

## The Starship Project

In 1979 the executive team of Beech Aircraft Corporation was considering whether to embark upon the Starship project, a venture with an estimated cost of \$250 million. Starship was the nickname for a new-generation aircraft design being proposed by the company's top engineers. It was, in every way, a radical departure from tradition. Perhaps the best way to describe it to an aviation layperson is to say that the proposed airplane appeared to be flying backwards. It was, in the jargon of the industry, a pusher-prop canard design. On such an aircraft, the main wing is at the back of the airplane, with a smaller wing (called a canard) on the nose. The engines point to the rear, and the propellers push the aircraft, rather than pulling it as in conventional designs.

On the Starship, the canard would have variable geometry. That is, the pilot could adjust the sweep angle of the canard just as the pilot of an F-111 can adjust the angle of the main wings. This adjustability allows the aerodynamic characteristics of the airplane to be tailored to the speed of flight, making the plane more efficient to operate in all phases of flight—from slow speeds at approach and departure to high speeds at cruise. The engines would be a pair of Pratt & Whitney PT6 turbines, driving four-bladed propellers turning rather slowly (max of 1700 RPM, with 1500 RPM at cruise). The combination is referred to as a jet-fan. It has the advantage of fuel economy and high speed, along with low noise and low vibration. Cruising speed would be about 345 knots at 31,000 feet.

The proposed airplane would be so revolutionary that a normal set of cockpit instruments would be anticlimactic. The proposal called for seeking competitive bids from the major manufacturers of aircraft flight instruments for an entirely new, space age cockpit. The most promising design was submitted by Collins Radio, with a fully-computerized instrument package. Cockpit displays would all be on full-color cathode ray tubes (CRTs), which would look like small high-tech television sets. There would be no needles

and dials. The total effect proved so awesome that one aviation journalist reacted to a mockup of the aircraft interior by declaring, "It's like looking at, or reaching out and touching, something from an age to come."

Most of the project's cost was for equipping a new design facility. Located at Beech Field in Wichita, the facility would contain a large bank of computers and computer-assisted design (CAD) equipment. Thoroughly modern, the facility would be capable of "paperless design." In a less modern facility, there can be long delays in waiting for a design to be drafted by hand and returned to the engineering team for correction and further work. In the new one, however, such work would be done instantaneously on CRT displays. A job which might take a month the old way could be accomplished in a day in the new facility. In the future, the facility could be integrated with the computer-assisted manufacturing (CAM) equipment, to make a unified design/manufacturing complex capable of extremely rapid modification of products.

A major reason that conservative Beech team was looking at such a radical and expensive proposal was because it would carry them into the next century on a sound technological footing. Beech's existing products, led by the venerable King Air, were high-quality aircraft, but were based on designs created in the '40s and '50s. With the '80s on the horizon, the executives felt the need to innovate. The financial analysts, however, were having difficulty fitting the project into the framework of standard discounted cash flow (DCF) analysis.

### Background about Beech Aircraft Company

At the time of the decision, Beech was one of the few remaining general aviation aircraft manufacturers still under the control of the founder's family. Founded by Walter Beech, a pioneer in business aviation, the company's first big success was his "Staggerwing Beech" design of the '30s. It was the first successful enclosed-

cabin private aircraft, and is still regarded as a very beautiful airplane. Later, he designed the Beech D-18, a twin-engine monoplane. It saw extensive service with the military in World War II, as well as in the airmail service. Surviving D-18s are still prized by small freight-carriers and bush operators. It was even a television star—Sky King’s original “Songbird” was a Beech 18.

After the War, Mr. Beech designed the hugely-popular Bonanza. With its characteristic V-tail design, it became the most sought-after single-engine airplane on the market. During the ‘50s, the company expanded its product line to include more modern twin-engine executive craft, topping the line with the Queen Air piston-powered airplane and the King Air turboprop. Over the years, Beech built up an enviable reputation for the highest-quality products in the general aviation industry.

Mrs. Olive Ann Beech ran the company for several years after her husband’s death, but was searching for a buyer for Beech Aircraft at the time of the Starship decision. Although the company had a strong product line and high customer loyalty, some of the managers and engineers at Beech feared that the company was in danger of falling behind technologically. Aircraft design was undergoing a revolution, with talk of new shapes, new materials, and new manufacturing techniques. If Beech was to appear attractive for the long term, it would need to upgrade its whole product line. A small start had been made at the low end of the product line, with the new trainer, the “Skipper.” By itself, however, the Skipper was not enough to carry the company into the 21st Century. The Starship was proposed as the spearhead of a whole new line of airplanes, from singles up to small airliners, based on new turbine engine technologies and new airframe designs.

Mrs. Beech and her advisors hoped that the Starship Project would enhance the company’s image in the eyes of potential buyers. In order to do so, it would have to be perceived as a strong foundation for future competitiveness. Beech’s current advantage came from its image as a producer of top-quality, high-performance, safe aircraft, but this alone was not a strong enough foundation for the future.

## **Description of the Starship Project**

The Starship’s appearance would be radical, as would the materials from which it would be built and the methods that would be employed in its manufacture. Most of the airframe would be made by bonding together panels of graphite composite (a material made by bonding graphite fibers in an epoxy matrix). Graphite composites conjure up images of the more familiar fiberglass, but in fact are stronger than steel and lighter than aluminum. When bonded into an airframe, there are no rivets or other imperfections in the surface, so aerodynamic drag is much less than for airplanes built in the conventional way from aluminum ribs and sheets. In addition, the color can be bonded in, making painting unnecessary.

The Starship would be strengthened at high-stress points with titanium. Although titanium had already been in use for several years in high-performance fighters and space-craft, very little experience had yet been gained with composites. No composite airplane, moreover, had yet been certificated (approved for sale) by the Federal Aviation Administration (FAA). However, the FAA philosophy seemed to be that the new material would be acceptable so long as the application of it had been well thought-out and tested.

### **Technical Data**

The canard design was chosen because it is more efficient than conventional designs. With a standard forward-wing design, the horizontal stabilizer (called the elevator) produces negative lift (a downward force) equal to about 10% of the weight of the aircraft. Thus, the engine and wings must lift 110% of the aircraft’s weight. With the canard, all airfoil surfaces are lifting surfaces. The pusher-prop design has the advantage that all of the surfaces of the airplane are in front of the turbulence created by the propellers, and so slice through the air more efficiently. Finally, the engine and propeller noise (which is great, due to the fact that the tips of the propellers are moving at nearly the speed of sound, and so create shock waves) are all behind the passenger compartment. The rearmost seat in the Starship would be twelve feet forward of the propellers.

The engineers were very confident of the structural integrity of such an aircraft, but had no

information about the damage that might be caused by a lightning strike. Fiberglass radomes were already being used on aircraft, especially military fighters, and they were prone to shatter when struck by lightning. Active lightning protection could be installed, but there was concern about the additional weight it would add. Furthermore, accumulation of ice on the exterior surfaces of an aircraft can be a problem any time of the year at the altitudes envisioned for the Starship, and the icing properties of graphite composite airframes were unknown.

### **Manufacturing Techniques**

Because the graphite composites were so new, no one had any experience in the problems that might arise in using them on a commercial basis in manufacturing. Basically, the process can be described in the following way:

- graphite cloth is cut to shape and laid out on a mold,
- it is coated with resin and allowed to set,
- the panels of various shapes are assembled and bonded together with strips of graphite cloth, coated with resin.

The whole process is analogous to putting together a plastic model, and requires much less labor (and much less skill) than the traditional technique of building up a metal frame and riveting on sheets of aluminum.

At the time, it was known that Cincinnati Milacron and several other companies were experimenting with computer-controlled machines for fabricating parts made of graphite and boron composites. By the late '80s or early '90s, full automation of the build-up process was anticipated. Furthermore, such machines would be able to produce parts at the same cost per unit regardless of whether they were making a small production run or a large production run. Hence, it would not be economically necessary to maintain an inventory of parts. Instead, parts could be fabricated as needed for assembly.

Machines were already being produced for the garment industry which could cut cloth, using computer-controlled lasers, to any pattern in any scale desired. That is, the pattern could easily be enlarged or reduced. Thus, it was conceivable that in the not-too-distant future, data from the design computers could be transmitted to the

computers in the manufacturing center to virtually automatically produce an aircraft from the Starship family, customized for a particular order. Inventory headaches would be largely a thing of the past, as the only items necessary to be kept on hand would be a few basic bulk raw materials.

Some of the engineers proposed an even more revolutionary construction method. There were experiments under way to test the feasibility of using a computer-controlled robot arm to wrap a single continuous filament of graphite around an inflatable mold. After wrapping the mold, epoxy resin would be sprayed over the ball of tread, and the whole thing would be baked in an autoclave (a large industrial oven). Such a process would enable the production of a very strong fuselage with no seams. The whole thing could be built from start to finish in three days. This compares to several months of construction time using traditional techniques.

### **Aircraft Power Plants**

There was also talk among aircraft engine manufacturers that new breakthroughs were likely to significantly reduce the cost of turbine engines by the early '90s. The greatest promise came from the new ceramics being developed. One day soon, ceramic turbine blades would be able to replace the metal ones currently in use. That would mean substantially reduced cost and easier maintenance. It was being predicted that sometime in the 90s, turbines could virtually replace piston engines in new general aviation aircraft.

Turbines not only offer greater speed and power, they greatly change the design parameters for airframes. Able to deliver several hundred horsepower in a package about the size of a shoe box, turbine engines give designers much more flexibility than do bulky piston engines. Furthermore, ceramic turbines would relieve designers from the problem of providing for a high-volume flow of air to cool the engine. The engineers behind the Starship proposal argue that designs capable of fully exploiting the potential of cheap turbine power will be at a premium in the 90's, but must be started early in order to be ready in time to gain the greatest advantage.

## **The Market**

The Starship was aimed at the executive aircraft market. Its gross weight would be kept, for certification purposes, below 12,500 pounds, making it an entry into the 6-8 passenger category. It would be nearly as fast as a pure jet, but much more efficient, being expected to cover one nautical mile per pound of fuel. That compares very favorably with even the most efficient of all production aircraft.<sup>1</sup> Despite its marvelous efficiency and cabin-class comfort, it was unknown how prospective buyers might react to the radically different appearance of the Starship. They might be very excited about it, but on the other hand, might be turned off by it.

It was felt that the Starship would not be competitive with pure jets at a price much above \$3 million (about the projected cost in 1985 dollars for a small jet of current design) and it would obviously be necessary to sell a large number of Starships in order to recover the quarter-billion-dollar cost of the project. Moreover, only a few hundred executive jets are sold each year. Therefore, it was virtually impossible that the original Starship design, by itself, could justify the project. If the project were to be justified, the Starship had to be viewed as the first of a whole new family of aircraft. Follow-on designs, however, had not yet crystallized.

## **Potential Competition**

Although no production aircraft were yet available which fully utilized the materials and technologies proposed for the Starship, several major manufacturers were working on new aircraft which did. A consortium led by Rockwell International was gaining experience with development of the B-1 bomber, which would make extensive use of composite materials and variable geometry flying surfaces., as well as a modified canard design. Other companies,

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<sup>1</sup>Currently, the Mooney 201 takes the top efficiency honors, covering 2.5 nautical miles per pound of fuel. The Mooney, however, burns gasoline, which is more expensive than the jet fuel that would power the Starship. Furthermore, the Mooney has a maximum passenger capacity of four (squeezed in very tightly), and cruises at about 180 knots. On a per-passenger basis, the Starship would be almost as fuel-efficient while at the same time being nearly twice as fast and far more comfortable.

notably McDonnell-Douglas, General Dynamics, and Northrop, were hard at work on designs to compete for Pentagon contracts to build the Advanced Technology Fighter (ATF) and Stealth bomber. Their designs would also make use of the materials and technologies envisioned for Starship.

Moreover, Beech was the only company contemplating an assault on the myriad technical problems of such designs without the help of federal funding or the promise of lucrative defense contracts. Some of Beech's decision-makers feared that a major government contractor, such as McDonnell-Douglas, might link with a general aviation producer in order to compete with Starship.

Critics also pointed out that Beech would bear the brunt of the headaches and costs of getting an advanced technology airplane approved by the FAA. Beech's followers would have a much easier time getting competing aircraft approved. Furthermore, none of the manufacturing technology contemplated for Starship would be proprietary to Beech, and know-how in its use would quickly diffuse throughout the industry.

## **Projected Schedule**

Burt Rutan, known in the aviation industry as the "guru of the canard" was available to do the basic design work and to make a 3/4 scale prototype, which was projected for 1983. From there, certification was projected in 1984, with production projected to begin by late 1985. Therefore, cash flows from the project would not even begin until six years or more after project initiation. It would be much longer before the Starship Project would have a chance to pay for itself through sales of new aircraft.

The most optimistic scenario that had been scrutinized by the financial analysts, for example, assumed sales of 400 aircraft per year for thirty years (beginning in 1986) with an after-tax contribution to profit of \$250,000 per aircraft (\$100 million per year, total). As optimistic as this scenario was, however, it promised an IRR of little more than 16%—not very attractive at the time (in 1979 the prime rate was nearly 20%).