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COMPOSITE AIRPLANES

A DIFFERENT BREED OF CATALYST

BY MARK PHELPS

LOVE IT OR HATE IT, composite aircraft technology changed the aerospace industry forever. Sometimes composites make up most of the airframe, as with the Cirrus series, Boeing's 787 Dreamliner, and a long list of kit planes and light-sport aircraft (LSA) from Glasair, Lancair, Flight Design, and others. With different aircraft, selected components, such as vertical and horizontal surfaces, fairings, and landing gear doors, are made of advanced composite materials.

Advanced composites have found a happy home in aerospace, and the industry has expanded the state of the art by leaps and bounds. In the homebuilt and LSA world, composite airplanes have left their mark over the past four decades. And in many ways, they are a different breed.

Ironically, Wikipedia defines the primary building material used for history's first aircraft as "an organically occurring composite of cellulose fibers in a matrix of lignin and hemicellulose"—otherwise known as wood. Aircraft skeletal structures evolved to stronger, more durable steel tubing with wood formers covered by fabric and, later, lightweight aluminum alloy riveted together in a monocoque configuration for maximum strength and minimum weight. For decades, that basic formula remained tough to surpass when it came to designing aircraft structural components.

FIBERGLASS

Fiberglass as we know it today was discovered by accident in a lab at Corning Glass in the 1930s. Attempting to weld together a pair of glass blocks to form an airtight seal, a young researcher named Dale Kleist mistakenly allowed a blast of compressed air to strike some molten glass. A shower of fibers resulted. Kleist had the foresight to recognize he had something there (or maybe he was thinking fast to cover up for making a big mess). Those glass fibers were eventually spun into threads and woven into cloth. Corning branded it Fiberglas.

Like straw in the mud used by Egyptians to make bricks, fiberglass cloth needed a self-hardening liquid "matrix" in which it could be embedded to form solid structure. In 1936, Carlton Ellis of DuPont was awarded a patent for a polyester resin that, when reinforced with the strengthening qualities of fiberglass, created the first composite.

Naturally, the new material was examined for tactical uses during World War II and used in limited ways, but the first large-scale commercial use of fiberglass came via the recreational boating industry.

In 1942, Corning Glass employee Ray Greene produced the first daysailer made from fiberglass, and a new era dawned on the marine world. Boats and fiberglass were made for each other. The medium also found a ready market among surfers, who shaped their boards out of polystyrene foam encased in lightweight, solid fiberglass.

The first widespread application of composites in aircraft came from the sailplane community, with composite gliders certified as early as 1967. In the early 1960s, Dr. Leo Windecker and his wife, Fairfax, both dentists living in Texas, began developing a four-seat powered aircraft, the Windecker Eagle ACX-7, and received an FAA type certificate in December 1969. With its molded fuselage halves split down the centerline and joined like those of a plastic model, the Eagle was 10 miles per hour faster than a V35 Bonanza at the same maximum gross weight and using the same engine power, even though it was 11 inches wider and 2 feet longer.

The speed advantage was attributed to the smooth surface (no rivets or lap joints) and the ability to design complex, aerodynamically efficient curves that would have been prohibitive in a metal airplane. It is also thought that the resistance of the Eagle's airframe to wrinkling and buckling under load reduced parasitic drag even further.

When Burt arrived at Wittman Field, he was inundated with people who wanted to build their own VariEzes. Thus launched the era of composite homebuilt aircraft.

In what would be a foreshadowing of certification programs for composite airplanes to come, the conservatism of FAA certification engineers required Windecker's Eagle to be 20 percent stronger than a comparable aluminum airplane, exacting an estimated 100-pound weight penalty. Through the 1970s, the underfunded company built only six examples for the civilian market, and efforts to secure a military contract as a radar-resistant aircraft were not fruitful.

PIONEERS

Most EAAers are aware of Burt Rutan's 1975 appearance at Oshkosh, debuting his rear-engine, canard-configured VariEze. Burt had already wowed the EAA crowd with his VariViggen, a wooden design inspired by Sweden's canard-equipped Saab Viggen series of jet fighters. He chose to add composite construction to his technology quiver for the VariEze, permitting far more freedom to design a sleek planform with minimal drag. Compared to the slab-sided VariViggen, the sleek VariEze's rigid polyfoam skinned-in fiberglass truly resembled something from outer space, and probably generated its share of UFO reports.

The VariEze was originally conceived as a flying prototype to explore canard aerodynamics. But when Burt arrived at Wittman field, he was inundated with people who wanted to build their own VariEzes. Thus launched the era of

Since Burt Rutan (rear) and his br... Dick arrived at Oshkosh wi... VariEze, the world of homeb... hasn't been the s...

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composite homebuilt aircraft. Improved versions included the larger Long-EZ and a host of designs from others (such as the side-by-side Cozy), inspired by the canard configuration and the design flexibility of composite structure.

The VariEze and its follow-on progeny are legend, not only within EAA, but throughout the world. Burt Rutan's company Scaled Composites, founded in 1982, produced the Voyager, a composite twin-engine, twin-boom flying fuel tank with just enough room for his brother Dick and fellow pilot Jeana Yeager. The pair flew around the world without refueling in December 1986. The trip took nine days.

Another pioneer of the era was the late Ken Rand with his single-seat KR-1 and side-by-side two-seat KR-2. These were wooden airplanes that had foam formers glued to the slab sides and covered with thin fiberglass.

In 1978, I had my first job in aviation, working in the admissions office of an A&P school outside Boston. That's when I first joined EAA, and I bought a set of Ken's plans for $25. I still remember standing around drinking coffee with one of the airframe instructors when I told him what I'd bought. He paused the conversation, took his wooden stir stick, bent it so it fit inside his Styrofoam cup, and dropped it on the ground. Then he stomped it flat with his work boot and said, "That's what they look like when they crash." (To be fair, today you can do the same thing with an aluminum soda can.)

By the time of the Voyager flight, other homebuilt designers had cut themselves into the composite herd. Two of the most notable are Tom Hamilton, founder of Glasair, and Lance Neibauer, founder of Lancair. Both designers chose to use the more conventional control configuration—tail in the rear and engine in the front. Both have been very successful.

Steeped in EAA roots, Klapmeier brothers Alan and Dale took composites to a whole new level with their Cirrus series of high-performance singles.


Looking like a refugee from the set of Star Wars, Burt Rutan's canard configuration probably generated its share of UFO "sightings."

CARBON FIBER

Lancair broke ground with a new form of "molded" composite that used carbon fiber, requiring high temperature curing in an autoclave—a large oven. The kit manufacturer designed the original mold, then constructed a production mold, upon which all the parts are assembled. Carbon fiber is more difficult to work with from scratch than fiberglass, but when the components are manufactured and shipped to builders as kits, it goes together similarly to the plastic models many of us built as kids.

One of the design elements of using more advanced materials such as carbon fiber is that the strength of the finished part can be affected by the angles at which the strands of cloth intersect. Torsion affects the material at specific angles that can be calculated by computer programs. One example of this refined technology is the

Tom Hamilton's Glasair series was among the first to put composite construction at the top of the wish list for countless homebuilders.

Terrafugia Transition roadable airplane (or flying car, depending on your perspective).

France's Dassault Systèmes (a sister company to Dassault Falcon Jet, which manufactures business jets) has partnered with the team at Terrafugia to provide detailed calculations optimizing the angles of the cloth strands for every square inch of the Transition's airframe, calculating all the curves and intersections. This allows the designers to use just enough material and thickness to provide the design strength, and no more. The object is to build in sufficient strength to the structure, but not overbuild and waste precious pounds—or even ounces—on unneeded material.

With its light-sport aircraft design limit of 1,320 pounds, every ounce saved in excess structural material on the Transition can be dedicated to useful load or other equipment, such as the ballistic parachute, avionics, and highway safety components.

Lancair's Legacy uses pre-impregnated carbon fiber and/or fiberglass systems sandwiching Nomex honeycomb material. The epoxy-based composites are cured in autoclaves at 270°F under vacuum pressure.

Kit manufacturers (at least the ones that expect to stay in business) perform extensive testing of their products. The Legacy was a refinement of the Lancair 320, with a new wing design and other airframe improvements. Testing included not only computer analysis, but also a full flutter test program starting with a ground vibration survey (GVS) using more than 40 accelerometer sensors covering the entire airframe. The composites were also tested under simulated extreme environmental conditions replicating the worst weather.

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BUILD ASSISTANCE

Ask a composite kit plane builder if it's really like assembling a Revell plastic model airplane and he will usually smile a little and admit it's closer than you might think. Except with your life-size airplane—upon which your life will depend—the incentive to be precise is heightened. In most cases, there ends up being a lot of sanding, trimming, aligning, and plumb-lining to ensure everything is aimed in the right direction when the resin cures.

One of the recurrent themes in building a composite airplane is the "rotisserie" jig used to rotate the fuselage during the building process. Having easy access to top, bottom, and both sides is mandatory. One Lancair Legacy builder, Stan Fields, also pointed out that assembling the pre-owned rotisserie he bought served as an entrance exam for his project. If he couldn't figure out how to assemble his rotisserie without instructions, he wrote in his builder's log, he shouldn't attempt to build his airplane.

Many builders host websites such as Stan's, and they can be a treasure-trove of information and advice. Some builders keep detailed notes on every stage of their project, and they are not shy about pointing out discrepancies or deficiencies in the kits, plans, or printed directions.

Of course, the best source of information is usually the factory that designed and built the kit, and many have comprehensive builder-assist networks, involving Internet help lines, videos, and the old-fashioned telephone, to help get you over any obstacles.

Glasair also has its Two Weeks to Taxi accelerated program for builders of its Sportsman. Based on the original GlaStar, the Sportsman 2+2 is a refined version of the two-place taildragger with the option of a cavernous cargo area or two rear jump seats. It places an emphasis on bushplane qualities, though it's also available in tricycle-gear configuration.

In 14 days of work at its Customer Assembly Center (CAC) in Arlington, Washington, builders can assemble their aircraft, start up the factory-new Lycoming engine, and taxi out for its first run-up. Glasair estimates that the final work to bring the Sportsman to first-flight status could take as little as another two weeks. The CAC provides precision tools unavailable in most home shops and expert assistance from the team that designed the Sportsman and produced the kit.

Lancair's Builder Assist Program has similar advantages. Originally conceived to help kit builders complete the complex Lancair IV-P pressurized kit, the program has been expanded to include all current Lancair models. In five days, builders can close out the wings and tail section of any Lancair, a process that was averaging up to 1,000 hours without the expertise and precision equipment available at the Lancair factory in Redmond, Oregon.

The other benefit of the program is building the personal relationships—putting a face to the voice on the other end of the customer-support phone when the builder needs help further along the road.

The Lancair Builder Assist Program also offers Firewall Fastbuild and Engine Fastbuild programs, reducing the time to install the engines to about eight hours, compared to the 100 hours builders have averaged without the assistance. There are also independent third-party builder assist programs that may be more local. Check with the factory for information on such programs—and for an endorsement of the provider.

THE LONG BUILD

But some builders savor the building process as much as flying—in some cases, even more. For them, the idea of using fast-build kits and accelerating construction would be like ordering a gourmet meal at a five-star restaurant and gulping it down as fast as possible. Speeding up the project is not to their taste.

One of the best parts of building a composite airplane is that the required tools and materials are relatively simple. The proper workshop area is critical. Perhaps the most important consideration is ventilation. Temperature control is also vital for resins to cure effectively. It is also recommended that lay-up work is done in a room separate from where trimming, cutting, and sanding take place to avoid particles settling on wet resin. The recommended work table should be 3 feet wide and up to 20 feet long, depending on available space.

Tools to build a composite airplane consist primarily of scales and pumps to mix the resin and blend it with the hardening agent; an article by Ron Alexander in a 1997 issue of *EAA Sport Aviation* recommends postal scales costing less than $100. Ron wrote that the following tools were also necessary: special fabric shears for cutting fiberglass cloth, utility knife, rotary pizza cutter, rubber squeegees, grooved laminate rollers, disposable paint brushes (in various sizes), sanding blocks, mixing cups, tongue depressors for stirring, latex gloves, and a charcoal-filtered respirator. Ron considered the following to be optional: a band saw, portable electric sander, Dremel for trimming components, and belt sander.

Composite materials have come a long way since the first application so many years ago. Their advantages over most metals include high strength, low density, high stiffness, dimensional stability (resistance to buckling and bending), temperature/chemical resistance, and relatively easy processing.

Of course, many of these attributes are also true of aluminum. New alloys have been developed that are now up to 10 percent lighter than previous forms of the aviation metal of choice, narrowing the gap between the two mediums even further.

But in the real world, there are people who simply prefer working with wood, fabric, or metal, and those for whom the smell of foam, resin, carbon fiber, and fiberglass cloth stir the imagination. These designers, builders, and pilots have made composite homebuilts and kit planes among the most exciting and high-performance aircraft in general aviation. *EAA*

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The intersecting angles of the composite cloth in the fuselage of the Terrafugia Transition are computer-designed for optimum strength at the minimum weight.

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