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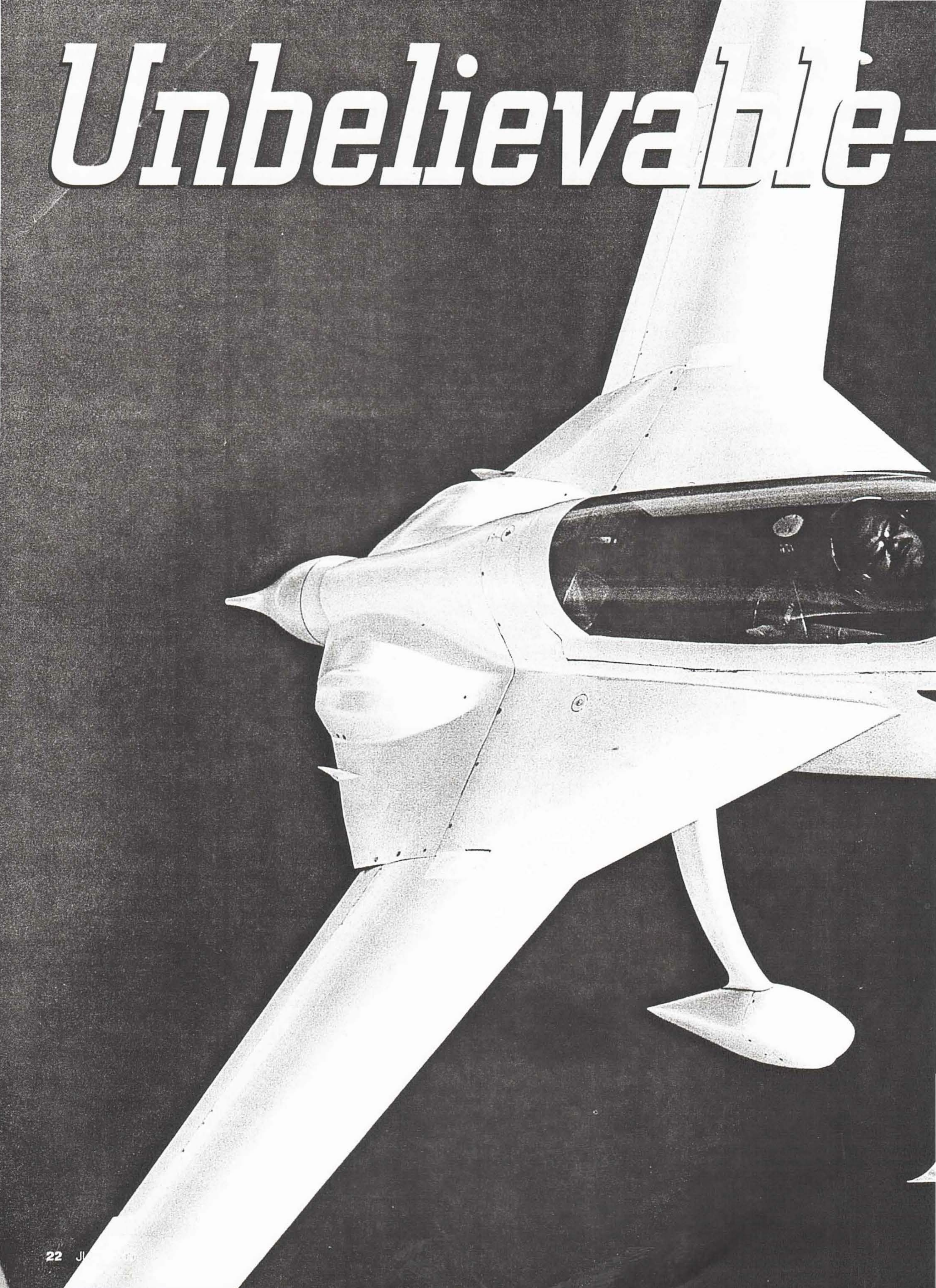
Unbelievable-Eze

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

Markings, Placards, Numbers

Closing the Engine GAP

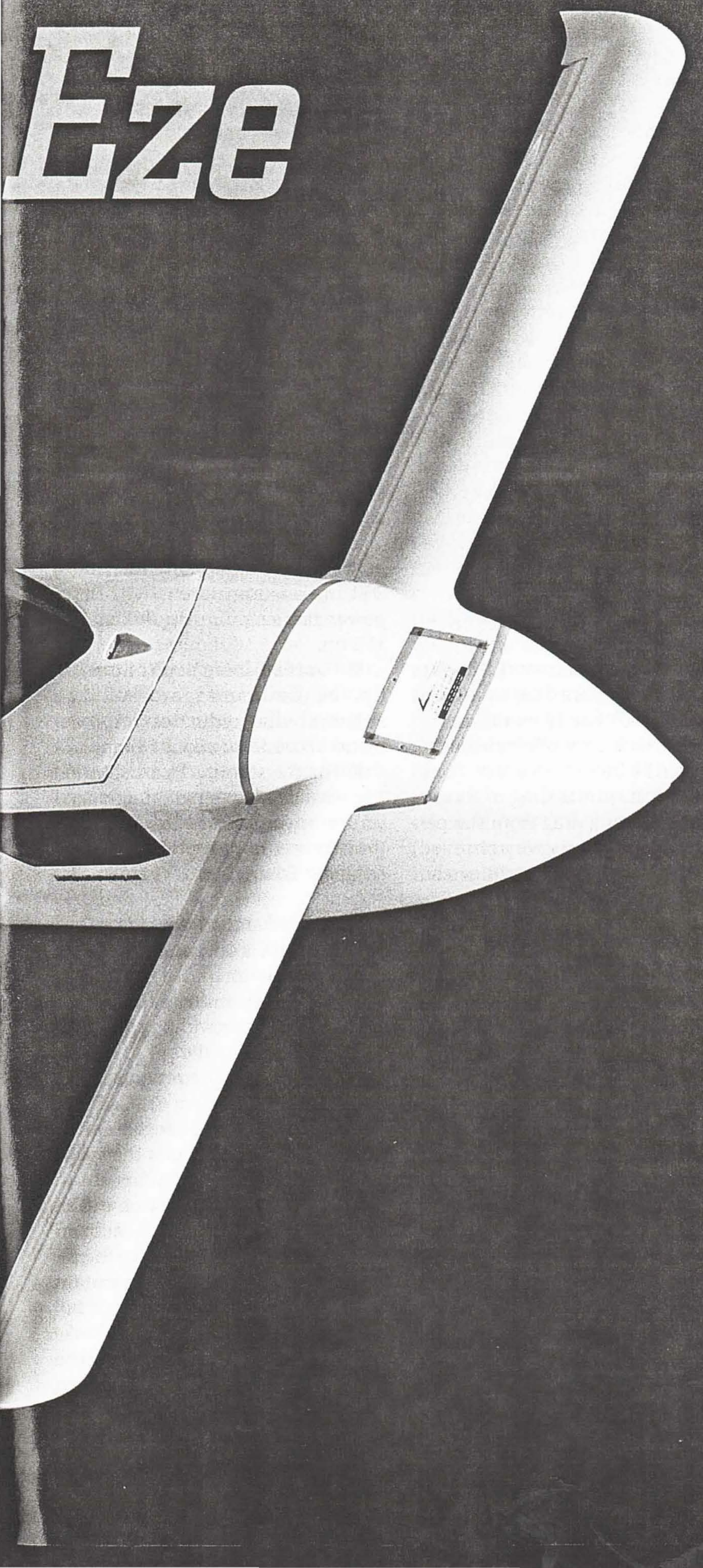
Unbelievable-



Eze

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

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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!

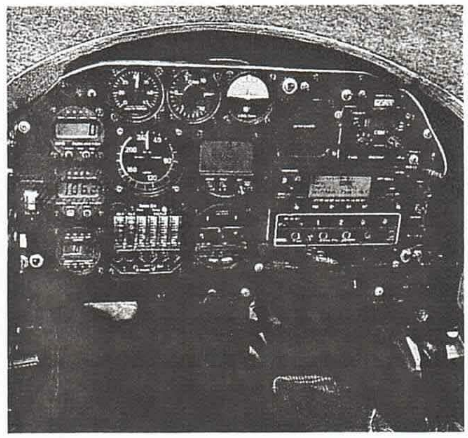
To extract more horsepower from the engine, the modifications are a custom propeller (Klaus' own design with 85-inch pitch), an eight-inch prop extension, a carburetor air ram inlet, and four individual exhaust stacks exiting into the cooling airflow stream at the cowl outlet.

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: $D = C_d 1/2 rV^2 S$ and $HP = 1/550(DxV)$, or substituting for drag, $HP = (1/550)C_d 1/2 rV^3 S$. 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.



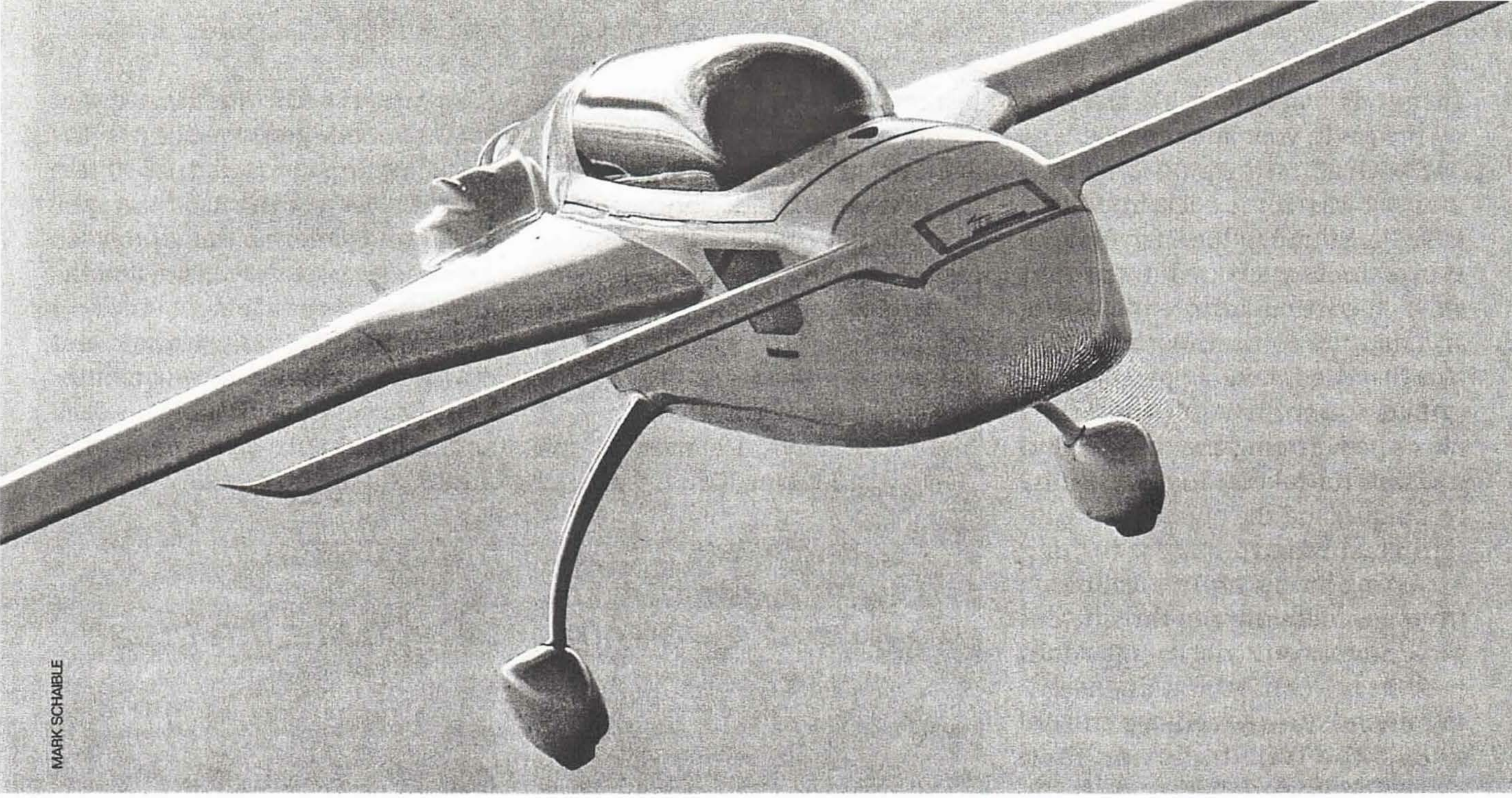
standard Eze and made either the drag or the horsepower modifications separately:

- 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.

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.

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

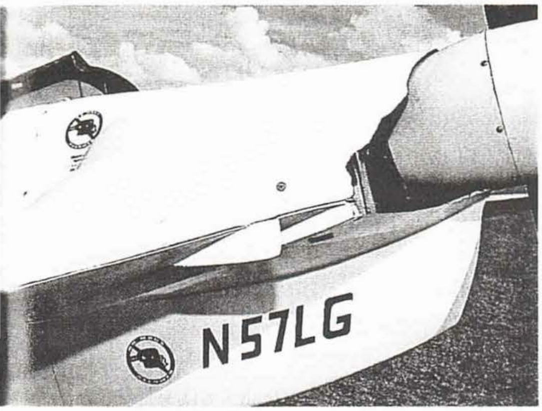
At maximum gross weight the Unbelievable Eze can cruise-climb at 175 KIAS and 500 fpm up to 13,000 feet. Amazing! On a good day my Eze is in about a 100-foot-per-minute descent at 175 KIAS (that's 201 mph at sea level)! What a revelation to see just how much potential this design has.

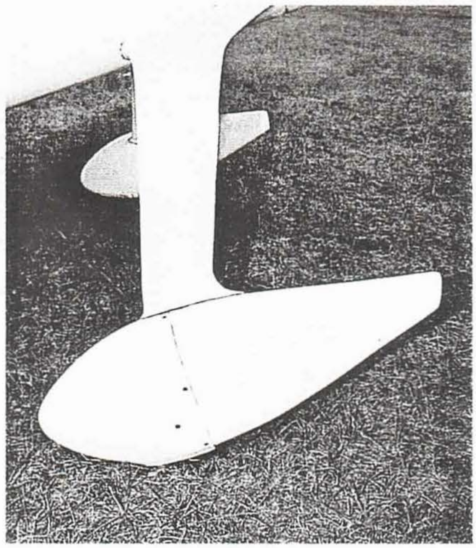
Leveling off at about 4,500 feet I watched the aircraft accelerate. Leaning a bit more and watching the rpm build, the airplane achieved an unbelievable 204 KIAS (235 mph) with 7.8 gph at 2,945 rpm! That works out to 217 KTAS (249 mph true airspeed)! In no wind you'd be getting roughly 32 miles per gallon 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.





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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.

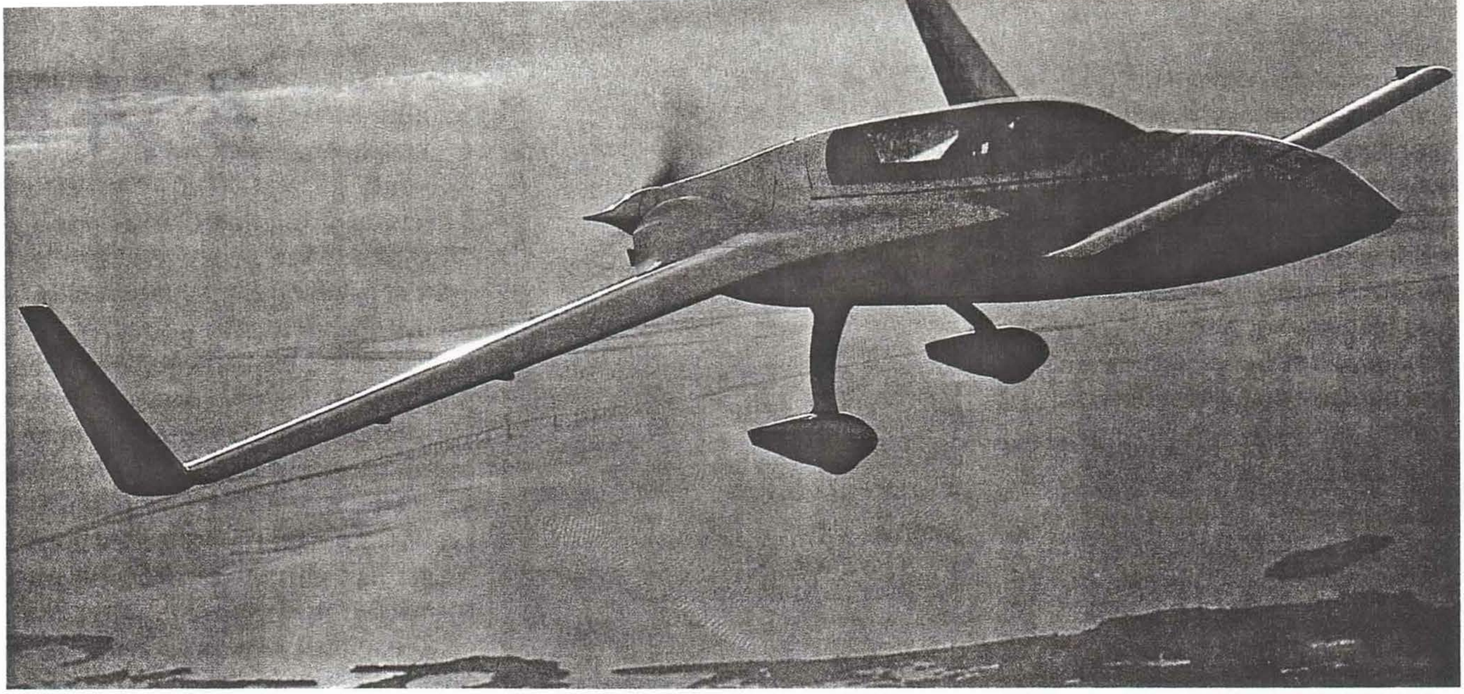
The full-deflection stick force was about 10 to 12 pounds compared to about 15 pounds on my aircraft. Needless to say, Klaus' aircraft is more pleasant in the roll axis. My aircraft also has small but noticeable adverse yaw at traffic pattern speeds, requiring attention to coordinating turns with rudder. 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



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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.