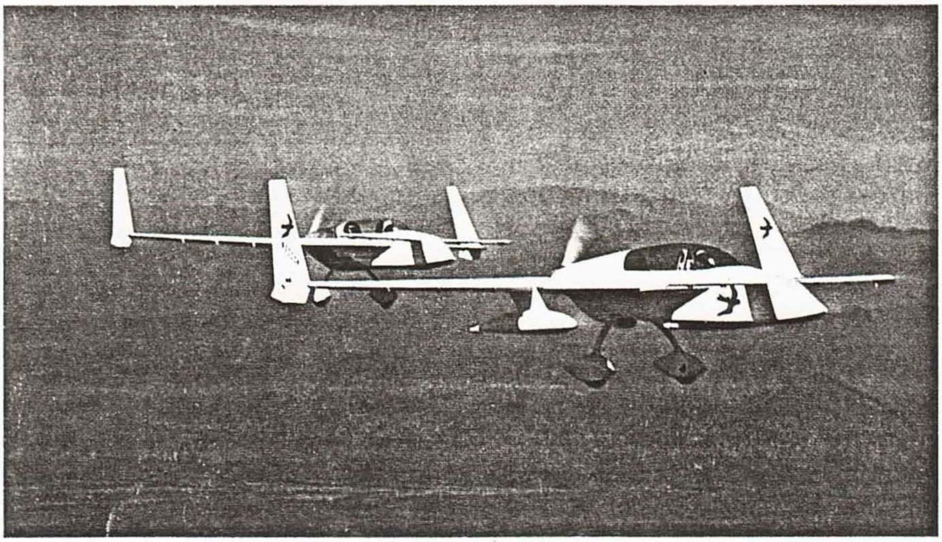
How Long-EZs Have Held Up

When composite construction was new, durability was a significant question.

BY GARY R. JONES



Friends Tom Partin and LeRoy Baker share some sky as they shared knowledge during their Long-EZ building projects.

When Burt Rutan's composite airplanes first came out, no one really knew how they would hold up from a structural and maintenance standpoint. I thought it would be interesting to contact some of the builder/pilots who had put hundreds —even thousands—of flight hours on their Long-EZs and get their comments.

A good place to start was the May, 1987, KITPLANES. A newsletter directory in that issue helped me locate my first contact, Arnie Ash, editor of the *Central States Newsletter* (Long-EZ), who gave me some useful computerized data. The central states VariEze and Long-EZ membership consists of 225 builder/pilots. This group had accumulated 10,491 flight hours in the VariEze, with the highest-time VariEze having 1350 flight hours. Average empty weight of the VariEzes was 664 pounds. By comparison, members of this group had accumulated 16,724 flight hours in Long-EZs.

These figures indicate the relative popularity of the Long-EZ, considering that the VariEze was introduced several years before the Long-EZ. The highest-time Long-EZ had 1382 flight hours and the average empty weight was 890 pounds. Ash said, "The composite structures have held up admirably even when left outside year round. The trick is to have followed the building instructions and applied a protective ultraviolet coating to the airframe before painting it. Out of the entire fleet of VariEzes and Long-EZs, only two metal aileron arms had broken. One of these belonged to me; I made a successful one-aileron landing with it. Since then, Rutan has come out with a new design for the aileron arm and Ken Brock distributes that new part with the Long-EZ hardware package."

With the help of several EAA chap-

PHOTOS: GARY R. JONES

ters and Ash, I was able to contact several high-time Long-EZ builder/pilots: Dick Kreidel (1600 flight hours), Kim Campbell (700 flight hours), Sheldon Olesen (800 flight hours), Tom Partin (400 flight hours) and LeRoy Baker (1000 flight hours).

Dick Kreidel

Dick Kreidel's Long-EZ has done just about everything. It flies him to and from work. He demonstrates its ability at airshows by performing loops, Cuban 8s and four-point rolls. It takes Kreidel and his wife to the Bahamas. It won the coveted Wright Brothers Award in 1984 and it has the distinction of being the only -EZ to be struck by lightning . . . lucky Dick Kreidel.

"I was on an IFR flight plan from New Orleans to El Paso, Texas," he says. "During the climb to FL 180, I had picked up approximately a quarter-inch of ice and out of 14,000 feet, my Long-EZ was hit by lightning. The plane handled normally so I continued on to El Paso. A thorough post-flight inspection revealed dozens of pinholes in both winglets, outboard leading edges of both wings had chunks of micro missing, the cable thimbles for the rudder cables were discolored from the heat and the magnetic compass was off 30°. I determined that the damage was of a cosmetic nature and not structural, so I flew the plane back to my home base in southern California. I repaired all the cosmetic problems and replaced the rudder cables."

While on cross-country flights, Kreidel's Long-EZ spends most of its time between 16,000 feet and FL 200 and has been as high as FL 250 to avoid weather. Kreidel uses and is very pleased with the AERO High Duration Oxygen System made by Aviation Oxygen Systems in Stratford, Connecticut.

LeRoy Baker (center), his wife and a friend pose with the family Long-EZ, which flew the Bakers to Oshkosh '88.

With its 22 cubic-foot bottle, he has 45 manhours of breathing oxygen aboard.

"With the O-320 powerplant I have to get to altitude to get the range I need. Between 16,000 and 17,000 feet, the Long-EZ has a no-wind range of 1000 nautical miles and the fuel burn is down to an affordable 6 gallons per hour. My longest non-stop flight was from Brackett Field, northwest of Orange County, California, to New Orleans, Louisiana. The trip took approximately 8½ hours at FL 220 to FL 250," Kreidel says.

"With the exception of being struck by lightning, I have had only one maintenance problem. At approximately 700 hours, I noticed that the speedbrake had considerable flex. On RAF's advice, I injected flox into assigned areas of the brake and added two layers of fiberglass cloth to the topside of the speedbrake. RAF immediately came out with a plan change that has the builder use a different core material, enlarge the plywood insert and use additional layers of fiberglass cloth. The Long-EZ has been a great airplane and has done everything I've asked it to do. What more could anyone want?" Kreidel asked.

Kim Campbell

In 1940, Kim Campbell and his brother built and successfully flew a Heath Parasol. After flying in WW-II as a pilot, he concentrated on raising a family and paying bills, and years went by before Campbell built another airplane. On their way home from vacation, Campbell and his wife stopped in Oshkosh to see what was new on the homebuilt market. One look at the Long-EZ put Campbell back into the building mode, ordering plans and composite materials necessary for the Long-EZ project. In three years, Campbell and his completed Long-EZ emerged from the family basement (and he didn't have to saw it in half to get it out).

"Building the canard just right was really tough." Campbell says. "In fact, I built three before I was satisfied with the outcome. It was difficult to get the shear web perfect without causing ridges on top of the canard. Besides, the plans had you build the canard right after the fuselage. It would have been better if the plans had you build something less critical so a person could increase his fiberglass skills." Several other builders told me the same thing. Sheldon Olesen built four canards for the same reason.

At age 71, Kim Campbell really enjoys his O-320-powered Long-EZ, flying it all over the North American continent including Alaska. Other than consumable items such as tires, brakes and spark plugs, his -EZ has been free of maintenance problems.

Sheldon Olesen

With the help of EAA Chapter 587, Sheldon Olesen was flying his Long-EZ over Wisconsin in two years and eight months. Sheldon says he had some real challenges building his Long-EZ. The canard was a real bear to build and half way through his project he developed a reaction to the RAF epoxy system.

Olesen says, "Even though I took proper precautions, my hands eventually broke out with a rash. I discovered that by wearing two pairs of gloves I could reduce the severity of the rash, and I completed my project. In spite of the rash, I enjoyed working with composites and I am presently building a Wheeler Express (a four-place composite) to accommodate my growing family."

Olesen says that his biggest maintenance problem has been repairing the paint from hangar rash. "My Long-EZ has been the most trouble-free piece of equipment I have ever owned," he says.

Tom Partin and LeRoy Baker

Driving along the highway outside of Phoenix, Arizona, Tom Partin noticed a winglet of a Long-EZ sticking over a backyard fence. Driven by curiosity and having ordered plans for a Long-EZ, he stopped for a look. Thus started a bonding between two men with one dream.

Partin's new friend was LeRoy Baker. Partin and Baker would eventually become hangar partners, each owning his own Long-EZ. Years before the hangar partnership, Baker shared his building experience with Partin and also gave him an occasional ride in his Long-EZ.

The Long-EZ was the first plane either man had built. Both chose the Long-EZ because of its flight characteristics, cross-country ability and the utility it offered.

Neither was disappointed with the end product. Construction of both planes went easily with the help of the official RAF newsletter, *The Canard Pusher.* When asked how they liked the finishing work of filling and sanding, they both got weak in the knees and broke out in a cold sweat. Having completed a Quickie Q2, I understand.

Partin's first flight came unexpected when a taxi test turned into a flight around the pattern. Rule No. 1 for taxi tests: Both the airplane and the pilot must be prepared for flight!

Partin is an electrician and travels a lot. The primary reason for building his own plane was to reduce the time spent on the road. For six months he flew from Deer Valley Airport in Arizona to Blythe, California. Five days a week he made the 300-mile roundtrip flight. Then it was Hemet Ryan, California (west of Palm Springs). He left Monday morning for the 250-mile flight and flew home Friday after work. Wherever his work took Partin, he had a fast and efficient way to get there. In two years he has put more than 400 flight hours on his Long-EZ .

With the help from his wife and friends, LeRoy Baker had his Long-EZ out of the carport and into the air in just 13 months. When Baker was asked why he built his own airplane he smiled and said, "Just for the fun of it."

The Long-EZ brought a lot of happiness and fun to the Baker family. It has taken them all over the United States and Canada. Partin and Baker planned to fly their Long-EZs to Alaska during the summer of '89. Simply put, these men know how to enjoy the EZ life. When I interviewed Baker, he had more than 1000 flight hours on his Long-EZ. He spends two to three hours each month doing routine maintenance. Partin and Baker told me their Long-EZs require very little maintenance to keep them in safe flying condition.

Mike Melvill

My last contact was with Mike Melvill at Rutan Aircraft Factory in Mojave, California. Melvill shared some facts. As close as RAF can estimate, there are more than 500 VariEzes and more than 500 Long-EZs flying. Melvill has more than 1500 flight hours in his Long-EZ and Dick Rutan has 1680 flight hours on his.

Even though RAF no longer sells plans, the company answers builder questions—provided the plans were purchased before July, 1985, and the serial number on the plans matches the name of the person calling. If your plans do not meet the above criteria, don't waste the phone call. With all the -EZ's being built and flying, getting an answer to a question should be possible even without factory support. All you would have to do is join any of the following groups:

1. Your local EAA chapter.

2. International VariEze and Composite Club, 2531 College Club, La Verne, CA 91750; 714/593-1197.

3. Central States, RR No. 5, Davenport, IA 52806; 319/386-5245.

4. Long-EZ Squadron 1, 104 Avenida Baja, San Clemente, CA 92672.

5. Long-EZ Squadron 2, 11451 Berwick St., Los Angeles, CA 90049; 213/488-7123.

KITPLANES and the EAA's *Sport Aviation* magazine classified ads are good sources for plans, but be aware that factory builder support will not be available, and a seller who copies plans rather than selling an original set is violating copyright laws.

Raw materials are available from Aircraft Spruce & Specialty, Wicks Aircraft and Alpha Plastics, and some finished parts are available from Ken Brock Manurfacturing.

Flying a Long-EZ

On a recent trip to Scottsdale, Arizona, I had an opportunity to fly Tom Partin's Long-EZ. The front seat is easy to get into and is comfortable, even for my 6-foot frame. Getting into the back seat requires the passenger to step into the pilot seat, then step around it to get to the rear seat. I figured if Partin's 85-years-young mother could do it, I could too. Because the fuselage tapers as it goes aft, I had a challenge getting my wide shoulders to make friends with the limited space.

As in life and aircraft designs,'most everything is a compromise. The passenger seat was designed for a small person.

With Partin in the front seat, we taxied for takeoff. I was to fly the -EZ from the back seat. With everything in the green and the mags checked, we were cleared for takeoff.

Partin's Long-EZ is equipped with an O-360 engine, installed after the original O-235 burned a hole in a piston, resulting in a deadstick landing into an airport in Chandler, Arizona, for Partin and his wife. To accommodate the larger engine, he beefed up the engine mounts and changed the cowl.

As Partin advanced the throttle on our flight, we were launched at a rate I'd compare to the Lear 25 I fly. We broke ground at 85 knots and rotated to hold 110 knots for the climb. Visibility from the rear seat was very limited during the climb. Looking over Partin's shoulder, I could see the VSI holding a steady 2000 fpm climb, and we were near maximum gross weight. Making a climbing left turn out of Deer Valley, Partin let me have the side stick. The side stick controls both the elevators and aileron but there are no rudder pedals for the rear passenger.

My first experience flying a airplane with a sidestick was in my father's Quicksilver ultralight. For me, the sidestick is more natural than having it between your knees or on a control wheel. I have a sidestick in my Q2 and I really like it. The only regret is that the Lear I fly doesn't have one. The popularity of the sidestick must be on the increase as the Lancair people now offer it as an option.

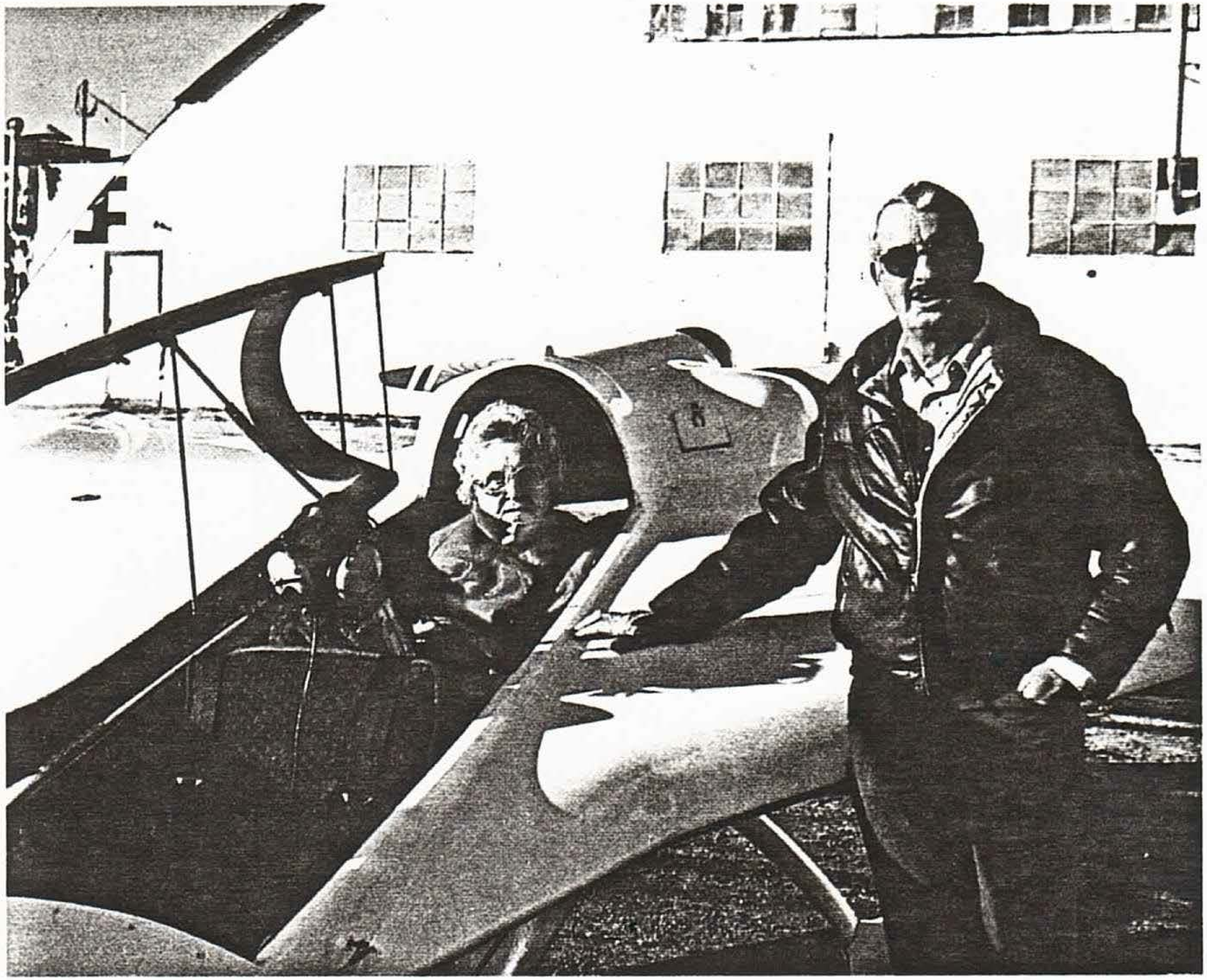
Once at altitude in the Long-EZ, I did steep and shallow turns. Ailerons are heavier and the roll rate is slower than I expected. A comparison would be to a Cessna 182. Control response along the longitudinal axis is comparable with no tendency to be sensitive.

Power-on and power-off stalls were accomplished. With its gentle porpoising, the aircraft demonstrated the typical stall response of canard-configured aircraft. No tendency to break right or left was experienced. With all the airwork completed, I asked Partin to trim the plane for hands-off. Trimmed, the powerful Lycoming shoved the -EZ through the desert air as straight as an arrow. No control inputs were necessary. I loved it. All you had to do was watch the scenery blast by.

I asked Partin if he had flown his Long-EZ in rain and whether the nose pitched down. He had and it does. Seconds before penetrating rain, the nose pitches down. After the canard is wet, pitchdown is less noticeable. With full aft trim, Partin still has to hold back pressure on the stick while in rain. The plane is controllable, but it would be fatiguing to fly any length of time like that. Other builder/pilots I interviewed said the same thing. The exceptions were those who had the new canard designed by John Roncz. They did not experience any pitchdown in rain.

Back in the traffic pattern, Partin took the controls for landing. Final approach was flown at 90 knots and touchdown came at 75 knots. Visibility from the rear seat is close to zero during final and touchdown. The canard blocks forward visibility and the fuel strakes block one's ability to see down. Even if there were a throttle for the rear passenger, I doubt that he/she would

The back seat of Tom Partin's Long-EZ accommodates his 85-year-old mother, despite the need for some gymnastics to clambor aboard.



be able to land without damage to the airplane. The fact that the rear passenger cannot lower the nosegear is a moot point.

Many an -EZ pilot has forgotten that item on the checklist, normally resulting in minor damage to the plane, but major damage to the pilot's pride. For sure, you would want an emergency crew standing by with a vacuum cleaner and dustpan if the rear passenger had to make the landing. The original VariEze flew in the spring of 1975 making the design more than 14 years old. Most of the VariEze and Long-EZ builders are happy with their investment of time and money. And from a maintenance standpoint, these Rutan designs have demonstrated a record that would make the Big Three envious. Obviously, this doesn't mean that an -EZ pilot ignores maintenance once the airplane is flying. Monitoring maintenance is necessary regardless of what kind of plane you are flying—homebuilt or production.

Despite the lack of a commercial source for plans and builder support, Long-EZs continue to be considered by potential builders because of their outstanding record of efficiency and durability. The VariEzes and Long-EZs have become homebuilt classics in a relatively short time. □

By Barnaby Wainfan

Let's analyze the purported advantages of pusher configurations.

One of the often-cited reasons for using a pusher configuration is the perception that a pusher can be more efficient than a tractor. While this can be true, a pusher propeller operates in a more difficult aerodynamic environment. Let's look at a few considerations the designer of a pusher should keep in mind.

Propeller Wake

One advantage of a pusher propeller is that the slipstream aft of the propeller does not blow on the fuselage. A tractor propeller blows air backward onto the rest of the airplane, creating a built-in headwind. This is more significant for single-engine airplanes, on which the slipstream flows over the entire fuselage. While this effect is real, it is also relatively small. The slipstream velocity increase behind the propeller for a typical light airplane in cruise is less than 10 mph. The overall effect is small enough that it does not give the pusher a significant advantage.

Another advantage often cited for the pusher is that the propeller wake of a tractor configuration interferes with laminar flow over airplane components downstream of the prop. This is partially true. Experiments on the Rutan Amsoil racer showed that there was extensive laminar flow on the forward wing even in the propeller wake. What the experimenters found was that there was a momentary disruption of laminar flow each time a propeller blade passed the wing and the blade wake hit the wing. Between blade passages, the laminar flow reestablished itself. The overall effect was that the drag of the wing was slightly higher than it would have been with undisturbed air flowing over it, but still significantly lower than it would have been with fully turbulent flow.

Fuselage Drag

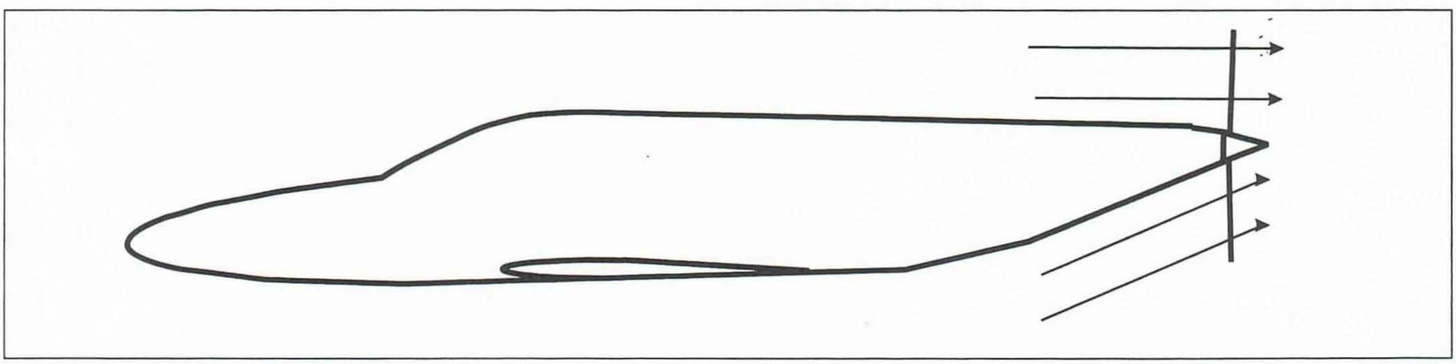
A pusher-engine installation frees the designer to shape the nose for minimum drag and good visibility. This means that the forebody can be shaped to sustain long runs of laminar flow and to have a smooth low-drag shape even if the flow is turbulent.

As we discussed in a previous article (June 2002), the pusher configuration makes the design of the afterbody more difficult. Integrating the engine tends to make the afterbody short and blunt, which increases the chance of significant separation and base drag. The cooling-air outlets on a pusher also tend to generate more base drag than a well-designed flush-ramp cooling-air exit on a tractor installation.

A poor afterbody design can increase drag far more than a good nose design can decrease it. This means that designing a low-drag fuselage for a pusher airplane can be tricky. But because the nose can be aerodynamically beneficial, the pusher does have the potential to have lower total fuselage drag if the designer gets the afterbody right.

Propeller Efficiency

The fuselage or nacelle can affect the airflow into both tractor and pusher propellers. For a tractor, the primary concern is the blockage of free airflow behind the inner portions of the propeller caused by the nose of the fuselage or nacelle. For airplanes with wide, blunt noses, as seen on many singles with direct-drive engines, this effect can be significant. The majority of this loss can be eliminated by using a modest-length prop-shaft extension to move the propeller forward of the cowling's front face and shaping the cowling to smooth the airflow.



On a pusher with an upswept afterbody, the blades on the lower part of the disk see a different airflow angle than they do at other points around the path of rotation. This makes the blades' angle of attack change as they rotate, causing inefficiency and noise.

ILLUSTRATION: BARNABY WAINFAN

A pusher propeller flies in the wake of everything upstream of it. If the afterbody of the fuselage or pod has significant flow separation, at least part of the propeller will be immersed in a low-energy, turbulent wake. This can dramatically reduce the propeller's efficiency. Even if the fuselage is smoothly shaped with a good afterbody, the propeller still must deal with the wake of the wing and sometimes the tail surfaces.

For maximum efficiency, the airflow into a propeller should be uniform and parallel to the propeller shaft's axis of rotation. This condition ensures that the blades are at the same angle of attack all the way around the propeller disk as they rotate. The blades can then be pitched to fly each portion of each blade at its optimum angle of attack. If the flow into the propeller is not uniform, the blade angle of attack varies as the blade moves around the path of rotation. This means that the blade will be at an off-optimum angle of attack part of the time, and therefore, it will be less efficient at producing thrust.

Distortion of the incoming airflow takes two major forms. The first is a non-uniform airspeed over the prop disk. This is caused by something upstream of the prop either accelerating or retarding part of the oncoming airstream. The most common cause of this type of distortion is flow separation on a surface upstream of the propeller. It can also be caused by a body, like a fuselage pod, that is not centered on the propeller shaft. A good example of this is an amphibian like the Seabee. The airflow immediately behind the fuselage pod will not travel at the same speed as the free air above it, and the propeller blade will see variations in airspeed as it rotates.

Cooling-air outlets, or any other internal-flow system that dumps a stream of low-velocity air upstream of the propeller, can also adversely affect propeller efficiency, particularly if the air impinges on the outer half of the propeller blades.

The other common form of airflow distortion into a propeller is angular distortion. In this situation, the airflow on one portion of the prop disk is not parallel to the airflow at another point in the path of rotation of the blades. Angular distortion can be caused by a misalignment between the propeller shaft and an otherwise uniform incoming airflow. This is typical for

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all airplanes in climb, as we tend to set the thrustline for best efficiency in cruise.

Angular distortion can also occur when airplane components deflect the airflow differently at different spots. One such situation occurs with a highly upswept afterbody just upstream of the propeller. The portion of the blades directly behind the afterbody will encounter flow that has been deflected upward as it follows the skin of the airplane, while the blade on top of the rotation path will see airflow that is closer to parallel to the free stream.

Wings and tail surfaces upstream of the propeller can also affect the angularity of the flow into the prop. This can be particularly severe if there is an abrupt change in the wing shape (such as the end of a deflected flap) directly upstream of the propeller disk.

Noise and Vibration

The propeller generates a large portion of the noise that comes from a piston-engine aircraft. As anyone who has heard a Long-EZ, Skymaster or Starship fly by can attest, pusher propellers have a different sound than tractors. This is because the blades hit the wakes of the airplane's upstream components as they rotate. Each time a blade encounters the wake of the wing or tail surface, the airflow over the blade is momentarily disrupted. The disruption causes a pressure pulse that is heard on the ground as noise. It also generates mechanical vibration of the propeller that can be transmitted into the cabin as structure-borne vibration.

If more than one propeller blade is disrupted at the same time, the level of noise and vibration is increased. For example, if a two-blade propeller is placed directly behind a wing or tail surface, both blades hit the wing's wake at the same time. This produces a double-strength pulse twice per rotation. A three-blade prop in the same situation would produce six single-strength pulses per rotation, resulting in a softer, higher-frequency sound and vibration.

The situation can be further improved if the propeller axis of rotation is displaced vertically so that it's above or below the wing. If the shaft is in the plane of the wing, the whole length of a propeller blade hits the wake at once. If the shaft is above or below the wing, the blade moves into and out of the wake progressively. This lowers the maximum amplitude of the pressure pulse and makes it less abrupt, reducing noise and vibration.

As you can imagine, a propeller flying in a partially separated wake behind a poorly designed afterbody is really loud.

Blade Fatigue

Blade fatigue is a vital safety consideration when choosing a propeller for a pusher configuration. The blades of a propeller operating behind a wing get pulsed twice per rotation as they hit the wing's wake. This excites vibration of the propeller blade. It is important to make sure that the frequency of this excitation is far from any natural vibration frequency of the blade, particularly if the propeller is metal. If the two-per-rotation vibration frequency excites any natural vibration mode of the blades, they will fatigue rapidly and fail.

Similarly, the blades get pulsed any time they hit a wake. If the airplane has a pusher propeller in the extreme tail, then the pulse frequencies caused by hitting the wake of the fin and tail planes must also be considered.

FOD

Foreign-object damage (FOD), is the mortal enemy of pusher propellers. Because the prop is behind much of the airplane, it can get hit by any object coming from the airplane. It's particularly vulnerable to rocks or other objects kicked up by the nosewheel during takeoff and landing. It is a good idea to have a wheelpant or some form of fender or splash guard on the nosewheel if there is any direct path from the wheel contact point to the propeller disk.

Pusher propellers will also eat anything that comes off of or out of an airplane in flight. Losing the canopy in flight may be a major inconvenience in a tractor, but it can easily destroy a pusher's prop.

While the pusher configuration offers some attractive advantages, it is inherently harder on propellers than the tractor configuration. The designer of a pusher must pay special attention to make sure that the propeller is happy pushing instead of pulling.

Aerodynamic questions of a general nature should be addressed to "Wind Tunnel" c/o KITPLANES, 8745 Aero Dr., Suite 105, San Diego, CA 92123.

Boosting Performance

Aircraft design, construction and pilot techniques determine the result.

By Bill Welch

Performance: That's what it's all about for some builders and ɔilots. How to get the best out of ʏour aircraft is the big question. There are plenty of generalities ıbout improving performance :hat most people in sport avia-ion know about, but that's only ɔart of the story. And there is ɪo single answer to optimizing ɔerformance. The right one lepends on the particular kind of ɔerformance you want, the air-craft design, and even the pre-ʌailing weather conditions. More :han anything, maximum per-formance depends on attention o detail.

Pilots tell some wild tales of ɔerformance and how to get it, ɔut most of these fall before a critical ook. The old term *getting on the step* is ɔne will-o'-the-wisp. Seaplane takeoff, vhere the aviation term originated, is lifferent. In that case, getting up from ɔuoyancy to planing on the bottom sur-ace forward of the step definitely educes water drag and facilitates takeoff. Although there are specific circumstances ı which a distinct step in airborne per-ɔrmance can be achieved, they depend n design faults such as bad flow that is leaned up at lower angles of attack.

ligh Speed

If speed is your object, surface finish, moothness (fairness) of contours and limination of leaks are important factors. . sharp break in a contour almost any-'here can trigger turbulent flow or sep-:ation and increase drag. Gaps around ɔors and canopies or between other ɔmponents can also cause a major :crease in drag. This is why taped joints 'e a common sight at competitions.

Figure 1 shows the drastic effect of ACA's *standard roughness* on the lead-ing edge of a wing. Automotive body fillers are often applied to improve surface quality despite the associated weight.

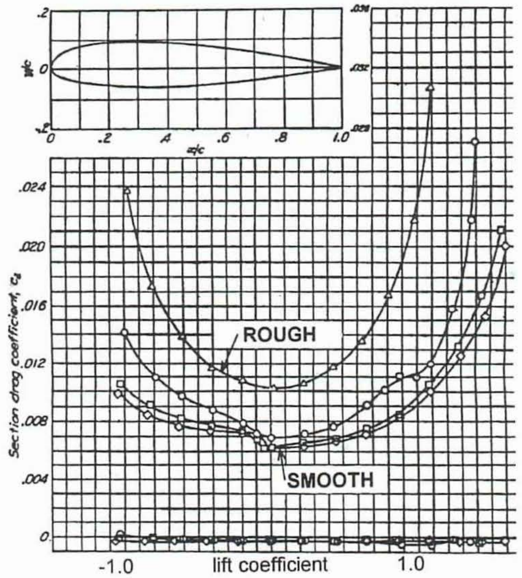


Figure 1. The upper curve shows lift and drag coefficients with leading-edge roughness.

Engine Power

But what about power? Speed demands all you can get of that, which in turn requires its own brand of TLC.

Vital questions about power include whether the engine gets all the air it needs at a good ram pressure. That alone demands careful design attention and workmanship in the execution.

Few aircraft have really good induction systems. First, the intake must be in the right place to obtain maximum total pressure recovery, and it must be the right size. Next, the pressure must be contained and conducted right to the carburetor or manifold. If there is an air filter in the system, it must be large enough and the velocity through it low enough to avoid serious loss of ram pressure.

Hot air leaking in when not needed can take a large bite out of available engine power. So can unintended heating of the basic induction system. The SeaBee, for example, suffered from a built-in temperature rise that reduced its available power.

Internal cleanup of the engine and accurately fitted components such as pistons and rings can be important. Power output tolerance for a type-certificated engine is 5%. There are shops that specialize in cleaning and tuning engines to maximum performance, sometimes called *blueprinting*. That's just to get the rated power. In some cases the rated power is exceeded by a variety of means including operation at higher speed.

Outside Influence

Most airplanes have a number of bumps and lumps or external features such as antennas, airscoops and exits. They all produce drag. Maybe not much individually, but in total they are significant. An external feature that is not properly faired can cause additional drag on the main body of the aircraft, beyond the drag of the extra feature itself.

Even those manufactured with supposedly favorable shapes generally fall short of optimum streamlining. The best thing to do with an antenna is to hide it. In an airplane with nonmetallic components, it is often possible to place antennas internally. On metal airplanes, wingtip caps may be nonmetallic and good enclosures for the antenna. Directional performance might require two connected elements at the two wingtips. Fin tips and leading edges also have been used to advantage.

An intersecting strut or unavoidable external antenna needs a fillet long enough to minimize the interference drag. According to Hoerner in his book *Aerodynamic Drag*, its length should be in the order of 10 times the strut or antenna chord. The best fineness ratio for a strut or mast is about 3:1. For a blister, as much as 15:1 is needed.

For a wing/fuselage or tail intersection, the purpose of a fillet is to open any re-entrant (closed angle) corners and reduce the effective thickness ratio of the wing at the juncture. In most cases where two different shapes join, the transition should be as gradual and as smooth as possible. Look at how a bird's wing and body are blended.

When external features are unavoidable, it may be possible to pick a location where the damage is limited. Numerous studies have shown that areas aft of the maximum thickness of a fuselage or aerodynamic surface is where protuberances add the least drag. In the vicinity of maximum thickness, the velocity near the surface is at a maximum, appreciably greater than free-stream velocity. To minimize drag, you would want to avoid anything sticking into these high-velocity areas.

Cooling It

The manner in which cooling air and engine exhaust are discharged can be very good or very bad for performance. If engine baffling is sloppy and leaky, more pressure differential is needed to move enough cooling air through the cylinder fins and oil cooler. When the inlet or outlet is in a poor location, obtaining that pressure difference will cause more drag than if the locations are well chosen.

Giving a little thought, you soon realize the pressures on aircraft surfaces vary wildly. Taking advantage of them is not difficult; you just have to pay attention and look at typical pressure distributions. Better yet, measure some pressures on the particular aircraft involved. A water manometer is simple to rig and safe to use.

Discharging the flow as nearly as possible parallel to the external flow is best, and if you can match the velocities with proper outlet sizing you have the best possible conditions.

For an oil cooler or a radiator, don't aim a concentrated stream of air at the core. Use a plenum chamber ahead of the unit so the velocity is as uniform as possible through the core. This arrangement takes the least total flow and causes the least drag. Merely expanding a duct does not work unless the expansion is so gradual that the flow remains attached to the diffuser walls.

Because there is twice as much energy in the cooling air and exhaust as is delivered to the propeller, it is even possible to recover some useful propulsive thrust with clever design. The P-51 demonstrated this principle in the early 1940s with an outlet area properly matched to the heat to be dissipated and the external flow.

Once you are satisfied the engine is delivering as much power as it should, and that cooling drag has been held to a minimum, it's time to optimize the propeller design for the desired result. Again, if speed is the object, the propeller can be fine-tuned for maximum airspeed at the maximum propeller rpm. This is not a simple task, and you need either a good propeller designer to advise you, or one of the available propeller specification computer programs to find the right combination of diameter, pitch, solidity and number of blades.

Low-Speed Performance

If takeoff and climb performance is your game, the propeller selection must be biased to favor these segments of a flight. However, this would penalize cruise speed and limit maximum speed because of the need to avoid overspeeding the engine. The solution to these problems is controllable propeller pitch.

Prop diameter is constrained by tip speed, which can impose a large penalty if excessive. The general principles apply: You need large diameter to have large thrust at low speeds. At high speeds, large diameter can hurt, and it is not needed for efficiency because ample mass flow through the system is inherently available at high airspeeds.

Although I do not generally recommend wingtip modifications, when dealing with an existing airplane and the need to maximize takeoff and climb performance, you may find them useful. The winglet or end plate can be used to improve induced drag in specific conditions. But it can be a tight tradeoff between cutting induced drag and increasing parasite drag. The main caution here is that these fixes may work only at high lift coefficients and will not improve high-speed cruising at moderate altitudes.

Another low-speed problem is that high-speed airfoils often don't behave well at low speeds where high lift coefficients and large angles of attack are needed. Consequently, the low-speed performance of some airplanes has been improved along with handling characteristics by the installation of a drooped leading edge. This is usually done on an existing airplane with a glove or cuff fitted over the leading edge to increase the camber of the airfoil. The leading-edge radius can also be increased for some further increase in maximum (stalling) angle of attack. STOL (short takeoff or landing) kits have been certificated for some lightplanes using these leading-edge gloves.

Flaps installed on some airplanes can reduce low-speed drag at moderate extension angles. This is a chancy situation, as the improvement would occur in a narrow speed range and would depend on precise technique. Either the manufacturer's recommendation or a careful examination of power-required and power-available curves with flaps extended is necessary to be sure of the potential benefit.

At Any Speed

External components such as fixed landing gear can be major drag producers or they can be easy on the power required. The key words are *well-faired* in real aerodynamic terms.

Long flowing shapes are usually not the best. Optimum length/diameter ratios for three-dimensional bodies are on the order of 3:1. This is because skin friction drag adds rapidly with increasing total wetted area. Much of the drag often originates in the junctures such as where the strut joins a wheel fairing. These can be treated with proper fillets similar to those at other intersections.

Common spring landing gear struts are flat, usually with rounded edges. Much better shapes can be used for composite struts or those made of metal tubes. The ellipse is appropriate, as it is difficult to predict the exact direction of air flow across the entire length of a strut. Elliptical cross sections are less sensitive to angle of attack than flat ones or those with sharp trailing edges, but they still have modest drag coefficients.

Retractable landing gear presents a different problem. Most are not well sealed when retracted. Some leave the wheel partly outside the airframe contours, making matters even worse. This is a case needing attention to minute detail.

Flying technique has a great deal to do with the performance actually realized in any aircraft. A pilot who continually applies unnecessary control inputs will reduce performance. On the other hand, an airplane without adequate stability will demand continuous control, and performance can be improved by the correct pilot technique. Even more improvement can be achieved by increasing the inherent stability. Sometimes a dorsal fin or similar extension on the horizontal tail is enough. Keeping the center of gravity as far forward as possible can also help an airplane that is marginally stable.

Operating the engine on optimum fuel/air mixture can make a little extra power available. With a controllable propeller, the engine can be operated at full throttle in many situations, which favors fuel efficiency and enables the pilot to attain the airplane's maximum range. Selecting the most favorable altitude for performance also helps to squeeze out every bit the airplane can give.

Selection of cruise speed is another opportunity to maximize performance. While you need to see the power-required and power-available curves for the airplane to find the best-range speed, you can always increase range by reducing cruise speed below normal levels.

Finally, you can often take advantage of weather data and forecasts to maximize cross-country performance. Most favorable wind (or least harmful) can usually be identified in the winds aloft forecast.

Here is an easy, little-known trick that you can exploit using the pressure-pattern navigation technique. With a first estimate of time en route, calculate the total drift, both cross track and along track, for all the winds along the route. Then offset your destination in the opposite direction the same distance, and navigate to this corrected location using only a single heading. This works because you are not flying a fixed track on the ground; you are flying in moving air. Therefore, you are aiming for the air that will be at your destination when you arrive.

General

There are many things the builder and pilot can do to obtain the very best possible performance from any existing airplane or building project. Most important of all is the careful attention to details and thoroughly analyzing any proposed deviations from a design. **KP**

Author Bill Welch died in February of complications from pneumonia. Bill's widow, Virginia, has allowed us to publish his articles still on file, agreeing that they are a tribute to his life's work.—Ed.

Commuting the Eze

Five years of overflying L.A. gridlock in a homebuilt.

By Bob Gray

Cary, Nancy and Canon Thomas show off their wings. But where does Boomer sit?

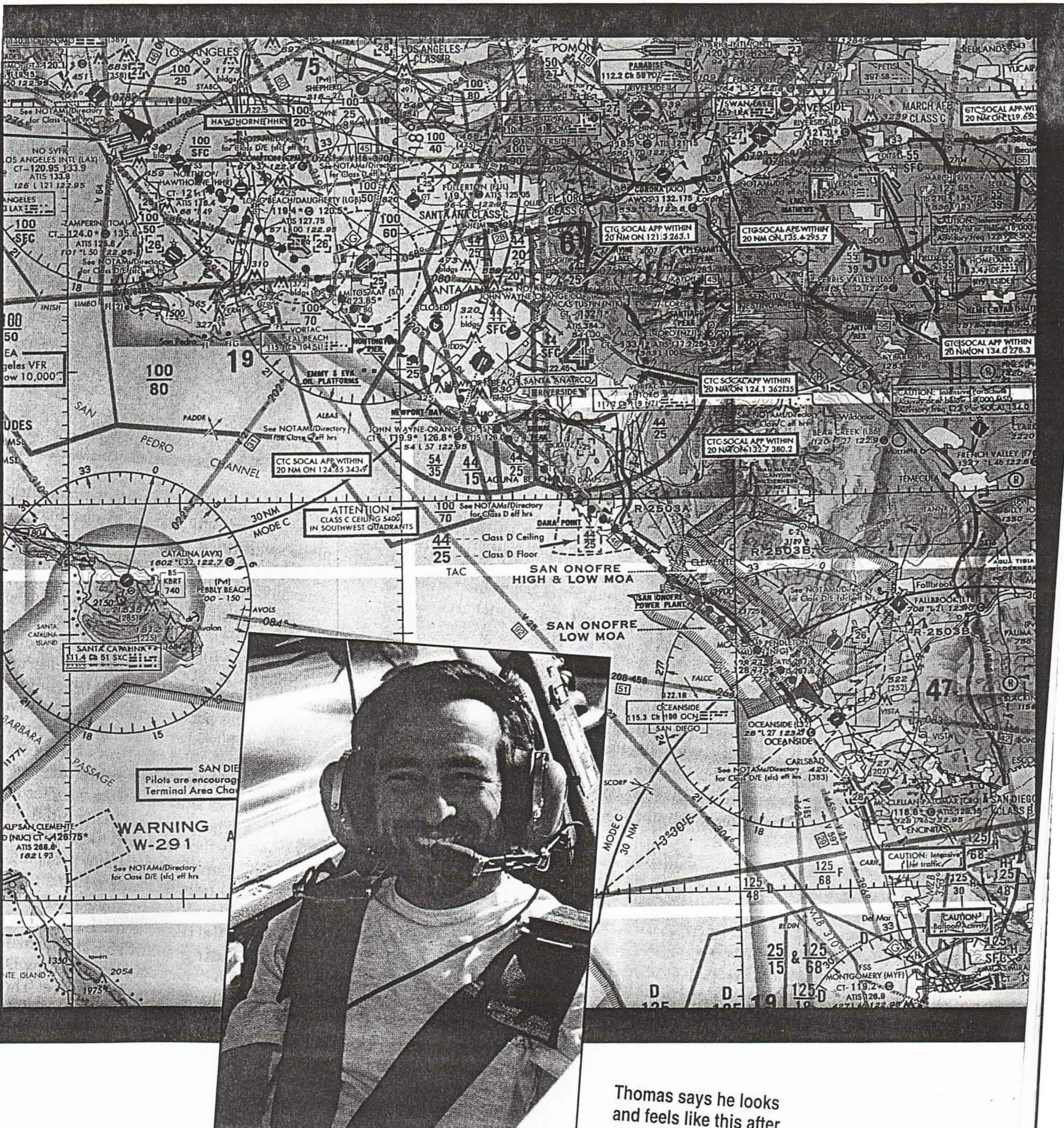
What starts the morning commute on four wheels, soon converts to three wheels, and finally arrives at the office on two wheels?

The answer is not a *what* but a *who*: Cary Thomas commutes 100 miles from his seaside home in Carlsbad, California, (just north of San Diego) to Marina del Rey, north of Los Angeles International Airport (LAX).

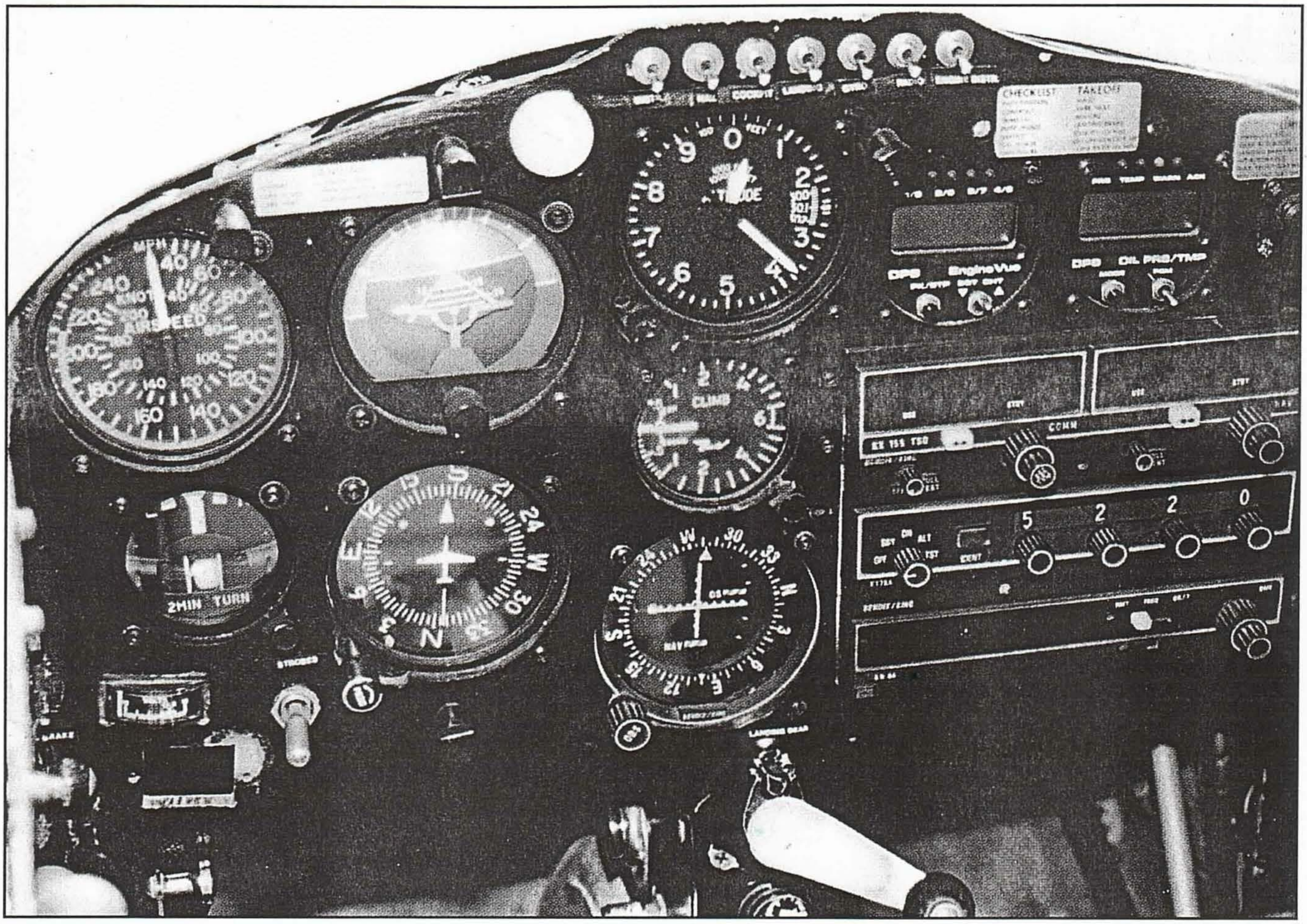
Thomas drives his car the short distance from his home to Palomar Airport, jumps in his VariEze, and flies northwest along the coast and through the VFR corridor over LAX, lands at the Santa Monica Airport, and bicycles the last 3 miles to work. He is administrative director of the Information Sciences Institute, a computer research lab that is part of the University of Southern California.

PHOTOS: STEPHANIE SANGUINETTI AND BOB GRAY

Way



Thomas says he looks and feels like this after each commuting trip in his VariEze.



Commuting

continued

A seven-button control stick adds convenience. Although equipped and often filed for IFR, the Eze is left at home in marginal weather.

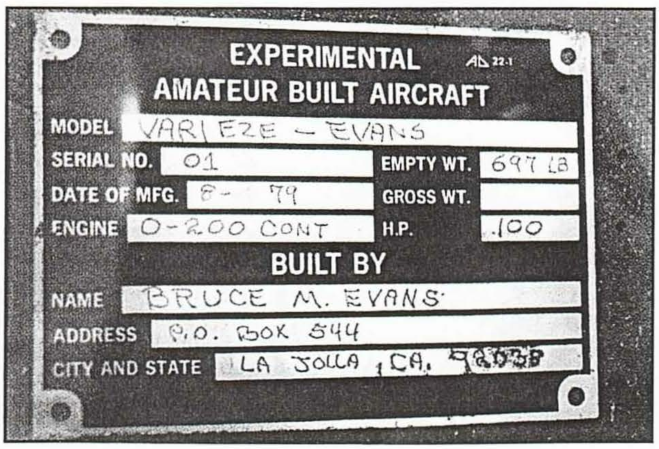
Not New at It

He has been performing this routine on about half of his work days for the past five years—except for a year and a half when the VariEze underwent a complete repaint and the installation of an updated instrument panel. Most of the other half of his work days, he needs a car to leave the center for meetings or the weather is unsuitable for flying. By car the commute takes at least 2 hours and 15 minutes and up to 3.5 hours depending heavily on the time of day and traffic conditions, including the number of freeway collisions. By homebuilt the trip takes 38 minutes VFR and 10 minutes longer when filed IFR.

Thomas has failed to complete the round trip due to weather on only two occasions. Fuel for the plane averages 4.5 gallons; the car takes more gas. He flies the same route and uses all the same navaids for VFR and IFR.

What It's Like

The typical commute starts with a briefing from FSS via the 800/WX-BRIEF telephone connection. He never flies in SIGMETS. If ceilings are below his personal minimums, he drives. His VariEze will hold enough fuel for two round trips with reserves, and he always leaves in the morning with full fuel. This ensures that he can get home or to an alternate if the weather turns bad. The plane is always preflighted exactly the same way to avoid missing something. He says that propping the O-200 (which lacks a starter) is perhaps the most exciting part of the trip. The VariEze has all King radios, including a KX155 navcom with VOR/GS and coupled to a King DME. They have been trouble free. Thomas uses a seven-button control stick so the radio flip-flop is done by just pressing his thumb. The six primary instruments are in the standard configuration for the traditional IFR scan pattern. Many weekends and plenty of planning were



The family commuter was built by Bruce Evans, who fabricated much of the around-the-world *Voyager*.

needed to pack that much gear into the narrow Eze panel.

Reliability Is the Key

The VariEze has proven itself to be a safe and reliable platform. It was built by Bruce Evans who, with pilots Dick Rutan and Jeana Yeager, built the round-the-world-unrefueled *Voyager*. When people question the wisdom of commuting in an Experimental airplane, Thomas tells them, "Hey, the guy who built my plane built the *Voyager*!" After hundreds of flights he has yet to experience an airframe problem. His only mechanical problems have been a propeller hit by runway debris and a cracked exhaust pipe, both easily repaired.

When Thomas first considered commuting by airplane, he only looked at factory-built models. But the smallest ones were too slow, the fuel costs were too high in the faster ones, and the retractables were too expensive. He was discouraged until Dave Ronneberg, developer of the Berkut, recommended that he consider a VariEze. The numbers worked out better than predicted.

"The Eze gets better mileage than my car, I can do the routine maintenance myself, and the nose-retract parking allows sharing a hangar with another Eze."

Only a pilot can fully appreciate the enjoyment of this kind of commuting. "Most days the flights to and from work are great," Thomas says. "I've seen rainbows over Catalina Island, watched the seasonal wild fires of Southern California light up the night sky, and been awed by spectacular sunsets over the Pacific. Flying over the traffic jams on the freeways really makes my day."

Thomas gives much credit to the San Diego EZ Squadron (established in 1976); some really helpful FAA controllers; his hangar mate Dave Kilbourne, whose Eze has more than 2500 hours on it; and his wife, Nancy, for their support.

The icing on the cake is how the commute affects Thomas's psyche. "When I drive the car, I arrive pretty wasted," he says. "My employees can tell by the smile on my face when I have arrived by VariEze." **KP**

Bob Gray is a professor retired from San Diego State University. A founding member of the San Diego EZ Squadron, he flies a VariEze that he spent 11 years building.