Manned Prandtl

The flying wing flies

BY BETH E. STANTON

ERICH CHASE, EAA 1049327, ran into his old friend Red at the Experimental Soaring Association Western Workshop in Tehachapi, California. Robert "Red" Jensen is operations engineer and chief pilot for subscale UAS aircraft at NASA Armstrong Flight Research Center. Red's boss, NASA Armstrong chief scientist Al Bowers, was giving a talk on the Preliminary Research Aerodynamic Design To Lower Drag (Prandtl-D) wing. The Prandtl-D wing design was inspired by early 20th century research by Reimar and Walter Horten and Ludwig Prandtl combined with observation of bird flight. Lift is distributed across a bell-shaped rather than traditional elliptical wing with twist, eliminating the need for a vertical tail and producing double-digit efficiency gains (see "The Prandtl-D Wing," Innovation, in the July 2016 issue of *Sport Aviation*).

Erich had been researching high-performance foot-launched gliders to build and was intrigued by the idea of using the Prandtl design. "I understood it not from the aerodynamic standpoint, but I got it that you twist the wing and get some forward thrust out of it," Erich said. "Because I'm a sailor, I know about twisting sails to get them to do different things."

Al and a team of graduate students and interns built quarter- and half-scale models of the wing over the last few years. Al's NASA report and technical paper, "On Wings of the Minimum Induced Drag: Spanload Implications for Aircraft and Birds," was published in March 2016. Since then, enthusiasts around the United States and abroad have been delving into equations and software, but a full-scale model had yet to be built. The quarter-scale models incorporated both the Horten brothers' and Prandtl's math. A subsequent half-scale model used a slightly different twist distribution that is pure Prandtl. When Erich decided that he wanted to build a full-scale model, this latest version had yet to fly. They didn't want to give him untested geometry for an airframe that would actually carry a person, so he built the proven earlier model.

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TO SEE THE PRANDTL FLIGHT TEST

Steve with spoilers deployed to check for pitch change.

The Prandtl wing lifts off on its third flight from El Mirage dry lake bed piloted by Steve Davey.

The Garage Band, L to R: Steve Slaughter, Albion Bowers (designer), Erich Chase (builder), Derek Abramson and daughter Annaliese, Steve Davey (builder and pilot), Red Jensen and son Ryan, Justin Hall.

BUILDING FULL SCALE

This is quite experimental, which I find enjoyable and challenging. — Erich Chase

Erich built the hollow, molded carbon fiber wing over the course of several months, using a three-axis CNC router, milling foam molds to build the skins. Proper non-linear twist couldn't be achieved with simple fixtures, so full female molds had to be fabricated. Halfway through the build, he halted and built a 12-foot model for early testing. The model did not fly well and exhibited tremendous adverse yaw with no roll authority. After much head-scratching and experimenting with different dihedral and anhedral angles to no avail, a CG issue was suspected. Red advised Erich to "start adding lead until it flew." Moving the CG forward was the magic solution. The wing flew perfectly, and he got back to work on the full-scale version. Four built-in tabs suspend a cage of aluminum tubes with a wheel in front and back and a sling seat to hold a pilot.

EL MIRAGE TEST

No one was more shocked by how well it flew than me. — Al Bowers

The team met November 6, 2016, at El Mirage dry lake bed in the Mojave Desert in California. Test pilot Steve Davey helped build the wing and is a longtime modeler and hang glider pilot. Everyone felt confident that the wing would fly, but they were concerned about the CG and control harmony. "This is all new and untested," Red said. "There are no plans to follow and nobody to copy."

With Erich driving the truck, the first tow accelerated to 20 mph, allowing Steve to get a feel for the controls. With the stick full aft, the plane did not rotate. When the second tow increased the speed to 25 mph, they discovered elevon flutter. After tightening the Spectra control cables and re-centering the stick, the flutter resolved. On the third tow, the wing lifted off the ground for about 3 feet and 20 seconds, "kind of like the Wright brothers," Red said with a grin.

Steve felt the heavy nose required too much back pressure and adjusted his seat position to refine control input. A series of low-altitude flights commenced, increasing altitude in 5-10 foot increments. "Steve was a little on edge for the first few flights, but then got very comfortable," Al said. A conservative flight envelope was maintained with a 35-40 mph tow speed, 1,000-foot towline, and easy S-turns with no heading changes. Steve flew nine flights total, the last two the entire 4-and-a-half-mile length of the lake bed. His highest altitude was 80 feet. He reported that it felt like he was "in orbit." See *www.EAA.org/extras* for a video of the flight testing.

They decided to end on a high note.

"While we thought we were safe, we didn't want to push our luck," Red said. "There were things we could do better like instrumentation, a real test pilot, and more car tow experience. We can always learn things from other people."

"When you see this thing fly, it's hard to get the image of the way birds fly out of your brain. I see seagulls and pelicans every time because it just has that same sort of long wing feel to it, so elegant and benign," Al said. "I'm used to seeing these larger unmanned gliders fly, but now someone is *in it*, flying it in the air," Al marveled. "There is this part of me that thinks I can't possibly be doing this, it can't possibly be real."

NEXT TEST

This is the spirit of homebuilding 100 percent — a group of guys wanting to try a new angle and bit of technology. — Red Jensen

Al joked that the guys call each other "the garage band." Although they are testing published NASA data, they have used all their own material and hardware up to this point. The next test, planned for spring or summer 2017 after the lake bed dries, is more ambitious. Renowned test pilot Mark "Forger" Stucky is slated to fly the wing up to 2,000 feet. Changes to the glider will include solid control rods instead of Spectra cables and improved harness arrangement for towing. Enhanced instrumentation for data collection will include alpha beta probe, pitot-static system, GPS, and control position transducers. Pressure ports on the wing with fiber optic shape sensors will measure wing load. That data — along with the NASA report, wind tunnel, and flight test data — will complete their experiments.

"Unlike in the business world where you have intellectual property that you want to protect, in research, you want to give it to everybody to provide you with more data to either corroborate or invalidate your theories. I understand that people are skeptical," Red said. "We hope to break down some of the skepticism. There is a potential for significant gains."

"We are 95 percent of the way where we think we ought to be with what we now know," Al said. "We will be able to take real data and prove to the world it really does have 'proverse' yaw and that you really don't need a vertical tail and there is a new way to design an airplane." EAA

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