★A★M★P★I★O★N
# LONG-EZ

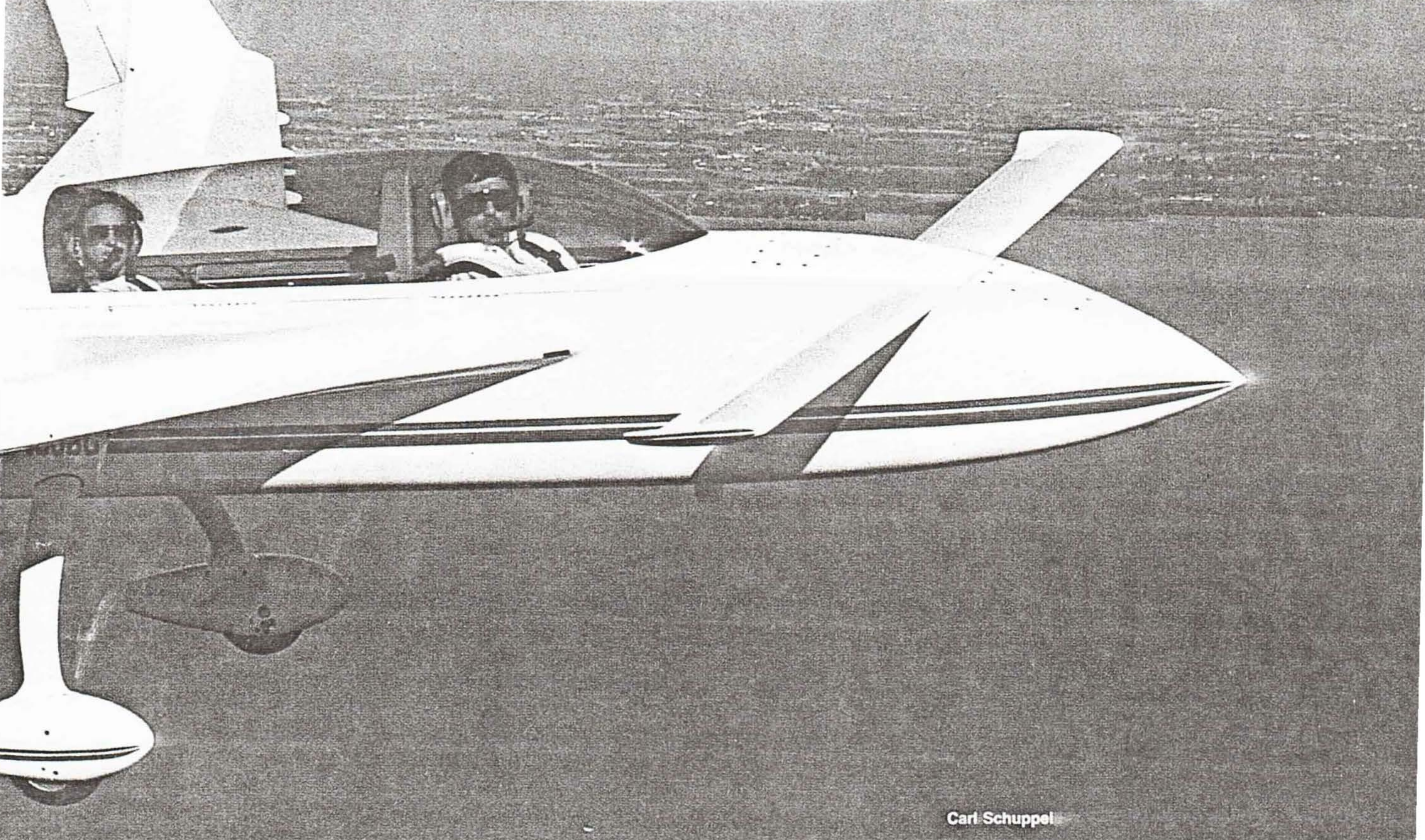
BY JACK COX

As he wheeled his car into his driveway and punched his garage door opener, Air Force Captain Bob Greider was thinking how great it was going to be to get a decent night's sleep again. He had just returned from a flight to Europe and was glad to have his C-130 parked back on the ramp at Dyess AFB in Abilene, Texas.

As the garage door came up and he began easing forward, Bob suddenly hit his brakes ... because something was sitting in his car's parking spot ... something with a sign that read, "Get me finished ... I'm going to the Bahamas!"

That "something" turned out to be the beginning of what would ultimately evolve into this year's Plans Built Grand Champion homebuilt at Oshkosh ... Bob and Ginny Greider's magnificent Long-EZ, N400BG.

The two of them had been talking about building an airplane for several years and had done a lot of looking at the various homebuilt designs available in the mid-1980s. Ginny had fallen in love with the sleek lines of the Q-2 ... but Bob had decided the Long-EZ was more suitable for the type of long distance flying they wanted to do with a personal airplane. Ultimately Ginny gave up her aesthetic preference in favor of Bob's more technical evaluation ... and began secretly foraging through Trade-A-Plane for Long-EZ projects listed for sale. She reasoned that if they bought a partially finished airplane, it would serve to overcome the inertia almost everyone experiences in the decision stage of a homebuilt project ...



DeKevin Thornton

DeKevin Thornton

Carl Schuppel

and get them to the Bahamas much quicker. She finally spotted one, located, to her pleasant surprise, in her hometown back in Arkansas, and thus it was that only a few minutes after Bob had driven away from their home to begin his Air Force flight to Europe, Ginny had surreptitiously sped away on her own mission. By the time Bob returned, she had purchased and hauled the project from Jacksonville, Arkansas to Abilene, parked it in the garage . . . and had emblazoned it with her "Get me finished . . ." sign.

(Yes, yes, I know . . . "Does she have any sisters, etc., etc.")

What Ginny had bought was a basic fuselage on its gear, plus a canard. Wings, winglets, the control system, canopy and everything aft of the firewall remained to be built . . . and all the exterior surfaces had to be finished and painted. Bob figured it would take about five years of part time work to complete the airplane, but Ginny literally bristled at such an estimate.

"It'll fly in three years or I'll give it away!" was her challenge to her husband . . . and the goal the two of them never lost sight of in the "trial by fiberglass" that lay ahead.

Shortly after starting work on the project in 1986, Uncle Sam transferred the Greiders to Davis Monthan AFB in Tucson, and naturally the Long-EZ was the first thing packed for the move west. Once in Tucson, Bob and Ginny found a house, located the nearest supermarket, drugstore and shopping center - then got to the important stuff, like making contact with EAA Chapter 81. Through the Chapter they learned they

DeKevin Thornton

would be living about halfway between two tremendous craftsmen, George Nopper and Gary Lichte. Though still under construction at the time, Gary's Glasair RG would become the Kit Built Reserve Grand Champion at Oshkosh in 1989 and George's Long-EZ (by then owned by Bob Eckes) would become the Plans Built Grand Champion at Oshkosh in 1990.

"Both had a tremendous influence on our project," Ginny says today. "Gary took almost eight years building his Glasair and George put some 8,000 hours into building what I swore was the first factory built Long-EZ I had ever seen . . . and we had a goal of finishing ours in just three years! They made us aware of a higher level of craftsmanship . . . and did not hesitate to let us know when some part we had made was lacking in some way. Their influence helped make our airplane what it is today and we're very grateful to them. 'If you are going to do something, do your best' is a simple philosophy Bob and I share . . . and George and Gary raised our level of expectation for what is 'best.'"

This realization of a higher level of craftsmanship manifested itself early in the construction phase. Bob and Ginny decided to build a new canard utilizing the Roncz airfoil to replace the original unit that came with the project . . . and found that it looked a lot better than what they had purchased. Next, they built the wings . . . and they looked better still. A crisis of conscience arose at this juncture, and the inevitable result was that all that Ginny had purchased in Arkansas and hauled back to Abilene . . . and subsequently to Tucson . . . was sold and a new fuselage was built. There was nothing wrong with the Arkansas project . . . it simply did not measure up to the Nopper/Lichte inspired standard the Greiders had now adopted as their own.

Work on the project proceeded on a part-time basis until Bob retired from the Air Force in June of 1989, after which he and Ginny shifted into a full-time, virtually round-the-clock work regime in order to meet their self-imposed three year completion deadline. Living in Tucson and working in an ordinary garage devoid of such luxuries as air conditioning resulted in some rather bizarre working schedules.

"It was often 120 degrees in the garage," Bob recalls, "and it was really hard to work in such conditions. To stay on our schedule, we had to resort to some rather unconventional practices . . . like getting up at three or four in the morning, jumping in the pool just to wake up and then after a glass of milk and a roll, working until eight or nine in the morning - until it got too hot to stay in the garage any longer. We'd have lunch, then go to bed about eleven in the morning and sleep until six or seven in the evening when it would be cool enough to go back to work again . . .

**Bob and Ginny Greider**

until one or two in the morning."

"Even working like this at night, it was still hot in the garage," Ginny added. "We'd often run out and jump in the pool fully clothed and come back wringing wet to work. The humidity is so low in Tucson that the rapid evaporation would cool you off. That's how we did most of the sanding . . . into the pool, back to sand, back into the pool, back to sand . . . day after day."

"And speaking of sanding," Bob was reminded, "we owe George Applebay 100% of the credit for the process we used to finish the airplane. George and my father have been friends since 'way back when, and he's known me since I was in diapers. George is one of the pioneers in the use of fiberglass in aircraft construction and is perhaps best known in the sailplane world. He developed the only world class composite sailplane this country has produced . . . his Zuni . . . and he has a business repairing glass sailplanes today. When we were getting close to the finishing stage, George said, 'Why don't you let me show you how to finish it right' . . . and we were more than happy to learn from him. What he taught us was a profiling and finishing system he has evolved over the years that results in about as perfect a finish as the hand and eye can accomplish together. It starts with contouring and continues with a mixture consisting of two parts gel coat, one part polyester paint and one part talc. You spray it on . . . and sand it off. In succeeding coats, you start dropping out the talc, then the gel coat, until your last coat is straight polyester paint. It's a catalyzed paint . . . extremely hard and durable, and more chemically resistant than anything else I know about. It's a labor intensive process . . . you sand and sand and sand . . . but the result is well worth all the effort. We get compliments on the finish on our airplane everywhere we go, and George deserves the credit. He's a credit to aviation."

During the profiling stage of the finishing, much of which was done during the aforementioned night shifts, a flashlight was used to do all the contouring of the curved surfaces on the airframe. By "shadowing" the surface, any little imperfection would show up and could be sanded out.

Once all the primary structure was completed, Bob and Ginny took advantage of Tucson's summer heat and post cured everything prior to painting. They simply wrapped each part and component in plastic bags, sat them out in the sun and let them bake for a full day at temperatures ranging up to 140 degrees.

When the new fuselage was built, a number of changes were made. According to Bob, "The whole front end of the airplane was lengthened and widened . . . the front seat and the instrument panel were moved about 5 inches forward and the nose was made about 6 inches longer. The cockpit portion was widened 2 inches. To balance all this, the canard was also moved 5 inches forward. I weigh about 200 pounds, so with me sitting 5 inches further forward, the canard had to move in that direction also. This, in turn, made the rear cockpit about 5 inches longer, which made a **big** difference. I'm 6' 2" and the standard Long is pretty snug for me. Just 5 more inches make a big difference in comfort when Ginny puts me in the back seat. Our canopy is also larger . . . longer, higher and wider. We designed a new canopy for the airplane and sent the measurements to the Airplane Factory (now the Airplane Plastics Company) in Fairborn, OH . . . and found that others were requesting a very similar enlarged canopy. There were enough of us, apparently, to allow the company to see their way clear to tool up to make them . . . and that's what we put on our Long."

Bob and Ginny had heard all the horror stories about the difficulties involved in installing a canopy, so they decided on an alternative method of installation that would, hopefully, circumvent such things as poor fit, warpage, etc. Essentially, this involved glassing the canopy in place on the fuselage . . . from the inside and the outside simultaneously. In order to do this, half the firewall was cut out (temporarily) so Ginny could crawl inside and work while Bob worked on the outside. The glassing was done at night to keep her from baking in what could have functioned nicely as a solar oven during the day, and a fan was utilized to keep fresh air coming in and resin fumes going out. After completion, the canopy was placed in a jig and maintained at 155 degrees for 12 hours to stress relieve it . . . the idea being that if at some point in the future the bubble takes a blow of some sort, it will be less prone to shattering.

"Throughout the construction of the airplane, we spent a lot of time on items such as this to enhance safety and make the thing more easily maintainable," Bob said during Oshkosh '90. "I suspect probably 20 to 30 percent of of the construction time was devoted to making the airplane more easily maintainable. I don't like working on airplanes. I like flying airplanes. Work is a necessary evil in order to go fly . . . so make it as easy as you can. A good example is our landing gear; by adapt-

DeKevin Thornton

ing a plate that goes on the bottom of the fuselage, we can completely remove the main gear in 30 minutes."

## THE PERSONAL SIDE

Before getting into N400BG's systems, we need to take another tack and delve into the backgrounds of the builders . . . because, as you will learn, both brought special skills and knowledge to the building of their Long-EZ that enabled them to make it the very special airplane it is.

Virginia "Ginny" Greider grew up in Jacksonville, Arkansas and was trained to do watch repair by the Timex Corporation . . . where she ultimately became a quality control inspector and training technician. Long interested in flying, she decided one day to go to a local airport and begin learning to fly gliders. Shortly afterwards she met one of the towplane pilots . . . and to soar right over the romantic interlude that followed, she ended up marrying the guy . . . who was, of course, Bob Greider, an off-duty Air Force pilot from the nearby Little Rock Air Force Base. Ginny had been born in Arkansas, grew up there and had never left the state when she walked down the aisle to tie the knot in December of 1975 . . . but before the month was out, Bob had come home from the base to tell her that they were moving to Tokyo for three years!

Aside from the usual trauma that accompanies a move, the Greiders had some pressing airplane problems they had to resolve in a big hurry. In anticipation of also learning to fly powerplanes, Ginny had bought half interest in a Tri Pacer and had found the airplane of her dreams, a Clipwing Cub, in an old farmhouse in the southern part of Arkansas . . . which she was having restored at the time. Bob had a couple of Ag Cats (he was doing crop spraying and glider towing in his off duty hours) and a J-3 Cub . . . and all of them had to go. They rationalized that they could sell their airplanes and sock the money away to draw interest, then buy whatever airplane they wanted when they returned to the States. Three years later, however, they were knocked out of their socks when they found what had happened to airplane prices while they were off in the Far East. Cubs were selling for four to five times what they had sold theirs for! This would be a major factor in turning their attention to homebuilts.

After returning to the U. S. and being assigned to Dyess AFB in Abilene, Bob, who had been involved in competitive shooting for years, was named to the Air Force pistol team. Ginny had been watching him shoot targets throughout their married life, but really didn't get interested until she was exposed to competitive action shooting. She finally told Bob she wanted to have a pistol of her own and learn to use it. Really good target pistols, however, are mostly custom made and Bob's unexpected reply was that, sure, she could have one . . . as soon as she made it. Ginny's rejoinder was just as unexpected: "All right, buy me a mill and I'll make my own."

He did . . . and she did.

In the course of her work at Timex, Ginny had been trained to do precision metal work, so with the proper equipment she was more than capable of making a target pistol. In fact, she became so adept at gunsmithing that soon the Bridgeport mill in her shop was joined by a heliarc welder, a lathe, surface grinders, buffers and other metal working equipment. After making her pistol, she and Bob made new, even better ones for themselves . . . and after her work was seen at various meets, Ginny began getting requests for parts and entire guns from other shooters. Soon that became her profession . . . and, ultimately, one of her pistols was used to win a world championship. Today, she makes custom parts for gun manufacturers as well as individuals and, of course, complete guns for those who want world class equipment. Ginny is quite well known in the world of competitive shooting and has been featured in gun magazines and on TV in **PM Magazine**.

Needless to say, her equipment and capabilities came into play in the construction of the Greider's Long-EZ. In a number of cases where they wanted closer tolerances . . . the nose gear and wing attach fittings, the canopy latches and all the flight controls, for example . . . Bob and Ginny machined the parts themselves, usually out of solid blocks of aluminum. The control stick mechanism rides in an encapsulated spherical bearing instead of phenolic blocks, and the entire system has less than a 32nd of an inch of total slop at rest. Under flight loads, there is no slop at all. Bob admits that a spherical bearing is probably gross overkill in this application, but it results in extremely smooth aileron/elevator operation, which makes things like formation flying much easier, he believes. On the other hand, such precision work does meet Bob's tongue-in-cheek criteria for any modifications homebuilders make in their projects: "It's gotta take longer to build, it's gotta cost more and it's gotta weigh more."

Ginny wanted gold accents in the airplane, so she bought a book and the dye and taught herself to anodize aluminum. As a result of her gunsmithing work, she was already experienced in nickel plating steel . . . so, ol' N400BG ended up with all the metal parts tinted either gold or silver.

Bob was born in Denver and grew up all over the midwest. His father was a geologist for Chevron and was constantly on the move in the search for oil. He was also an avid airplane modeler and that passion rubbed off on his son. Bob would go on to participate in AMA competition with Wakefield rubber powered models and both indoor and outdoor model gliders, setting senior division national records on several occasions.

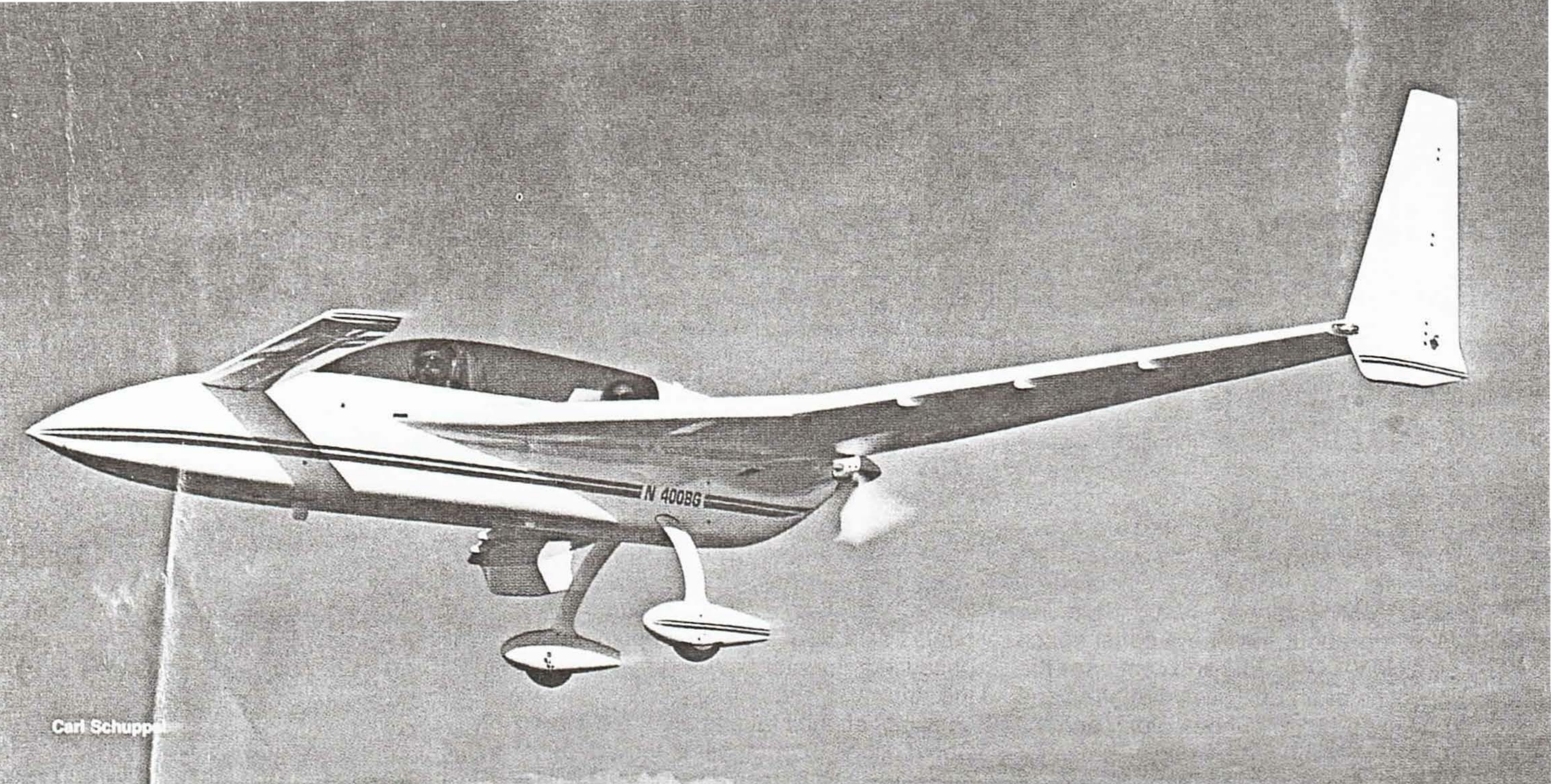
Bob attended high school in Denver . . . and was always into something. He began skydiving when he and a friend ". . . bought a surplus parachute and stuck it into a pack. A fellow had a Cessna 180 and we talked him into hauling us up . . . and we jumped out. We didn't know anything about reserves or packing dates. We had about 30 jumps behind us before we learned that the activity was regulated!" Bob would go on to legal, competitive jumping and still tries to get in 10 to 20 jumps per year.

"I enjoy jumping . . . it's fun. I keep my rig and I keep my memberships current and all that," he says.

While still in high school, Bob learned to fly gliders at Aspen, CO . . . at the insistence of his father who felt it was important to learn the basics of flight in gliders before moving on to powerplanes.

After high school, Bob moved to Greeley to attend college at the University of Northern Colorado. He majored in physics and math and graduated in 1969. Later, while in the Air Force, he would take advantage of St. Louis University's renowned extension programs to earn a Masters degree in business. While at the University of Northern Colorado, he was also in the Air Force ROTC and was commissioned at graduation. With the Viet Nam war still in progress, he was shipped directly to Vance AFB in Enid, OK for pilot training. As fate and the Air Force would have it, Bob became a C-130 pilot and would fly that versatile aircraft for almost all his 20 year military career.

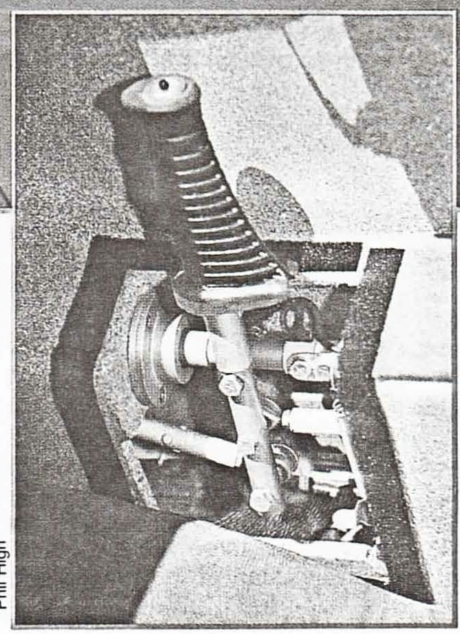
For much of his early years in service, he would fly out of Little Rock . . . and kept ending up back there after his combat tour in Viet Nam, the three years in Japan and temporary duty in many other regions of the world. As the years went by, he pulled a tour as an instructor pilot, and began being assigned to all sorts of R&D work that the C-130 was so admirably and uniquely suited for, some of which is still classified today. Of the things we can note here, he did a lot of low altitude parachute



Carl Schuppel

DeKevin Thornton

DeKevin Thornton



Phil High

extraction certification work (including the certification of the Humvee that replaced the venerable Jeep), and projects involving portable approach systems for special operations activities. Putting his physics and math background to work with his flying experience, he obtained a patent for a portable VASI . . . and he and Ginny manufacture components for the system today.

In addition to off-duty competitive shooting, skydiving and flying sailplanes, Bob got involved with an ag flying and glider tow business while at Little Rock . . . which, as we have already related, was how he met Ginny . . . and which, in turn, brings us back to the Long-EZ project.

## COMPLETING N400BG

The engine chosen for the Greider's Long-EZ was a 600 hour, 150 hp Lycoming O-320-E2D that had been removed from a factory airplane which had been rolled up in a ball in a windstorm. Bob and Ginny tore it down for inspection and after finding it still within new specs, put it back together and retimed the mags. It has operated faultlessly since being returned to service, has unusually low oil consumption and does not leak oil anywhere. Careful assembly and proper torquing of bolts are all Bob can suggest as reasons why the engine is so dry.

The engine was left stock, but was fitted with a 1986 Toyota alternator. The exhaust system is a four pipe affair . . . straight pipes . . . with carb and cabin heat muffs around them. A flush cooling air inlet was built into the bottom of the fuselage and an oversize oil cooler was used (there have been **no** cooling problems). The first prop mounted on the airplane was a Warnke Almost Constant Speed Propeller and it provided an excellent compromise between climb and cruise performance. Cruise at 2,700 rpm would average about 165 knots at any level the plane was normally flown.

Cleveland wheels and brakes were used, fitted with low profile, 8-ply Lamb tires. The standard Rutan nose gear was utilized.

Like most military and airline pilots, Bob was accustomed to flying behind a wide array of the best avionics and instrumentation available, so the panel in his Long-EZ had a high priority. There isn't room in an EZ for an overabundance of goodies if conventional instruments and avionics are used, so Bob took a different route: he bought Rocky

Mountain Instruments' microENCODER and Engine Instrument Monitor kits, built them and installed them in the airplane. The microENCODER combines the functions of an airspeed indicator, altimeter, vertical speed indicator, Mode C encoder and outside air temperature gauge in one small, lightweight black box . . . with the additional capability of displaying true airspeed, density altitude, pressure altitude and true air temperature . . . all within a single standard 3 1/8" instrument hole. The unit also can be used to produce warnings when preset altitude and airspeed limits have been exceeded. The outside air probes (there are two of them) are mounted in the nosewheel well and are exposed to ambient air.

The RMI Engine Instrument Monitor takes up about the same panel space as a NAV/COM radio and combines the functions of an EGT, cylinder head and oil temperature guages, fuel and oil pressure gauges, manifold pressure guage, fuel guage and amp meter . . . plus a series of timers for about everything that needs to be timed in the course of a flight. All these functions can be called up for display with the touch of a button.

A remote compass system was installed in the Long-EZ, with slave indicators in both cockpits. The rear cockpit was also fitted with an airspeed readout from the RMI Engine Instrument Monitor. The original avionics package consisted of a Narco AT150 transponder, NCS 812 transceiver with built-in DME function, and a VOR head, but a space was left vacant in the panel for future installation of a loran set. At Oshkosh it was being used as a glove box.

N400BG was finally completed on March 8, 1989 . . . three years and one week from the start of the project . . . and was taken to Ryan Field west of Tucson for its first flight. About 4,500 hours of total effort had gone into the building of the airplane, but only about 1,500 of that involved actual building time. The rest was expended in searching for supplies, setting up to accomplish some task, cleaning up afterwards, etc., which is typical of most plans built projects. There was a great temptation to take the Long-EZ to Oshkosh that summer, but some detail work remained and Bob and Ginny decided that if they went, they would see things on other Long-EZs they would want to incorporate into their airplane . . . and that would just further delay getting theirs completed. An added complication was the fact that they were still getting settled into their new home in Escondido, CA . . . they had moved west the week following Sun 'n Fun '89 . . . and into a new base of operation for the airplane at the Ramona, CA airport.

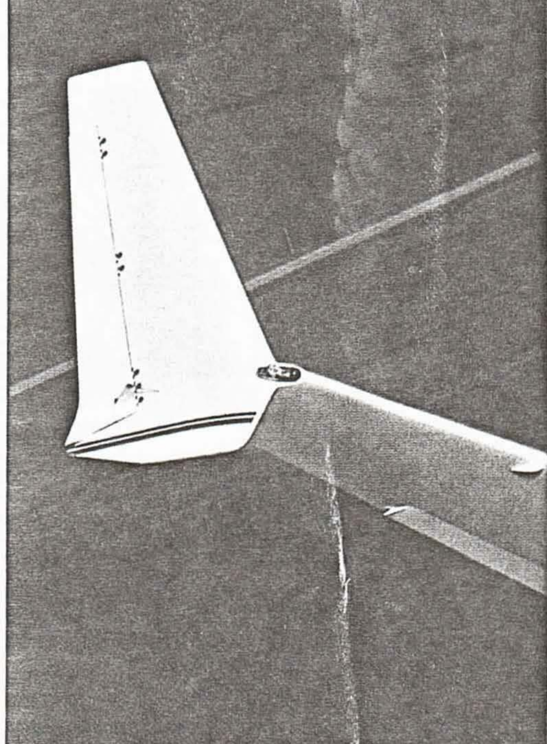
For almost the next year, then, they concentrated on all the little detail items, attending local and area events such as Shirl Dickey's VariEze/Long-EZ races at Jackpot and Kanab . . . so that by the time they headed for Oshkosh in 1990, they had nearly 180 hours on the airplane. The flight plan was for a wide arc through the Southwest so stops could be made in their former hometowns of Abilene and Little Rock to show their airplane to friends there. Taking off from Abilene, Bob noticed an odd swing just before liftoff, but did not know what had happened until he touched down at North Little Rock Airport a few hours later. A main gear tire had been punctured at Abilene . . . and the price was paid at North Little Rock in the form of a couple of trashed wheel pants. This was a big disappointment because it threatened the remainder of the trip and their long awaited first showing of their airplane at the EAA Convention . . . but as it turned out, there was no reason to worry. Practically by the time they could get out of the cockpits, they were surrounded by local EAAers who understood completely their need to get to Oshkosh. In typical can-do EAA fashion, the locals went all out to locate a new tire, get it installed and get the Greiders ready to fly on their way . . . within a matter of hours!

"By nine o'clock that evening, we were eating catfish in a local restaurant," Bob recalls with amazement. "This is a great example of what EAA really is . . . a family . . . a community of interest that takes care of its own. We would have never made it to Oshkosh without their help."

Bob and Ginny did make it to Oshkosh '90 . . . minus wheel pants . . . and had a great week talking to literally thousands of fellow EAAers about their airplane. It had been suggested to them by friends that perhaps they should rope off their Long-EZ, but Ginny was dead set against it.

"Throughout this project," she said, "we took pictures of every Long-EZ we came across and talked to owners for hours on end. All of them gave freely of their time and information, and we incorporated a great deal of what we learned into our airplane. I've felt all along that when we finally got to Oshkosh with our airplane, it would be time to start paying back all those favors. If one guy leaves here this whole week and goes home and starts working on his plane again because of something he saw on ours, or because of something we said that encouraged him, we've left a winner from this show . . . that's the way I feel about it."

The Greiders, it turned out, would leave with more than the satisfaction of



helping others . . . they would be named the winners of the 1990 EAA Plans Built Reserve Grand Champion award for N400BG. The only airplane in their judging category to score higher was . . . you guessed it . . . Bob Eckes' George Nopper built Long-EZ! That airplane, re-dimensioned and built to a tolerance of .032 of an inch, was probably unbeatable in 1990 or any previous year EAA has rewarded excellence in the construction of homebuilt aircraft. It was an honor in itself to finish a close second to that work of art . . . and, besides, they would still be eligible for Grand Champion in 1991.

Not without another long stretch in the workshop, however. In September, just a few weeks after returning from Oshkosh '90, Bob was coming home from a trip in N400BG when near disaster stuck. The Ramona airport was being repaved with asphalt and Bob knew it would be opened that morning at 11:00, so he timed his arrival accordingly. After making a precautionary pass down the runway to be certain it was clear of any sort of debris, he made an uneventful landing . . . but on rollout there was a sudden bang that jarred the Long-EZ from stem to stern. A large chunk of asphalt that had been missed by the rollers had been hidden in the blackness of the fresh pavement . . . and it all but ripped the main gear off the airplane. Back at his hangar, Bob got the airplane up on blocks and, unfortunately, found the damage to be even worse than it initially appeared to be. The gear bow was fractured, the mounting extrusions had been pulled out . . . and the entire bottom of the fuselage had been damaged.

The EZ was taken apart and trailered home, and over the next seven months much of it was rebuilt. New, longer strin-

BOB AND GINNY GREIDER'S

G★R★A★N★D C★H★A★M★P★I★O★N

# LONG-EZ


Carl Schuppel

gers . . . this time, ash . . . were installed in the fuselage and everything associated with the landing gear was replaced: new wheels, brakes, tires, axles . . . everything. With such an extensive rebuild underway, Bob and Ginny decided to take the opportunity to do a few more things they had planned to eventually accomplish anyway. New wheelpants to replace those trashed in Little Rock had already been on the agenda, so Bob began whittling away on a block of foam to make a plug in the shape he wanted them to be. He had been doing a lot of thinking about pants, as a result of hearing about problems other EZ owners had been having with theirs. Many, he had learned, had experienced softening of their gear legs by heat coming off the brakes, so his design was largely oriented toward better heat dissipation. As can be seen in the accompanying photos, this took the form of completely open ended pants. They were also designed to be attached by means of an intersection fairing built onto the lower end of the gear bow.

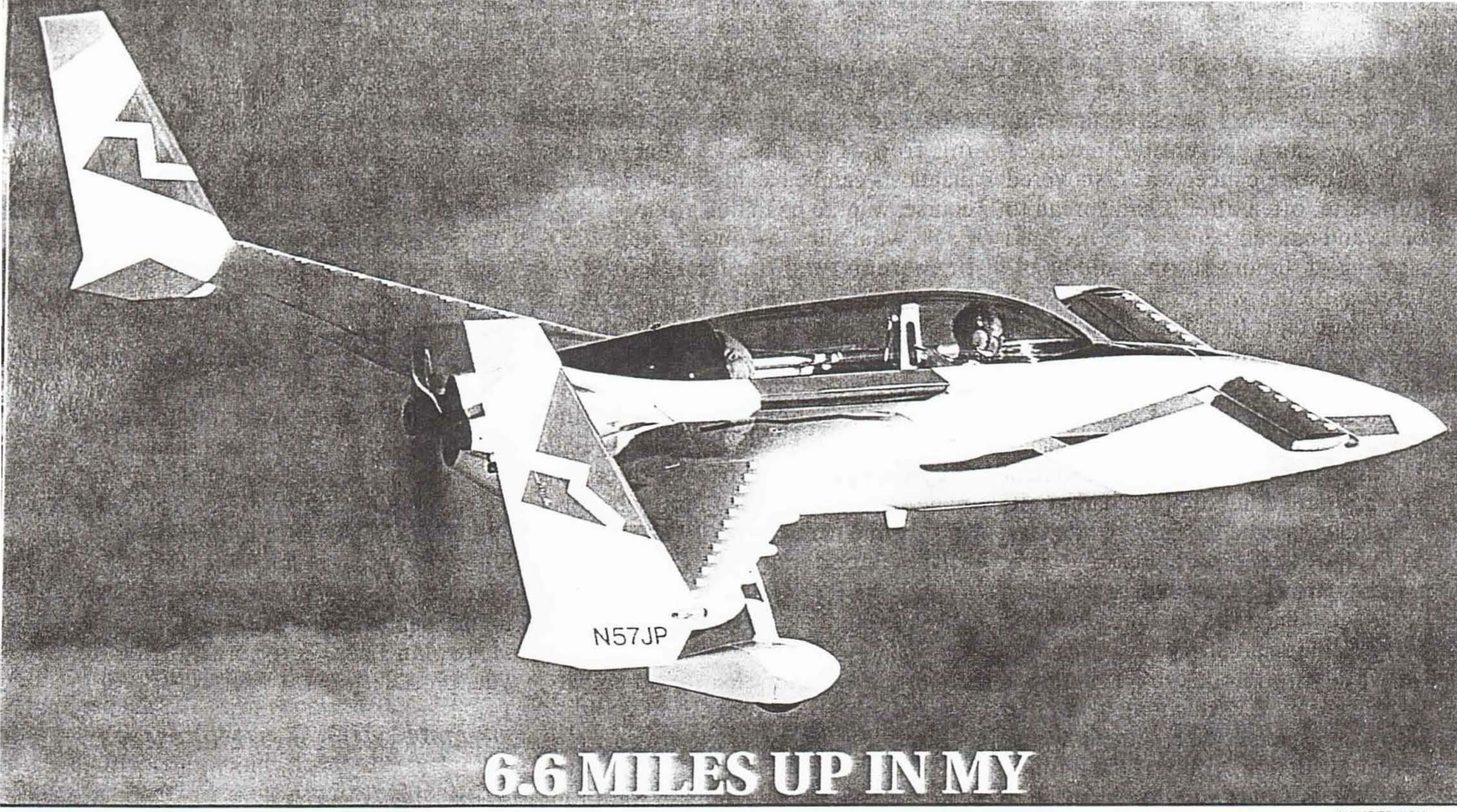
Both the original wheel pants and the new ones, incidentally, added about 15 mph to the cruise speed of the airplane . . . which obviously means the gear leg/wheel intersection is awfully dirty on the Long-EZ.

Knowing that points at Oshkosh were given for owner-built items, the Greiders decided to replace almost everything built by vendors. At Ginny's suggestion, Bob bought some books on prop carving and made his own . . . with carbon and Kevlar over a wood core. Ginny, likewise, pulled out the old upholstery, parts of which had been farmed out to an upholstery shop, and made all new seat covers. To do so, she had rented an industrial sewing machine and had spent a couple of weeks learning how to use it.

When the repaired fuselage and new wheel pants were painted, a new stripe pattern was applied, just to give the airplane in its reincarnated form a new look. It had been disheartening in the extreme to have to rebuild their airplane, but it was now better than it had ever been.

As usual, some of the last minute tasks were still being accomplished the night before their departure for Oshkosh '91, but Bob and Ginny made it . . . this time all the way to Wittman Regional Airport without a mishap. The week was much as it had been in 1990, with a constant stream of EAAers coming by to admire and ask questions about the Long-EZ, but as events would transpire, the second time was the charm for the Greiders. On the final evening, they were called to the stage in the Theater In The Woods to receive the much deserved Plans Built Grand Champion award for 1991. In the coolness of that Wisconsin evening, even the memories of all those miserable into-the-pool, back-into-the-garage sanding enduros in Tucson were quickly swept away. They had achieved the pinnacle of the homebuilder's craft.

Congratulations from us all!




JIM KOEPNICK

# 6.6 MILES UP IN MY Long-EZ

BY JIM PRICE

Setting a World Altitude Record is an outstanding opportunity to link with and learn from some of the best people in the world. A partial listing includes Burt Rutan, John Roncz, the University of Michigan Department of Aerospace Engineering, and the Carson City, NV EAA Chapter who were all wonderful to help with this project. My biggest surprise was finding nearly every time I asked for advice or help I was able to get it.

I always knew aviation people were special, but the responses I received were an affirmation of that fact. These folks are truly "World Class People."

My goal focused on setting an altitude record after deciding it would be challenging, yet possible. In my work at General Motors, we are often challenged to do more with less. One of my favorite managers terms this as "leveraging adversity." When I began this quest I didn't realize I would have to best a competitor with sponsorship, contacts and programs far surpassing anything that I had. What a great challenge!

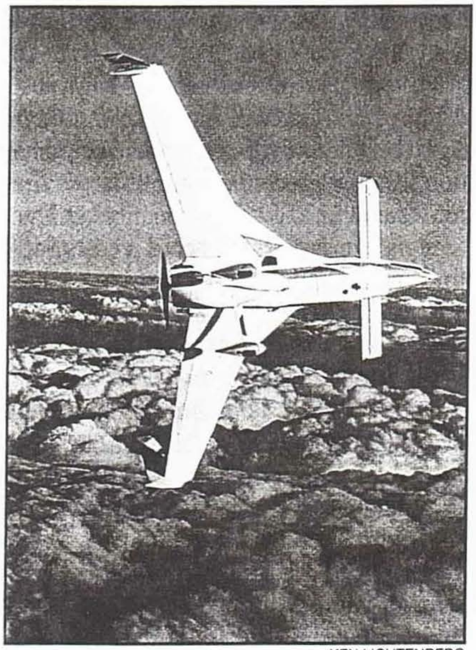
Initial study of FAI rules and records led me to believe I was best suited to go after the Altitude and Altitude in Horizontal Flight for C-1.a weight class (661 to 1102 pounds). A major concern was: could I get my Long-EZ, including myself and all required equipment, to the required takeoff weight of less than 1102 pounds? In the Long-EZ's eleven years and over 4,000 hour building process, I tried to keep weight to the minimum and still have a comfortable IFR equipped plane. As a testimony of how wonderful this plane is, I have already had it in all of the Continental United States (including Alaska), seven Provinces of Canada (including the North West Territories) and even to Mexico. All this in less than three years of flying. It's the best thing short of teleportation.

When completed (July 1994), its empty weight was 907 pounds, in the bottom 10 percentile of O-320 EZs. I still needed a lower empty weight so I began removing and weighing all non-essential items. I was able to get my airplane's empty weight down to 842 pounds. Nothing was overlooked; even the engine lifting eye was removed. I was sure this weight removal would permit me to make the C-1.a weight class. Weight removal brought about creative repositioning of equipment to keep the CG where I wanted it.

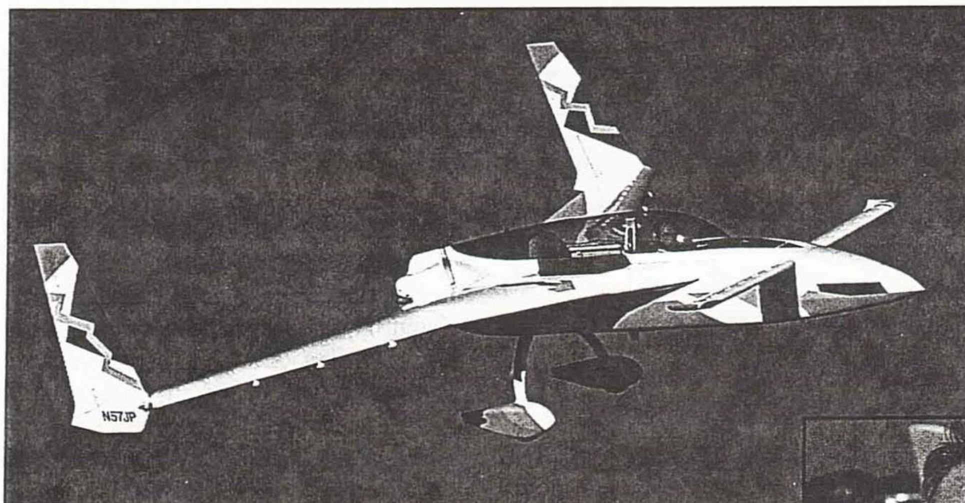
While working on airframe empty weight, I looked at myself and thought that I should kill some fat cells and shed some weight. I set a goal to loose 25 pounds and I was able to remove 30 with a self imposed exercise program and diet. After doing this weight review, I conducted a test flight to determine what my service ceiling would be. Examination of the rate of climb data to flight level 280 showed I could advance the existing record.

During the weight reduction process, I looked into what special equipment would be needed for the flight. Jeff Rose of **Electroair** offered a great enhancement for his dual electronic ignition system I had in my Long-EZ. The modification allowed me to exceed normal spark advance using a control inside the cockpit. The system worked wonderfully and allowed me to advance the spark timing much further than the normal system allowed.

All I had to do was to switch over to a



KEN LICHTENBERG



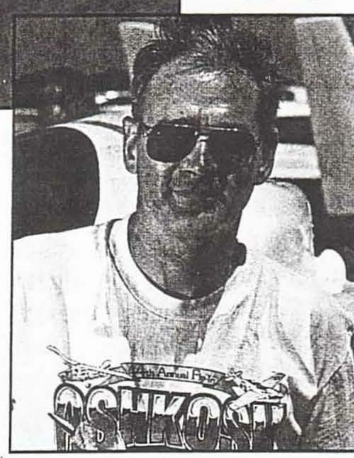

JIM KOEPNICK

manual mode at about FL 180, advance timing until I saw an rpm drop, then retard timing slightly from that point. This was done much like the setting of fuel mixture. It operated like the early cars used to do with their manual spark controls!

Another weight reducing piece of special equipment was Bill Bainbridge's ultra light weight alternator. The 8 amp unit weighs just 3.7 pounds and mounts on the vacuum pump pad. Bill's alternator allowed removal of my heavier 40 amp alternator yet provided plenty of power for my electronic ignition, transponder/encoder, handheld radio and GPS.

I knew this activity can be dangerous, so after inquiries, I linked up with the Air Force Department of Aerospace Physiology at Brooks AFB. Lt. Col. Sam Holoviak saw my level of commitment and offered to help me prepare for the record attempt. Sam was outstanding to work with and helped me better understand what a hostile environment I would be going into. Sam had a special way of getting my attention with statements like, "This is essential for your survival! (Can I make this any clearer?)." The two largest physiologic areas of concern were: Decompression Sickness (DCS), i.e. the bends and loss of oxygen supply. Per his suggestion, I found an Air Force base near my record setting location with an altitude chamber to treat me in case I got the bends. He also suggested doing what U-2 and SR-71 drivers do, pre-breathing 100% oxygen for at least one hour to get as much nitrogen out of my system as possible. To assure proper oxygen delivery, I purchased a special Air Force style pressure oxygen regulator. Because of low ambient pressure at the altitudes I went to, oxygen cannot be absorbed normally into the blood stream. It must be forced in using a pressure system and special oxygen mask. Obviously this oxygen system was an essential tool. I also had an emergency back-up supply of pressurized oxygen in case the regulator failed. The back-up oxygen system was one of the very few extras to go on the flight with me.

Lancair IV and Questair drivers need to be aware of some of the data Sam shared with me. Unpressurized flying above 21,000 feet will have a high DCS risk. Major variables are: altitude, exposure time, breathing gas, pre-breathing and exercise. At 28,000 feet, 50% of the tested subjects had DCS symptoms within 24 minutes. I took and highly recommend the Air Force physiology course offered through the FAA. It covers this information and other important physiological flight concerns.



KEN LICHTENBERG

Jim Price

During this preparation period, I flew to Minden, NV, to initiate local contacts. This trip with Jim Conners in a Prop Jet Bonanza was especially delightful. Jim knows the area very well and suggested I do my flight in Minden. Tony Sabino of Soar Minden, a local sailplane FBO, offered to help with some of the special flight equipment like the recording barometer and oxygen mask. Tony also steered me to local National Weather Office weather expert, Doug Armstrong, ATC personnel controlling this area.

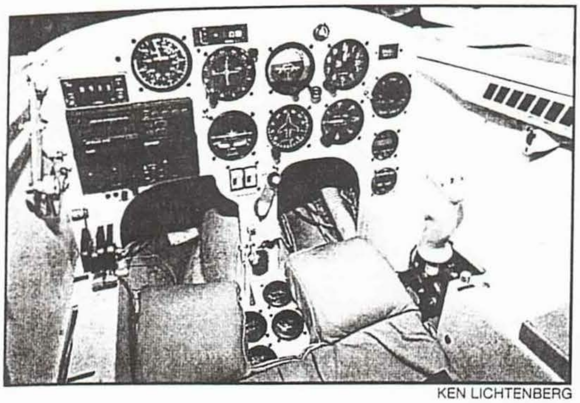
While in Nevada, I reviewed safety concerns which included selection of numerous emergency landing sites. These were selected because weather can change rapidly in this region and I wanted several options in case I got trapped on top of a cloud deck. One of the primary reasons I chose Minden was it is one of the few areas one can go up this high VFR in the special airspace called a wave window. I hoped I would be able to link to a mountain wave to assist my climb. . . unfortunately the wave I had hoped for never materialized in my two attempts.

After a review of the flight program status, an idea occurred to me. I decided to inquire at the University of Michigan Aerospace Engineering Department to see if they would conduct a critique of my progress to date. I hoped they could offer suggestions for improvements. Dr. Kauffman kindly scheduled a meeting for me. Four professors and 14 students were in attendance. They also found this record setting attempt to be an excellent opportunity to work on a challenging development program.

After a group review of the Army's Long-EZ flight test report, Professor Bill Ribbens noted the Long-EZ's minimum power speed was below the stall speed. Dr.Ribbens suggested a wind tunnel test to see if vortex generators (VGs) could lower the wing's stall speed and allow the Long-EZ to fly closer to the minimum power speed.

My timing was extremely lucky as a senior wind tunnel class was about to begin the next semester. Professor Dahm forwarded my test proposal to his students to see if any of them would be interested in taking on this project.

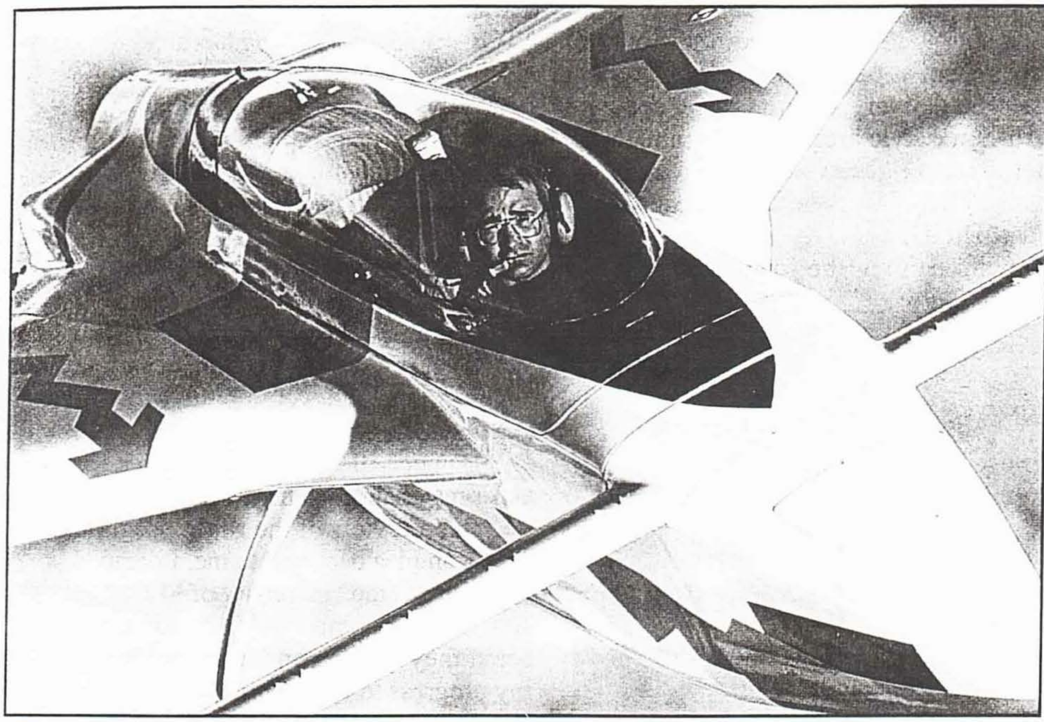
I was again fortunate as one of the stu-



KEN LICHTENBERG

How many VGs to install.

By running four tests we determined low speed lift could be significantly improved using VGs. The best tested placement of the VGs was at 20% of chord. The VG's size didn't much matter in lift but smaller ones provided less drag. VG pairs installed more closely together (every 4 inches) gave us the best lifting results.



JIM KOEPNICK

dent teams was interested in taking on a study of effects of vortex generator effects. Our team started by building an omega span Roncz canard airfoil and a half scale main wing section. We had a few exceptional events. Most memorable was when I told the students epoxy would cure faster at 100° than at room temperature. One of them decided if a little heat was good, a lot more would be better yet!

Oh well, our first airfoils had the foam cores melted. Rebuilding both airfoils would have caused us to be too far behind our targeted time line so we chose to just make another canard and not test the main wing airfoil.

I gave Charles White (president of Micro AeroDynamics, Inc.) a call and he provided me information about a normal VG installation and materials for testing. I asked one of the test development experts at GM to look at my project and he determined a simplified testing method to obtain the optimum placement of the VGs on my airfoil with a minimum number of tests. We decided to test three variables: 1. Large and small VGs; 2. Fore/aft placement of VGs (what percent of chord); 3.

Students Brian Wiear, Eric Roth and Eric Wang were all great to work with. It was a dream come true to do wind tunnel testing with such a prestigious group.

I spoke with the NAA several times to obtain all requirements for the flight. It took me much longer than I imagined it would to get information on several issues. One example was: when the NAA told me I needed certified scales to weigh the plane prior to my flight, I inquired who was the proper authority to certify them. The NAA person that I spoke with didn't know. After a month of asking around it dawned on me to stop at a truck scale on the freeway. The officer was very helpful and I found certification is done by the Department of Agriculture.

Other questions remained. Would an extra horsepower producer like nitrous oxide be legal? The rules state auxiliary power is not allowed. Because of this I decided to not pursue nitrous injection during my development process. I personally would prefer to see nitrous not allowed because it is such a radical horsepower enhancement. Once it is approved to be used for competition it seems like everyone will have to adopt its use in order to be competitive.

A lot of people have inquired how much this process of record setting costs. It cost $39 to get your FAI sporting license, sanction fees for a record are $350 for the first record and $275 for additional ones. Then to register a successful record it costs $400 for the first and $325 for the second. The observer gets $275 a day plus expenses, like their airline ticket, hotel, rental car, food, etc. I was lucky to get an observer who truly enjoyed doing this activity and he would only accept a bit of gas money for his plane. Also, it takes a long time to go through the steps of having a record certified. After I returned home from my flight, Dr. Ribbens spent a couple of days going over my data using the FAI formulas to come up with the altitudes that I had attained. My record flight took about eight months to be certified by the NAA and then the FAI. Needless to say, one needs a lot of patience to go through this process.

By this time things were pretty well in order so I flew to Minden where friends helped me prepare my Long-EZ for our flight. Stan Gorman came in from Tucson and Dave Jones flew his Long-EZ in from Susanville, CA. To help out, Jeff Rose even dropped in to make sure his ignition was working out O.K. for me. Dave Timms was even kind enough to bring over his specially made propeller which he used for his World Record. At the time he loaned me his propeller he was still the official World Record Holder!

My first test flight was to evaluate Dave's propeller for this flight. I think it would have been ideal at altitude but I could overpower it at lower altitudes.

Trying to minimize consumables, fuel and oxygen, I decided to use a flight profile that would get me up high quickly. By reducing climb time the total amount of airframe drag overcome during the flight is reduced, therefore less fuel would be used. The bottom line is I used a propeller of the same pitch and diameter I use normally. That gives me a great climb up to FL 300. After that the prop is overpitched and rpm gradually falls off all the way to 2100, which is well below the engine's power band. The next flight test purpose was to validate the effect of vortex generators. I did this up high while wearing a parachute. The main wing was tufted to assure that the canard would stall, as required, before the main wing. I entered into this test very carefully as it could be catastrophic if the main wing stalled and the plane went into a flat stall. The yarn tufts clearly indicated the canard was stalling before the main wing. It was fascinating to see airfoil sections behind vortex generators wouldn't stall but the area between them would.

On April 9, 1996, we had everything ready to go and I decided to go for an official record attempt. Tom Gribben, my official observer assigned by the NAA, came down from Reno. He checked things out and we were ready to go. Tom was a delight to work with and was very helpful in assuring that I complied with all the rules. I had a great run to 31,400 feet with good climb rate, even at that altitude, but I went down to the minimum fuel to meet the required FAA fuel reserves at landing so I aborted the run. I did have one wake up call. While at 31,000 feet I decided to change fuel tanks and found the fuel valve was frozen stuck. It wasn't a big problem as I had enough fuel on that tank to make it to the ground, but it was quite an exercise in such a cramped cockpit. As expected, the canopy frosted on the inside such that one couldn't see out.

Using a turn coordinator, airspeed and handheld GPS inside a frosted opaque canopy is quite a work out. Because of this, I was even more thankful I was in a canard design because of its docile stall characteristics. Everything worked very well and after computing and plotting the rate of climb every 1000 feet all the way up, I was sure I could do a lot better on a future run with just a bit more fuel. I knew of a few items I could remove to reduce weight — enough which would compensate for the additional fuel that I wanted for my next flight. With this testing done I found my scheduled vacation and good weather used up. I headed home on a commercial flight leaving the Long-EZ there prepared and ready to go.

I stayed in contact with Doug Armstrong, the weather expert, trying to find a good weather window in which to come out and accomplish my goal. On May 3 I got a call that things looked good and I flew to Reno the next day.

When I got out to Reno, John Grubb and his wife, Edie, took me under their wing and with the help of Dave Jones we quickly got everything ready to go. The winds weren't as good as I had hoped for, but I had no time to wait around so I decided to give it a go anyway. On May 5, 1996, we were ready to launch. We even went so far as to push the Long-EZ out to the runway to save fuel. Dave taped the entire front of the canopy down and John gave me one of his famous hand prop starts and off I went.

Later I looked at a tape of my launch and it was incredible to see the rate of sustained climb. Upon my first contact with controllers, I certainly enjoyed hearing, "Cleared to Flight Level 360!" There was a bit of mountain wave action north of my ATC authorized flight area, but I couldn't talk the controllers into letting me go over in that area. I had hoped by running a transponder the controllers would allow me more latitude in the flight area that I wanted to use. Unfortunately, it didn't work that way. I hope this doesn't sound negative, for I truly appreciate having this special area to fly in and realize that while the wave window is "hot," it requires special action on the air traffic controllers part.

This time I leaned the engine more judiciously to conserve fuel, the timing advance was working great and everything was going super until . . . At about fight level 310 I got a pop out of the airframe. On a pucker factor of one to ten, this hit a thirteen! My barometer recorder later showed that I leveled for four minutes while I evaluated what was going on. All flight controls and the powerplant were operating normally. I guess you'd have to be there to truly appreciate the scene. With the canopy frosted over I couldn't see if the wings were still on and it was already extremely cold at about -57° Fahrenheit. The culprit noise was caused by a very minor delamination of the canopy to its frame. The delamination was caused by the different material expansion/contraction rates between the canopy and the canopy frame which causes the canopy to twist. Since the canopy is right next to your ear I'm sure this sound seemed louder than it would have if it had been further away. The canopy is bonded to its frame in a way that it couldn't come off so after a careful evaluation of all systems I decided to go on.

As my climb progressed, stall and cruise speed slowly got closer and closer together and the plane felt like it was on a "bubble." Any control input made the plane feel like it would slide off the edge of the top of the bubble it seemed to be perched on. Believe me, you won't need a cup of coffee to get yourself going when you do a flight like this!

The air traffic controller I was talking to was having a difficult time understanding me as I didn't have a microphone inside my oxygen mask. I thought that by pulling my mask off my chin and having the microphone in that area it would work O.K. (it had in previous flights). So much for that theory. My encoder blanks at 28,000 feet so the controller was asking me quite often what my altitude was. With the workload I had, this was quite awkward for me. I even had my mask come unsealed because of pulling it up. This caused one of the lenses in my glasses to have condensation on it. The lesson I learned was that next time I will go up with a microphone in my oxygen mask.

When I approached my perceived maximum, I leveled off to video tape the altimeter, airspeed indicator and a clock. That documentation proved airspeed was maintained during the horizontal portion of the flight attempt. An electronic barometer recorder collected the altitude every ten seconds. After flying the required period of time (90 seconds level for the altitude in horizontal), I decided I had had enough fun for one day, and extended the nose wheel to increase drag and pointed the nose downward.

The altitudes I attained were 35,027 feet for altitude and 34,926 for altitude in horizontal flight; enough for the two World Records for which I had hoped! I landed with seven gallons of fuel, which was more than required. Data evaluation of my climb rate just prior to my leveling for the altitude in horizontal portion of the flight, showed I was still climbing at 90 feet per minute. The plotted rate of climb data indicates I could have gained approximately another thousand feet. When one is used to a plane that climbs 2,000+ fpm, 90 fpm doesn't seem like much.

A few interesting statistics about the flight were: temperature got to -61° Fahrenheit, it took one hour and ten minutes to climb and another twenty-five minutes to descend, my spark advance got up to nearly 50°. I do not know the manifold pressure reading at altitude as I didn't have that or any extra gauges. It was gratifying to see that both the April 9 and May 5 flights had the same climb profile to each altitude within a few seconds of one another. I knew a layer of longjohns with down jacket and pants would still allow me to get cold and I did, but not to an unbearable or unsafe state.

What is next? The altitude I reached was greater than the existing C-1.b Altitude in Horizontal Flight record. This heavier class starts at 1102 pounds. All it would require is another gallon of gas and I would be up in that weight class.

In order to get a bit higher (2,273 feet) and capture the C-1.b Altitude Record, I believe I will need to come up with some more tricks. I am looking into nitrous oxide to boost the horsepower. I also plan to look into obtaining sponsorship to defray some of the expenses. The project was truly a grand opportunity for me. It took a year and a half to prepare for this record, and it was marvelous to have all the assistance that I had. My sincerest thanks to all of you who were involved, many of which were not acknowledged in this article.

Be well and fly safely!

*(If additional information on Jim's record flight contact him at email: Hi-Long@aol.com)* ◆

# DYNAMICS ANALYSIS of Two Pusher Aircraft

BY DAVID LEDNICER
EAA 135915

*Dedication*
*This article is dedicated to the memory of Professor Edgar Lesher, who died on May 19, 1998.*

## INTRODUCTION

Previously, the application of Computational Fluid Dynamics to the RV-6, Nemesis® and Shadow was presented. In this installment, we will look at several pusher aircraft. Once again, the goal will be to see what we can learn from the application of computational analysis methods to these aircraft.

Pusher aircraft seem to hold quite an attraction for aircraft designers. Quite a few have been designed. Sometimes, the intent has been to eliminate the drag caused by the wake of the propeller passing over the components behind it. Sometimes, the intent was to eliminate the destabilizing influence of the propeller wake on regions of laminar flow on downstream surfaces. Sometimes, the intent is to place a major noise source behind the passenger cabin. Others have extended a theoretical argument that a pusher aircraft's propulsive efficiency will be superior, as the propeller will be ingesting and reaccelerating much of the air in the aircraft's boundary layer. For various reasons, these expectations have rarely been realized.

One particular category of pusher aircraft are those with long driveshafts, that allow the engine to placed quite far forward of the propeller. There have been many aircraft that fall into this category, such as Molt Taylor's Mini-Imp and the Cirrus VK30. The two representative aircraft of this type that will be discussed here are Professor Ed Lesher's Teal and the Lear Fan.

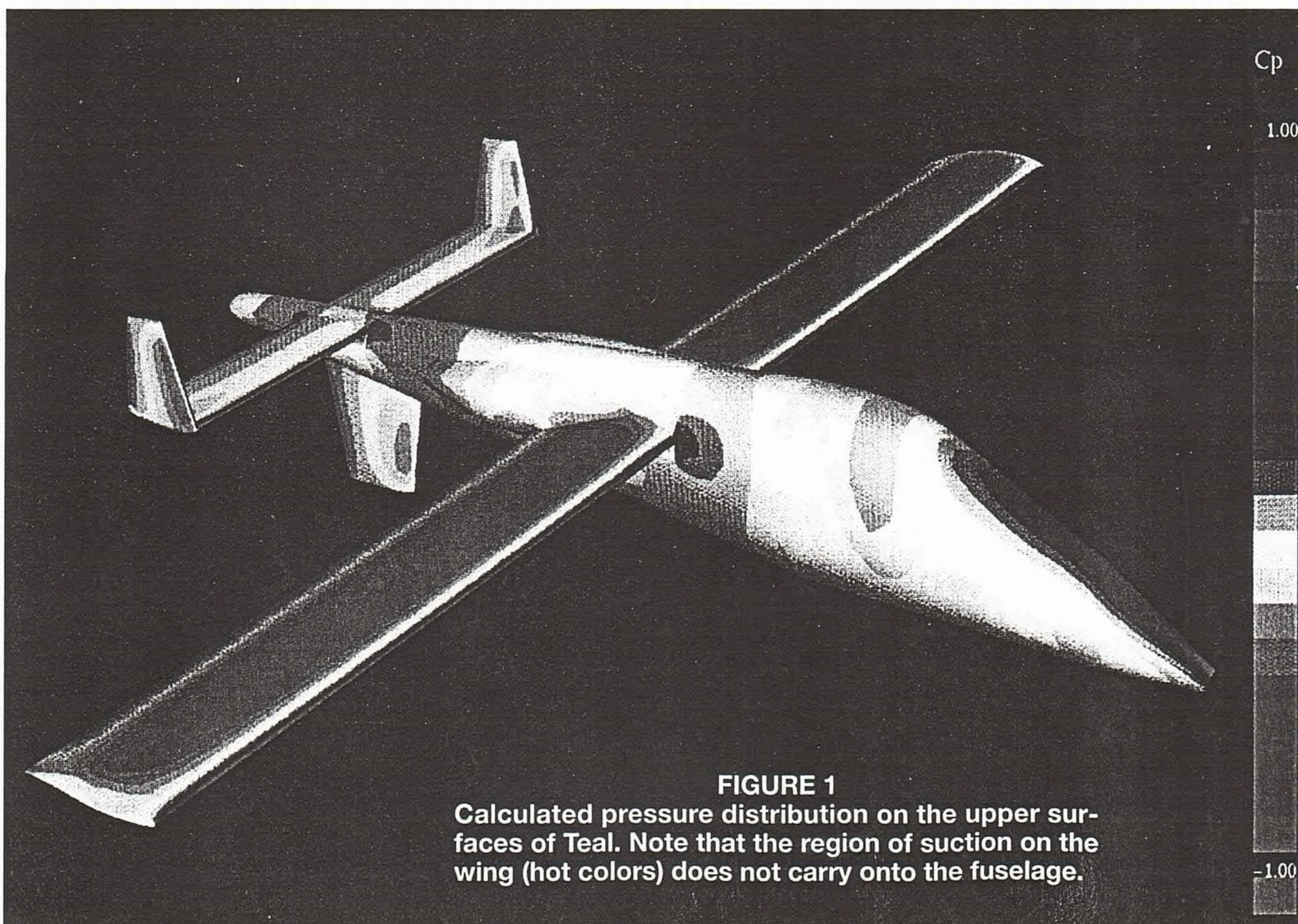



**FIGURE 1**
**Calculated pressure distribution on the upper surfaces of Teal. Note that the region of suction on the wing (hot colors) does not carry onto the fuselage.**

## LESHER TEAL ANALYSIS

Teal was designed by Professor Ed Lesher, starting in 1962, with the intent of setting new records in the FAI C-1.a category for aircraft of gross weight not exceeding 500 kg (1,102 lbs). First flight was on April 28, 1965. Powered by a 100 hp Continental O-200, Teal quickly proved to be a real record setter. Professor Lesher, flying Teal, at one point held the following category C-1.a records:

- 3 km speed, 173.101 mph, September 29, 1973
- 15/25 km speed, 169.134 mph, September 30, 1973
- 500 km speed, 181.546 mph, May 22, 1967
- 1000 km speed, 162.211 mph, June 30, 1967
- 2000 km speed, 141.834 mph, October 20, 1967
- Straight line distance, 1835.459 miles, July 2, 1975

Many of these records stood for quite some time, but they have now all been broken. These records are now held by pilots flying VariEzes and Formula One air racers. Teal is unique in holding such a range of records.

Considering my admiration for Professor Lesher and his aircraft, it is perhaps surprising that I didn't analyze Teal long ago. The inspiration instead first came to me late one evening in 1996. Years ago, I had been given an EAA publication, Metal Aircraft Building Techniques, that contains articles on both of the airplanes Ed has designed and built, Nomad and Teal. Upon examination, I realized that Robert Pauley's drawings accompanying the Teal article had everything I needed to prepare a computer model of the aircraft. With this information, I was able to build the model in a week's worth of evenings.

The pressure distribution calculated on the model of Teal, trimmed in cruise is shown in Figures 1 and 2. As

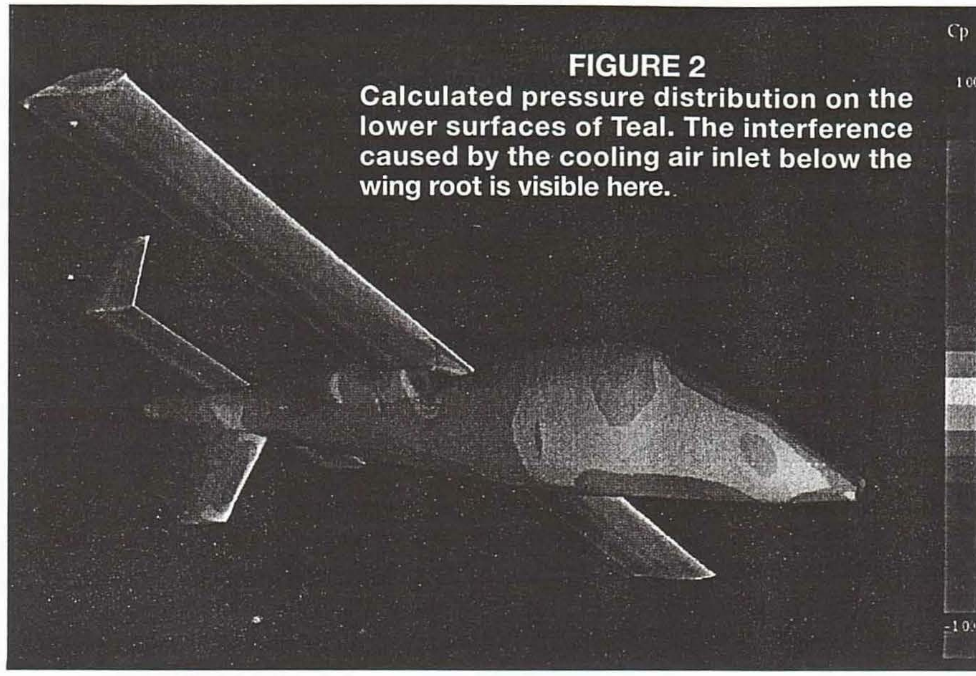



**FIGURE 2**
**Calculated pressure distribution on the lower surfaces of Teal. The interference caused by the cooling air inlet below the wing root is visible here.**

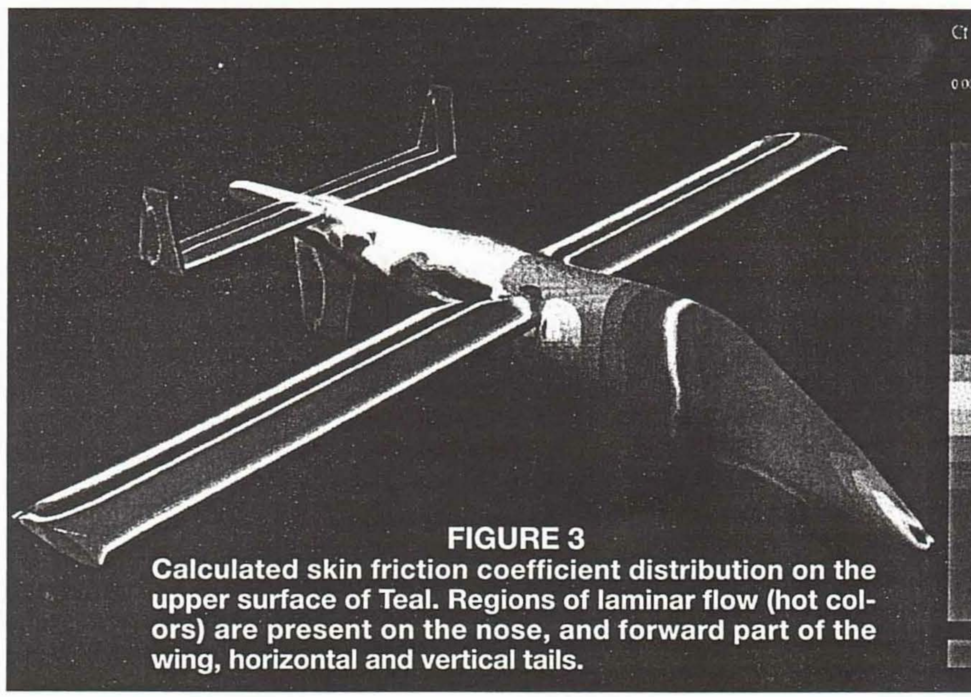



**FIGURE 3**
**Calculated skin friction coefficient distribution on the upper surface of Teal. Regions of laminar flow (hot colors) are present on the nose, and forward part of the wing, horizontal and vertical tails.**

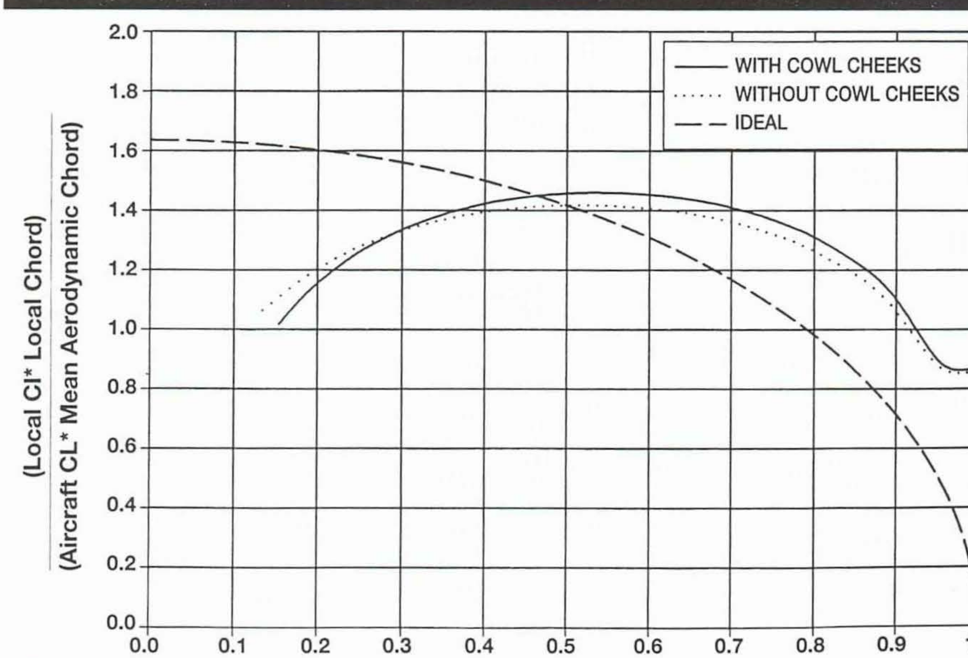



**FIGURE 4**

**Calculated lift distribution on the wing of Teal, in cruise, with and without the cowl cheeks present. The distribution plotted here is actually that of non-dimensionalized circulation, but as the wing chord is constant, the lift coefficient distribution has the same shape. The optimal shape of this distribution would have the greatest values near the left side of the graph, instead of having the decrease seen here.**

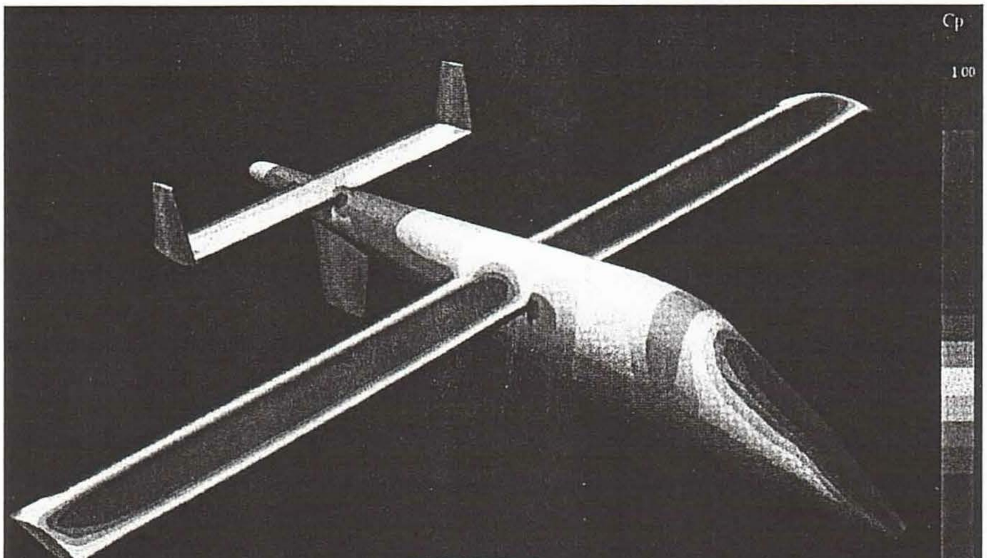



**FIGURE 5**
Calculated pressure distribution on the upper surface of Teal without cowl cheeks. Notice that the pressure distribution in the wing root region has changed only slightly and there is still no suction carrying over onto the fuselage.

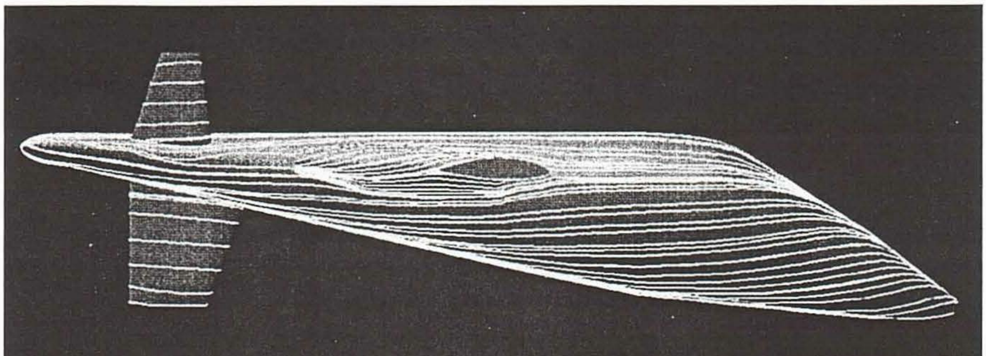


**FIGURE 6**
On-body streamlines calculated on Teal at cruise conditions (.64 degrees angle of attack). The downwards deflection of these streamlines in front of the wing, though slight, produces the reduced loading on the wing in the inboard region.

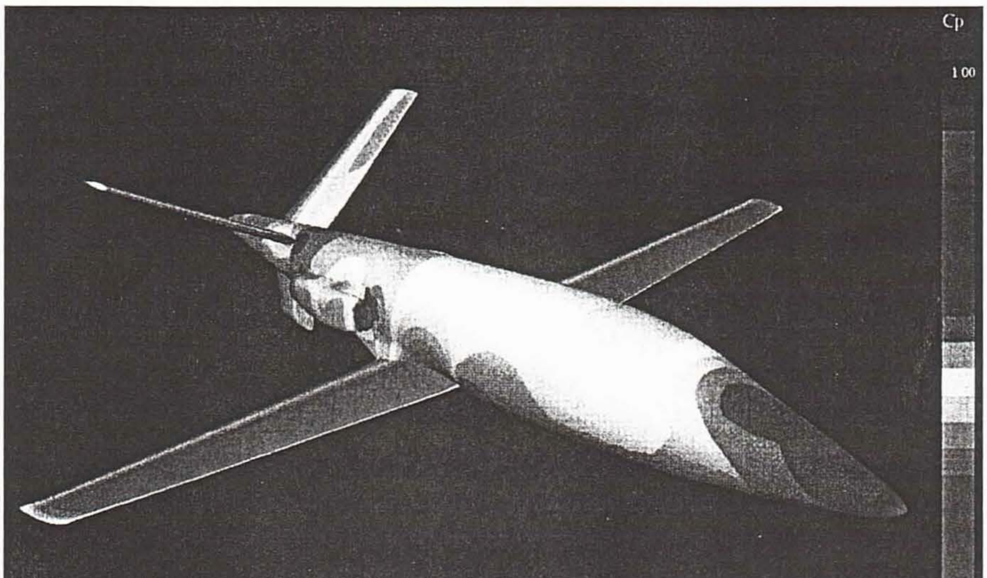
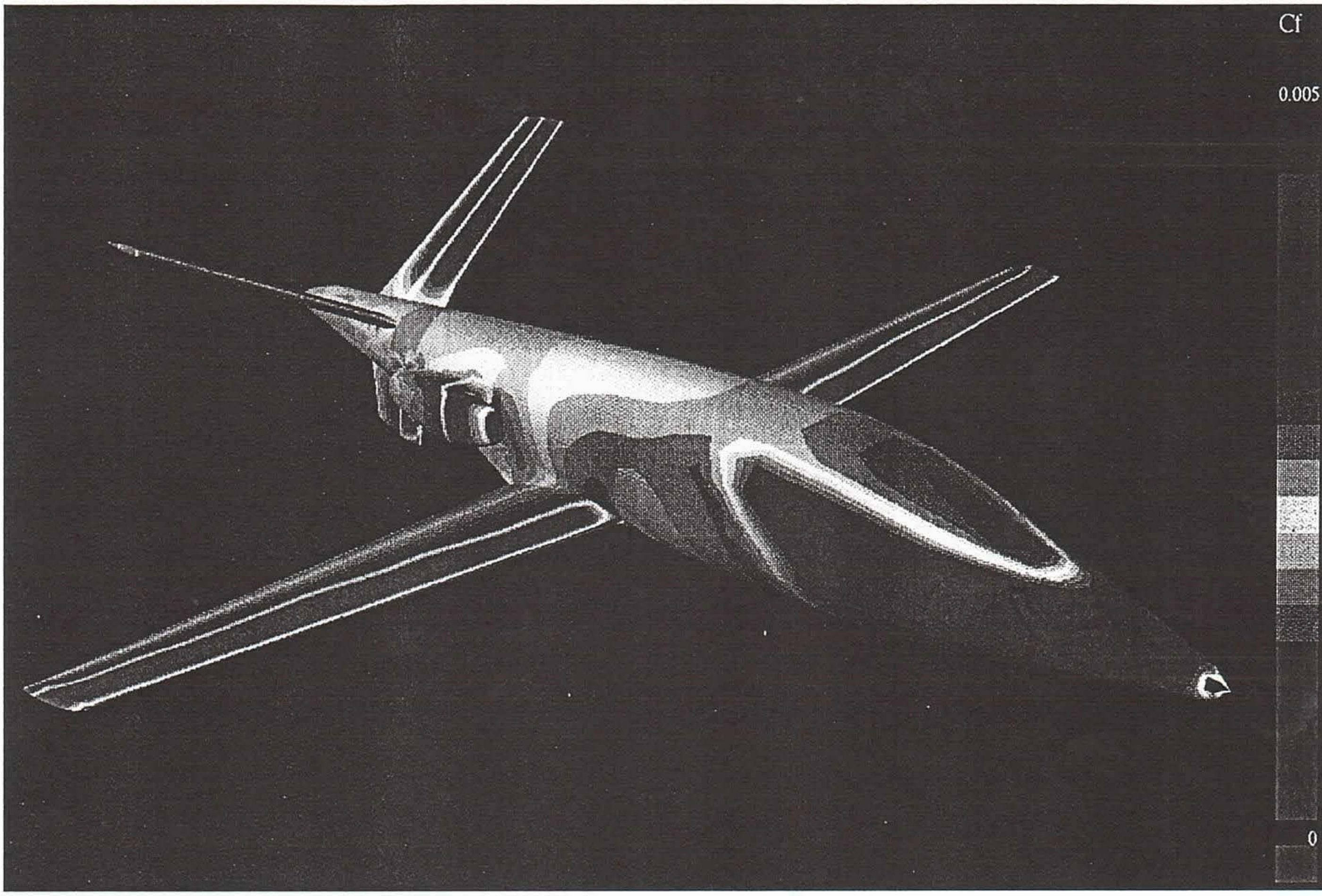



**FIGURE 7**
Calculated pressure distribution on the upper surface of the Lear Fan in cruise. Notice that on this aircraft, the wing upper surface suction carries over onto the fuselage.

the wing airfoil is a NACA 653-618, the maximum suction on the wing can be observed to extend to 50% of chord. This provides for the possibility of laminar flow on up to 50% of the wing chord. A look at the boundary layer solution (Figure 3) shows that this is indeed the case — laminar flow, with its low skin friction, is calculated to 50% of the wing chord.

An examination of the wing root region, on the upper and lower surfaces, shows the change in pressure distribution due to what appears to be the aerodynamic interference of the engine fairing with the wing. Checking the wing lift distribution (Figure 4), it can be seen that the wing lift drops off near the root, which is not desirable, as this makes the wing appear aerodynamically to be two wings, each with half the aspect ratio of the full wing. The end result of this is much higher induced drag. At first, it was believed that the location of the engine fairings is responsible for this. The computer model was modified by removing the engine fairings and was run again on the computer. The resulting pressure distribution (Figure 5) and lift distribution (Figure 4) show that this effect is still present. In the end, the calculated streamlines on the surface of the fuselage (Figure 6) explained the origin of this effect. To provide the necessary propeller clearance, the aft fuselage has to have a high upsweep angle. In cruise flight, this upsweep leads to the flow on the fuselage angling down to flow into this area. This local downwash area then leads to a lower local angle of attack inboard on the wing and lower lift in this region. This is a problem area that designers of pushers must keep in mind.

Ed's flight testing showed the power-on stick-fixed longitudinal Neutral Point to be at 49% of MAC and the power-on stick-free longitudinal Neutral Point to be at 39% MAC. The VSAERO calculations resulted in a power-off stick-fixed longitudinal Neutral Point at 47% MAC. As the power effects are stabilizing for pusher aircraft and 2% MAC is not an unreasonable value for this effect, the VSAERO results agree quite well with flight test. The stabilizing effect of the propeller is a useful feature of the pusher configuration. The 10% MAC destabilizing shift between stick-fixed (49% MAC) and stick-free (39% MAC) conditions gives a measure of how powerful this effect can be.




**Skin friction distribution calculated on the Lear Fan in cruise. Large regions of laminar flow (hot colors) are present on the nose and forward parts of the wing, inlets, horizontal and vertical tails.**

Additionally, Ed's flight testing yielded a flat plate drag area for Teal of 1.61 $ft^2$. The wetted area calculated by VSAERO is 274.5, which compares quite favorably with that of Formula One air racers such as Nemesis (253.7 $ft^2$), Madder Maxx (265.5 $ft^2$) and Shadow (270.1 $ft^2$). Dividing Teal's flat plate drag area by its wetted area gives $C_{Dswet}$, a measure of aerodynamic cleanliness. This value, .0058, is in the region of such aircraft as the P-51B Mustang (.0053), Spitfire IX (.0056) and P-63C King Cobra (.0060). In view of Teal's clean external design, it is likely that quite a bit of its drag is buried in the engine cooling system.

## LEAR FAN 2100 ANALYSIS

The Lear Fan 2100 was designed by Bill Lear to be the first of a new generation of high performance turboprop business aircraft. Since the early 1950s, Bill Lear had advocated the safety of centerline thrust aircraft, as well as the performance gains of improved aerodynamics and pusher

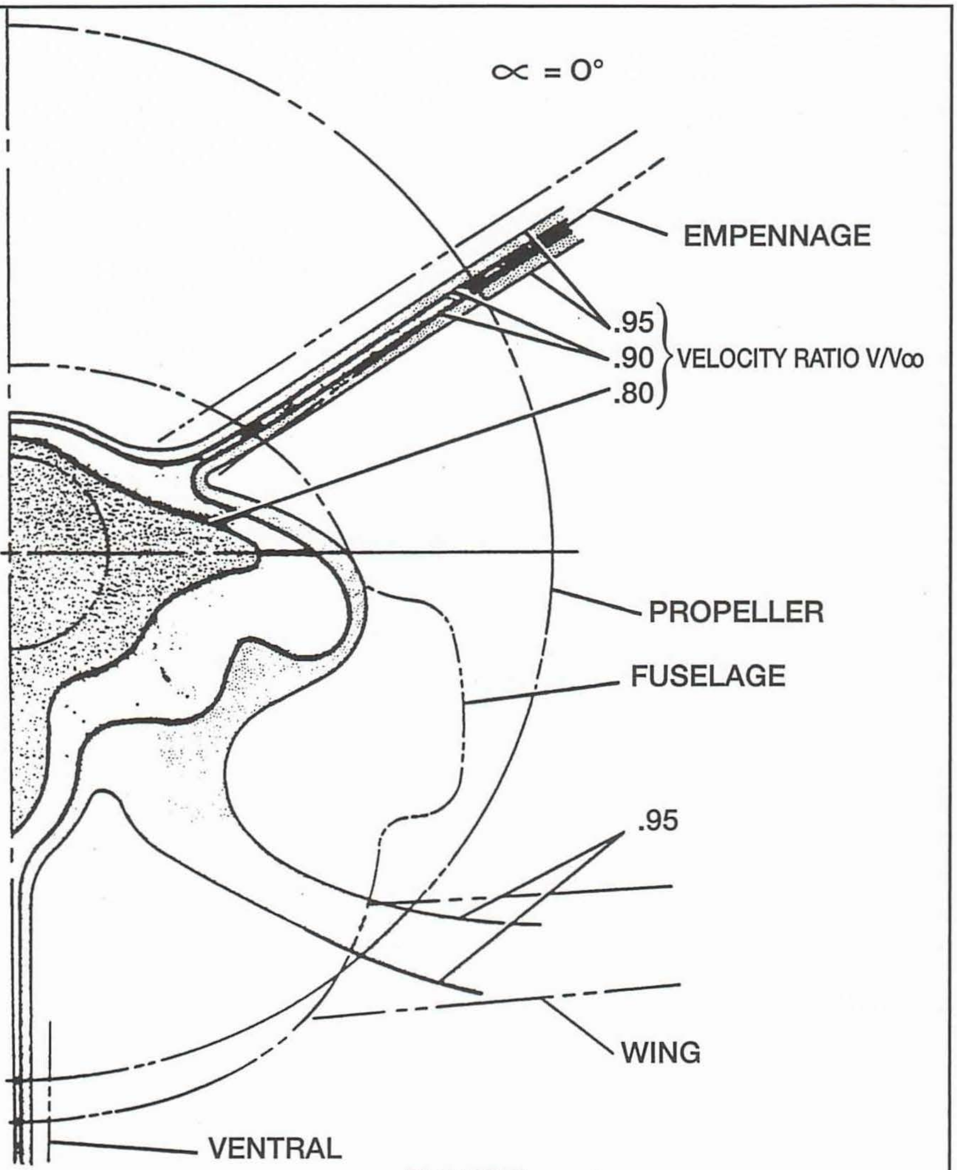
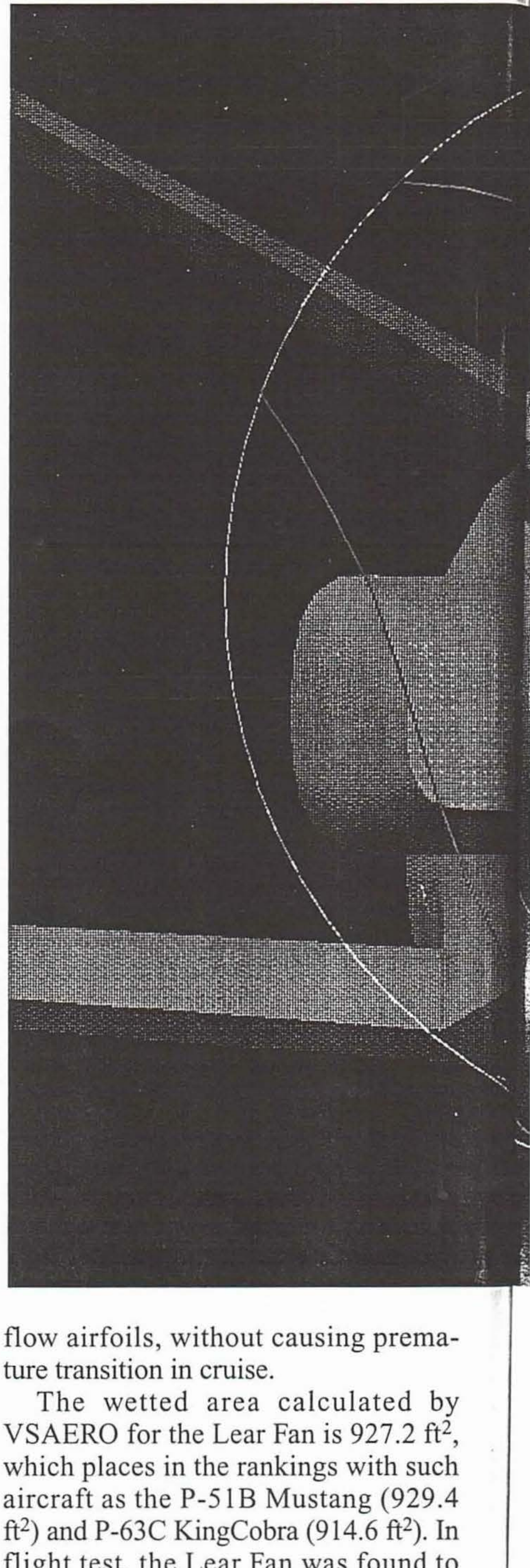



**FIGURE 9**

**Regions of velocity deficit measured at the propeller plane of the Lear Fan in the wind tunnel. Most of these regions are due to boundary layer growth on surfaces upstream. (Figure from AIAA paper 83-2465, "High Speed Propeller for the Lear Fan 2100," by Ian Gilchrist)**



configurations. In the late 1970s he initiated work on what would become the Lear Fan 2100. The prototype made its first flight on December 32, 1981. Unfortunately, development problems brought about the demise of the project in 1984. One of the prototypes survives in the EAA Museum in Oshkosh and another is in the Museum of Flight in Seattle.

Luckily, my co-worker Ian Gilchrist had saved a set of loft data on the aircraft after the demise of the Lear Fan company. With this information, I was able to build the computer model to use here. Due to the complexity of the geometry, this model took longer than Teal to be completed.

The calculated pressure distribution on the Lear Fan in cruise is shown in Figure7. The wing airfoil was designed for laminar flow over 50% of the wing chord, with a drag bucket extending over the cruise lift coefficient range of the aircraft. The pressure distribution shows that indeed, the maximum suction on the wing extends to 50% of chord and the calculated skin friction coefficient distribution (Figure 8) shows that the wing is capable of supporting laminar flow to approximately 50% of chord. The shaping of the forward fuselage can be seen to also produce a region of accelerating flow, which should have allowed laminar flow here too. Flight test drag polars revealed that the wing did indeed have extensive laminar flow. This laminar flow was achieved with B.F. Goodrich deicing boots and stall enhancing triangular leading edge vortex generators installed on the wing. The triangular leading edge vortex generators solved an abrupt stall, typical of many laminar flow airfoils, without causing premature transition in cruise.

The wetted area calculated by VSAERO for the Lear Fan is 927.2 $ft^2$, which places in the rankings with such aircraft as the P-51B Mustang (929.4 $ft^2$) and P-63C KingCobra (914.6 $ft^2$). In flight test, the Lear Fan was found to have an equivalent flat plate drag area (f) of 4.46 $ft^2$. Dividing this value by the wetted area gives a $C_{Dswet}$ of .0048, less than that of Teal or the other aircraft mentioned previously. This verifies that the Lear Fan achieved the aerodynamic efficiency envisioned by its creator.

One concern surrounding pusher aircraft is the reduction in propeller efficiency due to the prop's ingested flow distorted by upstream components, such as the wing and horizontal tail. CFD can be used in an attempt to solve for this

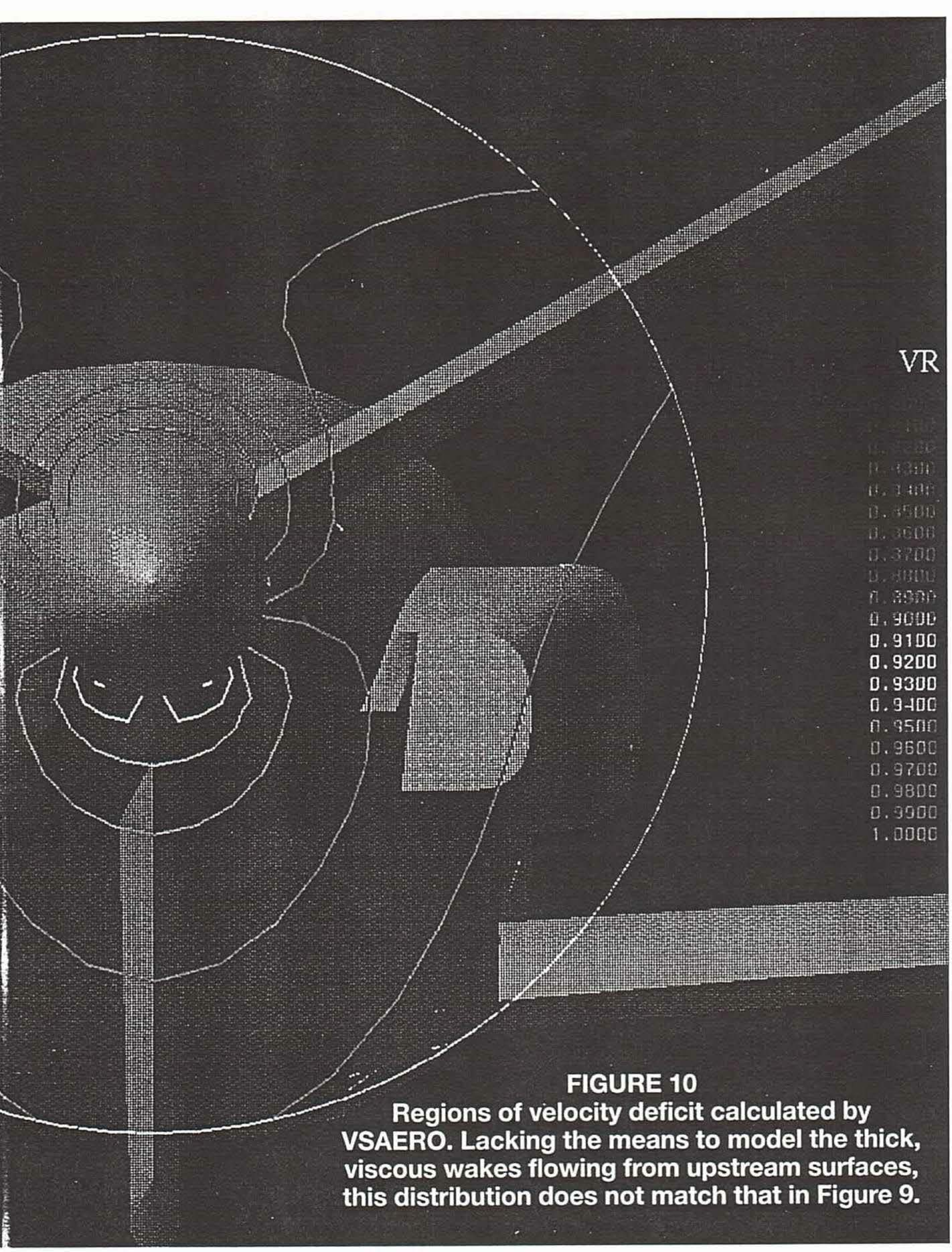



**FIGURE 10**
**Regions of velocity deficit calculated by VSAERO. Lacking the means to model the thick, viscous wakes flowing from upstream surfaces, this distribution does not match that in Figure 9.**

flow distortion at the propeller plane. For a tractor propeller, the result shows only minimal distortion and can be neglected. However, for a pusher propeller, the result can be quite significant.

During the development of the Lear Fan, measurements were made in the wind tunnel of the flow distortion at the propeller. The regions of reduced inflow velocity that were measured are shown in Figure 9. In comparison, the regions of reduced inflow velocity calculated at the same conditions by VSAERO are shown in Figure 10. It can be seen that majority of this deficit in inflow velocity is not calculated by VSAERO. This is because computer codes formulated like VSAERO generally ignore some of the physics of the flow, due to the simplifying assumptions used in the program. In particular, the thick, viscous wakes coming from the wing and horizontal tail are not modeled as they flow downstream. It is these wakes that produce the regions of reduced inflow velocity at the propeller. It should be noted that the flowfield distortion on the Lear Fan was found not to produce excessive propeller vibratory loads or to reduce the propeller's efficiency, which was measured to be 83% at 304 kts. and 35,000 feet.

In contrast to the difficulties in calculating the inflow velocity deficit, the flow angularity at the propeller of a pusher aircraft can be accurately calculated by VSAERO. As an example not connected with the Lear Fan, during development of the Beech Starship, the flow at the propeller plane was both calculated using VSAERO and measured in the wind

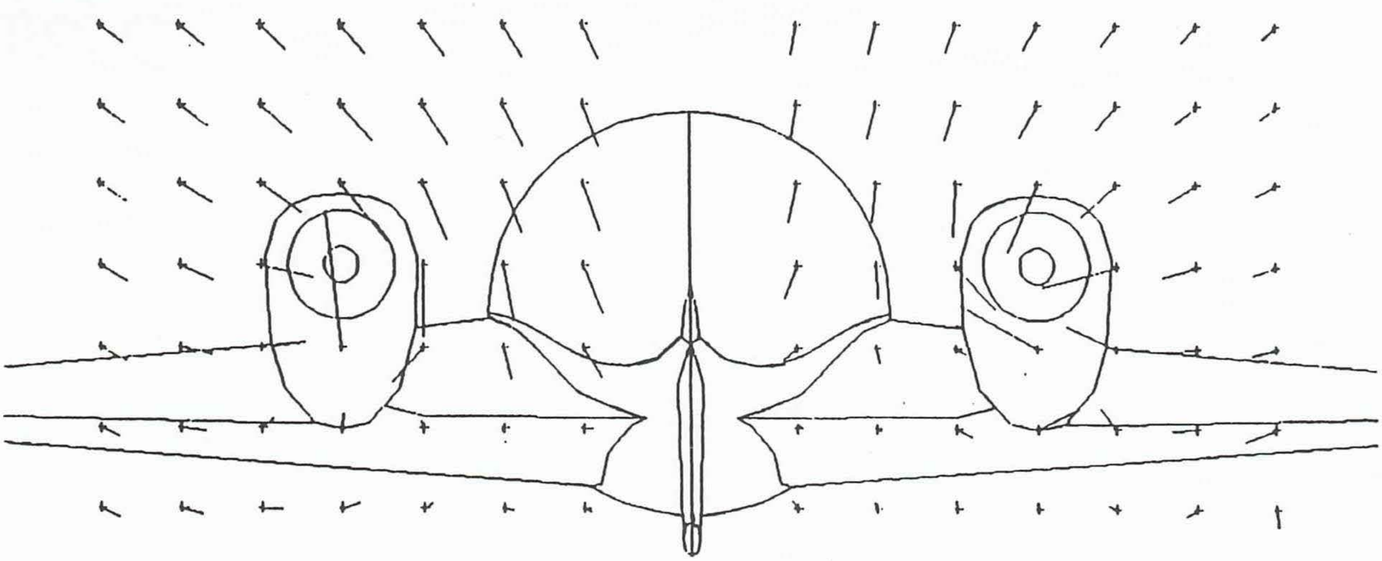


FIGURE 11

**A comparison of flow angularity measured in the wind tunnel (left) and calculated by VSAERO (right) at the propeller planes of the Beech Starship. (Figure from AIAA Paper 88-2511, "Flowfield Study at the Propeller Disks of a Twin Pusher, Canard Aircraft," by Neal Pfeiffer)**

tunnel. A comparison of the results from these two sources are shown in Figure 11. Similarly, during the development of the Rutan Voyager, flow distortion that I calculated at the rear propeller, using VSAERO, was an important input to John Roncz's propeller design effort. A contrast between the distortion at the front propeller and rear propeller of the Voyager is shown in Figure 12. While attempts were made on the Starship to improve the uniformity of the flow into the propellers, on the Voyager, the propellers were designed to cope with the existing nonuniformity. Obviously, this is another potential problem area that the designer of a pusher must keep in mind.

## CONCLUSION

Two pusher aircraft have been analyzed here and their important design features have been discussed. While the off-stated advantages of pushers have not been refuted, light has been shed on problem areas associated with this configuration. I believe that carefully designed, a pusher configuration can offer superior performance to a tractor configuration. However, detailed analysis tools, such as CFD, are necessary to allow the full performance potential to be realized.

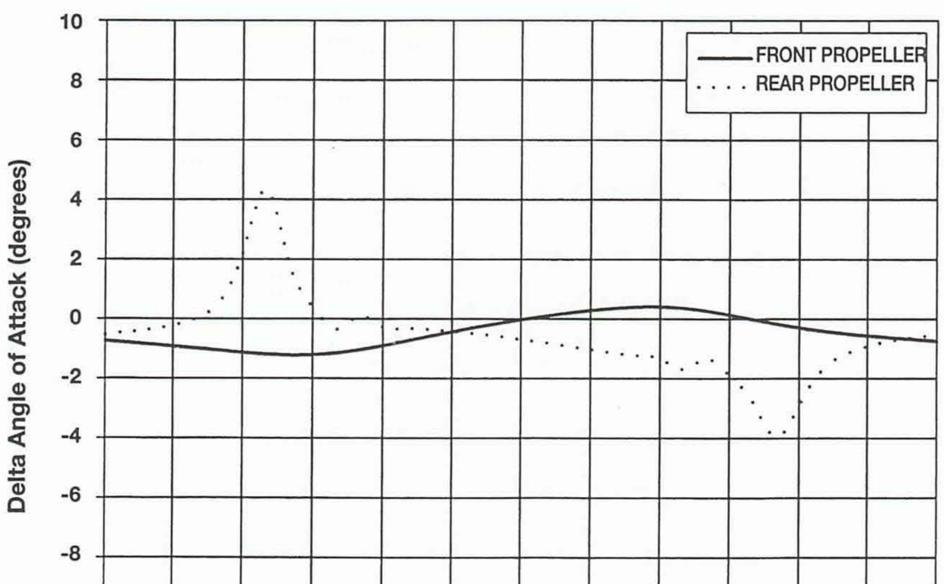



FIGURE 12

**Changes in propeller blade angle of attack calculated by VSAERO on the Rutan Voyager at 75% radius. Note that while the front blade experiences only small changes to its angle of attack as the blade revolves, the rear blade sees large and sudden changes in angle of attack.**

### *Author's Note*

*As noted at places in the text, I have had personal connection to both of these aircraft, and the Beech Starship and Rutan Voyager, which were mentioned in passing. During my time in engineering school at the University of Michigan, Ed Lesher was one of the primary influences in shaping the direction of my career and I have always admired the aircraft he designed and built. This inspired my interest in modeling Teal. A co-worker of mine, Ian Gilchrist, who prior to working at Analytical Methods, worked on the development of the Lear Fan, is my connection to this aircraft. Through Ian, I have been privileged to meet Moya Lear, Richard Tracy, Jim Chase and many of the other engineers involved with this aircraft. Lastly, during my time working for John Roncz, I was involved with the development efforts on the Beech Starship after it first flew and the Voyager. Unfortunately, the pattern here is that I developed connections with and analyzed all of these aircraft after they were designed and built!*

*As noted in the first article in this series, I am an aeronautical engineer, specializing in applied computational fluid dynamics. Based in Redmond, Washington, I work for Analytical Methods, Inc. My aerodynamic (and hydrodynamic) consulting projects at AMI have included submarines, surface vessels, automobiles, trains, helicopters, aircraft and space launch vehicles. I can be reached at: dave@amiwest.com or: Analytical Methods, Inc., 2133 152nd Ave NE, Redmond, WA 98052.* ◆

# PROPELLER, PUSHER DESIGN

Alex Strojnik convincingly demonstrated that a pusher configuration is necessary for ultimate drag reduction. Why? Well, in order to go, say, 200 mph in a tractor engined aircraft, the air stream along the fuselage will have to go 220 mph. That adds up to over 20% increase in skin drag. Add to that the horribly dirty front-end, the disturbed and turbulent airflow over the fuselage, and you are wasting a very significant part of the available thrust.

But pushers have their own dirty little secrets. Their major drawback is that the airframe disturbs the air before it reaches the propeller. This causes the prop to go into all sorts of undulations that wastes power and can lead to catastrophic failure. Have you ever noticed that all canard style aircraft have a unique slapping prop noise? Well, that is the sound of the prop fighting with the dirty air from the engine cowling behind the aircraft.

My recommendation is that props that are used on pushers for any extended period of time are made of wood. Many attempts have been made to run various composite and metal props. Composites and metal don't seem to be able to handle that kind of flexing.

So we have to run a fixed pitch wood prop on pushers.

There are ways to limit the amount of turbulence in the air entering the pusher prop disk. NASA's research on cruise missiles and RPVs shows that the trick is to increase the distance between the flying surfaces in front of the prop to one chord length. This gives the disturbed air a little more distance to calm down before it hits the prop. A slim fuselage in front of the prop helps a lot too.

The bottom line is that a well-designed pusher airframe should require less thrust than a tractor configuration.

My thanks go to the pioneers, Molt Taylor, Ed Lesher, Alex Strojnik and Burt Rutan. The air is less disturbed behind them! ◆

## Meet Copperstate Dash Winner

# VIRGINIA SKIBY

ARTICLE AND PHOTOS BY JACK COX

Virginia Skiby

Four years ago Aircraft Spruce inaugurated its Copperstate Dash, a cross-country, all-out speed race for aircraft with engines displacing no more than 320 cubic inches. Beginning at the Apple Valley, CA airport, it ends at the Coolidge, AZ airport, having covered a straight line distance of 304 nautical miles. Intended as a fun way to attend the annual Copperstate EAA Regional Fly-In at Mesa, AZ, various classes have been established within the 0 to 320 cubic inch envelope for both certified and homebuilt aircraft.

Amazingly, the overall winner — the fastest aircraft in any class — has been the same pilot aircraft combination for the past three years. Thirty-seven-year-old Virginia Skiby of Bakersfield, CA has pushed her Lycoming O-320 powered Rutan VariEze, N75VE, to usually resounding victories every October and must reign as the odds-on favorite in all future Copperstate Dashes until someone finally manages to beat her.

So who is this seemingly unbeatable pilot who has soared to stardom on the racing scene in such dramatic fashion? Then Virginia Martin was born in Bakersfield in 1961 and spent the latter part of her high school and early college years helping her father, Warren, build the VariEze she races today. She helped do the wet layups and literally spent years of her spare time sanding the composite airframe. So pervasive was that task that it even figured in her dating and eventual marriage to her husband, Martin Skiby.

"I'd show up at her house for a date," Martin recalls, "but I couldn't take her out until I helped her complete some construction task on the VariEze."

N75VE was completed in five years and five months, flying for the first time in 1982. Virginia was not yet a pilot, but began taking flying lessons during the latter stages of construction. She soloed in a Beech Skipper, but built up a lot of the solo time for her Private ticket in the VariEze. She passed the checkride for her license in 1983.

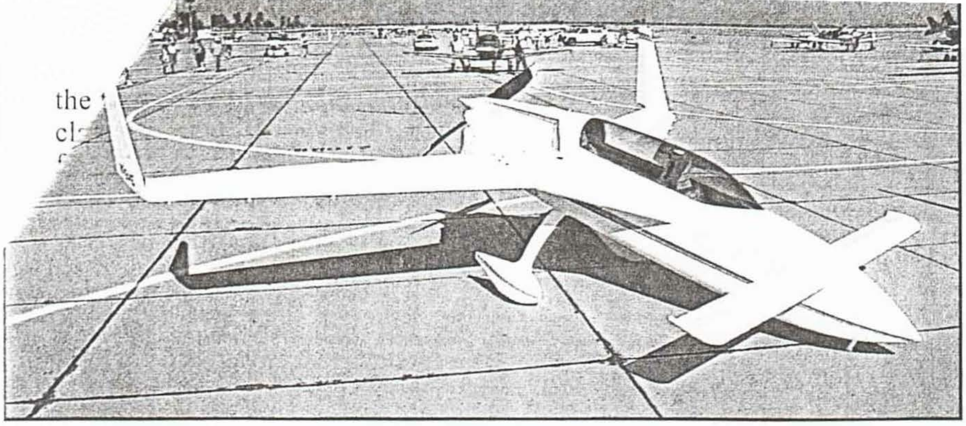
Virginia's racing career began with her participation in a CAFE 400 in 1989. The VariEze had been powered initially with an 80 hp Continental A-80 but was quite fast even with that small engine.

"Most of the credit goes to Virginia's dad, Warren Martin," husband Martin Skiby says. "He built the airframe per plans, absolutely straight, and it has been fast from the beginning. He's about to turn 81 and is still teaching me things about fiberglass work. He's just an absolute craftsman, a true perfectionist and craftsman. He built this airplane, a Q-200 and has been involved in several other projects."

While participating in the CAFE 400s, which were efficiency races, fellow competitors kept telling Virginia that she should start running in Shirl Dickey's RACE series. By this time Martin had learned to fly and had become a partner in a Continental O-200 powered VariEze, so they decided to attend one of the races at Jackpot, NV and let Martin try his luck with the bigger engined Eze.

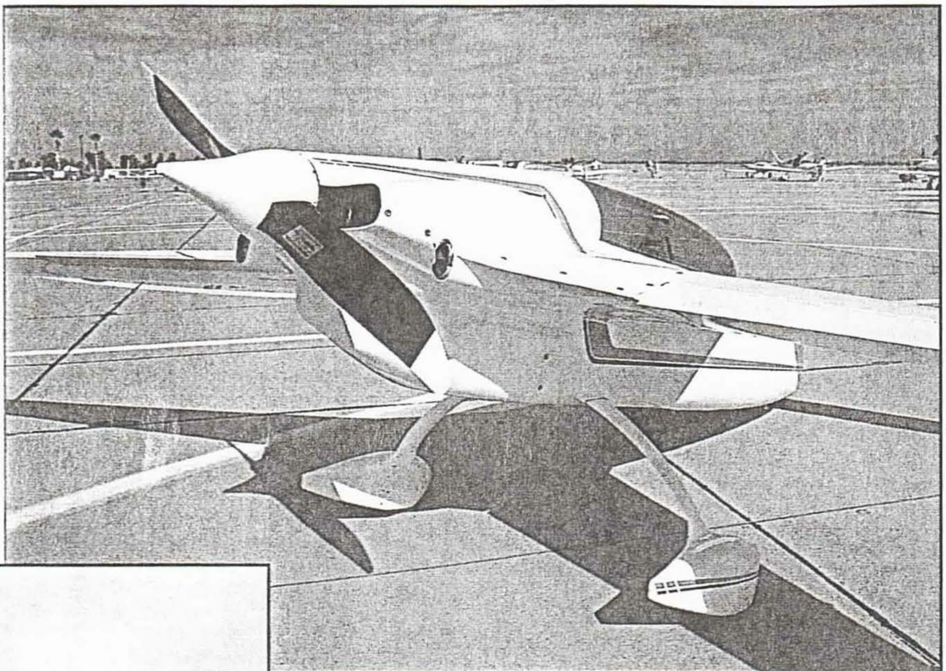
"While Martin was being signed up to compete, Shirl kept razzing me to enter my Eze, just for fun. I had no intention of racing. I had just 80 hp, for heavens sake. Why would I race? Well, I did run, and I think I went about 191 mph with that little engine. The next year, I raced our partner's 100 hp VariEze and swept them clean. There were three races then, and I won them all. After that I was addicted! You start winning and, boy, that was it."

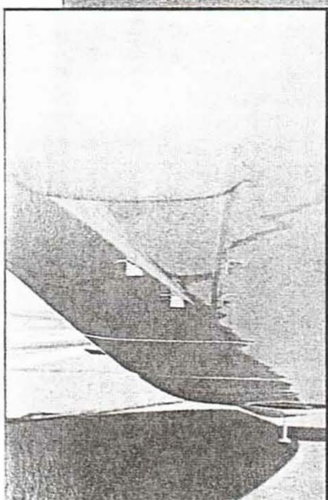
After her initial, spectacular success, the family decided to put Virginia in a real racer. N75VE was so fast with just 80 hp that they decided to put a bigger engine in it so it would **really** go. VariEzes had been designed to handle as much weight as that of a Lycoming O-235, so they decided to install an early, narrow deck 150 hp O-320, which was only marginally



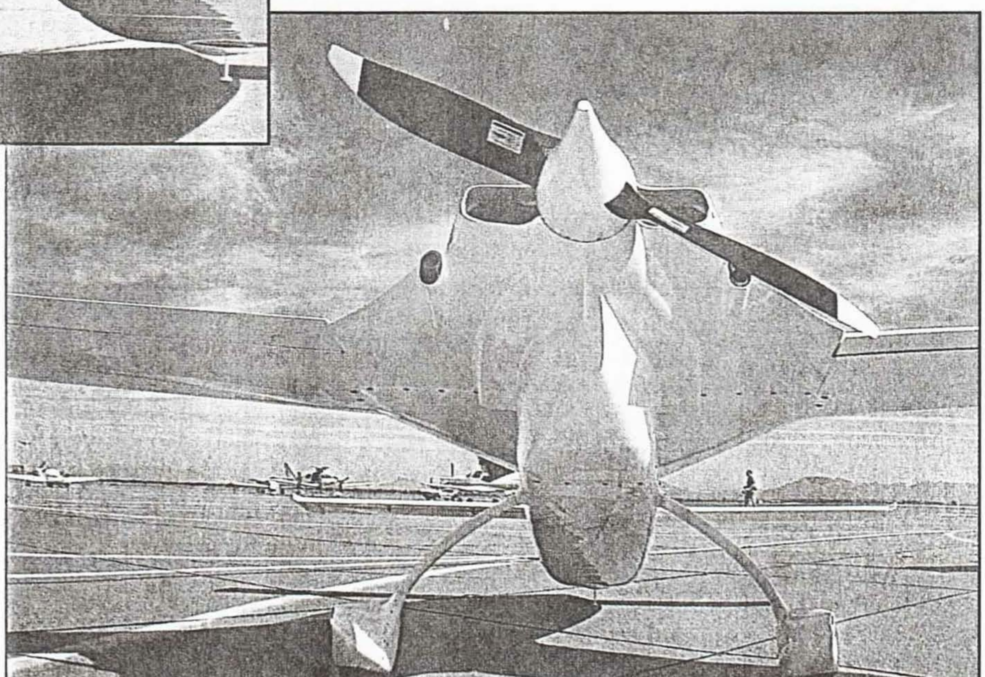
heavier. After looking around, the engine they were finally able to acquire had quite a pedigree. It was the workhorse that had powered Burt Rutan's first homebuilt, the prototype VariViggen, and, later, after the VariViggen airframe was donated to the EAA Museum, had served as the front engine on the prototype Defiant.

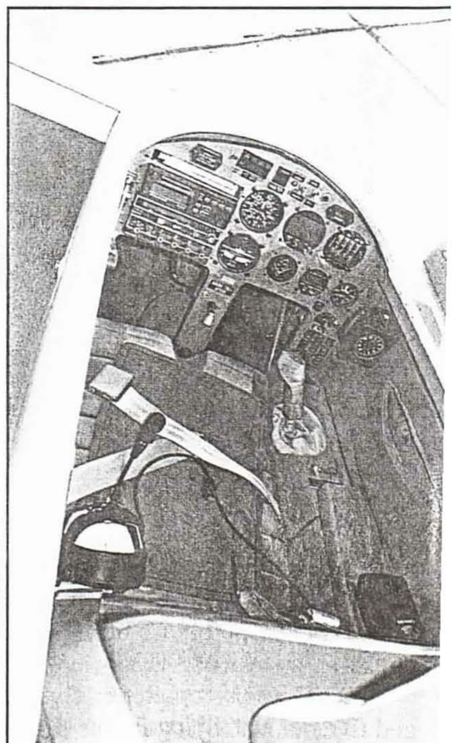
A number of other modifications were made to 75VE during the course of the engine change. Virginia's father and husband, Martin, redesigned the rudder actuation system to keep the



**Speed mods — internal rudder cables, vortex generators around the belly scoop, Klaus Savier prop, pressure recovery spinner and wheel pants — and very light weight.**





cables internal, designed and built a new cowling for the larger O-320, new wheel pants and a new spinner, which was essentially a scaled-down version of the Beech Starship spinners. The nose of the aircraft was extended about eight inches, a nose gear retraction door was added and work was done on the canard. They are not going to divulge all their speed secrets, of course, but will say that the canard incidence was altered to a slight degree to produce more speed. The airplane will still fly at 50 kts. (58 mph) without the canard stalling, and Virginia can trim it hands-off at over 250 mph.

Several propellers were initially tried, but the Skiby's finally settled on one of Klaus Savier's carbon-coated wood props. It produces four more knots of top speed on about 50 less rpm than anything previously tried. A little rate of climb was lost, but the airplane is so overpowered and has so much climb performance even with an all-out racing propeller that a few less feet per minute are insignificant.

Some convenience and creature comfort items were also included in the revamping of 75VE. A starter was installed on the Lycoming, and an electrically actuated lifting nose strut was installed — along with a 35 amp battery to power them. This allows Virginia to pull the airplane out of its hangar and go flying without any help. When she does, she's more comfortable than before because a new interior was also installed.

Even with the big engine and additional equipment, 75VE weighs only 810 pounds — and that includes some beefing up of the landing gear to safely handle the added weight.

Along with Klaus Savier's propeller, one of his Light Speed electronic ignitions was installed, replacing one of the mags. According to Martin, "It has been absolutely trouble-free since it was installed. I haven't changed the spark plugs in probably four years. They stay perfectly clean, and the airplane is really fuel efficient, even with the big engine. When Virginia cruises alongside our Cessna 337 at 180-185 mph, she's burning about .8 gph."

There were some initial problems with the Lycoming. After about 100 hours, an exhaust valve failed and put the Skibys down in Barstow, CA — resulting in the replacement of the top end of the engine. Then, in 1995 while preparing for the first Copperstate Dash, the crank broke. Fortunately, it was one of those breaks that kept the crankshaft keyed in place and Virginia was able to nurse the Eze some 50 miles back home to Bakersfield. Martin says her first words, upon opening the canopy, were, "There's something wrong with the engine and it sounds expensive!" After that incident LyCon completely rebuilt the engine and it has been going strong ever since.

Even as fast as she was before, Virginia was a holy terror once she returned to the racing circuit with the rebuilt O-320. She flew the Eze to Sun 'n Fun three years ago and beat everything with four cylinders except Bruce Bohannon's Formula One racer, Pushy Galore, and has been beaten just once in the RACE series, by the O-360 powered Berkut — just barely. Otherwise, she has swept her class in all events, including, as noted, each of the last three Copperstate Dashes held to date. (Klaus Savier won the inaugural event.)

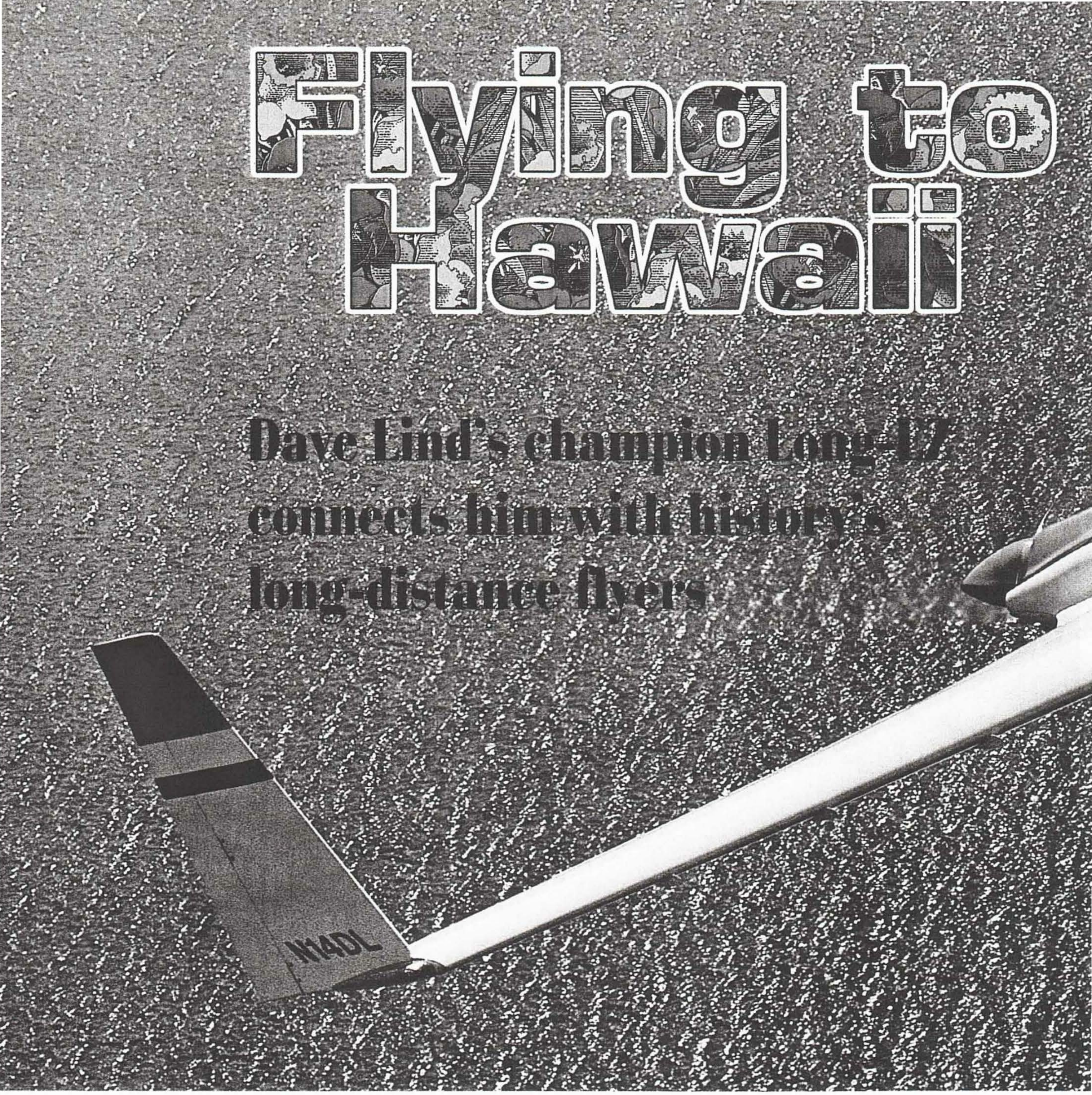
Flying . . . and racing . . . are Virginia's hobbies. In the workaday world she is a licensed ultrasound technician and, more recently, the financial officer of Datacom, a communications cabling company Martin founded five years ago. She is also a mother — she and Martin have two children: Jennifer, 9, and Jason, 7. Both have grown up at the airport and take airplanes and flying as an integral part of normal life. Jason, she says, was born to fly and loves everything about aviation.

The Skibys are currently building an E-Racer, which they plan to power with a six-cylinder Continental IO-360, possibly with a turbocharger, and a constant speed propeller. With the Cessna 337 they use in their business, she and Martin are not lacking for airplanes, but her VariEze remains Virginia's favorite.

"It's my love," she says. "I've checked out in the Skymaster and have my multi-engine rating, but it doesn't compare with flying my airplane. I have about 700 hours and most of it is in the VariEze. I just love it." ◆

# Flying to Hawaii

## Dave Lind's champion Long-EZ connects him with history's long-distance flyers

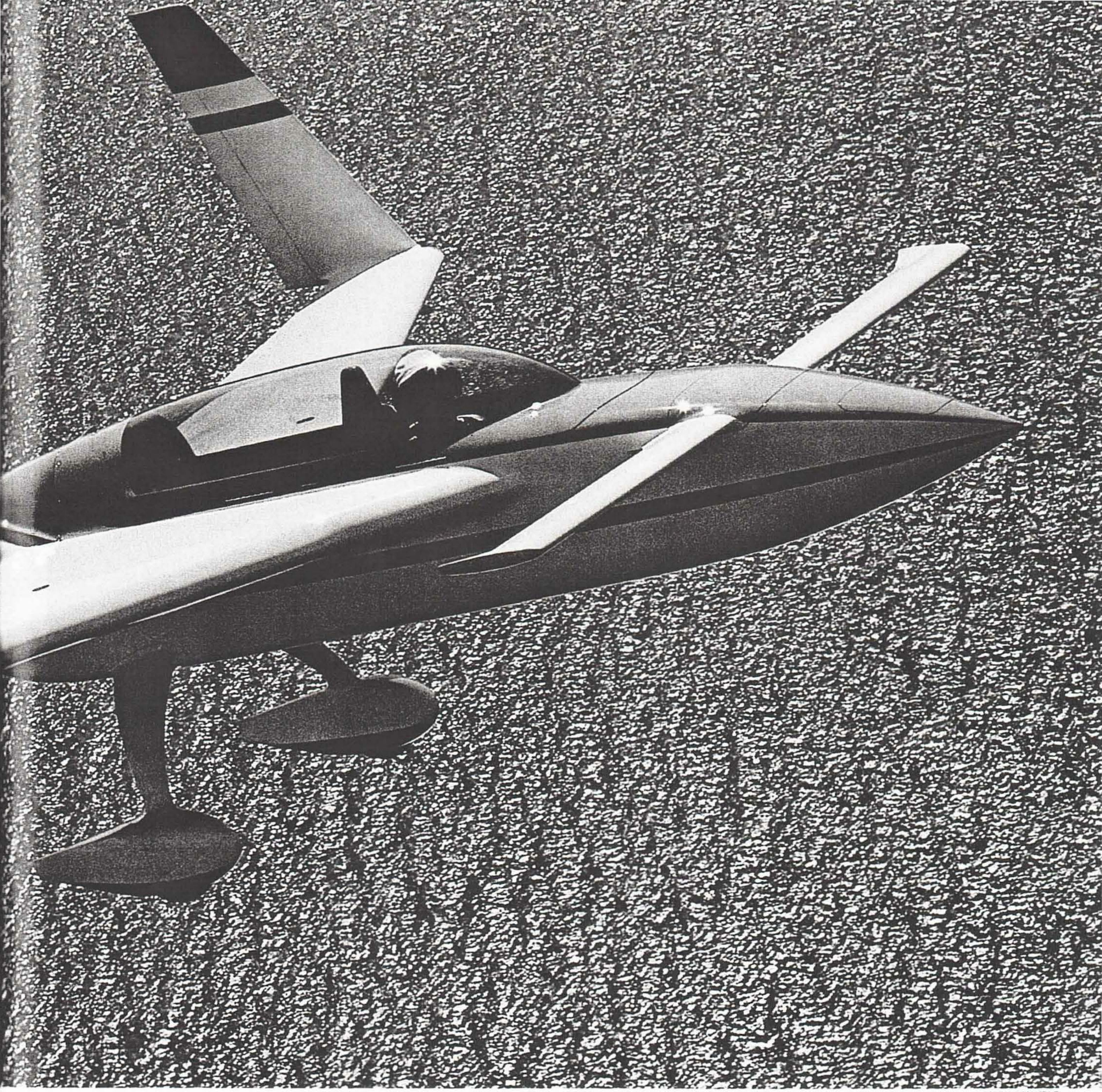



**Jack Cox**

You have to be a very long way from anywhere to hit the "nearest airport" button on your GPS and have it display "No NRST!"

When Dave Lind (EAA 276290) of Del Mar, California, had that sobering experience in his Long-EZ, N14DL, he was indeed a long way from anything—except the Pacific Ocean 10,000 feet below him. He was, in fact, at the midpoint of a long-planned solo flight from Carlsbad, California to Kona, Hawaii and had punched his NRST button just out of curiosity to see what it would display. The unexpected reply was impersonal technology's way of informing him just how far he actually had his soft, pink bod hung out over the abyss—and the little shiver that momentarily raced up and down his spine was not from the cold of altitude!

Dave Lind was born in Willmar, Minnesota in 1937 but moved with his family to San Diego before he was 5 years old. He grew up in nearby Pacific Beach, was educated at La Jolla High School and San Diego State, then enlisted in the Navy in 1961 in hopes of becoming a military pilot. Unfortunately, he could not meet the Navy's uncompromising vision requirements, so



MARK SCHAIBLE

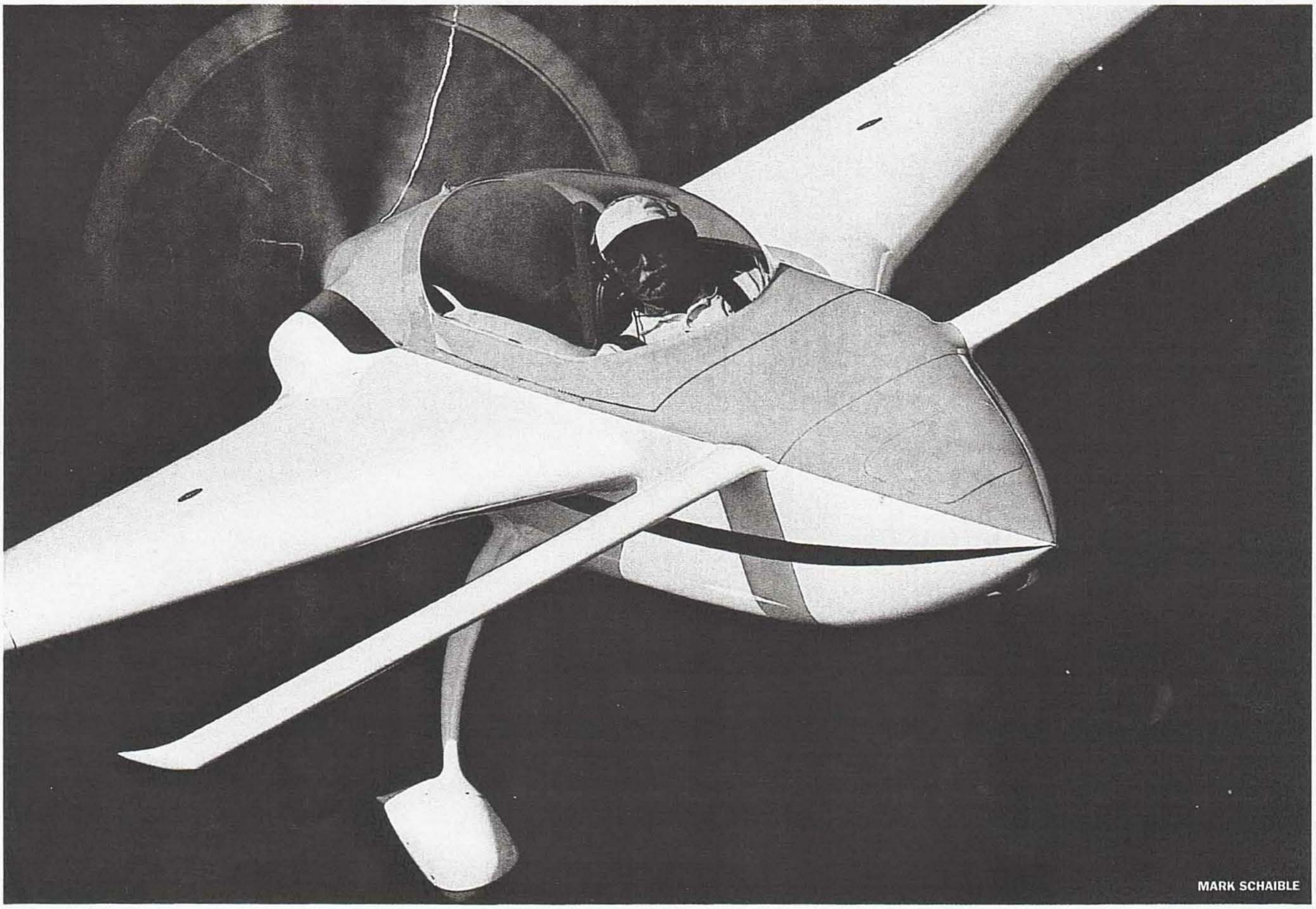
he opted for bombardier/navigator training instead.

Ultimately assigned to the right seat of a tanker version of the Douglas A-3B Sky Warrior, he flew a full Mediterranean cruise off the USS Forrestal and, later, served on the USS Coral Sea off Vietnam. The aerial refueling role was critical to combat operations in the Gulf of Tonkin, with the A-3Bs "Whales" always aloft to refuel aircraft that were running low and in danger of not making it back to the carrier.

On one occasion, Dave's A-3B tried to save an A-4 so badly shot up that its pilot could not maneuver to inject his refueling probe into the trailing basket. With no other option, Dave's pilot literally backed his A-3B up to the A-4 and made the refueling connection. As it turned out, the battle damage to the A-4 was so great that the pilot ultimately had to eject, but by that time the refueling from Dave's A-3B had allowed him to get close enough to the carrier to be quickly rescued.

Although denied Navy pilot training, Dave was still determined to learn to fly. In 1964, while stationed at Naval Air Station Whidbey Island, just north of Seattle, he flipped a coin to decide whether to take skiing or flying lessons, and bought a block of 42 hours of flight instruction after the coin fell in favor of flying. The cost? $210!

He learned to fly in a Piper J-5,


MARK SCHAIBLE

then bought a 1940 Luscombe 8C and used it to get his commercial certificate, CFI, and instrument ratings. He sold the Luscombe when a transfer from Whidbey Island was imminent, but he later owned a little Mooney Mite for a year or so while stationed in San Francisco. He really enjoyed the Mite, and its fighter-like agility would stick in his memory and eventually play a big role in determining his next personal airplane.

By a stroke of good fortune, the airlines were hiring when Dave returned to civilian life in 1966 and despite having relatively low time as a pilot, he was signed on by United. He began his airline career as a flight engineer on the DC-6 and progressed through the 720, DC-8, and 727 before easing into the right seat of the 727. Flying as first officer continued through the DC-8 and 747 until Dave made captain on the 737. He flew the Boeing 757 and 767 during most of the past decade, until the FAA's mandatory age 60 retirement rule finally caught up with him in 1997. He had logged nearly 19,000 hours by that time.

During his career, Dave was able to fly all over the world, but one of the most enjoyable routes was Los Angeles to Hawaii and return. Like most pilots, he had always enjoyed reading about the exploits of the long-distance flyers of aviation's early days, and had always been in awe of the fortitude it obviously took to venture off alone over thousands of miles of open ocean in a single engine airplane. The airline trips to and from Hawaii were routine enough to allow him to think a lot about the pioneers of that route, the Dole racers, Amelia Earhart, and others—and the seed was planted for a similar adventure of his own.

In the early 1980s Dave was given a ride in a VariEze by a fellow United pilot and he instantly fell in love with the airplane type. Its Star Wars configuration, the fighter-like agility he had been impressed with earlier in his Mooney Mite and, significantly, the aircraft's very long range capability, as evidenced by the world records Dick Rutan and Jeana Yeager had been setting in the prototype Long-EZ and, later, Dick's EZ, N69SH, and, especially, Rodie Rodewald's flight from Hawaii to Oshkosh in 1982 combined to place the airplane in the "must have" category for Dave.

Although initially concerned with his ability to construct an airworthy aircraft ("I'd never built anything in my life at that point, other than a chicken house."), he bought the plans for the Long-EZ in 1984 and began what would turn out to be a nine year period of construction. In retrospect, Dave says that several years were added to the building time by his summer ritual of attending fly-ins to carefully inspect all the EZs, pick the brains of their builders, and incorporate the best of the new ideas and innovations he encountered. Mike Melvill at Rutan Aircraft Factory (RAF) was a great help throughout the project, he recalls.

From his discussions with other builders, Dave decided early in the project to install a Lycoming O-320 in his Long-EZ. He deliberated for some time over whether to go with the 150 hp version so auto fuel could be used, or with the 160 hp 100-octane version. Ultimately, he decided in favor of the 160-hp model, an O-320D3G, and bought a new engine. That decision was influenced to a great degree by his wife, Mary, who cast a decidedly jaundiced eye at the idea of her husband flying around with a "second hand" engine.

Burt Rutan designed the Long-EZ around the Lycoming O-235, so Dave's choice of the heavier O-320 was the first domino to topple over in the chain of modifications that additional weight would dictate, beginning at the nose of the aircraft. Partly for looks and of necessity for weight and balance, Dave lengthened his EZ's nose by nearly a foot, making room for the battery and the little converted hair dryer that is popular among canard aircraft builders for use as a foot warmer. He also managed to squeeze in a small Halon fire extinguisher.

Back in the cockpit, Dave canted his instrument panel about 70 degrees to provide more room for the top row of instrumentation and still clear the canard behind it. Constructed of aluminum, it bolts securely to the airframe and retains the structural rigidity of the panel called out in the RAF building instructions. Dave knew at the beginning of his project that he would ultimately fly the EZ to Hawaii. Because that required an IFR flight plan, he installed a TSOed King radio, transponder, and GPS. He also installed a Navaid AP-1 single-axis autopilot capable of tracking either a GPS or VOR course, which he subsequently came to consider a life saver on 16 hour long legs over open ocean.

Dave says that he is forever being asked if his fuselage is wider than normal. It isn't, but it does appear to be—an effect resulting from his decision to install his circuit breakers on his instrument panel rather than on the arm rests, as many EZ


MARK GODFREY

**Dave Lind and his EAA AirVenture '99 Champion Long-EZ, N14DL. A recently retired United captain, Dave and Mary, his wife of 37 years, have four children. One is a nurse and the other three are airline pilots.**

At the midpoint of his solo flight from Carlsbad, California to Kona, Hawaii, he punched his GPS's NRST button just out of curiosity to see what it would display.

builders do. He had the space to do this largely by virtue of using tiny digital instruments to display engine function readouts. His airspeed indicator is, in fact, the only "steam gage" on his very professional appearing panel.

Elsewhere in the cockpit, Dave installed one of fellow San Diego-area Long-EZ builder Lee Carlstrom's canopy lock mechanism that incorporates a lever that extends down and blocks the throttle when the canopy is open. Dave also modified the little clear plastic window on the nose gear well that is used to visually check whether the gear is up or down. He hinged his so it can be opened to provide additional front-seat ventilation. A separate NACA duct provides fresh air for the rear seat.

The rear seat area also contains a removable thigh support. Unscrewing two bolts allows it to be popped out to make room for baggage—or for the 40 gallon aux tank used on the flight to and from Hawaii. Dave did eventually learn to ski, and he used the shape of the grip on a favorite ski pole as the model for carving his EZ's walnut stick grips.

In the Long-EZ's strakes, the inboard portions that are used for storage, Dave installed an EPIRB for the flight to Hawaii. "That stands for Emergency Position Indicating Radio Beacon. It's designed for boating and it begins transmitting when it gets wet. In an airplane, it can be activated manually. It's like an ELT, but it also transmits a user identifying code, so that rescuers will know the type of airplane, the identity of the pilot and can call his home to verify the information. It's a neat little unit. I bought it for the Hawaii trip, but I'm going to keep it in the airplane," Dave says.

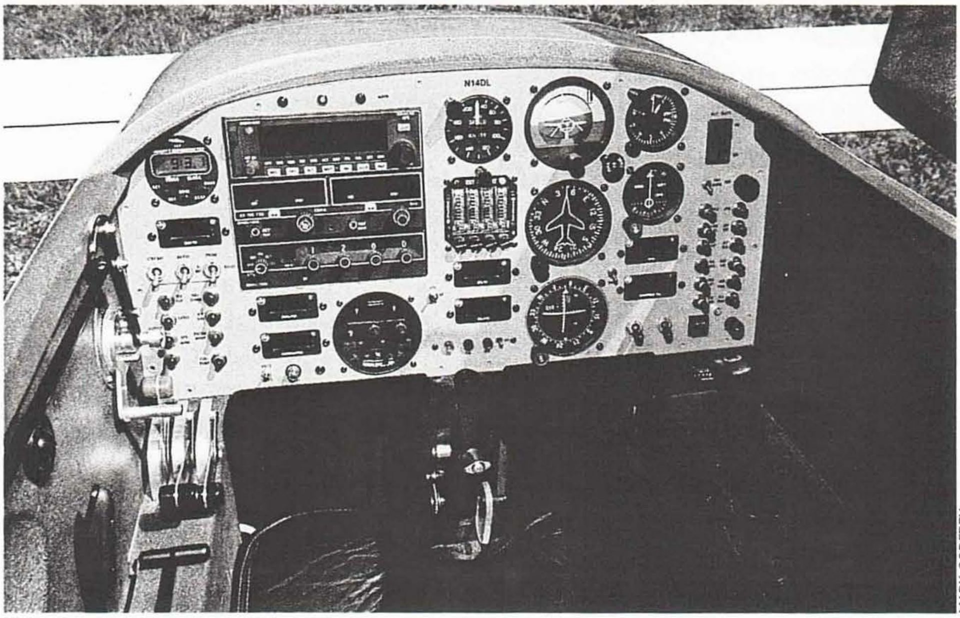
A couple of additional items installed specifically for the Hawaii flight included a relief tube that runs down the left main gear leg inside the streamline fairing and a length of conduit that was built into a wing to allow a trailing wire antenna for an HF radio to be paid out from the bot-

JACK COX

**The extended nose of N14DL provided room for the aircraft's battery, a heater and fire extinguisher.**


JACK COX

**Dave Lind's Satellite 406 Emergency Position Indicating Radio Beacon (EPIRB), which he bought for use on his flight to and from Hawaii in July of 1996. It carries a code that identifies the airplane and pilot/owner.**



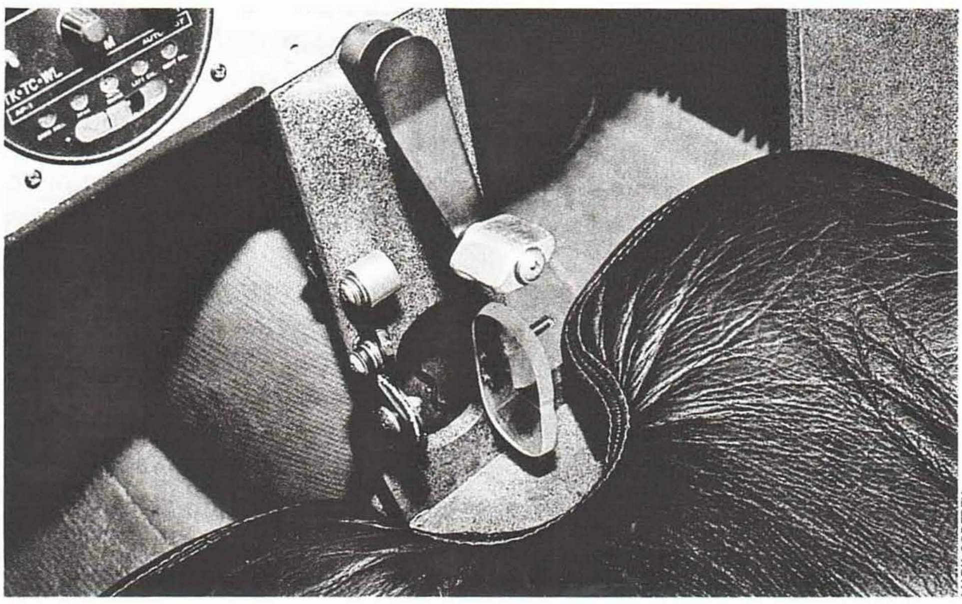

MARK GODFREY

**N14DL's very professional instrument panel contains just one "steam gage," the airspeed indicator.**

tom of a winglet. The HF radio, itself, had to be mounted under Dave's left knee to be accessible for tuning.

Back outside, a John Roncz canard, designed to eliminate the loss of lift in rain, was used. Dave also chose to use a flush NACA inlet to supply cooling air for his engine, rather than the stock external belly scoop. Knowing that the NACA inlet has to have a very precisely sized and shaped inlet and run-in ramp to be effective, Dave first built a rather elaborate wood tool in which to lay up his ramp. All the extra effort paid off because the engine and oil have cooled just as he hoped they would.

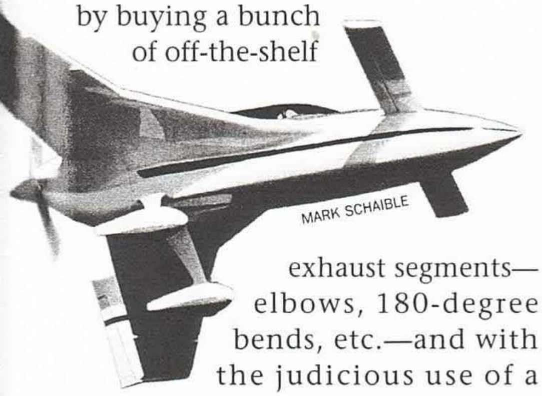
Drag reduction was a major goal throughout the project and Dave knew that the airflow around and through the cowling would be the most critical part of that effort. In addition to the NACA inlet, he wanted a really tight, low drag cowling, but that meant he had to have



MARK GODFREY

**N14DL's nosewheel inspection window hinges open to provide fresh air for the pilot.**

the exhaust system tucked in very closely around the engine. He began by buying a bunch of off-the-shelf



MARK SCHAIBLE

exhaust segments—elbows, 180-degree bends, etc.—and with the judicious use of a hacksaw, cut and fitted them to the desired angles, tacked them together by various means and had a professional do the finish welding.

As often is the case, the first version was found to be prone to cracking, so he built another one incorporating slip joints and retaining springs at each exhaust port. Keeping the airplane as light as possible was a simultaneous effort, and the cowling was a primary target. Dave built up molds for the top and bottom cowl segments in the shapes he wanted, then laid up just two plies of fiberglass in each. Attaching these very flexible pieces to the airframe, he pushed, pulled and twisted each of them until they were in the desired shape, then built rigid frameworks around them to temporarily hold them in place. Pulling them off the airplane, he turned the cowl segments upside down and epoxied in a layer of Kevlar to provide the necessary degree of rigidity, without adding a lot of weight.

With the airframe completed, the final systems and components were installed, including 5:00 x 5 Cleveland wheels and brakes, a Catto two-blade propeller, and a spinner kit from Aircraft Spruce. When finally completed, but still in primer, the EZ, now registered as N14DL, had an empty weight of 918 pounds. With a starter, battery and IFR panel, this was a number Dave was justifiably proud to see come up on the scales.

He flew the airplane for the first time on August 5, 1993—out of Brown Field in San Diego. Not wanting to glaze his new cylinders, he taxied just enough to find that the brakes were working properly for steering, then blasted off and flew for an hour and 20 minutes at the high power settings Lycoming recommends for breaking in a new or overhauled engine. All went well, with just a few minor squawks encountered, and after they were worked out, it was time to take the bird home again for paint.

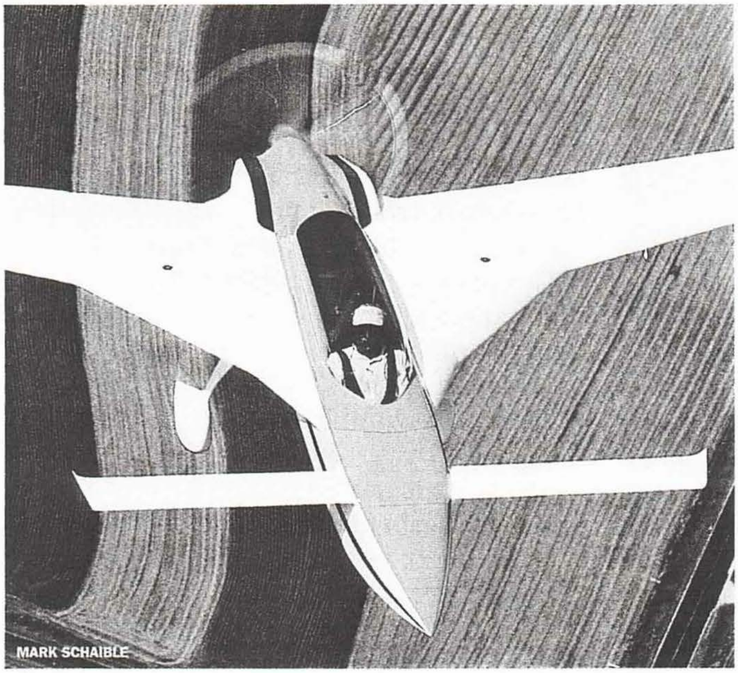
Dave built his Long-EZ in his family's two car garage, and he also painted it there. Never having spray painted before, he read all he could on the subject, bought and borrowed the best equipment he could find, practiced until he thought he had grasped the basics of the art, then, still with a great deal of trepidation, began painting his left wing. Knowing he could not make his temporary paint booth totally dust free and realistically expecting to have to sand off a lot of his early learning curve errors and start over, he chose to use the single-stage PPG Concept paint. It was supposed to be readily sandable—and it was. Dave ultimately ended up with a beautiful finish that certainly belies the fact that it was his first effort at fiberglass finishing and painting. Of course, much of his success was the result of all the time and effort he put into sanding and filling, sanding and filling...and still more sanding and filling, in preparation for painting.

Initially, N14DL did not have wheel pants, but once Dave began racing in Shirl Dickey's series of closed-course events, a pair of Klaus Savier's slick pressure recovery pants was purchased and installed, along with fairings for the main gear legs. Another Catto two-blade prop was given a try, but it was ultimately replaced with a Catto 60x82 three-blade that Dave liked much better. In addition to his own, Dave tried eight or 10 other propellers on his EZ, and the Catto three-blade turned out to be the fastest and smoothest of them all. It also produced the most initial acceleration.

The Catto props, which are wood with a composite covering, have been quite durable, Dave says, and he has been very happy with them. They are heavy, he concedes, but their performance and especially the smoothness of the three-blade more than make up for it, in his opinion. The three-blade prop required a new Aircraft Spruce spinner, and this time Dave was careful to give the cutouts for the blades a generous radius to avoid the cracks he encountered with his two-blade spinner. He had tried to make the cutouts fit the prop contours too closely, including some rather sharp corners, and produced some points of high stress that quickly induced cracks. Although many assume his present spinner is chromed, it is actually polished - the result of a lot of good ol' elbow grease.

With the addition of the wheel pants, gear leg fairings, three-blade prop, etc., the airplane's empty weight increased to 957 pounds—but that was more than offset in Dave's priorities by the performance increase that resulted. When he began competing in races without wheel pants, he did not do well against competitors who had been tweaking their EZs for years. After all his modifications, however, his top speed increased to 200 knots (230.31 mph) and in his most recent events, including the 1999 Copperstate Dash, he has always finished first or second in his class. He plans to continue cleaning up the airframe until the very last knot is squeezed out of it.

His racing has been challenging and a lot of fun, but Dave's great adventure in 14DL was his flight to Hawaii and return in July of 1996. To prepare for the trip, the first order of business was to increase the airplane's fuel capacity. The normal strake tanks held 56 gallons, but some pretty comprehensive flight planning told him he needed nearly 100 gallons to have the reserve he wanted. This was not going to be a publicized, record-seeking flight with a razor thin margin for error. It was, rather, simply a personal challenge, something he felt would result in a great sense of accomplishment, so he wanted much more than enough fuel to complete both the anticipated tailwind-assisted flight to Hawaii and the longer duration return home to California.


MARK SCHAIBLE

Dave made up his aux tank by using pour-in-place foam to make a plug that fitted into every nook and cranny of the rear seat area. The result was a composite tank with a capacity of 40 gallons. That gave him a total of 96 gallons, which was well within the cruise performance envelope he had established for the flight. Interestingly, Rodie Rodewald had lugged an amazing 140 gallons aloft for his Hawaii to Oshkosh flight in 1982, but Dave's ultra-clean, 160-hp Long-EZ was so much faster than Rodie's 115-hp O-235 powered EZ that he simply did not need that much fuel.

With GPS, accurate navigation was a given, but Dave did borrow a friend's handheld unit as a back-up. Otherwise, most of his remaining preparation centered around getting his high-frequency (HF) radio to work. Composite airframes are always problematic platforms for HF radios unless a lot of effort is expended to provide a ground plane of some sort, and Dave was not completely successful in this regard. He managed to get the radio to work well on the frequency commonly used during the day, but never on other frequencies. Since his legs to and from Hawaii were largely in daylight, this was never a major concern.

When Dave departed from Carlsbad, California, his EZ weighed close to 1,800 pounds. He got off in 2,500 feet and had no problem climbing to his cruising altitude of 10,000 feet. As forecast, the July weather was good, and about a third of the way into the flight, he began picking up the easterly trade winds, which eventually increased his groundspeed by as much as 25 knots. For much of the flight, all went exceedingly well, but, finally, the human element did come into play and caused some anxious moments. Dave had installed an electric fuel pump with its own separate on/off switch to transfer fuel from the rear-seat aux tank to the left strake tank—a little at a time—until it was empty.

"Well into the flight, when I had about 15 gallons remaining in the aux tank, I got tired and distracted by something and forgot to turn off the pump when I should have. The pump made a different noise when the aux tank went dry, and when I heard that, I knew that, uh oh, I had overfilled the left main and had pumped probably eight or more gallons overboard! My immediate thought was, 'Am I going to make it?' Then I began thinking how embarrassing it would be if I didn't. Fortunately, however, the trade winds kept speeding me up and I eventually landed with nearly 17 gallons left. I should have had 25," he says.

"Just to be sure about my fuel situation, I landed at Hilo, on the eastern side of the Big Island, rather than Kona, on the west side, which had been my destination. I spent a couple of days at Hilo, flew around the active volcano on the island, saw where the lava flows right down into the ocean, flew over to Maui, and then back to Kona to meet my wife. She had brought some foil tape with her and we ran a strip of it down the right wing in hopes it would improve the HF radio operation, but it didn't. At least we tried.

"I departed from Kona for the flight back to Carlsbad. I took off at sunrise and just never could get out of the trade winds. I finally landed 16 hours later at Carlsbad, at 12:30 p.m., with 10 gallons of fuel left. The plan had been for Mary to leave shortly after me on United to Los Angeles, then take the shuttle down to meet me when I arrived. As it turned out, she missed her connection and I beat her home by about three hours!"

With a full measure of justification, Dave is proud of his Long-EZ. In building it, he proved to himself that he was capable of turning out not only an airworthy aircraft, but one with such a high level of craftsmanship that it was awarded a Champion trophy at EAA AirVenture '99—which means it was in very close contention for Grand Champion in the largest, toughest field of competitors the sport aviation world has to offer. Since its completion in 1993, it has provided Dave with a highly stimulating dual challenge: serving as a racer in which to stoke his competitive fire, and as a test bed for his creative efforts to go ever faster (and thus more efficiently). N14 Delta Lima has also become a direct connection between Dave and his long distance, over-ocean heroes from the pioneer days of aviation.

Foam, fiberglass and epoxy are, in retrospect, just a small part of all his Long-EZ has become to Dave Lind. ◆

# BUILDING AN


PAMELA KELLEY

**Ever wonder how building an airplane might fit into your family's life? Here's a real-life story about building an airplane . . . from the right seat occupant's perspective.**

Sometimes I think back to the days when we were building our Lancair Super ES and wonder how we found the time to build an airplane. Some mornings I wake up, open the bedroom curtains, and still expect to see the vertical stabilizer just outside our window. The luxury of coming home and actually being able to pull the car into the garage is something we're still relishing.

It's been two years since our first flight in our ES. My husband, Lon, was in the left seat, Wayne Williams (an ES pilot from El Dorado, Texas) was in the right, and I was in the back. The weather was crummy on January 12, 1998, cool, but not cold, low ceiling but flyable, and a Monday, of all days.

It was a thrilling ride, filled with the sound of the IO-550 roaring down Andrau Airpark's Runway 15, acceleration that didn't stop as we lifted off the ground, the rush of air through the four fresh air nozzles, the flash of strobes, and tears in my eyes. How did we do it? How did we find the time? How did we ever face up to the expenditures? How did Lon know this was the plane for us?

We make periodic pilgrimages to the Northwest for vacation, for the region's clear summer skies, mountains to hike, family to visit, and because the area is a Mecca for homebuilts. I was just getting used to the idea that we might be in the market for a homebuilt kit when we toured the Lancair facility in Redmond for the first time. We owned a 1968 Mooney with two other couples and had a stable flying base. Lon and his partners took care of the plane—one was an A&P, so annuals were no problem. The wives traded off keeping the books and paying the bills.

It was an ideal situation, but things change. The first was the plane itself. When it was 90° F or better, the Mooney struggled over Carbon County, Utah, and some of the headwinds around Albuquerque really slowed us down. One partner was thinking of buying a house in the country, and the other was dreaming about a homebuilt of his own. Then, in anticipation of family guests for our youngest daughter's wedding, our partners helped us build a roof over an "enlarged patio" behind our home.

The stage was set.

After some really serious discussions that involved money, time, and curtailing our outside activities, we were thinking seriously building an airplane.

Lon deserves a lot of credit. He didn't hurry the decision, nor was this going to be his project. If we were going to build a plane, it would be because it was something we both were committed to. We had enough money to get started, and we knew that we'd still be working our jobs. But one by one we disengaged from other activities, telling our friends that we'd be building an airplane and would be busy for a couple of years. It was hard at first, but that announcement gave us an immediate cheering section.

Why the Lancair ES? It appeared to be a good four-place airplane—room for another couple and baggage. We enjoy exploring the West, and the ES would give us a great traveling plane. With its bigger engine, we'd have more power and speed.

We ordered the tail kit, and it arrived in November 1994. We'd cleaned the garage and built the cradle for the horizontal stabilizer. I had the financial spreadsheets blocked in on the computer so we could build our airplane expenditures into the budget. Then I decided that this project warranted something special. I'd keep a photojournal of our progress. We'd take pictures for the FAA, and I'd keep a record of the building process. I'd note the hours we spent working, the construction progress, try to capture a "quote of the day," include any visitors, and record the weather.

# AIRPLANE . . .

## A VIEW FROM THE RIGHT SEAT

We had gorgeous weather that fall. Working all Christmas break, our neighbors heard the air compressor running frequently. Really intrigued by what we were doing, our family and friends dropped in.

The epoxy pump doled out the correct ratio of hardener. On a 4-by-8-foot table (plywood sheet on saw horses) I unrolled the yards of fiberglass, measured 20-inch wide diagonal strips on the bias, and cut them out with my good sewing scissors. This was a priority project, right? I spared nothing. My quilter's roller cutter turned out to be perfect for cutting the BID (bi-directional cloth) sandwiches of fiberglass, epoxy, and the one mil plastic sheeting.

I stored the cutter in a mayonnaise jar with solvent until the plastic handle got gooey. Lon made an aluminum handle and I was back in business. A wallpaper seam roller took out the air bubbles. I wore a hardware store apron with a B-17 patch sewn on for luck; I had cotton glove liners and vinyl gloves, safety glasses for splash protection, and old clothes. I was enjoying the few skills that I could bring to the table.

The first of three 3-inch thick instruction manuals covered the tail and wings kit, so I started my first photojournal "Tail and Wings." We were airplane builders, the garage was our weekend workshop, the soup was simmering in the kitchen; we had begun.

By construction day 25, it was June. We closed out the horizontal stabilizer and made the elevators. The wing kit arrived, and we repeated the procedures on a grander scale—and on the patio, not in the garage.

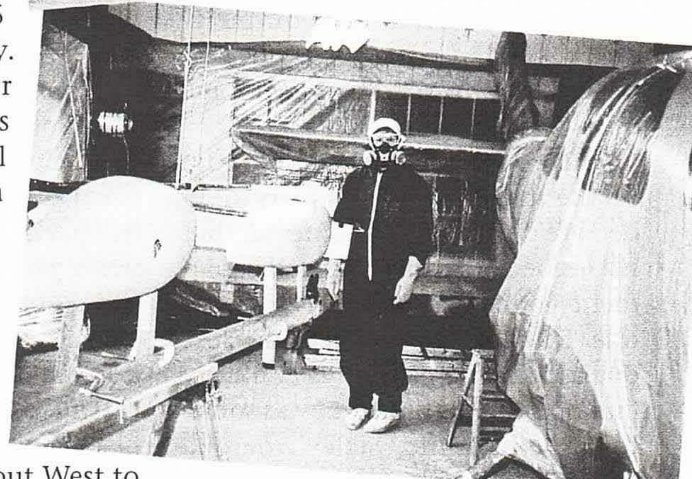
The ES wing and spar extension measures 17 feet. It stretched diagonally across the patio from laundry room's outside door. Because there was no chance of moving this assembly after we started, we decided to be safe rather than sorry. We replaced our old washer, and it arrived with a matching dryer. The airplane was clearly a priority now!

### Photojournal Log: June 17-18, 1995 —Days 27-28

"Drilled and cleaned out the fuel probe holes and microed the plastic guides into place. Spend the rest of the weekend finishing off the rib micro fit and cap strips and then applying the 3 BID reinforcement. There was a lot of area to cover and I used the 20-by-20-inch pieces of fiberglass I'd cut quickly. I'll need to order 25 yards more on Monday. We started planning for next week. No guests this weekend, but the girls all called in to wish Lon a Happy Father's Day.

"Quote of the Day: Lon—I need to get out and do some approaches with Dave."

By this point we knew we'd taken on a big project. On our annual trip out West to visit family, we checked in at the Lancair factory in Redmond and got a needed boost. The finished planes looked beautiful! We toured their "custom panel" workroom. Seeing all those beautiful instruments and



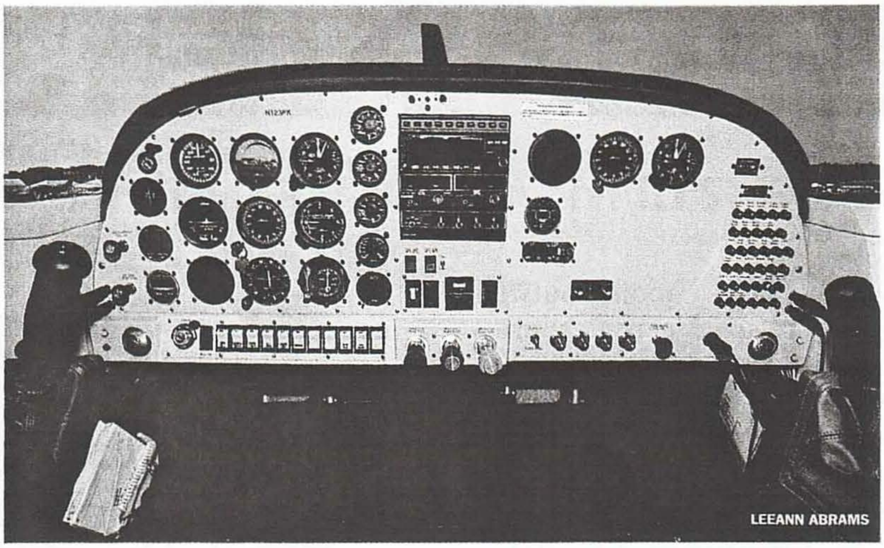
**Top - Pam tries out the specially contoured seats**

**Middle - Sanding flush the interior in preparation for the ensolite and headliner.**

**Bottom - All decked up for painting.**

finished airplanes inspired us. We hiked in the Cascades and flew home in the Mooney, ready to get back to building.

By August we were closing out the left wing, and coating the gas tanks was the next big step. They had to be very clean, and the measurements for the bottom skin had to match the chambers of the tanks we'd made. We went over the measurements repeatedly. And it was hot. The first batch of epoxy coating exothermed in our pots before we could apply it. Using smaller amounts and an ice water bath for the reserve, we painted our tanks. They looked like gray porcelain sinks when we were done.


LEEANN ABRAMS

**Designed on a door, balanced on saw horses in their kitchen, Lon rearranged instruments until the final pattern was determined.**

"Quote of the Day: Pam—Houston, we have gas tanks!"

Keeping the photojournals got me through the weekends that seemed to show little progress for our constant work. Some weekends I'd check off instructions and it would seem like we were really making progress. Other times it wasn't until I sat down at the computer and recorded what we'd accomplished that weekend that I felt some achievement.

There were bills to pay and record on the spreadsheets, and parts to order. We'd purchased a starter kit, but we needed other supplies and equipment—primer and painting tools for one. The lead shot for the wing close out had the folks at Carter's Country (ammo supply) thinking I was something of an Annie Oakley when I'd stop on the way home from work to buy eight 25-pound shot bags at a pop. I opened an account at Aircraft Spruce; if I faxed our order in on Monday, we'd have our materials by the weekend. By now we could see some real progress, and we ordered the fuselage kit from Lancair.

By Thanksgiving 1995—after 565 dual hours—we'd finished the wings and tail and stored them in our garage. I started a new chapter in our photojournal—"Fuselage."

As Lon backed the trailer up the driveway, I was impressed with the fuselage crate's size—two and a half sheets of plywood long! Where would we put all of this? We were so excited we opened the crate and the boxes just kept coming.

As I look at the pictures we took that night, it was our Christmas! Lon posed under the fuselage shell and looked through the "windshield." Surrounded by plastic bags full of parts and bolts and washers I held the main gear tires in my picture. Both of us were grinning like a couple of kids. By the time we finished accounting for and storing all the parts the house had shrunk. It was a parts warehouse; I only hoped I could find it all as we needed it.

We tore down the crate and used it to build the fuselage cradles. Separating the two wing tables and placing one of each side of the fuselage, we shimmed them to the right wing-support height. Out rolled the wing. Our "plane," as we now knew it, a fuselage and wings, just fit our workspace. The left wing without its wingtip ended at the laundry room door. The right wing reached clear across the driveway in front of the garage door. We built an extension on the front of the garage to keep the rain off. Our neighbors cheered us on, which was a good thing; it was all a peculiar sight from the street.

Work progressed through the winter. A few times we had to figure the temperature into our plans and then we used heat lamps to hurry the epoxy. The ES was on the cover of *AOPA Pilot* magazine that January with the headline "No assembly required." Lancair had announced plans to build a certificated version of the ES. That in time we could have purchased factory built ES never phased us. We were into building!

By February we were fitting the wing fairings to the fuselage. Our ES looked like a flying boat and we were getting plenty of exercise. Half the time Lon was on his back fitting the lower fairings or we were putting the flaps on or off, pulling the wings out or pushing them in. My sneakers were wearing out faster on the tops than the bottoms.

By April 1996, we were on our 94th day, carving away fuselage skin with the grinder to make way for the gear legs. The wings were back in the garage, and we modified the cradle so we could raise the fuselage and set up the gear. The checklist was moving along. We invited our flying club for a look-see and hamburgers. When people say they accomplish things with their friends' help, I know what they mean! Hearing all those "wows" and "you did this" was music to our ears!

## Photojournal Log: July 4-7, 1996—Days 114-117

"It's Saturday night and Lon and I have been building our airplane nonstop. Tonight we went out for dinner to give ourselves a treat for all the sweat in the past three days. With no sign of rain and a relentless sun beating down, we are building the vertical stabilizer under the back deck with two fans blowing on our heads! 96 degrees is pretty hot.

"We've had fun putting the vertical part of the tail together. The right side of the stabilizer went up first, got hysoled onto the fuselage, and became the backbone for the ribs and webs. The NACA scoop went on next and we will have cabin air—Lancair promises! Next we spread the comm antenna carefully vertical straight up the stabilizer and floxed it in place (to get the best reception.) Lon attached the cable and we took a picture for the book.

"I constructed the plenum chamber by myself. The NACA scoop is a new design to me: I would've installed it *backwards* and on the *outside* of the *front* of the plane. Instead it's a cut-out opening in the back of the plane with a 2.5-inch diameter hose transporting the air to the cabin via the cabin air duct. It'll pour fresh air over the front and back seat passengers. This idea better work, I'm going to need some cool air."

That summer we left Houston on an upbeat note and never appreciated our mountain hikes more. By August we were installing the windows, and by the end of September the fuselage was one piece, no longer a boat with a lid. Our project "out back" was clearly an airplane. More plastic sheeting and more priming and finishing work followed. In November, with a friend's engine crane—it's nice to have friends with engine cranes—we bolted on our Continental IO-550.

Don't ask me how we actually moved it to the engine mounts, but we used pulleys, ropes, and lots of guts! For days afterward I thought—how often does a wife hang a $29,700 engine off the front of a fuselage with her husband, in the backyard no less?

The next day I called our insurance man to see about insuring our static display. We needed coverage.

I started the photojournal's next chapter: Engine and Systems. We now had 1,164 dual hours on the project and it was our 158th day. We started climbing the airplane interior learning curve. I spent a good part of the time inside the plane leveling the fuselage's irregular surface. All the perimeters of the windows, doors, and armrests needed building up first with BID, and then cork to provide a smooth sanded surface for the headliner and window frames.

AeroPlus, a Houston aircraft interiors shop, was recommended to us. We spent a Saturday there choosing the interior materials and had a lesson on how to finish off the fuselage interior and hang a headliner. It was fun, we saw many examples, and the owner, Joe Hernandez was patient.

We watched his team working on new interiors and then came home to our "hangar" and started work. I remember being scrunched up in the baggage compartment and breathing through a facemask as I carefully sanded the cork filler. When I had my headliner pattern ready, I cut the material with extra allowance for the curves. Then Lon and I carefully glued it up.

Someday (maybe) I'll write a book on how to do your airplane's interior. Joe Hernandez taught us so many tricks of the trade. I feel we did a good job, but the last window frame was the most perfect. We'd reached the top of the learning curve. Joe made our leather seats, cut the foam to fit our bottoms, and carved the back seat bench to our design so our passengers would not roll into each other.

Valentine's Day 1997 brought a dozen red roses and a surprise letter from the FAA—our registration number would be N123PK. I felt a rush of happiness followed by tears of joy. For a husband to build an airplane with his wife and expect it to proceed like a job at work is unrealistic. It takes the pre-plan, the agreement, the teamwork—*and* the roses!

There was so much emotion involved with this project. We based all our daily decisions on the ES's construction. But there was always the nagging question: After investing all our time, sweat, and money, would it really be the airplane we wanted? It was a gamble at best, and a trial by fire. Operating under these parameters we certainly got to know each other better. Lon demanded my best and it was hard for me to admit that we'd have to redo some of my work. My ego took some hits, but I kept focusing on getting this plane in the air, sitting in my right seat, and seeing the beautiful West unfold before me as we flew to Oregon.

Lon was working on the panel frame and arranging the instruments. By March, two saw horses held a door for a tabletop in the kitchen. The panel was under construction during the week. We sanded the primer on the fuselage on weekends and finished the interior. By April the ES was on its gear, the interior was nearly finished, and the window frames installed, despite an argument that almost undid me. It must have been the contact adhesive, or maybe it was the slope of the fuselage, but a window frame with an outside curve and an inside curve cannot be made out of a single piece of plastic framing material. It just doesn't lie down into the curves. That was our second big argument.

From March until Memorial Day, our construction hours consisted of sanding, filling, and sanding again, readying for the paint. I have sincere respect for my random orbital sander. I've since learned that some homebuilts remain in "getting ready to paint" limbo for years. We didn't spend years and we might have spent more time, but if we'd dragged this process out over the summer, I might have lost it. I was getting pretty tired of this "pregnancy," and Lon was really missing having



Pam and Lon pose in front of their homebuilt Lancair ES.

an airplane to fly since we had sold the Mooney.

The push now was to transform our patio into a clean, ventilated paint booth. The fellow at the paint store loved our dimensions and eagerly filled our order. We chose Honda "heather mist," and the Honda dealer tried to sell us a companion Accord! We knew composite airplanes need to be painted a light color, but cream or white were not going to do it. We wanted a metallic fleck that would gleam like a P-51 in the sun and complement Texas' beautiful blue skies. Our blue stripes break into a rolling surf near the cowling and a proud Star of Texas rides the waves. At Sun 'n Fun approach would call us "silver low-wing." HighTech Signs, the same shop that does the logo for the Houston Rockets, laser cut my design, and a picture of our plane is on their bulletin board. It was their first brush with aviation, and they loved to hear the progress report during my lunch-hour visits.

### Photojournal Log: June 6-9, 1997—Days 211-214

"These four days are blurred together into four long days of painting. The weather held—in the high 80s with partial cloud cover. We ended up calling in for an extra vacation day on Monday. We just weren't done."

About the painting saga, that we worked hard will suffice. The fuselage is too big to cover at once. Then there was the second color for the stripes and the detail work. The belly went okay, but we weren't happy with part of the tail and re-did the back half of the plane. We're talking two compressors in tandem to pressure the sprayer, with me mixing the paint, Lon applying two base coats, masking, then the design and two clear coats. We learned a lot about flashing and dribbles. The light was good for some of the "shots" and could have been better for others. In quick summary, one Jurassic bug snuck into our paint booth and it's is now permanently preserved between the paint and the clear coat.

In July, we hit the Oregon Trail flying commercial—they lost our luggage! We stopped in Las Vegas on the way home. (Lon kept me going with some fun stuff, too.)

Despite a great vacation, I had some kind of mental deterioration afterward. I was having a hard time getting back to the plane. I flew home for my mom's birthday, then to a nephew's wedding, and then I puttered around the house for a couple of weekends while Lon worked on the panel. I was drifting, and not in the direction of helping get the ES finished. Still, we had some fun with the panel. One night we plugged in our headsets, put the antenna out the window, and monitored Houston Approach from the kitchen.

Labor Day weekend I stripped the interior out of the plane and weighed each piece for the record. We did nut plates for the strobes and wingtips, cracked one of the lenses (and ordered a new set), and installed and wired antennas. I floxed in the ELT bracket; we wired the position light. By Monday night, with 24 work hours added to the record, I ended Day 231 with a good cry. I was pooped.

Days 232 and 233 were another 14 hours of work. It was above 90 degrees with high humidity and no wind. Lon worked relentlessly. We floxed in the boost pump bracket and it cured right up. Then we finished off the front seat footrest.

Our flying friends Will and Jinny came over with a homemade apple pie made with Michigan apples they had just picked and flown home to Houston. Our friends were really encouraging us now. Mooney partners Betty and Dave came to see the plane and took us out to dinner. Will and Jinny gave us a ride to our flying club outing, and we took our albums to show everyone our latest progress.

By Day 238 we were making flight-ready installations, and the instruction manuals were getting lots of check marks. Sunday night I went through all the manuals and at each "flag" noted what we needed to do finish that part. The list ran 31 items, starting with "Grind space in the stern post for the anti-collision light wires and trim tab" and ending with "Brakes—install fittings and secure all lines, make flight ready."

By the end of October it was a little cooler and we were methodically working down the list. As we were installing the cabin door, Lon surprised me with news of a November trip to Paris! End of the "Fuselage" photojournal—620 dual hours, Day 240.

The next photojournal was "Assembly and Flight." The excitement (tension) was building. We installed the panel; it was tight, but it fit. We were connecting things now and going through an enormous amount of wire. I let everything go around the house and my body showed up for work five days a week.

We were getting ready to move the wings and prop to Andrau Airpark. With dollies underneath and the fuselage supported with blocks, we removed the gear and lowered the fuselage and fully installed engine onto two dollies. To get it off our patio we had to roll the nose into the garage and then swing the tail out onto the driveway. The tail just cleared the roof and the horizontal stabilizer just made it past the gutter spout. We were prepared to saw down the corner of the garage if needed!

My emotions were close to the surface as the fuselage rolled down the driveway on December 6, 1997. Lon was directing the move and I felt a few tears rolling down my cheeks. With neighbors helping, we winched the fuselage onto the trailer and tied it down. Before dawn on Sunday morning we drove to the airport with flashing lights and an escort of neighbors to protect the horizontal stabilizer. Our wing tables, wings, and gear were already in the hangar. As we carefully jacked up the fuselage and pulled out the trailer, we bolted on the gear. The guys slid the wings into the fuselage and we bolted them down.

During the next four weeks we put our plane together. Checklist after checklist was detailed; prop, wingtips, rudder, elevators, ailerons, flaps were installed; more wiring and hookups to the panel were made. We crawled over the ES like ants invited to a picnic. The house had been emptied; the drawers of hardware in the garage were empty. The slings hanging in the garage were empty. With the gear gone we could now vacuum Lon's study. On a chilly Saturday we brought out the front seats and our friends Marie and Greg came for engine start. With a "thumbs up," the prop spun, the engine roared—our bird was alive. We celebrated with hamburgers.

By December 27 we were doing fast taxies, checking for leaks, inspecting all the systems, going over all our lists again and again. Weight and balance measurements were certified. We calibrated the gas tanks two gallons at a time. It took all day, but when we were done, one more instrument was up and running. A FAA inspector came out and gave us our flight limitations. We drilled four little holes in the tail and riveted on our Builders Registration plate: Lonny and Pamela Kelley—we were cleared for flight after 1,873 dual hours—Day 272.

We sent "First Flight" announcements to family and friends with a picture chosen from a "day in the sun photo op" on the field. How could we ever thank our friends who had experienced this with us, our neighbors who had brought over a couple of cold beers on those tired Sunday nights, and our kids who indulged our dream and looked forward to our visits?

After completing flight testing, all we did in 1998 was fly—160 hours in all: Florida twice, Colorado, Cape Cod, and all around Texas. We visited our kids, friends, and my folks. Building this plane has been one of the most rewarding experiences of my life. How many projects can a husband and wife share that result in something as amazing as an airplane? I can see into the wings when we're at altitude. I can imagine the air going across the engine and through the oil cooler. And the plenum chamber works. We have lots of cabin cooling air. ◆

# All About Bolts

**An up-close look at what holds an airplane together**

MICHAEL DiFRISCO

Just as the human cell is the basic building block of muscles, organs, tissues, and bones that make up the marvel that is the human body, the ubiquitous bolt is the most basic component of an airplane's construction. Like the human cell, without bolts, the airframe would never come to life.

The seemingly endless variety of bolt sizes and shapes can often overwhelm the new builder. Most likely the seemingly endless bins of bolts at your local hardware store have mesmerized you. Speaking of the hardware store, it *is not* the place to purchase the bolts and nuts you need for your aviation project.

As the builder of an experimental category airplane, you can legally use hardware-store nuts and bolts in your project—but with rare exceptions *you should only use approved aircraft hardware*. The reason is simple: hardware-store bolts are made of a low-carbon, mild steel with a tensile strength of about 55,000 psi (pounds per square inch)—pretty weak. Aircraft quality hardware is made from a nickel alloy, corrosion-resistant steel. Heat treating further strengthens aircraft quality hardware to a minimum of 125,000 psi. Brings to mind the

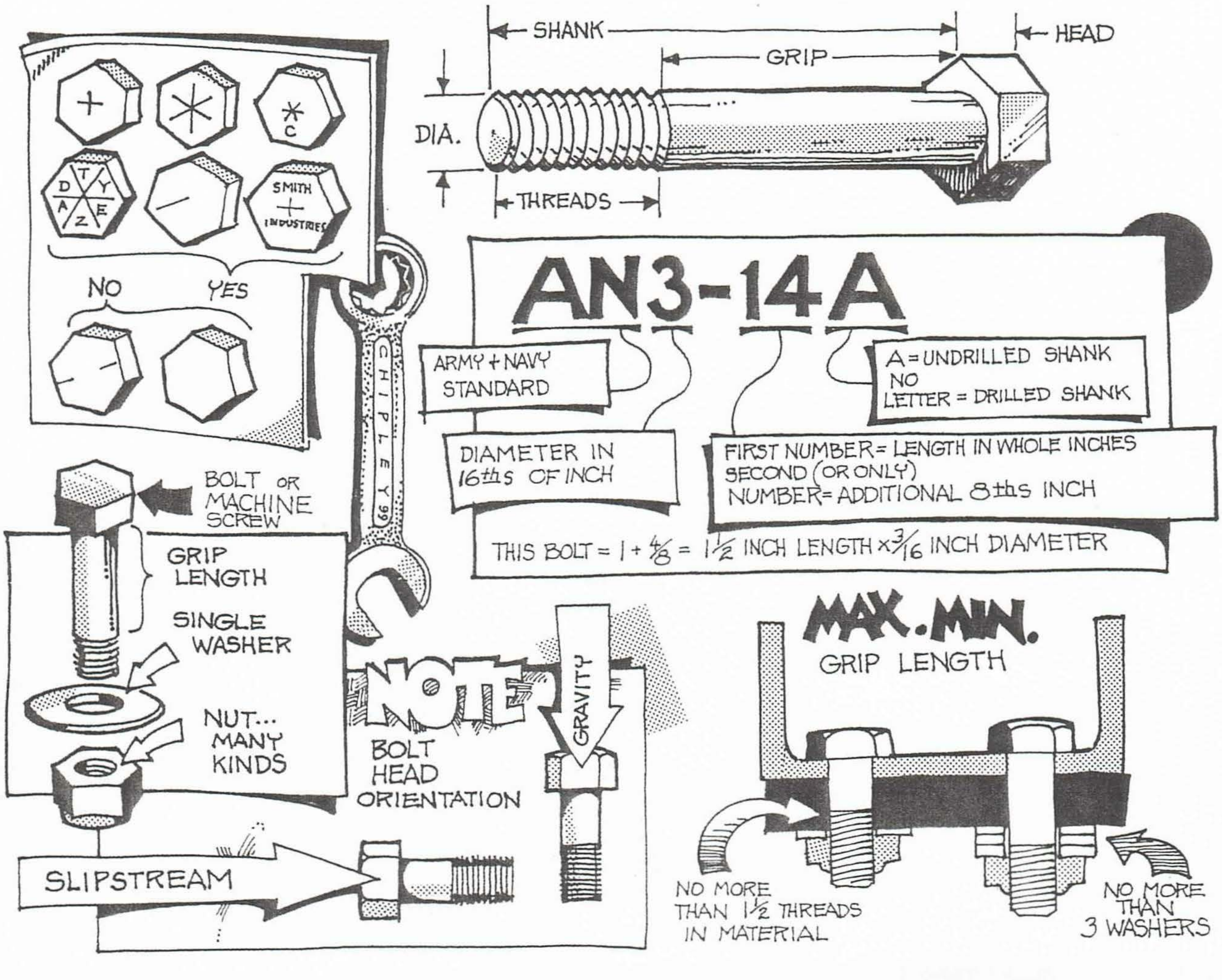



ILLUSTRATION: TOM CHIPLEY

"hefty, hefty, hefty, wimpy, wimpy, wimpy" TV commercial. Hardware is not the place to try to save money on your project, so always go "hefty."

## Bolt Standards

Aircraft quality hardware is often called "AN" hardware, which stands for Army/Navy, the two military branches that established the criteria for acceptable aviation hardware way back when. Joining AN in the succeeding years are National Aerospace Standards (NAS) and Military Standards (MS, also called "mil-spec"). However, unless you're building a spacecraft in your workshop, AN hardware suffices for most applications, and the better homebuilder's supply sources are well stocked with the AN fasteners.

You can identify an AN bolt by the marking on its head. These markings take many forms, but they do follow some basic rules. A bolt with no markings on the head is a non-certified bolt—the hardware-store wimpy variety.

Other head-codes can be simple asterisks or crossed lines, letter codes identifying the material from which the bolt is made, or even the name of the manufacturer. (See illustration.) These markings typically mean you're looking at a corrosion-resistant steel aircraft bolt.

You'll be dealing with AN bolts from the smallest AN3 (3/16-inch diameter) bolt, to the largest AN20 (1-1/4-inch diameter) bolt. But flipping through the latest Aircraft Spruce & Specialty catalog, you'll discover additional alpha-numeric designations following the AN number. Although there's no need to memorize the countless bolt codes, there is a method to this cryptic madness. See the accompanying illustration for how to decode an AN bolt designation.

## Bolt Vibrations

Airplanes vibrate, and vibration can cause bolts to wiggle loose and no longer fasten thing together. This is a bad thing in any aircraft, so AN bolts have features that allow you to prevent them from vibrating free.

*Without bolts, the airframe would never come to life.*

Some AN bolts have a hole drilled through their head, shank, or both. Usually, the hole drilled in a bolt's shank is for a cotter pin. If the hole is drilled in the bolt's head, that's where you use safety wire to make sure the bolt won't vibrate loose. On bolts with a drilled head the letter H follows the AN designation. A bolt with a drilled shank has no letter after the alphanumeric AN string. If the bolt is not drilled, the letter A follows the AN code. Typically, you use a lock washer or elastic stop nut with an undrilled bolt.

Sometimes a designer specifies a close-tolerance bolt. Because standard shank diameters can be off as much as .003 of an inch, in applications where a "perfect" fit is required to minimize wiggle—like a wing attach fitting—you need a close-tolerance bolt. Close-tolerance bolts have a small triangle embossed into the head, and are generally coded AN173 through AN186.

## Bolt Grip

You don't need a ruler to learn how long a bolt is. Just look at the code on its head. More important than learning the bolt's length is deciding how long a bolt must be for a particular fastening job. A bolt's length is the length of its shank, and the length isn't always enough information to make the correct selection.

The unthreaded portion of the shank—the grip—is designed to carry shear loads. To securely fasten two things together, the bolt's grip should equal the depth of the hole through which the bolt passes (see illustration).

Sometimes "equal" is just a bit off, and as a general rule you can have no more than 1.5 included in the bolt hole. If more than 1.5 threads extend into the hole, your grip is too short, and you need to get another bolt.

Your bolt's grip is too long if you have to add more than three washers to the bolt before adding the nut. If that's the case, you need to get a bolt with a shorter grip.

Don't get into the habit of hacksawing AN bolts to the proper length. This invites corrosion by exposing un-plated steel to the elements, and cutting and rethreading AN bolts weakens them.

It may not always be possible or practical, but when installing a bolt, it's always best to have the head of the bolt up or facing into the slipstream (see illustration). That way, if a nut inadvertently becomes loose or

### Glossary

**AN—Indicates an aircraft-quality piece of hardware. Stands for Army/Navy, the two service branches that first established criteria for aircraft-standard hardware.**

**Head—The hexagonal portion of the bolt over which the wrench fits.**

**Grip—The unthreaded portion of the shank.**

**Shank—The portion of the bolt designed to fit into the hole in the material. The length of an aircraft bolt is measured from under the head to the end of the shank.**

**Torque—The pressure applied to tighten the nut onto the bolt.**

falls off, gravity, inertia, or air pressure might just hold the bolt in place until you can replace the errant nut.

## Nuts & Washers

The nut's sole purpose is to prevent the bolt from separating from its fitting or fastened material and to add pressure to keep the bolted components from "working" against on another. And like bolts, an ordinary nut won't do for aviation because of vibration and the high stress loads the fasteners must endure. AN nuts are categorized by the methods of security: self-locking, or stop nuts; nuts in conjunction with lock washers; or by external safetying—a cotter pin or safety wire.

The self-locking nut is the most common type used in aircraft construction. It has an elastic fiber or plastic insert that provides friction against the bolt's threads, resisting vibration. If you want proof of their gripping power, try turning the nut with your fingers. You'll get it started, but when the threads bite into the insert, you'll be looking for a wrench (unless you're Superman). If you can turn a self-locking nut on by hand—trash it. You can reuse self-locking nuts, but when they lose their gripping power, they are worthless—and unsafe.

There is an all-metal variety of self-locking or "stop nuts." They have a manufactured distortion that provides friction similar to the elastic insert. You primarily use all-metal stop nuts forward of the firewall because self-locking nuts with elastic inserts are only rated to 250°F.

You use an AN castle nut with a drilled-shank AN bolt. To safety the two, you pass a cotter pin through the "notches" in the castle (see illustration). Generally, you don't use nuts with drilled-head AN bolts. They screw into a tapped receiver of some sort, like the prop flange on an engine, and you pass safety wire through the head to keep it from vibrating out.

The lock washer is least common type of safetying. You must use it in conjunction with an AN flat washer, and combined it adds weight and complexity to the assembly.

The primary purpose of a washer is to spread the compression forces of the tightened nut and bolt combination over a wider area of the material to which it's being attached, and to protect the material from the tightening nut. The AN960 is most common washer. The number following the dash in the designation indicates the size of the bolt for which they're designed. Common AN washers come in a regular thickness, or a thinner version—typically used as a shim along with a castle nut—designated by an L for light, after the AN code string.

### Putting it all together

*Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair, FAA Advisory Circular AC 43.13*, lists the various "torques" for given bolts and applications. If you don't have a torque wrench, a good rule of thumb is to just tighten them until they're good and snug, but not over tightened. Hercules need not visit your workshop to torque your fittings.

You can also approximate the torque you're putting on a nut by estimating the pounds of pressure you're applying to the wrench along with the length of the wrench. For example, if AC 43.13 specifies 25 inch-pounds for an AN3 bolt, and you're using a 6 inch wrench, applying about 4 pounds of pressure to the end of the wrench yields approximately 24 inch-pounds of torque (4 x 6 = 24).

Obviously, there's a lot more to learn about aviation hardware, and the Sources box suggests a few of them.

## Sources

**To learn more about aircraft bolts, these resources were the references for this article. If they are available from EAA, their item number and price are in brackets. To order, call 800/843-3612.**

***Sportplane Construction Techniques* by Tony Bingelis [F01395—$24.95]**

***Kitplane Construction*, Second Edition, by Ron Wanttaja [F00580—$29.95]**

***Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair*, FAA Advisory Circular 43.13 [F00191—$18.95]**

**Aircraft Spruce & Specialty catalog, 1-800-824-1930, or www.aircraft-spruce.com**

# *Building Basics*

# Understanding the Matrix

## Composites are a combination of cloth and resin

H.G. FRAUTSCHY

COMPOSITE CONSTRUCTION has been a part of homebuilding for 25 years, but with all its variations, it can be a bit confusing. At its most basic, "composite" refers to a woven cloth or filament combined with a plastic resin to create a component that is applied over a core material like foam (used on the VariEze and called "moldless" construction) or formed with a mold (usually used by kit manufacturers).

Different materials are used to weave the cloth used in composite construction, and they range from simple fiberglass to exotic materials made of Kevlar (an aramid fiber), carbon graphite, or ceramic fibers. When combined with the appropriate resin, each cloth has particular strength attributes that make it more or less suitable for a particular application.

Because the cloth/resin composite bears all the primary flight loads imposed on the airplane, using the cloth with the correct strength, weight, and workability is essential. Composite cloth uses weaving patterns that maximize its strength in both directions (bidirectional or BID) and just one orientation (unidirectional or UND).

To give it strength in both directions, BID cloth is woven with half its fibers parallel to the selvage (the woven edge of the fabric) and the other half at a right angle to the selvage. To lay BID into compound contours (like cowlings and wheel fairings), builders can cut it on the bias, or on a 45-degree angle to the selvage.

UND cloth is woven with 95 percent of its fibers parallel to the selvage, which gives it exceptional strength in that direction but little strength at right angles to it. It's used in areas where the primary loads are imposed in one direction, such as wing skins and spar caps.

Manufacturers use two different weaving patterns. A plain weave is the familiar over-under checkerboard pattern you might remember from the pot holder you made for your mom in kindergarten. It's strong, but its tight weave makes it less pliable. The "crow foot" weave is less common, but it's desirable for high thread-count fabric that must conform to compound curves.

The beauty of composite construction is that each surface does not have to be made up of only one type of cloth. Designers can specify combinations of various cloths to create a structural sandwich. For example, you could create a spar cap of UND cloth covered with a series of BID cloth plies to create a wing control surface. Here are the types of cloth materials and resins in general use today.

**Fiberglass**, combined with epoxy resin, is the most basic of composite material. It's made of fine glass filaments gathered

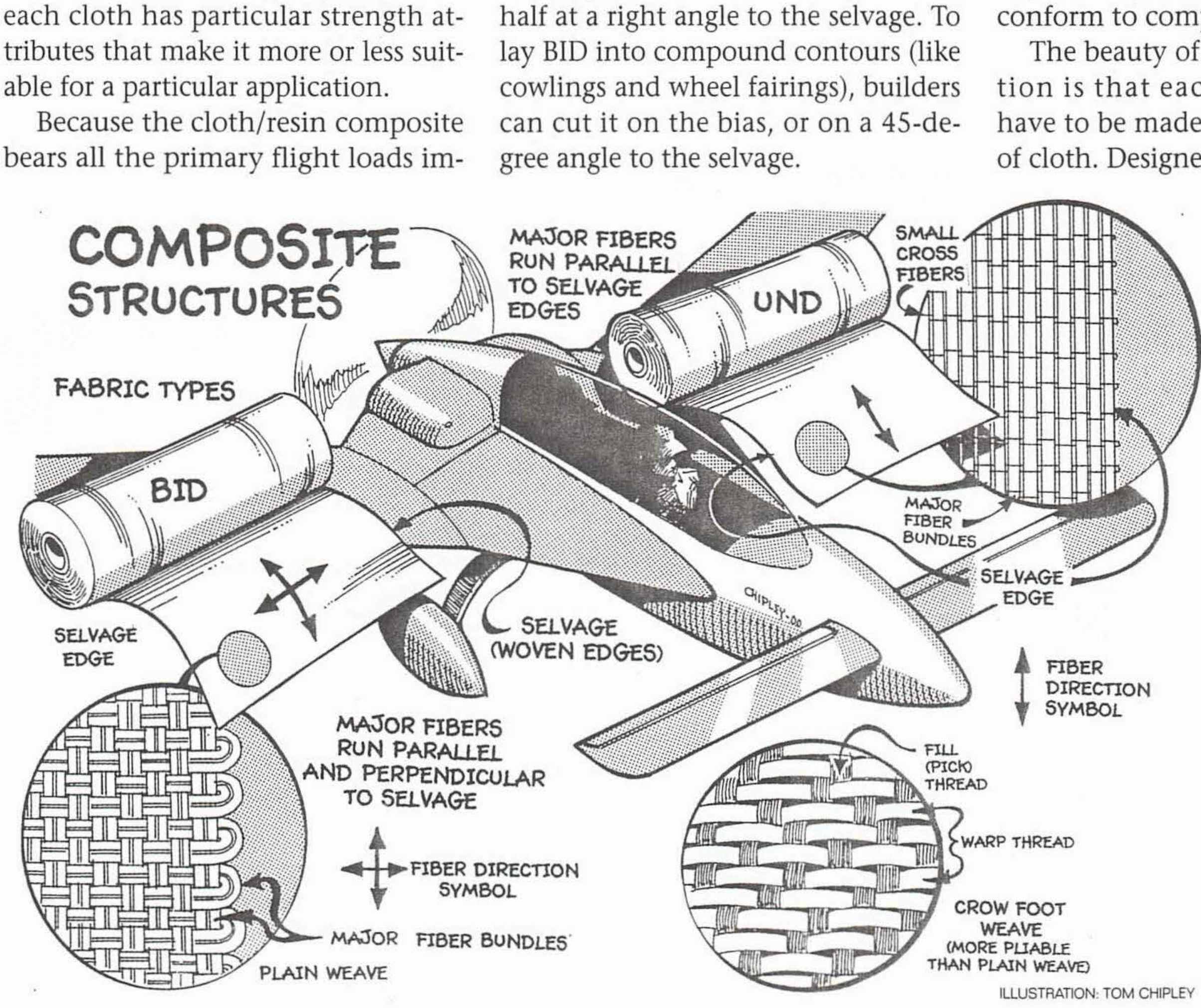


ILLUSTRATION: TOM CHIPLEY

into yarn that's woven into cloth of hundreds of different weights and weaving patterns. As fiberglass has been developed, it's been designated as E Glass and S Glass.

E Glass is the standard cloth used over the years to make components such as wingtips and wheel pants. S Glass is a newer fiberglass formulation that is 30 percent stronger, 15 percent stiffer, and three times more expensive than E Glass.

**Kevlar**, an organic aramid fiber Du Pont introduced in 1972, offers exceptional weight savings over fiberglass and has excellent durability when exposed to jet fuel, oil, water, and temperature variations. A Kevlar component weighs one-third less than an identical component made of fiberglass, but it costs much more than glass.

Kevlar can be difficult to work with. Cutting and drilling raw Kevlar and completed parts requires procedures and tools particular to the material, and builders should reserve these tools for Kevlar alone because using them on other composite materials dulls them. Manufacturers often use high-pressure water jets to drill and cut Kevlar without fraying it. A rigid backup reduces fraying when drilling and cutting Kevlar in the home workshop.

**Carbon Graphite** is another relatively new composite fiber, and many manufacturers have chosen it as their primary composite material because it can replace multiple layers of fiberglass and creates a lightweight panel with superior strength and durability.

**Ceramic Fiber** incorporates even newer technology that turns mineral fibers into cloth. When laminated, it can create components that approach the strength characteristics of S Glass, but it will withstand temperatures of nearly 3,000°F, perfect for lightweight firewalls. But it's expensive, with a square yard running around $200.

All of these fabrics are available in special tapes and strands that resemble heavy threads (often called "Tow"). These tapes and filaments can be used to strengthen structural composite components.

## Resins

Fabric alone doesn't make composite material. It requires an adhesive matrix to hold the fabric in a specific shape that can accept the loads imposed on it. Epoxy resin is the most commonly used adhesive matrix, and it's mixed with a hardening agent.

By itself, epoxy is weak and heavy. The first lesson builders must learn is how to work the resin into the weave of the fabric with a roller, brush, or squeegee to get the full benefit of its adhesive properties—without adding unnecessary weight to the component. Properly done, the resin/glass weight ratio should be less than 55 percent. Any more resin is additional weight without additional strength. In prepreg, tightly controlled production environments, manufacturers are able to approach ratios closer to 35/65 percent resin/cloth while still maintaining the strength of the part!

Many composite fabrics are available with the proper amount of catalyzed resin pre-applied to them. Called "prepreg" fabrics, they are often used in conjunction with the vacuum bagging process to create parts with a consistent distribution of mass, weight, and dimensions. Special handling requirements (like refrigeration and precise humidity control) to keep the resin from curing preclude most homebuilders from using prepreg material.

Like the fabrics they are applied to, there are different brands of epoxy resins that have different cure rates, or the time it takes the resin to harden. Early composite airplanes, like the VariEze, used Shell Epon 815 epoxy resin, followed by an RAE epoxy. With time, a number of builders developed an allergic reaction to RAE epoxy, and some of them had to abandon their projects.

To minimize the toxicity of the resins, the industry created Safe-T-Poxy in 1980, and its successor, E-Z Poxy, in 1996. Other epoxy systems have also been created for the homebuilder, many of them adapted from the marine industry.

Next month we'll address the other aspects of composite construction, including the various foams in use, vacuum bagging, tools, and finishing.

## Composite Safety

**Working with composites exposes builders to a new set of hazards. Besides developing an allergic reaction to the chemicals, some older resins contain known carcinogens. To protect themselves, builders should wear chemical resistant gloves or barrier creams, respirators, and eye protection.**

**Cut and sand composite materials with care because small carbon graphite fibers, for instance, can lodge themselves in unprotected skin and cause irritation and, possibly, infection until the offending fibers are cut out. Before working with any composite material, read all accompanying literature and follow the recommended safety procedures.**

Sport Aviation®

www.eaa.org

EAA'S MONTHLY MEMBERSHIP MAGAZINE

June 2000

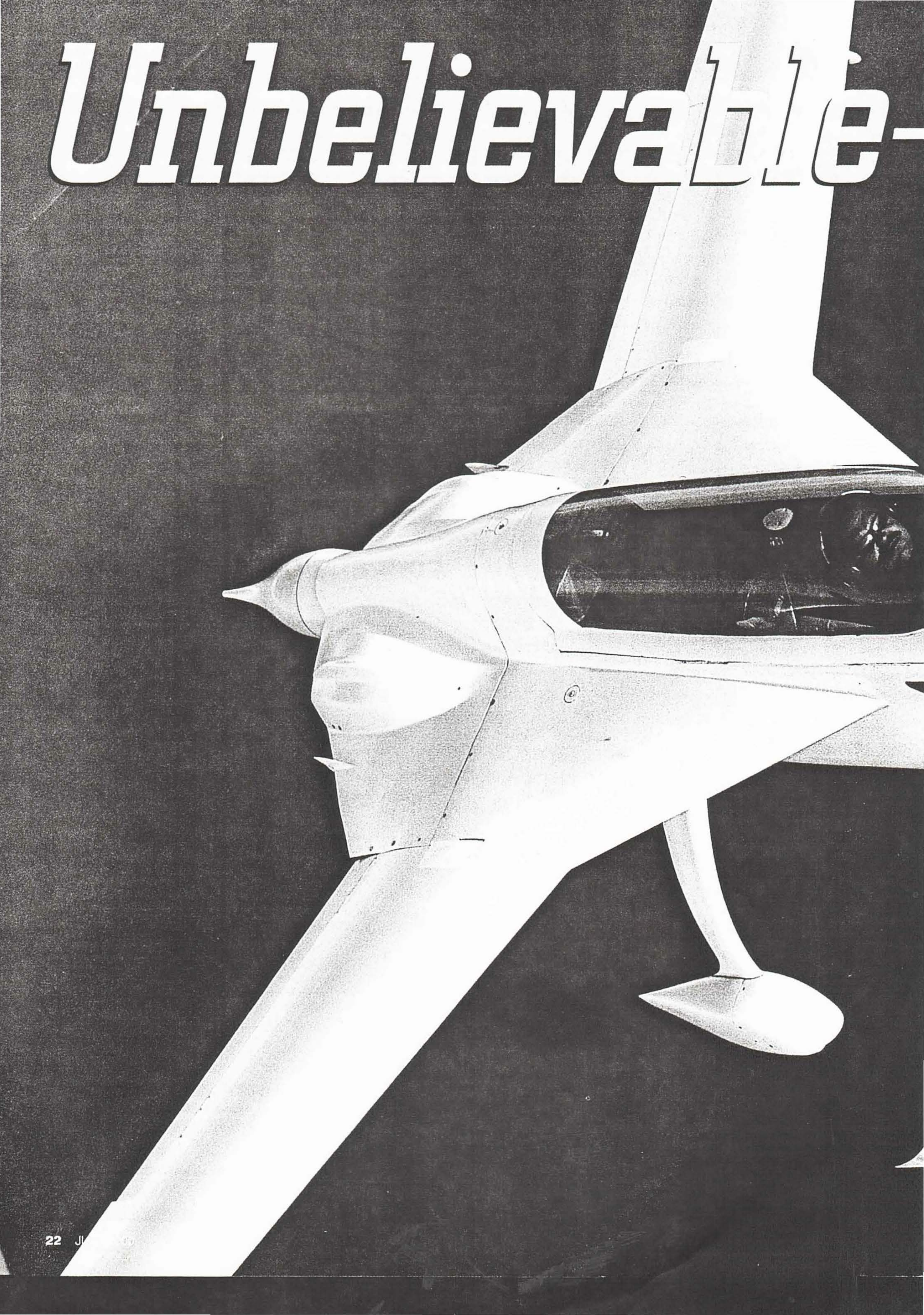
## Unbelievable-Eze

Modifications make the most of a design's performance and efficiency

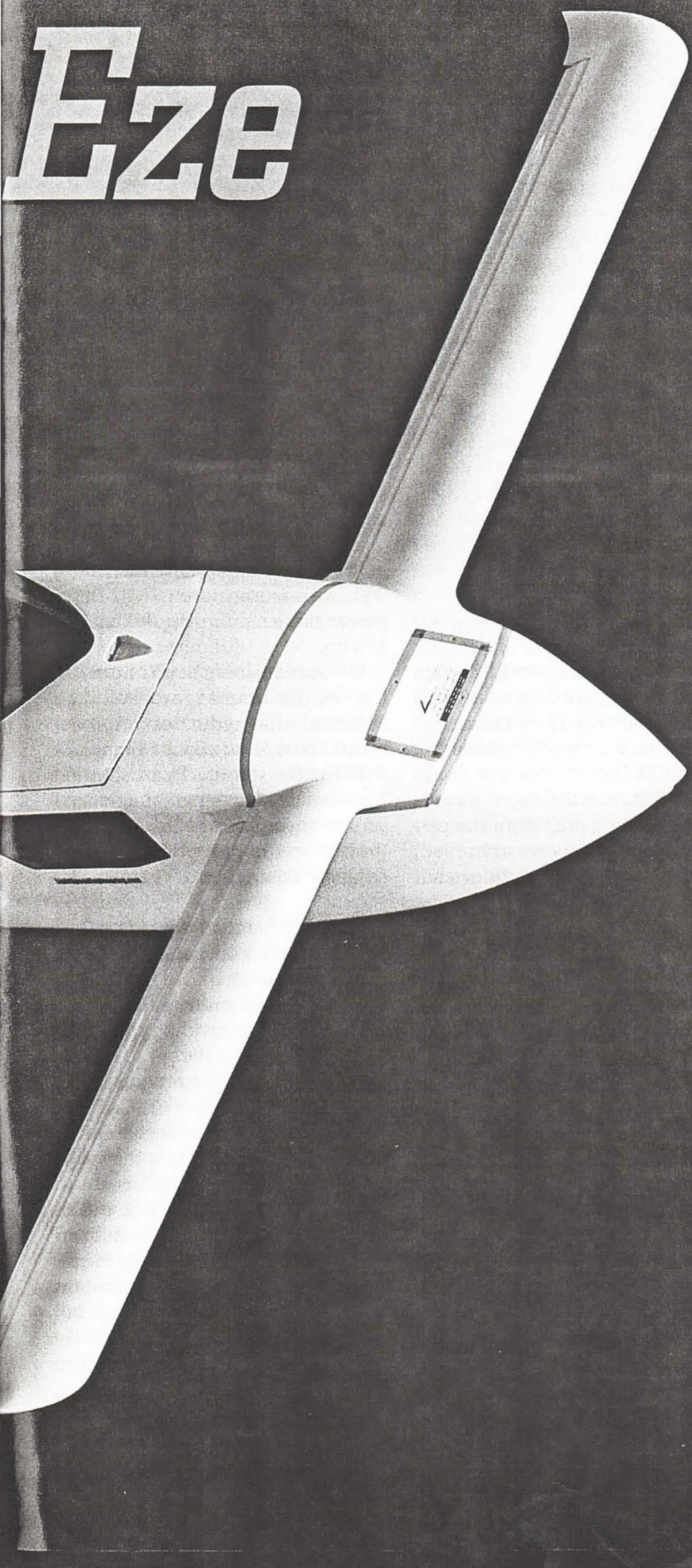
**Markings, Placards, Numbers**

**Closing the Engine GAP**

# Unbelievable-



# Eze



MARK SCHABLE

**Modifications make the most of a design's performance and efficiency**

CHARLIE PRECOURT

When the "god of aviation" smiles on you, the result is often an unbelievable flying experience forever etched into your brain. For me there was my first solo at 16, later flying the F-15 in Germany, then the amazing U-2, and, of course, a thrilling first flight in my own VariEze. Later memories of flying the MiG-21, the famous Spitfire, and the incredible Space Shuttle will forever be with me. And then there was Klaus Savier's VariEze. Better to call it the Unbelievable-Eze. If you're addicted to performance like I am, then you're bound to appreciate the label.

I've been flying Klaus' electronic ignition system on my VariEze for some time, and he recently invited me to fly his aircraft for some inspiration to make even more improvements. I was amazed! There's certainly a lot worth sharing with you after the great opportunity I had to fly his aircraft.

### *The Aircraft*

Klaus' VariEze is well known to most of us from his records and race victories. If you look at it casually you'd not think anything special of it. Klaus himself calls it "ugly" because the paint job has been altered in so many places. But air molecules don't know the difference between various shades of primer and finish paint. All they care about is smooth contours. The drag reduction changes he has made to the aircraft have made it much sleeker than any other Eze out there.

The Savier VariEze weighs 670 pounds empty with an O-200 engine (very light by VariEze standards). The following are the notable deviations from the plans-built configuration.

The canard is Klaus' design and it retains excellent handling and stall characteristics while achieving overall lower drag. It is at a lower incidence to accommodate the lower angle of attack that comes with the higher cruise speeds. It's specifically designed to maintain the same stall margin of the main wing. The winglet airfoils are also modified to give lower drag at the expense of some yaw stability, but this decreased stability wasn't significant during normal and accelerated flight maneuvers.

Addressing these two changes, Klaus prohibits hammerhead-type maneuvers to stay out of trouble with potential winglet stall, and avoids high pitch rates (stick snatches) during 1-G stall entries to preclude any possibility of a deep stall. It's unlikely that a deep stall could be achieved without moving the center of gravity significantly aft, but his self-imposed operating limitations are a smart approach.

Another modification was made to the wing airfoils near the ailerons. The span-wise distribution of lift is different in the aileron area from that on the standard VariEze. In addition to addressing drag, this change improved the aircraft's roll performance, making it a lot more pleasant to fly in the roll axis than the plans-built configuration.

Klaus also modified his engine, increasing the compression ratio, porting the cylinders, and installing an Ellison throttle body and fuel pump. He also installed a custom carbon composite oil sump and a ram air inlet to the Ellison. The magnetos were replaced with his dual electronic ignition system. He estimates the engine provides 145 hp at sea level at 3,000 rpm. Not bad for a 182-pound O-200 that started out with 100 hp rated at 2,750 rpm!

The Unbelievable-Eze incorporates a number of other modifications. To address drag, the modifications are a two-piece nose-gear door that leaves no cavity open to the airflow aft of the tire; custom wheel pants and main gear strut fairings; a modified NACA female air inlet and boat-tail lower cowling; new lower winglets similar to a scaled down Long-Eze lower winglet; custom "bat tips" on the canard (miniature upward turned winglets now pretty popular on Ezes); a custom "Hershey Kiss" prop spinner; aileron fences (small surfaces mounted vertically on the trailing edge of the wing at the outboard edge of the ailerons); and very tight seams everywhere!

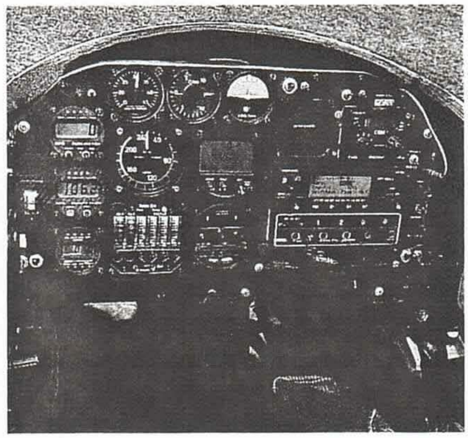
To extract more horsepower from the engine, the modifications are a custom propeller (Klaus' own design with 85-inch pitch), an eight-inch prop extension, a carburetor air ram inlet, and four individual exhaust stacks exiting into the cooling airflow stream at the cowl outlet.

### *Low Drag, High Speed*

Rutan Aircraft Factory (RAF) data shows the flat-plate drag equivalent of a standard Eze is less than 1.5 square feet, or a flat plate measuring just over 14 inches on a side could represent the entire drag of the aircraft. Estimating drag from the performance numbers we achieved, Klaus' VariEze has about 28 percent less drag than the standard configuration (or an equivalent flat-plate drag of one square foot!). The combination of increased horsepower and reduced drag works together for huge performance gains.

From the RAF flight manual, a standard VariEze has a top end of roughly 200 mph true airspeed (TAS) at sea level on 100 hp. Klaus gets approximately 251 mph TAS on 145 hp. The drag and horsepower equations can give us some back-of-the- envelope comparisons: $D = C_d 1/2 r V^2 S$ and $HP = 1/550(D x V)$, or substituting for drag, $HP = (1/550) C_d 1/2 r V^3 S$. Using both the flight manual numbers and Klaus' data as endpoints to enter into the above equations, you can guesstimate the respective contributions of the drag and horsepower improvements. Here are approximations of what would happen if you took a

**Klaus' nonstandard instrument panel is optimized for racing and fuel efficiency. Right, blue tape seals seams and decreases drag.**



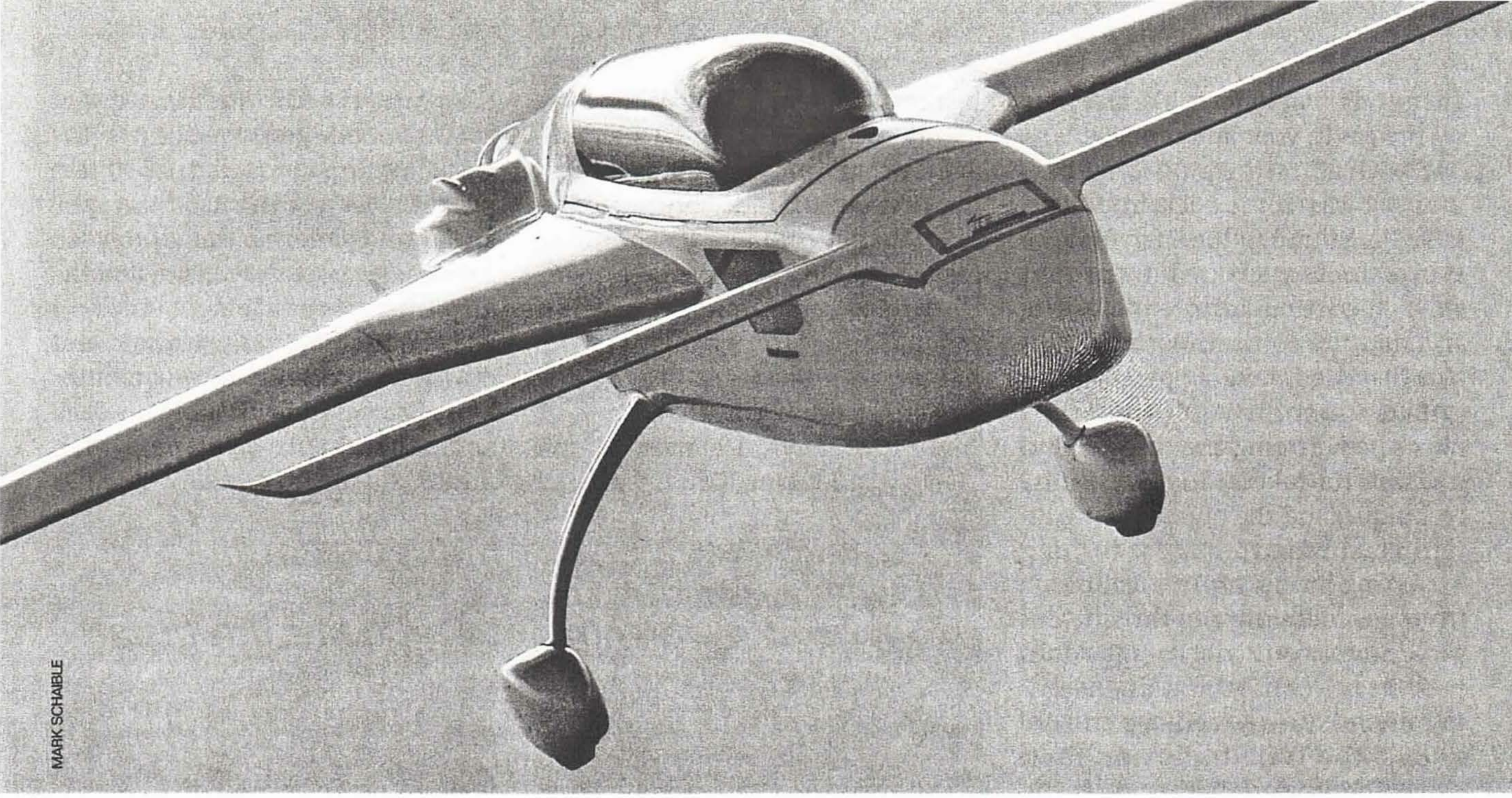
standard Eze and made either the drag or the horsepower modifications separately:

- For the standard Eze to achieve 251 mph from increasing horsepower alone requires approximately 188 hp.
- For the Savier VariEze on 100 hp, the maximum speed would be 218 mph (drag reduction improvements account for about 18 mph).
- For the standard VariEze with 145 hp (i.e., Klaus' engine), the maximum speed would be 226 mph (horsepower improvements account for about 26 mph).

### *Cockpit Evaluation*

Klaus' cockpit is optimized for racing and fuel efficiency. He has a nonstandard instrument panel that's well adapted to providing speed and efficiency cues to the pilot. A scan around the cockpit reveals these unique features:

On the left console a toggle switch that electrically positions the speed brake in any intermediate position replaces the speed-brake handle. This is a big advantage over the standard VariEze, which requires the pilot to hold the handle to maintain anything other than full open or full closed. The intermediate speed brake positions control airflow into the cowl, which prevents shock cooling on descent. Klaus also attached the speed brake switch to his throttle with a tether that automatically re-




tracts the speed brake when throttling to full power, a great safety feature for go-arounds.

The throttle quadrant is a standard Eze arrangement minus carb heat, which isn't installed because Klaus has an Ellison throttle body. He added a primer control, but it's located in the engine cowl, where it is convenient for hand propping (the VariEze does not have an electric starter due to the weight penalty).

On the lower left instrument panel are switches for Klaus' two independent electronic ignition systems. Because they rely on aircraft electrical power, an auxiliary battery provides ignition in the event of electrical system failure. The separate aux battery switch is logically located adjacent to the ignition switches.

Also on the lower left panel is a KS Avionics Tetra II Plus engine monitor that indicates CHT and EGT for all four cylinders, oil pressure, and oil temperature. The indicator displays these parameters in a "vertical tape" format that is really nice for managing the engine. Two lights on the instrument warn of shock cooling/CHT over temp and oil over temp. During descent for landing at reduced power, if the CHT shock-cooling light flickers, you can fan the speed brake open a bit to reduce the cooling airflow to the engine.

A fuel flow computer (quantity and flow indicating system) is on the instrument panel's left side and displays fuel flow to the nearest one-tenth of a gallon per hour. This is great for optimizing leaning for cruise. The display toggles through fuel remaining, fuel flow, and time remaining at the current flow rate and fuel used. A digital tachometer is on the instrument panel just above the throttle.

Klaus uses a Rocky Mountain Instruments airspeed computer ( Encoder). With a flip of a switch its LCD presents indicated airspeed and true airspeed in mph or knots. A standard airspeed indicator is installed as a backup. Adjacent to the airspeed indicator is the manifold pressure gauge and a glider-style variometer. For added safety in the event of unexpected weather, a 2.25-inch electric turn-and-bank indicator is installed, as well as a wing leveler auto pilot.

On the panel's right side are the avionics, including a primary and standby comm radio and a panel-mounted GPS with moving map. On the panel's lower right side are the switches for the avionics master and the fuel pump, and the throttle body installation required a fuel pump retrofit. This caused me a bit of a problem in flight, but more on that when I cover the flying characteristics.

## Flight Test

Klaus and I met at the Rosamond Airpark just outside of Edwards AFB, California, for this flight test. Together we flew to Mojave, where there was more room to do a decent flight evaluation. This gave me a chance to evaluate the aircraft from the front and the back seat, as well as operating in and out of small and large runways.

**Engine Start and Taxi**—The VariEze requires hand propping, but with Klaus' electronic ignition systems this it simple. With a cold engine, a couple of shots from the primer control mounted under the cowl and barely cracking the throttle gave a smooth start. More impressive was the engine's low vibration level. It can idle down as low as 450 rpm, and it really purrs. The low cockpit noise level and engine smoothness throughout the rpm range were truly remarkable. Advancing power, the smoothness leaves you hard pressed to believe there is a propeller attached to the aircraft; it simply feels like stepping on the gas in your automobile!

For the first hop out of Rosamond, I was in the back, and Klaus talked me through the aircraft's idiosyncrasies as we taxied to the runway. Of particular note is throttle and mixture control. With the Ellison installed, takeoff power is attained at a throttle setting below max open. Setting the throttle and mixture for takeoff involves some technique, and the objective is to attain maximum torque for turning Klaus' big propeller. The technique involves reducing the throttle approximately one inch of manifold pressure below full throttle and leaning the mixture to achieve an EGT rise on the Tetra indicator, then check for around 2100 rpm on the digital indicator.

On takeoff out of Rosamond, Klaus achieved 2150 rpm early in the takeoff roll. With two people (340 pounds) and half-fuel on board, we broke ground in about 1,500 feet on the 3,600-foot runway (1,085 pounds gross, 2,400-foot elevation, and 75°F), quite normal for an Eze in spite of the high-pitch propeller. The low cockpit noise level was really impressive! Klaus attributes this to the longer prop extension and the propeller design, as well as the well-tuned and balanced engine. The lower rpm levels help a lot, too.

Klaus demonstrated the aircraft throughout its entire operating regime. We leveled off quickly at 4,500 feet and the aircraft accelerated in level flight to 230 mph indicated with no effort. He performed a series of rolls, hard turns, slow flight, approach to stalls, and the one-G canard stall so I could be familiar with his aircraft before jumping into the front seat. What a machine! After a 15-minute orientation we dropped into Mojave to swap seats. But after pulling into the chocks Klaus thought I should fly solo to really appreciate the performance. What a trusting soul. After several "Are you sures?" Klaus insisted, so I jumped in the front and he gave me a final brief before I taxied out to the runway.

**Takeoff and Climb**—Unable to achieve the rpm that Klaus had on our first takeoff, I discontinued the takeoff after rolling a few hundred feet and taxied clear of the runway for some "remedial" instruction from Klaus. After going over the proper technique for setting throttle and mixture again, I was able to comfortably get 2,150 rpm and felt better about taking Klaus' pride and joy into the air! This peculiarity is the only item I would call a deficiency in Klaus' aircraft. It would be nicer to just push the throttle to the stop and be confident that you're at full power. But there was a steep learning curve for the required technique and I adapted to it easily during the flight.

*Manufacturers can learn a lot from the experimental movement and from the great achievements of people like Klaus Savier.*

None of Klaus' modifications had any effect on takeoff handling, but the preferred climb-out speed was much higher so the propeller could be operating near peak efficiency. Nosewheel rotation was crisp and predictable at around 55 knots, and at main gear liftoff (approximately 70 KIAS) I immediately noticed a similar (but smaller) disharmony between the roll and pitch axes that most VariEzes have. In the Eze pitch forces are lighter than roll forces, but Klaus has done a lot to improve this. I was off the ground in about 1,300 feet. Under these conditions the flight manual says a standard Eze would be off the ground in about 1,000 feet, so the change in takeoff performance resulting from the high-pitch cruise prop is noticeable but minimal.

The aircraft accelerated smartly to 130 KIAS and I started a climb to the west. In my Eze I usually climb at 100 KIAS, but Klaus' aircraft climbs just as well or better at 130. After setting in at 135 KIAS I estimated that at 900 pounds gross weight, the Eze was climbing at around 1,500 feet per minute. At this speed the deck angle was comfortable and provided a good view over the canard, and the airplane's side fuselage windows added quite a bit to the forward and downward visibility during climbs. Most Ezes climb with a higher deck angle than Klaus' airplane, which means the canard partially obscures the view of the horizon.

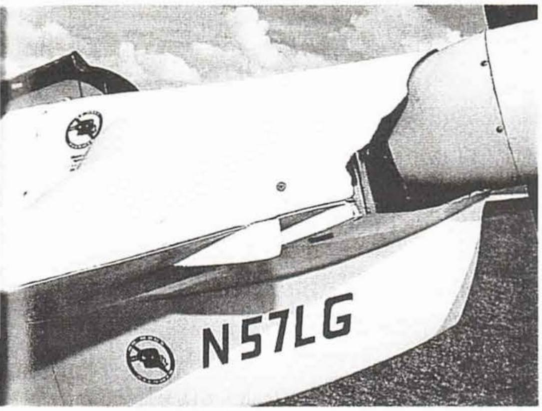
At maximum gross weight the Unbelievable Eze can cruise-climb at 175 KIAS and 500 fpm up to 13,000 feet. Amazing! On a good day my Eze is in about a 100-foot-per-minute descent at 175 KIAS (that's 201 mph at sea level)! What a revelation to see just how much potential this design has.

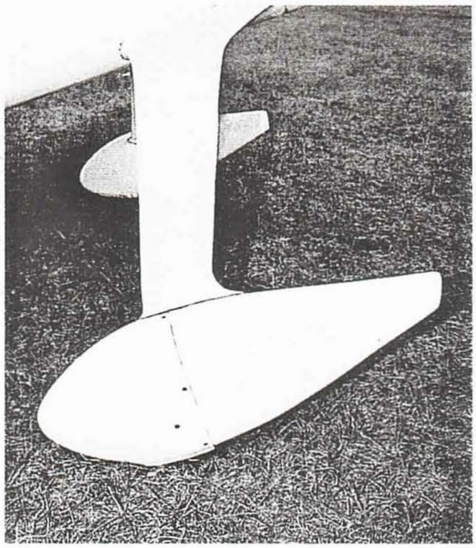
Leveling off at about 4,500 feet I watched the aircraft accelerate. Leaning a bit more and watching the rpm build, the airplane achieved an unbelievable 204 KIAS (235 mph) with 7.8 gph at 2,945 rpm! That works out to 217 KTAS (249 mph true airspeed)! In no wind you'd be getting roughly 32 miles per gallon at these speeds. I didn't get the chance to take it this high, but Klaus calculates that at 17,000 feet he gets 4.2 gph at 205 KTAS (235 mph). That's a no-wind fuel economy of 56 mpg! Awesome!

**Aircraft Handling, Stability, and Control**—The uninitiated might think that an aircraft this highly modified and extracting this kind of performance might be tricky to handle. That did not prove to be the case, and I was hard pressed to see any significant handling differences in Klaus' Eze—other than *improvements*.

**Longitudinal Stability**—The longitudinal stability characteristics of

**Aerodynamic modifications to Klaus' VariEze include: a two-piece nose-gear door; custom wheel pants and main gear strut fairings; a modified NACA female air inlet and boat-tail lower cowling; new lower winglets; custom "bat tips" on the canard (see lead photo); a custom "Hershey Kiss" prop spinner (see cover and lead photos); and aileron fences.**



LEE ANN ABRAMS PHOTOS

Klaus' Eze are similar to a standard Eze. The longitudinal static stability gradient is somewhat shallow, meaning low stick-force changes for a given airspeed change. The uninitiated will also find the Eze a bit sensitive in pitch. Minimum speed is approximately 55 KIAS, where a mild (about 1/2 Hz.) pitch bucking at very low amplitude (± 2 degrees in pitch) occurs.

My VariEze exhibits a slightly higher frequency and amplitude pitch buck at full aft stick at 55 KIAS. Like the standard VariEze, the Unbelievable-Eze's stick-force-per-G gradient in maneuvering flight is positive. Expect somewhat high forces (mostly due to the sidestick configuration's limited leverage) when maneuvering at higher G. This can be a good trait because it prevents overstressing the aircraft.

**Lateral Directional Stability**—Again I found minimal differences with the standard VariEze. Lateral-directional stability was positive throughout, but the amount of yaw generated per unit deflection of the rudder seemed slightly less than a standard Eze. This may be due to Klaus' different winglet airfoil design, or it may have simply been a difference in rudder rigging between our aircraft, but was not a significant difference.

Dihedral effect was strong, as it is in the standard Eze, and rudder alone would easily generate roll rate. Coordinating rolls with aileron and rudder results in the best roll rates. I performed several aileron rolls and noted the stick forces to be quite a bit lighter than on my aircraft. Full stick deflection rolls at 160 KIAS were on the order of 120 degrees per second; the rate in my Eze is about 90 degrees per second.

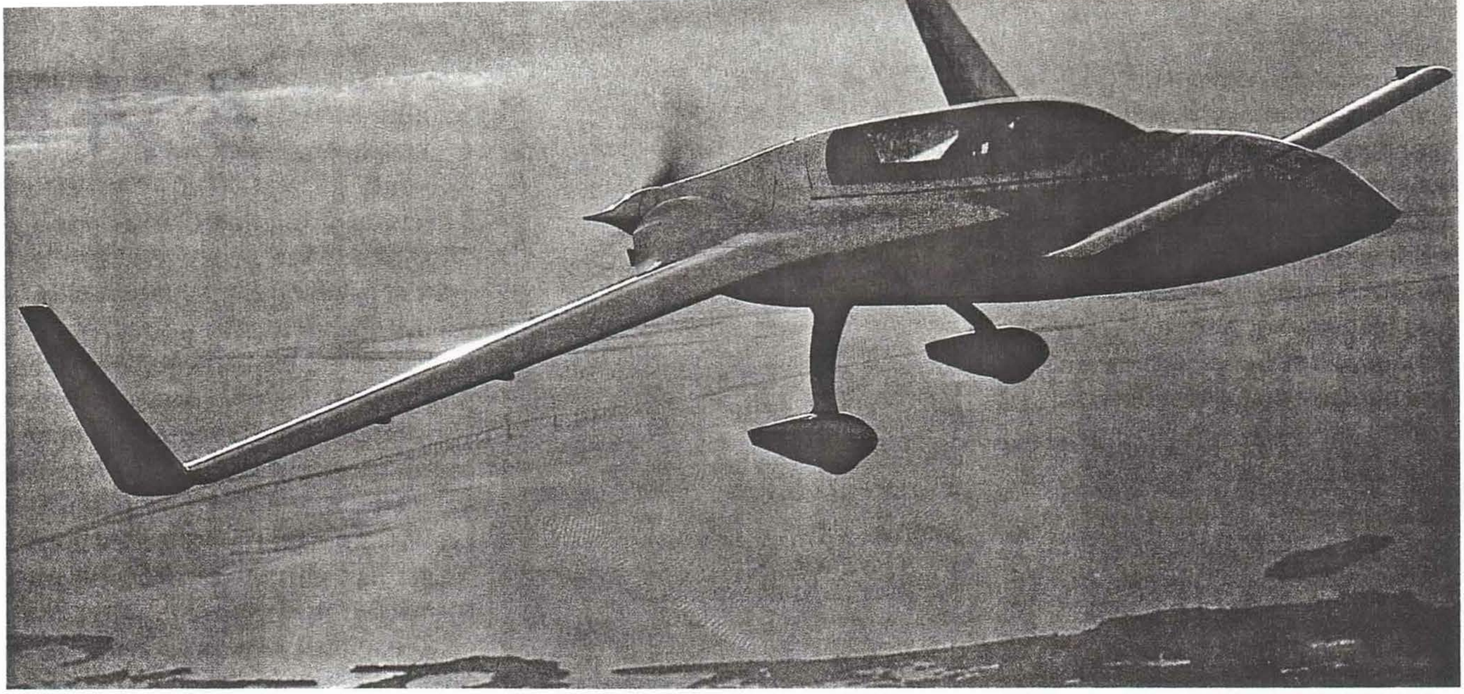
The full-deflection stick force was about 10 to 12 pounds compared to about 15 pounds on my aircraft. Needless to say, Klaus' aircraft is more pleasant in the roll axis. My aircraft also has small but noticeable adverse yaw at traffic pattern speeds, requiring attention to coordinating turns with rudder. Klaus' aircraft has less of this tendency. That may be due to the aileron fences he added as well as his wing and aileron airfoil modifications.

Another remarkable trait of Klaus' aircraft is the trim condition throughout the flight envelope. The aircraft remains trimmed in roll and yaw at all airspeeds. Spiral stability is neutral, meaning the distracted pilot will not find his bank angle increasing without input. These characteristics make for pleasant long cross-country flights and an autopilot truly optional.

It's important to note that we all can't just change our airfoils and propellers and expect an aircraft as well behaved as Klaus' Eze. Making changes like Klaus has is serious business and should be done with good aerodynamic understanding and slow, thorough flight test verification. Klaus has done all of that. In the Eze's normal operating ranges, to include aggressive maneuvering flight, Klaus' aircraft handling qualities are as good or better than the standard Eze. Klaus has wisely set the appropriate operational limits on his design to stay within a safe envelope. So with a proper approach and good test practices, the new envelope can be every bit as safe as the basic design.

**Approach and Landing**—At the speeds Klaus' Eze cruises, slowing down is a significant problem. Pulling the power for descent while indicating more than 200 mph results in a significant CHT drop, but opening the speed brake about 20 percent will stop the CHT warning system's blinking light. This is a great feature for managing the engine.

After lowering the gear I looked through the window between my legs to visually confirm the down position and thought I saw loose cabling flapping free inside the wheel well. Then I remembered that Klaus had modified the aft nose-gear door installation. It's a spring-loaded door with a bungee cord to hold it closed. When retracted the nosewheel pulls up on the bungee, which in turn pulls the aft door closed behind the wheel. It's a simple system that



MARK SCHAIBLE

works really well.

The pattern and landing were just like my own VariEze. The aircraft has good controllability on final, throughout the flare, and on touchdown. Approaching the final flare I noticed that the view out the side fuselage windows was something new—kind of like being in a helicopter! I took a few glances to see if there was anything visually useful, quickly realized there wasn't, and returned to the normal cues down the runway and peripherally. To the uninitiated, having those extra windows could be distracting, but adapting to them is straightforward, and greasing it on the runway was really easy.

### Performance Comparison

As a final exercise I compared the performance numbers in the RAF flight manual to the Unbelievable-Eze. As noted, takeoff performance is slightly degraded. Climb rates are significantly greater in Klaus' Eze. The manual's maximum rate-of-climb speed is 80 KIAS, and the sea level rate of climb at 1,050-pound gross weight is 1,550 fpm. Klaus' Eze achieves that climb rate at 130 KIAS!

At 4,500 feet the manual's full-throttle speed is 200 mph indicated. Klaus' Eze is essentially 50 mph faster. Flight-manual fuel economy is 28 mpg at 200 mph at 8,000 feet. The Unbelievable-Eze is nearly double that, and its 30-gallon fuel capacity translates to nearly 1,500 miles nonstop!

Because of the drag reductions Klaus has achieved, engine-out glide performance is significantly improved. The manual's glide ratio at 75 KIAS is approximately 15:1. RAF data are 15.8:1 with the engine at idle and 10.5:1 with a windmilling engine. The ratio for a failed engine and stopped prop isn't available, but other Ezes have demonstrated 15:1 with a stopped prop. Klaus has achieved 20:1.

The landing performance numbers are unchanged. Rollout distance was estimated at about 1,300 feet from a touchdown of 70 KIAS (900 pounds gross weight at 2,300 foot density altitude).

This test hop was truly a pleasure, and I thank Klaus for sharing his pride and joy with me. The aircraft is a masterpiece in speed and efficiency and is fun to fly. I'd like to see a single lever engine control (just dreaming: how about an electronic fuel injection system?) to reduce the workload of managing the throttle body. I'm hard pressed to recommend any other changes to improve a nearly perfect aircraft. The notable characteristics were the really quiet cockpit, the amazing top end speed and efficiency, the perfectly rigged control system, and the great maneuverability.

The other important finding was how much potential there is in basic aircraft design for improved efficiency and performance. When the major manufacturers can give us horsepower increases of 50 percent like Klaus has achieved without a weight penalty, can reduce drag by 20 percent or more, and can improve fuel efficiency by nearly 100 percent, then we'll see great things in aviation.

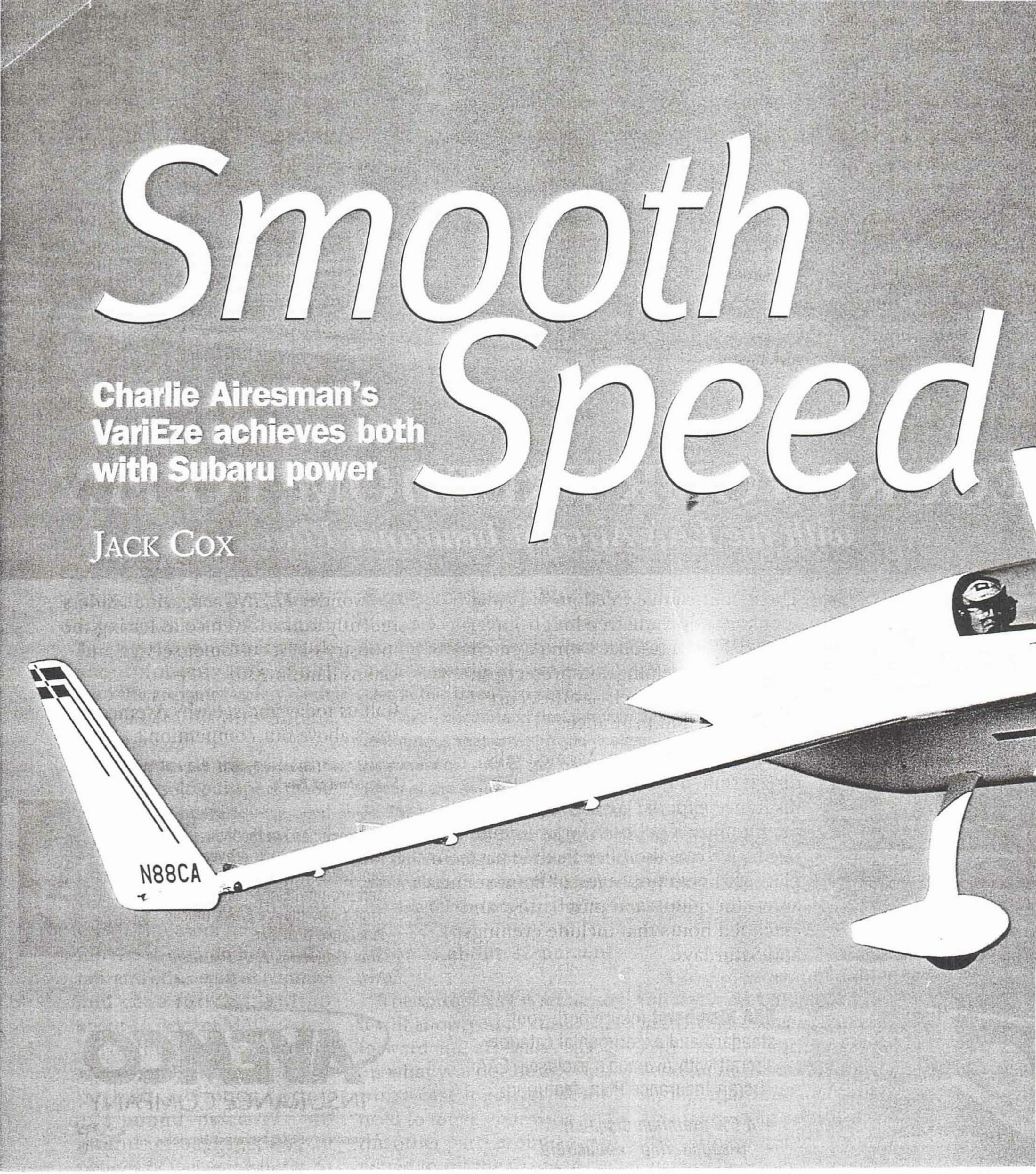
Manufacturers can learn a lot from the experimental movement and from the great achievements of people like Klaus Savier. For an old fighter pilot/astronaut addicted to performance, this is an aircraft I'd love to have for an off-duty toy! Klaus' improvements have inspired me to keep working on improving my own Eze. I may never attain his level of performance, but it certainly is the standard to strive for.

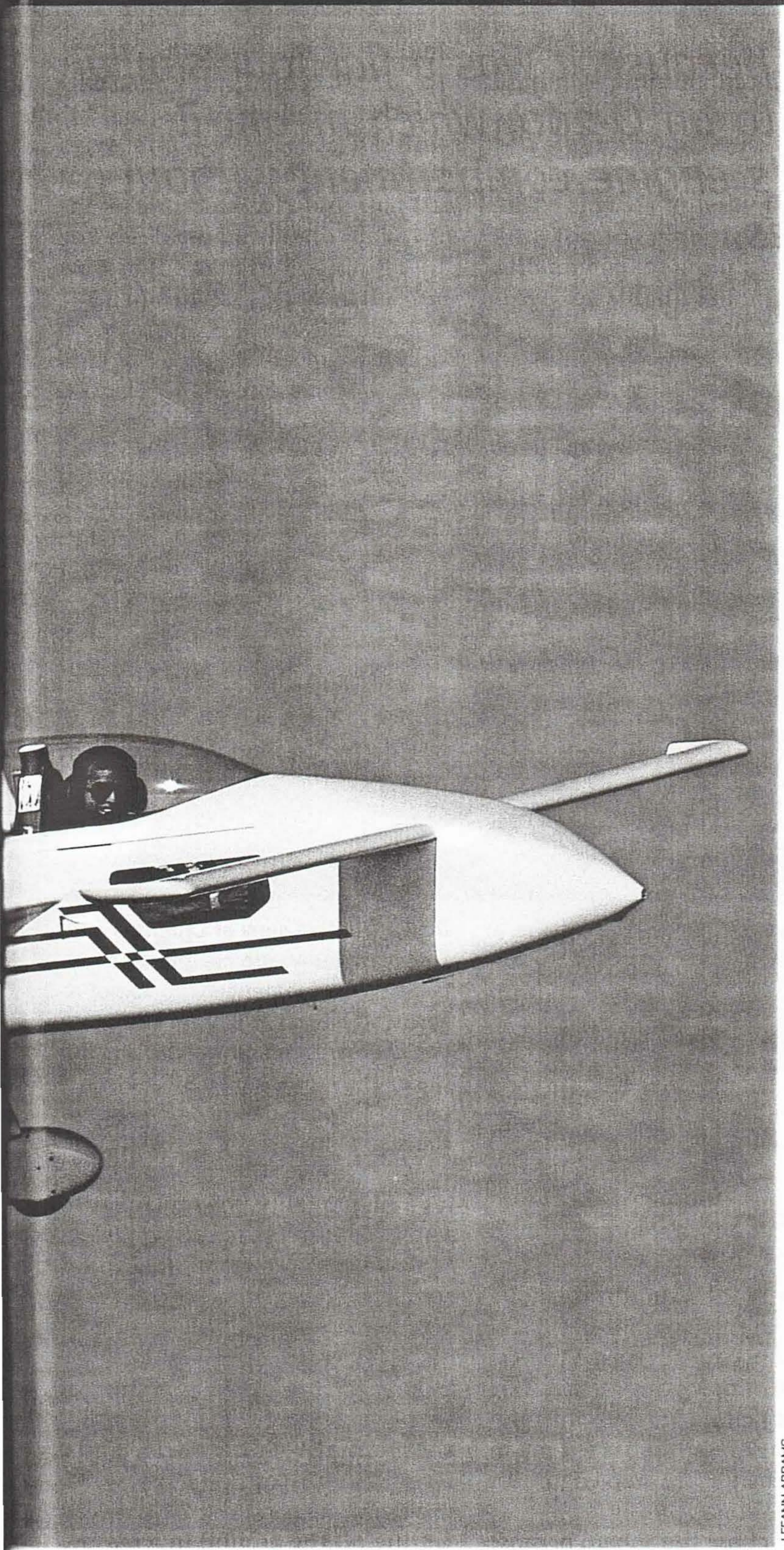
*USAF Colonel Charlie Precourt is the Chief Astronaut in NASA's Shuttle and Space Station programs. He has 7,100 hours in more than 65 aircraft types, and as a test pilot at Edwards AFB, he flew the F-15E's developmental test program in the late 1980s and taught at the USAF Test Pilot School. He's flown four space missions, including three docking missions with the Russian Space Station Mir, twice as mission commander. He built his own VariEze in the late 1970s and continues to fly it in his spare time.*

# Smooth Speed

**Charlie Airesman's VariEze achieves both with Subaru power**

JACK COX





LEEANN ABRAMS

**Charlie adapted several of Klaus Savier's VariEze airframe modifications, including side windows in the fuselage for a better view downward.**

Most EAAers are familiar with the exploits of VariEze aces Klaus Savier and Gary Hertzler. They have set a host of records in their respective Ezes by refining their airframes, engines, and propellers to a degree that even designer Burt Rutan probably never envisioned when he introduced the revolutionary little canard airplane in 1975.

Though lesser known, others have chosen the VariEze as the test bed for their ideas on drag reduction and overall efficiency. Among them is Charlie Airesman of Cumberland, Maryland, who grabbed the attention of the EAA world in 1993 when he completed the Sun 100 race at a speed of 225.45 mph.

That speed garnered him only 17th place, but knowledgeable EAAers recognized that the 16 racers finishing ahead of him had the advantage of 120 to 340 additional cubic inches of engine displacement to power them around the triangular racecourse. No one else was close to Charlie in terms of miles per hour per cubic inch.

Charlie ran that race with a Continental O-200 boosted to 9-to-1 compression, with an Ellison throttle body injector and one of Klaus Savier's early electronic ignitions. He had also borrowed Klaus' composite racing propeller and pressure recovery spinner. The firewall aft modifications were only part of the story, however; Charlie put just as much effort into refining the airframe.

When he built the Eze Charlie narrowed the firewall to reduce the acuteness of the fuselage's aft end taper because he knew that trying to bend the slipstream more than 6 or 7 degrees back to the prop was a source of a lot of drag. A 6-inch prop shaft extension helped to stretch out that taper.

Charlie eliminated still more drag by means of a flush NACA belly air scoop for the engine, with the inlet reduced to 24 square inches;

*Charlie chose the Subaru because it was a flat four similar in configuration and size to an O-200, which meant it would fit into the VariEze's engine compartment without extensive airframe changes.*

flush-fitting nose gear doors and belly board; and wider, airfoil-shaped main gear legs. He even machined his main gear wheels down to permit the use of narrower wheelpants!

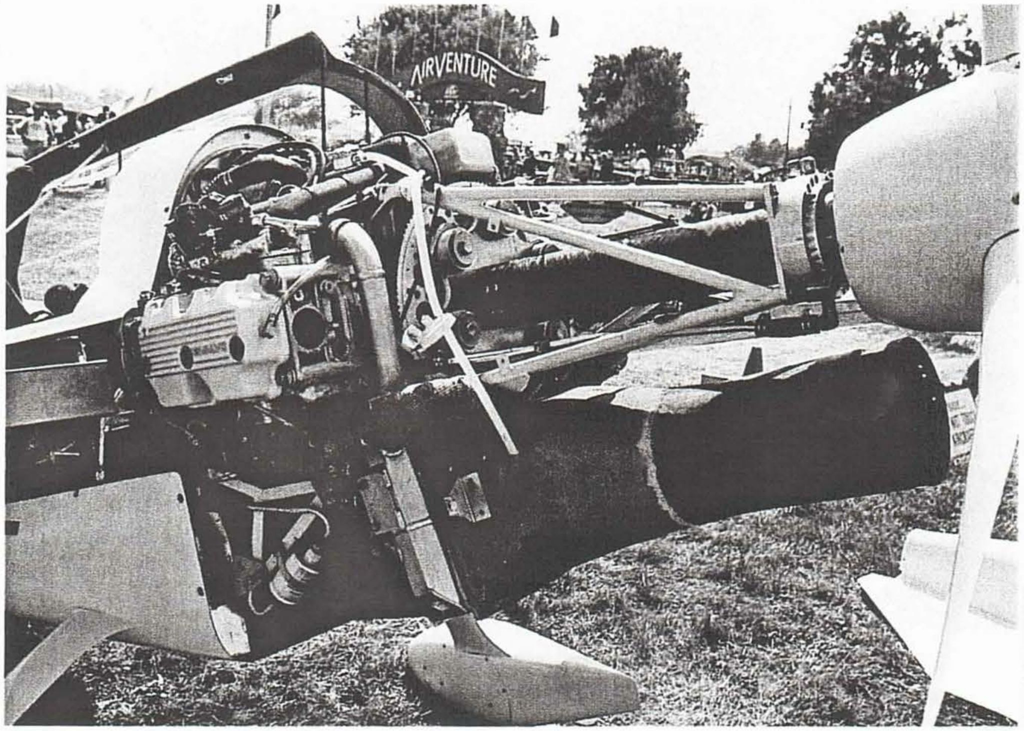
While modifying his VariEze provided him with the means for satisfying his creative urges, Charlie was never satisfied with its engine. "I'd always been impressed with how the VariEze airframe cruised so fast on so little power," Charlie says, "but the torsional resonance of its aircraft engine drove me nuts. You'd land, get in your car, and its engine would be as smooth as glass—a contrast that bothered me every time I flew."

This is not a criticism aimed solely at the Continental O-200, Charlie points out. It includes all the flat fours used in lightplanes. The great Harold Morehouse designed the progenitors of all the current Continentals and Lycomings in the late 1930s (he was employed, successively, by both companies).

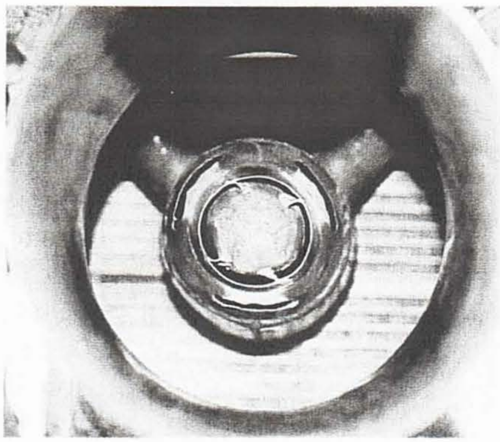
Morehouse had to work within the limitations imposed by the metals and lubricating oils available at the time. In practice that meant slow-turning engines with large displacement for the power derived. Unfortunately, that also meant that, compared to modern high-revving auto engines, they were—and are—real thumpers.

Charlie's radical solution for his engine's inherent roughness came as the result of a rare engine failure. "On a cross-country out west, the Continental ate a cylinder and caused a lot of internal damage. I was looking at a high dollar rebuild—new crank, new cylinders, the whole nine yards—so I decided it was time to do something different. I wanted the smoothness of a higher revving, smaller displacement engine, and I wanted to take advantage of the lower cooling drag I thought I could achieve with liquid cooling. This is what led me to adapt a Subaru EJ-22 auto engine for use in my VariEze."

Charlie chose the Subaru because it was a flat four similar in configuration and size to an O-200, which meant it would fit into the VariEze's engine compartment without extensive airframe changes. He was also impressed with the Subaru because it's a high quality powerplant with an excellent record for durability.




JACK COX PHOTOS



**Obvious in this view of Charlie's engine installation are his square tube, bed-type engine mount; the use of a flywheel; tubular mount for the carbon-fiber wrapped driveshaft; and the augmentor tube. Left, Charlie's bullet-shaped muffler is buried inside the augmentor tube.**

There were some potential showstoppers, however. As far as Charlie was concerned, the weight of a reduction drive in an airframe as small as the VariEze—and a pusher, at that—was out of the question. But the alternative, direct drive and a fixed-pitch prop, posed its own problem, the compromise between getting off the ground in a reasonable, safe distance and going really fast. It was a problem because Charlie knew his bias would be in favor of speed.

This was a real dilemma until he saw Bruce Bohannon out drag a

MiG-17 at Oshkosh in his Formula One racer, *Pushy Galore*.

"It was a pusher, it was direct drive, and it was getting its thrust from high rpm. I thought, by golly, the Subaru can easily turn that fast, so I ought to be able to make one work in the VariEze."

Charlie initially replaced the Continental O-200 with a 2.2 liter Subaru EJ-22 with a 19-inch long, 3-inch diameter, 0.125-inch wall, 4130 steel drive shaft; two of Klaus Savier's Lightspeed electronic ignitions; and a carburetor.

One modification Charlie really didn't want to undertake was fabricating a custom carbon fiber intake manifold, because it would mean losing the tuned lengths of the stock intake. But the custom intake was necessary to fit the engine in the VariEze's tight cowling. To avoid the probability of having to go through several fixed-pitch propellers to find the best pitch for takeoff and cruise, Charlie used a Warp Drive ground-adjustable propeller he cut down to a diameter of 52 inches.

Weight and balance became a problem once the heavier water-cooled engine was ready for installation, forcing Charlie to come up with an engine mount that would move the Subaru as far forward as possible. His initial efforts were to somehow adapt the O-200 mount, but he ultimately designed and built a totally new bed-type mount that tied into the landing gear structure—the configuration that flashed into his mind one night while lying awake puzzling over the problem.

One of the principal goals of the re-engine project was to significantly reduce cooling drag, and the setup Charlie settled on was an essentially straight-through passageway for the air. After entering the flush belly scoop, it would pass through an 8-by-1.75-inch inlet, expand to the 12-by-12-inch radiator, pass across the bottom of the airfoil-shaped, carbon fiber oil pan, and then exit through an augmenter tube 6.5 inches in diameter. The exhaust system consisted of straight pipes that dumped into the augmenter tube to help extract the cooling air.

The first flight of the re-engined VariEze was in 1999, and as is usually the case with so radical a transplant, some things worked well and some did not. The first problem manifested itself the instant the engine cranked up for the first time. It was LOUD! Straight pipes into an augmenter tube functioned like a megaphone, but at least there was little back pressure to reduce power output. A greater concern was a higher than desirable oil temperature, due in part to the lack of an oil cooler, which Charlie had hoped to avoid to save weight.

Another problem was the carburetor. Charlie says it was a nightmare from the start, and he was never able to get the mixture distribution right. This was a contributing factor to the most serious operational problem of them all—"really anemic takeoff performance."

Initially, Charlie attributed that problem to his prop, which restricted the engine to 3500 rpm. He managed to get the revs up to 4000 by reducing the prop's diameter still more, but that only increased the top speed a bit. The takeoff roll just got longer.

There were some successes. As hoped, the engine was extremely smooth, and despite the carburetor problems, the fuel burn was slightly less than with the O-200. Top speed was about 200 mph. On balance, the engine was reliable enough for Charlie to fly to EAA AirVenture Oshkosh 1999, a trip that would result in a major improvement in the airplane's performance.

At EAA AirVenture Charlie sought out Tracy Crook, who had developed a controller for the electronic ignition/fuel injection system on his Mazda rotary engine conversions, and was pleased when Tracy agreed to build one for his Subaru.

"Tracy really came to my rescue, " Charlie says. "I installed his system, and it really worked well. It is totally redundant, except for the coils and injectors. If I lose an injector, I lose one cylinder, and if I lose a coil, I lose two cylinders. I could make those redundant, also, but it's such good quality stuff that I don't think I'll have a problem. To use Tracy's system I had to reinstall the stock Subaru starter (in a non-stock location), but I was tired of hand propping, anyway."

While he had the airplane down, Charlie decided to build a second, more powerful Subaru conversion for his Eze. It began as a 2.5 liter EJ-22, but to gain the greater efficiency of higher compression, he installed 2.2 liter heads, which raised the ratio to 11.5 to 1. High by aircraft standards, that much compression was not anticipated to be a problem in the Subaru because it's liquid cooled and Charlie intended to use 100 LL avgas rather than lower octane auto fuel.

Hoping to reduce the oil temperature, Charlie moved the radiator back behind the oil pan—and it worked. The coolant temperature had always been low enough that he felt secure in reducing the augmenter tube's diameter from 6.5 to 5.5 inches. Cooling remained adequate, but Charlie says he should have left the diameter at 6.5 inches, and he had to extend the prop shaft a bit to clear the repositioned radiator and augmenter tube.

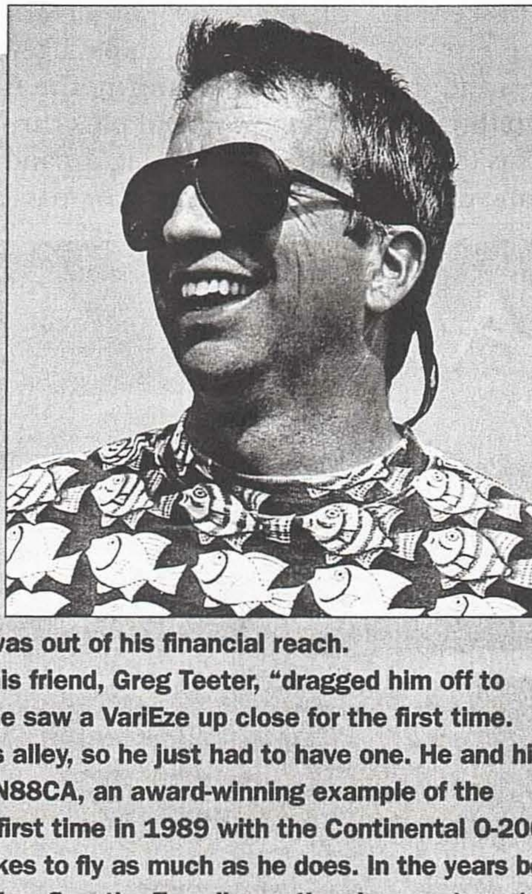
A significant decision was to revert to the Subaru's flywheel. Cut down to 10 pounds, it was required for the starter and to help dampen firing pulses that could lead to drive shaft failure. In combination, the flywheel and the rubber isolators Charlie used further added to the engine's smoothness and helped dampen torsional loads.

Charlie addressed the noise problem in a somewhat novel fashion. He built a bullet-shaped muffler into which the two-into-one exhaust pipes from each bank of cylinders extended, and he positioned the muffler in the center of the augmenter tube. It proved to be an effective (and necessary) solution, but he found he had lost several inches of water column negative pressure when he measured the flow through the augmenter.

For the second-generation engine Charlie built his own two-blade composite prop—composite laminate over wood, actually—with very thin tips. It was driven by a new 2024 aluminum extension shaft, 3 inches in diameter, 1/8-inch wall thickness, and wrapped with carbon fiber for additional stiffness.

When completed, the engine ran per-

## Charlie Airesman


JACK COX

**Charlie Airesman was born in Cumberland, Maryland, in 1956 and has lived there all his life. A controls technician for a gas transmission company, he works on complex equipment like industrial turbines. He built model airplanes as a youngster but always assumed that flying and aircraft ownership was out of his financial reach.**

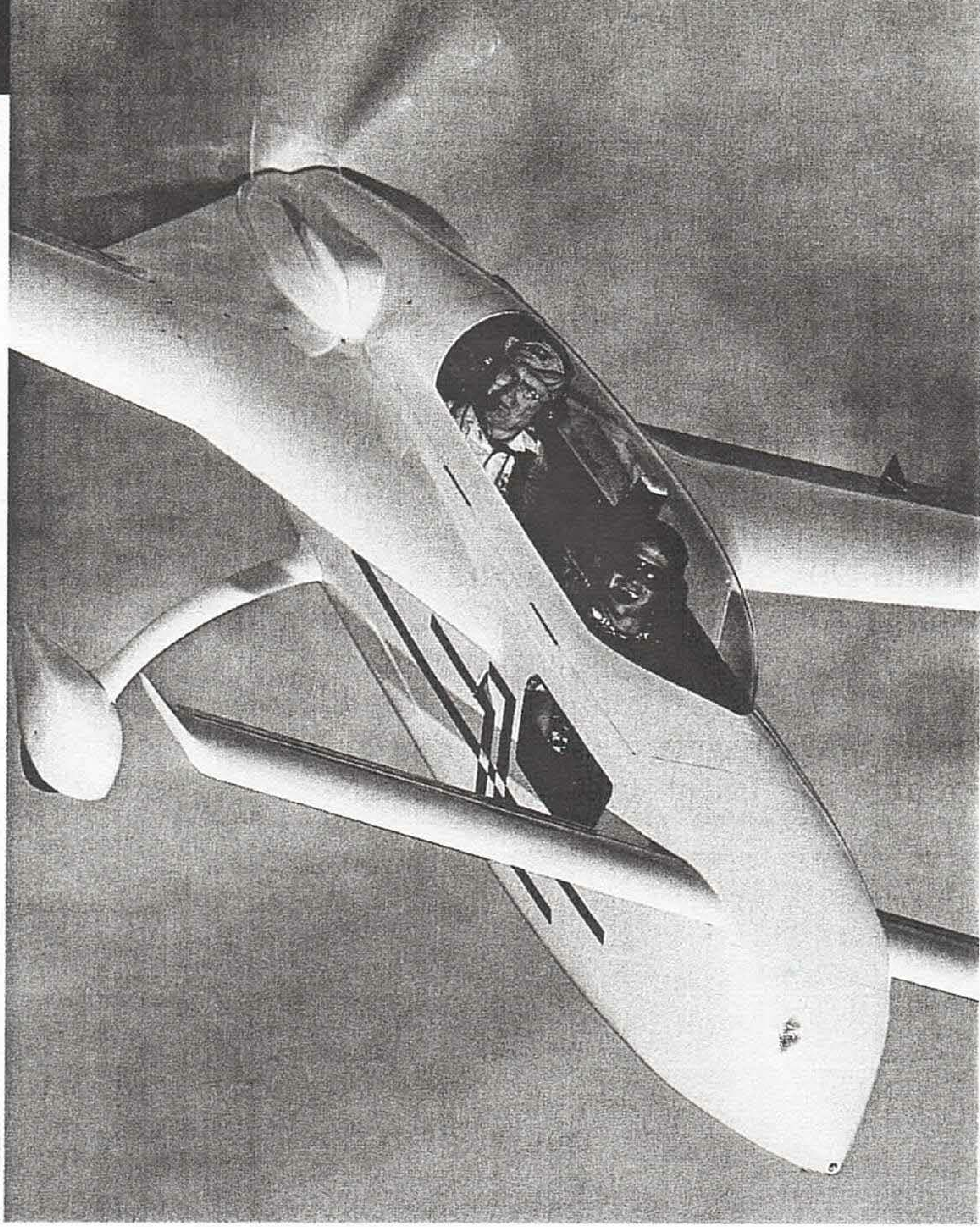
**That changed when his friend, Greg Teeter, "dragged him off to Oshkosh" in 1986 and he saw a VariEze up close for the first time. Building was right up his alley, so he just had to have one. He and his father, Charlie Sr., built N88CA, an award-winning example of the type, and it flew for the first time in 1989 with the Continental O-200.**

**Charlie's wife, Dee, likes to fly as much as he does. In the years before the engine change they flew the Eze all over the place, out west, to the Bahamas, to Cape Hatteras for wind surfing, and to the Florida Keys (where they flew on their honeymoon). Change has come to the Airesman household, however. They now have two young children, so the VariEze no longer fills their aerial transportation needs. Charlie is now well along on a Cozy he intends to power with two Subaru EA-81 turbocharged engines, and it will look like a mini Beech Starship.**

**"I need two airplanes," Charlie says, "one to work on and one to play with. When I get the Cozy flying, maybe I'll get the VariEze the rest of the way up to speed. I think there's potential left in both the Subaru engine installation and the airframe for even greater efficiency."**

fectly, boosting the Eze's top speed to 238 mph—but the takeoff roll was still too long. "With two aboard on a hot day, I felt I needed 4,000 feet of pavement to be safe on takeoff. I could get off in 2,500 to 3,000 feet, but the climb was such that I needed the extra runway to clear obstacles," Charlie said.

He still managed to fly to EAA AirVenture Oshkosh 2000, and, once again, a friend came to his rescue and solved a major problem. "Gary Hertzler is a good friend, and he agreed to design a three-blade propeller for me with airfoil sections that would provide a lot of lift. He sent me an e-mail spreadsheet, and I simply printed the sections out on the computer. Then I used them to cut a plug for each blade out of foam and pulled molds off the plugs. I put the molds together and built a prop that was all composite, except for maple drive lugs," Charlie says.



LEEANN ABRAMS

"Man, what a difference! When I first ran it up, I got about the same static rpm as with my two-blade prop—but I was shoving on the brakes hard and could feel the nose going down. 'This thing is going to work,' I thought—and it did. It reduced my takeoff roll significantly and increased the rate of climb."

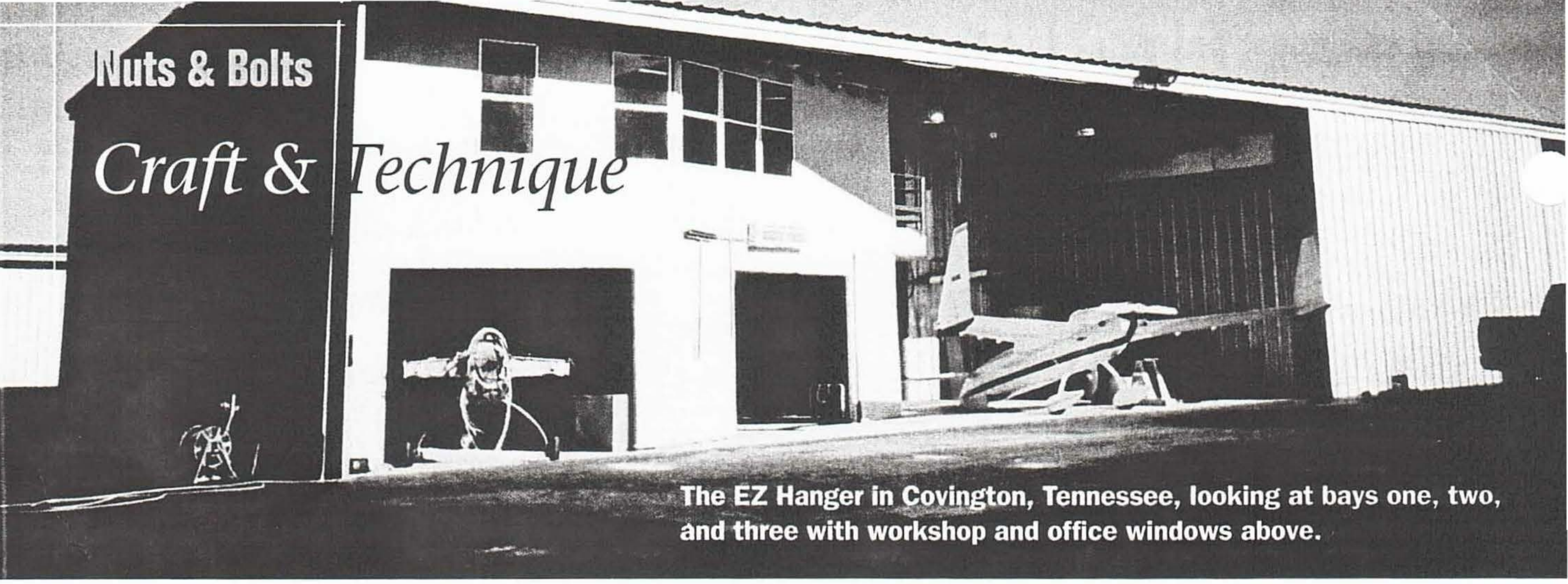
When he arrived at EAA AirVenture 2001, Charlie had achieved most of the goals he'd set for the Subaru conversion. "Gary had designed the three-blade prop for 4000 rpm. It is 53 inches in diameter, and the pitch is 61 inches. I get 2800 static rpm, and at low speed, just flying around sightseeing at 160 to 170 mph, it turns around 2800 rpm. At 3100 rpm I initially climb at 1,000 fpm. When climbing to altitude, I climb faster to get the engine rpm higher, typically at 175 mph and around 700 fpm. I have no problem climbing to 17,500 feet, and, yes, I have an oxygen system. I don't cruise any slower than 160 to 170 mph, and I'm at less than a quarter throttle there, burning around 2.5 to 3 gallons per hour. After all these years, people still don't seem to realize just how efficient the VariEze airframe is. The flat plate area is very small, and with the canard, you're not dragging a down-loaded tail through the air. Combine that with a high compression, liquid-cooled engine, and you have a very, very efficient airplane," Charlie says.

"At 10,000 feet I see 210 to 215 at 2450 rpm and 4 gph. On cross-country flights, if the weather and head winds permit, I usually cruise above 15,000 feet at full power—3600 rpm at 225 mph burning less than 5 gph. Top speed at sea level is down slightly from what I was getting with the two-blade prop—232 mph at a shade under 3670 rpm—but that's a more than acceptable trade-off for the increased takeoff and climb performance. The Subaru is as smooth as I hoped it would be and very economical to operate. While it is not as noisy as the Continental, it is still not as quiet as I had hoped for."

A question that always comes up regarding auto conversions is weight. Even with a starter, nav lights, a coolant radiator and the necessary connecting hoses, a gallon of coolant, two batteries (redundancy for the electronic ignition/fuel injection system), and little extra items such as a roll trim system Charlie built using a power window motor, the airplane weighs just 30 pounds more than when equipped with a Continental O-200. The new empty weight is 730 pounds. Charlie says he considers anything more than 700 pounds to be excessive for a VariEze, but notices little difference in the airplane's handling or performance.

Cost is another factor EAAers want to know about. Because his project stretched over several years, with a number of significant reworks and changes along the way, it is difficult for Charlie to put a number on the cost of his Subaru conversion, but it is less than a new or fully rebuilt O-200. He does caution other VariEze builders to think long and hard before starting a similar project, however.

"Unless they have the background and facilities to build a lot of things themselves, such as the carbon fiber intake manifold, prop shaft and its tubular mount, oil pan, etc., it's probably not a good idea to start such a project. It would cost a fortune to farm this stuff out to someone else. If, on the other hand, they like to tinker, it's a lot of fun." EAA



The EZ Hanger in Covington, Tennessee, looking at bays one, two, and three with workshop and office windows above.

# Of Fiberglass & Foam

## The EZ Hangar

ANN MCMAHON
EAA 391418

"EZ HANGAR," SHE SAYS WITH A bright chirp. A long silence follows as Valerie Harris listens attentively to the caller's story, occasionally answering a question with an expert reply.

Unless you're the original builder and hold the repairman's certificate, the EZ Hangar is one of a few places in the United States that can properly repair structural and systems damage to a canard aircraft.

Valerie and her husband, Robert, have been working on EZ-type aircraft for a decade now. Both are aircraft and powerplant (A&P) mechanics. Robert is an FAA designated airworthiness representative (DAR) who specializes in experimental aircraft, and Valerie holds an inspection authorization (IA).

Using their many talents, skills, and experience, Robert and Valerie provide a range of services for owners of composite airplanes. These include condition inspections for canard and other homebuilt aircraft, preventive maintenance, installation of modifications, factory-mandated airframe changes, main gear changes, wing repair, alerts for airworthiness directives (ADs), and major and minor structural repair.

Unlike an individual builder, the pair has seen what works and what doesn't work on numerous makes and models of aircraft. And they have a working knowledge of all the improvements and enhanced techniques that have come along since Burt Rutan first designed the EZs 30 years ago.

*"It is one thing to construct a plans-built aircraft. It is quite another to take a wreck and not only make it look good again, but be structurally sound as well."*

On any day, you can find several Long-EZs and VariEzes in the EZ Hangar facilities in Covington, Tennessee, just north of Memphis. The EZs are in various stages of repair. The Rutan Aircraft Factory no longer sells plans for the Long-EZ or VariEze, but the designs were so popular when they appeared in the 1970s that more of them are being built than any other scratch- or kit-built aircraft. As a result, a number of these glass canards are still flying. Valerie and Robert would like to keep it that way.

The two met in 1988 in Memphis. Always fascinated by aviation, Valerie helped her first husband, who was an A&P, restore a T-34, but he didn't support her pursuit of formal A&P training. It took Robert to do that. He was her mentor, having met her while helping out with the T-34 restoration. He began teaching his eager student a wide range of shop skills, and they married several years later.

Robert has been a line mechanic for a major airline for 15 years and has built two VariEzes. His new wife found a basket case VariEze and bought it, and the two of them restored it and then sold it. The EZ Hangar was born.

To augment the business of ca-

**Valerie performs a Condition Inspection on a customer's Long-EZ.**

nard restoration, their business plan called for completing repair work for aviation insurance companies, and in doing so, they have developed yet another set of unique and valuable skills. "It is one thing to construct a plans-built aircraft. It is quite another to take a wreck and not only make it look good again, but be structurally sound as well," says Valerie.

The pair has literally resurrected canard pushers others would have written off as totaled. These wrecks arrive at the shop looking like an untidy mass of splintered fiberglass and wires. A few months later they're once again airworthy craft. It is amazing what these two can accomplish.

Currently, Robert and Valerie find their business evolving again. Robert, an expert draftsman who thinks in three dimensions, likes thinking up new features for canard aircraft that provide increased utility and performance. Since Robert and Valerie got into the design business, many canard aircraft have benefited from Robert's various improvements. These skills led the pair to a contract to design and construct Les Shockley's Twin Jet canard, an air show plane based on the Long-EZ. The Twin Jet airframe was completed in 2001.

Their new venture is the design and preliminary construction of the Valkyrie, a single jet engine aircraft based on the Long-EZ. They estimate the Valkyrie will fly in two years. This jet-powered canard has a foot wider fuselage than the original Long-EZ, fully retractable gear, dual cockpits with split canopies, and a beefed-up structure for the higher gross weight and to support the GE T-58 jet engine.

Both Robert and Valerie are testimonials for realizing your dreams and having the courage to stay with it. When asked what advice they would provide to those, young and old, yearning to get into aviation, Valerie says, "No matter what happens to you, never let your hopes or desires settle for second best."

You can reach the EZ Hangar at 901-475-3686.