Whither Starship

Five years after its introduction, Beech's all-composite advanced turboprop is still masked in mystery, although now more is being revealed about this exciting design.

By John W. Olcott

Five years and several million dollars after its introduction at the 1983 NBAA convention, the Beech Starship is certificated and heading toward delivery to its first customer in the second quarter of 1989. Even now, however, the all-composite, radically configured turboprop is veiled by a lack of public knowledge and an abundance of speculation concerning the twin engine aircraft. Beech offered only guarded information concerning the aircraft's performance and handling qualities throughout the Starship's gestation (which actually started in 1979 and was kept a dark secret until *Aviation Week* broke the story in August 1983), its development and its ongoing certification (which continues now for the purposes of crew determination, autopilot usage and approval for flight into known icing).

No one except a few selected Beech employes were allowed to pilot either the 0.85 scale model of the design, which first flew on August 1, 1983, or one of the three full-size prototypes that have been operational for several years. Even Starship orderholders were not allowed aloft in NC-3 (the prototype used for FAA final certification tests) during a recently completed nationwide tour of the aircraft to discuss performance and delivery plans with key Beech customers.

As Beech stonewalled pleas from journalists and other interested parties to fly the Starship, or to learn details about the aircraft's specific characteristics, rumors soared. Word spread that the early Starship needed more aerodynamic refinement in its nacelles and prop design to achieve its predicted speed, that it was heavier than expected, that its large tip sails and wing sweep excited a pronounced Dutch roll, that its large wing resulted in more gust sensitivity in rough air, etc. The less said by Beech, the more rumors flew. Reflecting on the enormity of Beech's effort to plow new ground in aircraft design and development, some wags recalled the words of J. Lynn Helms, who as CEO at Piper is said to have told his engineers that a pioneer was a farmer with an arrow in his rump.

Performance Released

Slowly, however, the Starship is emerging from the fog of mystery and suspicion that has caused considerable speculation about its success and Beech's wisdom in undertaking the pioneering effort of successfully certifying the world's first all-composite, pressurized aircraft.

Preliminary performance data based upon the configuration of the design certificated June 14, 1988, for example, was released August 23. According to Beech engineers, the Starship at midweight (about 12,300 pounds) has a maximum cruise speed of 336 knots, which is within 3.5 percent of the target of 348 knots (400 mph) announced in 1983.

Beech says the Starship's maximum range is 1,670 nm, about 4.0 percent less than the design goal specified five years ago. Gross takeoff weight is said to be 14,250 pounds, considerably higher than the 12,500 pound figure announced in 1983 but only 250 pounds more than Beech was stating in 1986, shortly before the FAA finalized, in February 1987, Amendment 34 — Airworthiness Standards and Operating Rules for Commuter Category Airplanes — to FAR Part 23, the basic certification used for the Starship.

Empty weight is reported at about 9,500 pounds including unusable fuel, oil and standard avionics. It should be noted, however, that Starship avionics, consisting of an extremely sophisticated and capable EFIS, are far more extensive than normally found in a turboprop (or medium-size jet, for that matter). Also, the Starship is significantly larger than the typical turboprop in its power and weight class. The aircraft's max payload is given as 2,539 pounds, about 145 pounds less than the figure Beech released for B/CA's *1988 Planning and Purchasing Handbook.*

Rate of climb, however, is about what Beech predicted — an impressive 3,250 fpm. Airport performance enables a takeoff distance of 3,380 feet at the aircraft's gross weight of 14,250 pounds and a landing distance over a 50-foot obstacle of 2,650 feet at its max landing weight of 13,538 pounds. (Takeoff and landing distances are subject to improve with final testing of the Starship's anti-skid braking system.)

The Starship is pressurized to a differential of 8.4 psi, which provides a sea-level cabin to 21,400 feet, and the aircraft can maintain an 8,060-foot cabin pressure at its certified ceiling of FL 410. With one engine inoperative, the Starship can climb to a service ceiling of 19,000 feet.

Compared with Beech's King Air 300, the Starship provides a noticeably larger cabin — 4.43 feet longer, 0.54 feet higher and 1.1 feet wider — than the $3- to $3.2-million, conventionally configured and constructed turboprop. The Starship's speed is 20 to 25 knots faster, its pressurization is 2.9 psi greater and its altitude capability is 6,000 feet higher. The King Air 300, however, has a maximum range that is about 90 nm longer than the nearly $4 million Starship's and has a max payload about 320 pounds greater.

New Ground Broken

With Starship performance established and production underway, more is being revealed about Beech's significant and long-term commitment to develop not only a new aircraft but also a new design and composites fabrication capability as well.

Beech, noted and often mildly criticized for its conservatism, launched the idea of a King Air replacement in 1979 and generated 12 preliminary designs at that time, three of which were significantly influenced by the concepts of Burt Rutan, the highly innovative designer of the *Voyager* and the VariEze (among other multi-wing aircraft). Rutan, however, was not a consultant to Beech when those efforts were underway.

One of the preliminary Beech designs, PD 330, although smaller, looked amazingly like the recently certificated Starship in drawings dated January 30, 1980 (see illustration. Later that year each of the 12 preliminary designs was dropped since King Air sales showed no signs that a replacement product was needed in the near future.

Two years later, in 1982, interest in new development was resurrected under the leadership of Brainerd Holmes and Linden Blue, chairman and CEO of Beech, respectively, after Raytheon purchased the Wichita-based general aviation manufacturer. It was then that Burt Rutan was hired as a consultant. Work was resumed on an advanced turboprop, and the Starship emerged as a serious project designed to move Beech into a new dimension of engineering and production technology, although it was not until a few weeks before the aircraft was introduced to the public at the 1983 NBAA show that the aircraft was officially given its name.

The 0.85 scale version of the Starship, built by Rutan's Scaled Composites, stirred much excitement during secret tests conducted at Rutan's facilities in Mojave, California during August 1983.

Returning to Wichita in a Beech King Air after observing one of those initial flights, Linden Blue and his director of strategic planning, Ernie Sturm, were discussing what the unusual machine should be called. As Sturm remembers the occasion, the nighttime sky was crystal clear and the stars exceptionally bright. Gazing upon the beauty of the vast sky over the western plains, Strum suggested the name "Starship" for the exciting, futuristic design. While Blue liked the idea, others at Beech had reservations. Someone proposed calling the aircraft the Beech X-2000, while someone else pushed for Enterprise as the official designation.

Nothing had been decided, however, as Blue prepared to tape a presentation on the aircraft to be shown at a special Beech press conference in Dallas just prior to the NBAA convention. Blue called Sturm moments before the taping was to commence and asked if he had any additional thoughts concerning names. Sturm, who is now president of Flightcraft, a large FBO located in the Pacific Northwest, replied that "Starship" was still his first choice, but clearly the decision was Blue's. Thus the aviation world was introduced to *Starship I.*

Linden Blue conceived of the all-composite Starship being built in major assemblies by outside contractors to Beech. That idea was scrapped in 1984 in favor of bringing all the composite fabrication in-house, thereby delaying the Starship program by about a year and thrusting Beech into a massive technology development program in the potentially lucrative and prolific arena of composite design and manufacture.

Learning Composites

While the decision to bring all the composite fabrication in-house delayed the Starship program, it provided Beech with an asset that may eventually be worth much more than the $300 million the company has spent so far on the aircraft's design and certification. Unlike the mature technology of aircraft fabrication from aluminum, composite manufacture for aerospace is in its infancy. There are few experts, and each composite design presents its own manufacturing challenges, since strength and weight efficiency are highly dependent on the orientation of the fiber elements in the composite matrix and in the final layup. In order to obtain maximum benefits from composites, manufacturing techniques must be an integral part of the design process. Only by working with the problems of composite fabrication can a company learn to design and build an efficient composite aircraft.

Beech worked the problems of composite design and manufacture long and hard until it amassed an impressive (and proprietary) database of composite technology. Beech also has purchased or built a formidable array of specialized facilities for laying up and curing composite parts of significant size. One of Beech's eight autoclaves is the largest in diameter and the second largest in length in the United States, and is among the largest in the world.

Sheets of composite fabric are cut to precise shapes by a large computer-controlled Gerber Cutter, which has a working surface that is 60 feet long and five feet wide, and can cut up to five plies at one time. The quality of individual elements of composite material is checked and noted in a computer file, and finished parts are inspected using the latest in ultrasonic testing equipment. Beech has a 500,000-square-foot facility devoted to composite manufacture, including a semi-clean room of 155,000 square feet.

More than facilities are needed, however, to build composite structures economically. Knowledge, experience and judgment also are mandatory, particularly if manufacturing costs are to be kept in check. Designing a part made from composites and developing the appropriate production tooling and procedures is far more expensive than fabricating a similar part from aluminum, assuming that the objective of the design is to maximize the structural efficiency of the composite component. Beech, therefore, chose to forego some weight savings to achieve greater ease of manufacturing and to be conservative with respect to certification. The company also initiated a comprehensive 70-hour training program for potential workers within its composite operation. Passing the three-week schooling is a requirement before being assigned to work with composites at Beech.

Beech engineers say that total costs of a finished composite part have dropped from about 10 times that of an aluminum structure to three times, and with further development they think that a goal of twice the cost of an aluminum structure is within reach. The company also has used its experience to design and patent specialized structural members, known as H-joints and V-joints, using composites.

The Starship's real payoff to Beech may be the extensive experience in composite design and manufacture the company now has and is increasing daily. Recently Beech was awarded contracts, valued at an estimated $200 million, to build composite winglets and landing gear doors for the McDonnell Douglas C-17, and it anticipates applying its knowledge of composites to a variety of other products.

Progress Comes Slowly

Composite technology was not the only new ground Beech had to cultivate. Certificating a tandem-wing design when the FAA's criteria for flight characteristics is based upon years of testing conventionally configured aircraft presented significant challenges — and delays. Stall behavior for aircraft with a forward stabilizing wing or canard is not like that of a typical design, particularly since the Starship is said to resist a stall because of its novel configuration. After testing a variety of exaggerated or abused stall entries, Beech decided to use a stick pusher to define the Starship's minimum flying speed, thereby bypassing the problem of needing to detect a stall in the cruise configuration. The stick pusher is disabled when the aircraft is configured for either takeoff or landing.

Another delay associated with the Starship's forward wing resulted from a reduced pitch damping at certain conditions of low speed at high altitude. When exposed to a sudden pitch control input in a particular corner of the flight envelope, the Starship did not return to its trimmed condition in the required number of pitch cycles. The cause of that problem was traced to a partial separation (that is, stall) on the upper surface of the forward wing. Beech engineers eliminated the unacceptable condition with vortex generators, but determining the correct placement of those flow devices postponed certification by three months.

Considerable time was needed to determine how the Starship's composite structure would respond when exposed to extremes of temperature and humidity. Composites, some more than others, absorb moisture and lose strength.

To provide the FAA with the considerable data the agency requires on structural integrity under all conceivable conditions, Beech exposed the Starship structure to 85-percent relative humidity and 160°F for three months to simulate the most damaging environment likely to be encountered anywhere in the world. The components then were subjected to typical strength and fatigue tests, which they passed with flying colors.

Resistance to fatigue and corrosion are apparently two of the Starship's greatest assets. The aircraft sailed through its fatigue trials, according to Rick Abbott, Beech's principal engineer for composites structures, and cleared all its structural and damage tolerance testing in 1987. (Typically, fatigue testing continues long after the first customer aircraft is delivered, but the Starship's progress in this area was more rapid than metal aircraft.) In fact, all structural substantiation needed for certification was generated in sufficient time to meet Beech's goal of a certified Starship by the end of 1987.

Extensive testing, both visually and by using sonic technology, assures the Starship customer that each aircraft component, as well as the assembled machine, meets the stringent quality standards established by the FAA. A variety of characteristics, including porosity, waviness, delamination, abrasions, punctures, disbonding and fiber breakage, are checked during the many quality inspections incorporated in the Starship's manufacturing process. Every piece of fiber purchased by Beech, for example, is inspected before being used to fabricate a part, and each completed part is inspected after manufacture, according to company officials.

Suspense Remains

While worries concerning certification are rapidly disappearing and performance numbers are in hand, questions remain in the minds of Starship watchers. Stating a reluctance to discuss marketing data that might be used by the competition, Beech has not released specific information concerning the number of orders currently on the aircraft, except to say that it is more than 50 and that production is committed for about the next two years. The first demonstrator Starship, NC-4, will not be completed until the spring of 1989, and the first customer aircraft, NC-5, will lag that aircraft by about one month. So we must wait to learn more about how this novel aircraft actually flies. If exciting and attractive lines, sophisticated structural design and advanced avionics are the stuff of winners, the Starship should do well.

What is clear is Beech's strong commitment and significant capabilities in composite design and manufacture, a potentially profitable asset that was made possible by its development of the Starship. B/CA