The SPIN DOCTOR

Craig Catto: master of fixed-pitch props.

BY ERIC STEWART

Paulo Iscold's 223-mph CEA-308 on the tarmac in Brazil with its Catto 58x69. The 308 was unable to break the world record until it was fitted with the Catto. *(Photo: Paulo Iscold)*

Craig Catto is nearing his fifth decade building propellers for Experimental aircraft. Those first propellers still hang above his desk: small hand-carved wood props that spun at 8000 rpm in front of the McCulloch 12-hp two-stroke go-kart engine he was using to motorize his Icarus II hang glider. He tells the story of testing them in the backyard of his childhood home, using bathroom scales to measure thrust and methanol to send the tips past Mach 1. One can only imagine what the neighbors thought.

These days Catto tries to avoid the sound barrier and depends on aerodynamics, rather than methanol, to push the envelope; the deafening scream now is not from his propeller tip speed, it's from demand for his props. Riding the coattails of the Van's RV revolution, word quickly spread to other Experimental communities about the awesome performance of Catto props. His props are so hot in fact that there is a four- to six-month wait time, and if he gets the type certificate for Super Cubs, he figures he'll be able to take orders for $1,000,000 worth of props over the three days of the Alaska Aviation Trade Show.

Catto's propellers dominate the biplane class at Reno and hold numerous world records in speed, time to climb, and altitude. His props have powered the last four consecutive winners in the Experimental bush class at the Valdez fly-in STOL competition, helped take Bruce Hammer and his Glasair 1 to first place in last year's AirVenture Cup, and pulled NASA's Pathfinder to more than 80,000 feet in 1998. Recently, Catto props have become popular among unlimited aerobatic pilots due to their excellent performance and low inertia; Australian unlimited aerobatics champion Paul Bennett has a Catto up front on his Pitts S-1S.

Bruce Hammer won the AirVenture Cup with his Catto-fitted Glasair. He also came in 3rd in the Sport Air Racing League's unofficial "trifecta" with an average speed of 263 mph.

P(recocious)-Factor

The Icarus II motorization began in 1975, when Catto was just 15—before he even had a driver's license (though he had just gained his glider ticket). "I can't believe my parents let me do that," he quips, as he recounts the story. When I ask how he had the confidence to attack such a project, he laughs and simply says, "I had no clue. I didn't know any better."

The Icarus II was a foot-launched glider, and when Catto first took his motorized version to the sand dunes along Pismo Beach (south of San Jose where he grew up), the rat finks in their dune buggies laughed at the tall geeky kid with the Rube Goldberg contraption of wings and wires. Undaunted, Catto dove into the wind, at first "barely moonwalking over the ground," he laughs, but soon buzzing along 12 feet above the dunes, a bevy of Super Beetles trailing behind and cheering him along as he flew up several miles of coastline. He landed with his 15 minutes of fame secured, and an entrepreneur. His first aviation business was selling the Icarus II motorization kits—complete with hand-carved propeller, of course.

Within two years, he was selling kits for a pair of flying-wing gliders of his own design, the CA-14 (wood wing) and CA-15 (fiberglass and stamped aluminum). He still has the informational brochure, which is surprisingly professional in its layout for someone fresh out of high school (Catto graduated high school in just two years). He continued

Photos: Eric Stewart and courtesy of Catto Propellers

DragRacer 25 speeds around the course at Reno behind its Catto. Karl Grove attests to the prop's great acceleration and high race speeds. *(Photo: Karl Grove)*

to buzz around in ultralights of his own design, winning "best float" at the 1977 Everett, Washington 4th of July Parade (flying 200 feet above the parade route with the King Broadcasting logo on the underside of his wings), and being featured on the TV show, *To Tell the Truth,* that same year, and in *People* magazine a year later. All while still a teenager.

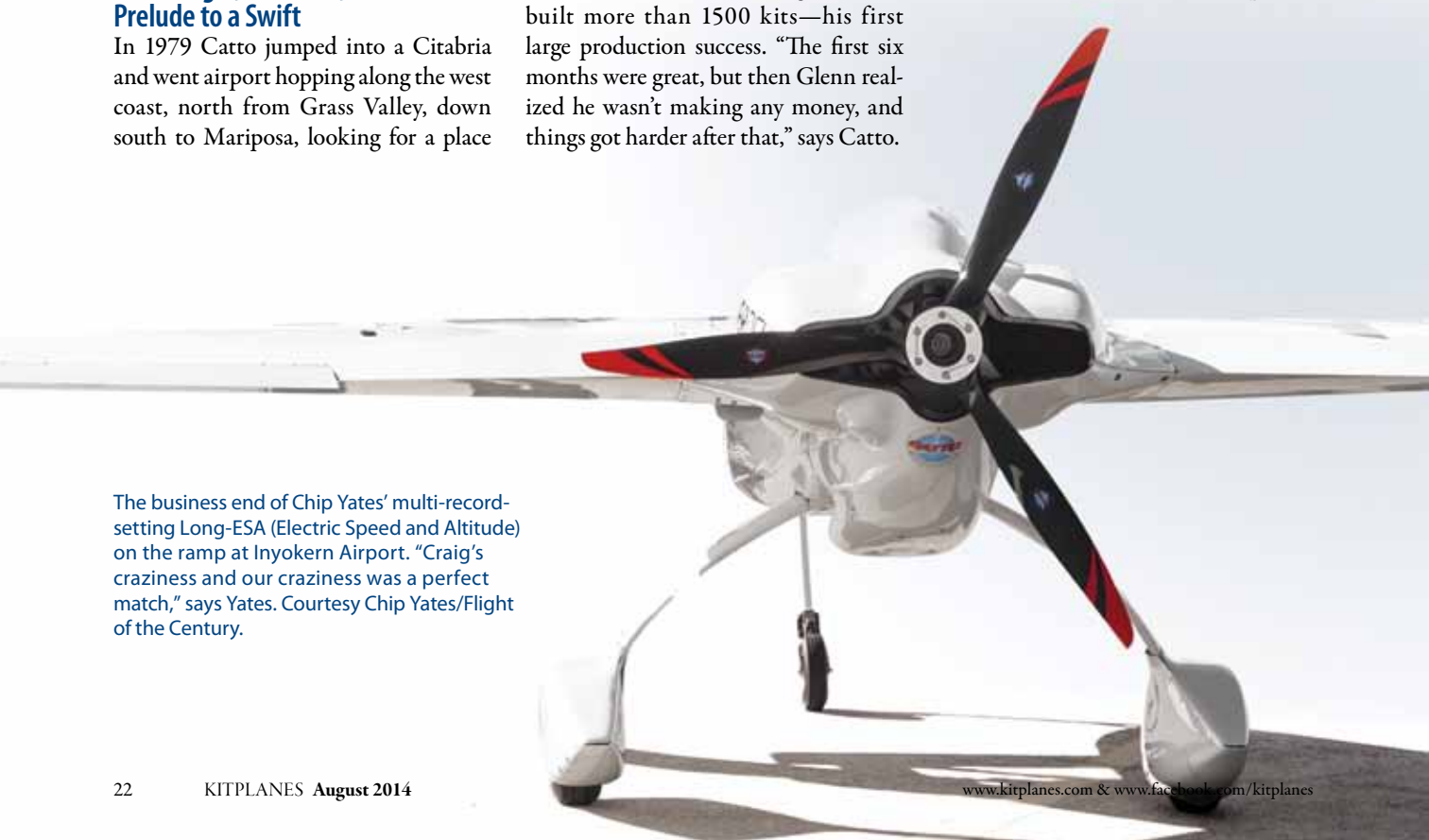
Goldwinger, Odd Jobs, and Prelude to a Swift

In 1979 Catto jumped into a Citabria and went airport hopping along the west coast, north from Grass Valley, down south to Mariposa, looking for a place to set up shop (to the relief of his parents' neighbors, no doubt). At Jackson County Airport, about 40 miles southeast of Sacramento in the foothills of the Sierras, he found a large hangar he could rent for $500 per month. There he established a factory to build kits for a canard ultralight he'd designed called the Goldwing.

In conjunction with Brian Glenn, to whom he had licensed the rights, Catto built more than 1500 kits—his first large production success. "The first six months were great, but then Glenn realized he wasn't making any money, and things got harder after that," says Catto.

When production ceased in 1982, Catto decided to build propellers full time. He moved his shop up to his home atop Mokelumne Hill, where it has been ever since, until moving back down the hill to a new 10,000 square foot facility at Jackson Airport earlier this year. That said, Catto's curiosity and entrepreneurial spirit run wide and his professional work extends far beyond propellers: in addition to hang gliders and ultralights, he built two airplanes of his own design, the *Solo* (a composite ultralight resembling the Cessna 150) and *Acro-X* (a composite knockoff of a Star Wars TIE-fighter). He has built wings and tails for several gold class Formula 1 Reno racers (*Endeavor, Outrageous* and *Scarlet Screamer*), patented an articulating snowboard, and even sold his design for a solar-powered electric standup scooter to a Japanese company. He visited the country twice. "It was an awakening for me to see that level of social organization," he says with admiration.

As we flip through Catto's scrapbook, we begin talking about flying wings (Catto was invited by owner Howard Long to fly the prototype Mitchell wing). He was one of the initial developers of



The business end of Chip Yates' multi-record-setting Long-ESA (Electric Speed and Altitude) on the ramp at Inyokern Airport. "Craig's craziness and our craziness was a perfect match," says Yates. Courtesy Chip Yates/Flight of the Century.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Catto's Acro-X (left) and Solo (right). Craig joined the "Caterpillar Club" when he was forced to bail out and parachute from 500 feet when the Acro-X lost its canopy, jamming in the wing cross brace wires. Looks like a cross between a Vari-EZ and a TIE-fighter? Yep, both Lucas and Rutan had premiered their classic works a few years earlier. Note the wingtip-mounted wheels, a la the original Quickie. The Solo was a composite ultralight resembling a Cessna 150.

molds for rigid-wing hang gliders, and I ask him if he is familiar with the *SWIFT*. Familiar turns out to be an understatement. "The *SWIFT* wouldn't be here if it weren't for the work we'd done," says Catto.

The story begins in January 1985, when Catto, Brian Robbins, and Eric Beckman set out to design and build a revolutionary new hang glider that they named *Odyssey*. Key to the development of the *Odyssey* was a rigid wing utilizing a molded D-tube of composite construction. Few aircraft so well embody the definition of composite: the wing skin was fiberglass, Kevlar, carbon, and Mylar over ribs of aluminum and foam. The project progressed rapidly over the next two years, and in 1989 Brian Porter joined the team and piloted the *Odyssey* to first place in the U.S. National Hang Gliding Championships in Dunlop, California.

Coincidentally, a team of grad students under the leadership of aeronautical engineering professor Ilan Kroo at Stanford University had also begun work on designing a high-performance glider with some of the same objectives as the *Odyssey* at almost the exact same time. In contrast to the *Odyssey* team though, Kroo's team had never gotten beyond computer analysis, although as an article in the January 1991 issue of *Hang Gliding* wrote, "The design became perhaps the world's most thoroughly analyzed glider." Fortunately, one of the Stanford PhD. students met Porter at a fly-in, and it wasn't long before the Stanford team, building on the lessons learned with the *Odyssey*, flew their own rigid-wing hang glider called the *SWIFT*.

Catto points to another picture of a fly-in in the scrapbook. The ultralight-crowded field looks curiously like a baseball diamond. "Yep, it's a baseball field at Half-Moon Bay. This was the Half-Moon Bay Air Race," Catto confirms. There are crowds of people more or less defining the edges of the "runway" that points out to sea, and a party atmosphere. "Looks like the crowds waiting for Lindbergh, doesn't it?" laughs Catto. It's easy to forget that for a brief heyday in the '70s and '80s, hang gliding was a huge part of the Experimental aviation movement and together with ultralights served as a gateway—as it did to Catto—for many of today's captains of Experimental aviation.

Catto's Numinous Corkscrews (CNC)

Until recently, Catto built all his propellers by hand. Laser-scanned measurements have revealed that pitch was accurate to within 0.2 degrees, and profile accuracy was "pretty scary," says Catto. "I scared myself sometimes when I threw templates on. I'd carve them

A 23-year-old Craig Catto poses with a stack of hand-carved propellers for ultralights at his Moke Hill shop, ca. 1982.

Catto prepares to take off with the *Icarus II* at the former Sky Sailing Airport in Fremont, California. His brother Chuck faces the camera. We see here a rare application of Levis as wheelpants.

Catto above Jackson, California in his Goldwing, ca. 1980. The hills near Lake Tahoe can be seen in the distance.

The CubCrafters Carbon Cub SS comes standard with a nickel leading edge Catto 80x50 and some serious ROC mojo. *(Photo: CubCrafters)*

down, throw the templates on, and it was spot on. When I saw that, I said to myself, 'I've been doing this too long.'"

Fortunately in 2009, Catto was approached by CubCrafters to supply props for its Carbon Cub SS kits. Catto realized then that there was no way he'd be able to meet demand without introducing automated manufacturing processes (he had a single helper and made at most eight or nine props per month). So, with zero experience in industrial manufacturing, Catto purchased a laser scanner, a used 5-foot x 10-foot CNC router, Rhino 3D CAD software, and CAM software.

"The manuals for these four tools were over 900 pages. So every night after work, I'd come in and read the manuals to figure out how to make this thing work. I even called the cable company and told them to temporarily suspend my TV subscription so that I could focus," says Catto. "I would sit in my kitchen and read and think I had it figured out, then go out to the shop and get as far along as I could on the CAD. Then I'd stumble, so I'd go back and read some more, and I'd get through the CAD and make it to the CAM. Suddenly it was creating tool paths, and now I could actually hook it up to the CNC machine to make stuff."

Within 6 months, Catto had decoded the system and began manufacturing his first CNC'd props. These days, the CNC chatters constantly. The number of full-time helpers has increased from one to five, and the

company is currently shipping 50-60 propellers per month. A second CNC machine has been added to the tooling stable, and Catto has his sights set on gaining STC approval for Cubs and eventually even Cessnas.

Performance

So how about performance? At the slow end of the spectrum, Catto's props have become all the rage for STOL aircraft, since the low speeds do not necessitate a constant-speed prop and a premium is placed on weight savings. Fixed pitch are, of course, significantly lighter than constant speed, and Catto's props are among the lightest fixed-pitch propellers, typically weighing 10 to 14 pounds, depending on diameter and number of blades. The results from the annual Valdez STOL competition speak for themselves.

Catto Props has also recently teamed up with Just Aircraft to produce propellers specific to the SuperSTOL (see the October 2013 issue of KITPLANES® for the SuperSTOL and Highlander kit review). Previously, customers were limited in their choice of props for the Rotax installation, with optimization being achieved via ground-adjustable units that were geared more towards higher cruise speed LSAs.

Frank Knapp's Valdez-winning *Lil' Cub*. "We have run the Catto on *Lil' Cub* for 500 hours in Arizona deserts and Alaska river flying. It has held up very well under those tough conditions and pulls better than any other prop we've tried." *(Photo: Brady Lane)*

"I'll talk about this out at Oshkosh this year," says Catto, "but the problem with ground-adjustable props is this: ideally if you increase the pitch one degree at the tip, halfway out should be about two degrees, and four degrees nearer the hub. But on ground-adjustables, you change the whole blade the same one degree. This changes the spanwise loading—it can be all over the place, so you never have an ideal spanwise loading. That is where we can typically see big improvements in efficiency." By designing a prop customized to the SuperSTOL and Highlander engine and aerodynamics, Catto's props are much more efficient—to the tune of 25–30% improved climb rate with no penalty in cruise.

"I've been trying for years to get props made for STOL aircraft, and there wasn't a manufacturer I approached who didn't say 'no,'" says Troy Woodland, designer of the SuperSTOL and Highlander. "One told me to send them a purchase order for 50 props and they could do it. Well, at Oshkosh last year, I was again in the tent of one of the big manufacturers trying to convince them to make me a prop, with no luck. I went back to my booth and 15 minutes later Craig happened to walk by, and we started talking props. He committed right then and there to make a prop for the Rotax/SuperSTOL and Highlander combo.

"As far as I'm concerned, this prop is a game-changer for us. I can take off in

How They're Built (Minus a Few Trade Secrets)

Current Gen 5 props begin with a wood blank, typically a laminate of five layers of eastern rock maple. Since Catto props feature an outer skin of carbon fiber, the wood blank serves primarily as a convenient machinable core, rather than a structural role. The strength and stiffness of carbon fiber allows Catto to make larger diameter propellers than are possible with the thicker airfoils of wood-only props. This is why Catto props tend to perform on par with metal props: propeller efficiency is directly tied to the disc area of the prop. Disc area is, of course, πr^2, so even a small increase in prop diameter can yield significant improvements in efficiency.

One limiting factor, however, is that as diameter grows, so do tip speeds. As tip speeds approach Mach 0.8 or so, propeller efficiency drops off significantly, since the upper surface of the airfoil actually begins going supersonic and this creates unnecessary wave drag (and noise)*. The carbon fiber allows Catto to use thinner airfoil sections, which delay the onset of drag divergence and supersonic flow over the upper surface, thus allowing the larger diameter (i.e., higher tip speeds approaching Mach .92) propellers. "By using carbon we can produce blade profiles that are as thin as metal props, but with the advantage of lighter weight, as well as layup schedules that allow us to address issues with resonance or loading. When an airplane with my prop goes by, you hear more of the engine, and less of the prop."

Back to the blanks: These maple cores are then rough oversize cut to planform shape on a large bandsaw, followed by another oversize cut on the backside to minimize CNC work there. The blank is then loaded rear side up on Catto's CNC machine and the center hole cut and lower surface CNC routered to an accuracy of ±.001 inch. The propeller is then removed, the lower surface laminated with unidirectional and bias carbon fiber, and the propeller returned to the CNC table.

Once the upper surface has been machined (CNC time is typically 2.5–3 hours per prop, depending on the diameter and number of blades), the prop is again removed and this time placed on the laminating stand to receive the upper surface carbon fiber laminate, as well as a final outer coat of fiberglass, which serves to protect the carbon and is easier for contour work.

A pair of three-blade prop blanks awaits the initial rough cut. A third blank on the table is being traced with the template outline.

The CNC routs a rough-cut blank to the coordinates programmed from Craig's computer. A variety of tool heads can be seen to the upper right of the head: the machine automatically changes out heads according to the CAM cuts Craig has specified.

my parking lot (see the video at *http://tinyurl.com/l5ux2v9*) on any given day, and before, in order to pull that trick, I needed a breeze. Getting 400 pounds of thrust from a Rotax is unheard of—I used to be getting 375 pounds or less, depending on the prop—and now we are getting 440 pounds on a stock 912S. To me a 20-pound increase used to be huge, so 65 pounds is just unbelievable.

"With development, our planes have gotten a bit heavier. I'm usually not worried about getting in somewhere, but I was sometimes nervous about getting back out. Catto's prop has solved that problem for us. And with the SuperSTOL landing gear, prop clearance is not an issue." Within 24 hours of announcing the joint venture, Catto had three orders for Catto Highlander props.

Catto has also recently finished certifying his props for the LSA Carbon Cub SS to ASTM standards—the first propeller manufacturer to achieve ASTM status. "Overall we've been very pleased with our relationship with Catto Propellers," says Randy Lervold, general manager at CubCrafters. "The ASTM certification standards are going up all the time, and the propeller standards have become particularly difficult. The ASTM requirements for a propeller now require five hours at full rpm, 45 hours at 90% power, and 100 hours total service time. We worked closely with Catto on the certification, and the propeller performed flawlessly. Even before the ASTM certification, we had been using Catto props, which have consistently outperformed everything else we have tried."

In between slow and blistering is the vast playground of most Experimentals that are Catto's bread and butter: RVs, Zeniths, Velocitys. Catto actually got his start in the Experimental aircraft market with the Long-EZ/pusher crowd. "For canards it's not a matter of 'if' something goes through the prop, but 'when,'" laughs Catto. "My props are known for taking the abuse. Over the years I've had

A plate of 1/8-inch aluminum is also bonded to the rear hub at this time. "What we've found through experience is that for the working surfaces, you don't want a composite surface in there because of heat build-up. If it starts to work [i.e., rub], heat will build up rapidly with those firing pulses. If that is on the composite, the epoxy matrix will melt very rapidly, and that's when the prop comes off—the whole prop will come off because it shears the propeller bolts. And we've had it happen. So that's when I developed the aluminum plate bonded to the composite surface. So now it's like gluing your propeller onto the metallic installation. And if there is any working, it's between two metallic surfaces, and not a composite surface, which is real important."

Props with electroformed nickel leading edges will have the edge vacuum bagged on at this time, and after final contouring and smoothing, it's off to the paint booth. Most Catto props are delivered either black or white, with trim colors on the tips, although they do get the occasional request for more elaborate (and more expensive) paint schemes. Total manual labor per prop is about 12–14 man-hours (on top of the CNC time), and Catto performs the final inspection and balancing before the prop is shipped to the customer.

Most Catto props today are manufactured to the same standards as unlimited aerobatic props—essentially a max rpm of 3600, well past the redline of Lycomings. Unlike wood props, Catto propellers do not need regular re-torqueing: the carbon skin completely envelopes the propeller, protecting it from the effects of humidity. The carbon also allows Catto to set a higher safety margin for torque values: Catto propeller bolts are torqued to 38 ft-lbs, as compared to around 18–22 ft-lbs for regular wood props. And although at this point Catto has a pretty good idea of how to match props to most airframe/engine combinations, all props come with one free re-pitching if the customer is not satisfied with out-of-the-box performance.

—E.S.

**Remember that lift is created by air flowing faster over the upper surface of the airfoil than the wing's (or propeller's) actual speed through the air. As an aside, the phenomenon of local supersonic flow at subsonic speeds is occasionally visible on passenger jets as an optical distortion near the leading edge—look for it the next time you fly commercial.*

Craig rough cuts a blank according to template outlines for specific aircraft/engine combinations. The rough cut reduces CNC time.

(Left) Daniel Tamayo wets out a layer of unidirectional carbon fiber. It was a cold day in the shop: note the propane heater warming up Daniel's workspace (and cans of resin). (Right) Tamayo applies a resin/flox mixture around the hub. The last outer layer of fiberglass can be seen here. Once cured, the prop is ready for final sanding by hand.

four canard owners call me and credit my prop with saving their lives when major airframe parts—including an entire lower cowl—went through the prop and it still got them back home safely."

As many customers with unique needs attested to in the research for this article, Catto is quite willing (and even excited) to test new propeller ideas—especially projects that push the performance envelope. Bruce Hammer, winner of the 2013 AirVenture Cup, had tried numerous props on his Glasair. "Catto's was by far the best and strongest. One great thing about Catto is that he is very receptive to new ideas and working with the customer. If the prop is not performing the way you expect, he doesn't blame it on you or make you feel stupid; he works together with you to educate you and determine how to get the best performance for your airplane/engine package."

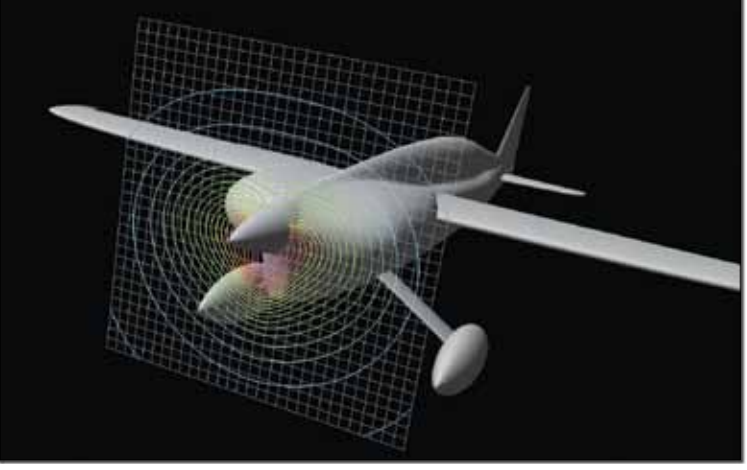
The ultimate litmus test, of course, for any prop is racing. Mike Thompson, Sport Air Racing League (SARL) chairman and founder, echoed Hammer's sentiments: "Exposure to the hyper-speed crowd (like Bruce Hammer) made me understand that high-rpm composite props are the key to success. Attached to the motor of most serious small race planes in the 100- to 250-hp range you will find a Catto prop." Thompson was also impressed with the smoothness of the prop as compared to his non-race aluminum fixed pitch, as well as Catto's uncanny ability to accurately predict speed at race rpm based on customer-supplied data in the non-race configuration.

Due to the extremely high rpm used on Formula 1 racers, Catto's wood core design can't handle the stresses imposed on the blade by high-G turns; for this, a solid carbon blade is necessary. However, his props are popular in the Biplane class where engine rpm is less extreme. Karl Grove, pilot of *DragRacer*, credits Catto with being instrumental to the continued improvement of Race #25 over the last four years at Reno.

"Catto is perhaps one of the most down-to-earth guys that I've met in air

Manny España (left) applies epoxy to the inside of the nickel leading edge fitting while Daniel Tamayo warms the LE with a heat gun to promote epoxy flow and thus a good bond. The white tube is connected to a vacuum pump for vacuum bagging the nickel to the LE.

No, it's not the mythical ultra-high efficiency single-bladed prop…Manny España applies body filler to a blade that will be used as a mold for the nickel leading edges. The nickel LEs are formed by electrodeposition and take 12 hours to "grow."



(L) Propeller inflow velocity isobars calculated for Paulo Iscold's *Anequim,* which will attempt to break the C-1a world speed record. Catto used Iscold's calculations for the propeller streamtube slowdown to modify the inboard pitch distribution. Initial performance of the final result (R) closely matched theoretical expectations. *(Photo: Paulo Iscold)*

racing and aviation," says Grove. "Since the first time we met, Catto has continued to push the envelope every year with new concepts and prop designs in the search for that extra few rpm or hundredths of a second. He's always up for a challenge and ready to tackle the impossible by developing new construction techniques, new testing equipment, and diagnostics—where in my opinion he leads the industry."

Catto props are also a favorite for absolute speed and other records, where the prop can be optimized for a single flight condition. "Catto has been very supportive of our projects," says Dr. Paulo Iscold, professor of aerodynamics at UFMG in Brazil, consultant to several Red Bull and Reno air race teams, and holder of four world records with his CEA-308. "The first prop that he sent for our 308 was almost perfect, and the second prop was better than perfect. I'm not afraid to say that Catto's props are the best aerodynamic setup in the world today. He has been trying many different ideas through the years, and his propellers incorporate many features that are not listed in the usual literature. On the 308 I must remind you that we set the 3 km absolute speed record and the 3000 m time-to-climb record with the same prop!"

Catto props have set ten FAI world records in speed, altitude, and time to climb. By the time this article reaches press, that number may have increased if Iscold's *Anequim* achieves its predicted performance in its attempt on the C-1a record.

Catto will have a booth at AirVenture this year and will be giving two talks on propeller design and the CarbonCub ASTM prop certification. Stop by and say hi to the Doctor of Spin. ∓