Bizarre-looking propellers with eight or more slender, twisting blades are being proved in wind tunnels and will soon be flight-tested. The goal: prop liners that fly at jet speeds—on 20 to 30 percent less fuel. Experts say the technology is too good to pass up.

By JIM SCHEFTER

The throaty whine of the scimitar-shaped propeller blades changes pitch slightly, just enough to let the 120 passengers know that they’ve reached their 37,000-foot cruising altitude. Outside, the propellers churn through the thin air at 900 rpm, and the airliner builds speed to nearly 550 mph.

To passengers long accustomed to jet travel, the trip seems routine. In most respects it is. But the propeller-driven plane they are flying—at jetlike speeds—is the first of a new generation of air transports.

After a quarter-century of jet domination, propellers may be on the way back. The new propellers, called propfans, are dramatically different from any that came before. Turbine-powered, with eight or more thin, helically curved blades, they can deliver the speed of jets while cutting fuel consumption by 20 to 30 percent.

“You’re going to see propeller-driven airliners again by the 1990s,” predicts William E. Arndt, manager of the prop-fan test-assessment program at the Lockheed-Georgia Co. “The technology is too good to pass up.”

The new prop-fans are the result of a 10-year development effort by NASA and private industry. The program moved slowly until last year. “There was a long list of objections to propfans,” says Bruce Gordon of General Electric Co., “including noise, vibration, complexity, and maintenance costs.”

Then in mid-1984, GE suddenly announced independent development of a radical new engine-propeller combination. Almost simultaneously, NASA signed a $69.3 million contract with the Lockheed-Georgia Co. to flight-test a prop-fan developed under NASA sponsorship by Hamilton Standard. The agency also provided fresh funding for the GE project.

To discover what triggered this new surge of an old technology, I traveled to Lockheed’s sprawling plant in Marietta, Ga., then to Hamilton Standard in Windsor Locks, Conn. And I
liners as fast as jets

talked to the manager of GE's prop-fan program.

Reinventing the prop

The prop-fan, like the turboprops developed in the late 1950s, is a hybrid that mates a turbine engine with a propeller. Power from the turbine turns the propeller, which moves air back and provides forward thrust. In a pure jet engine, the hot combustion gases from the turbine are exhausted backward to provide thrust.

"The most efficient way to power an aircraft is to generate thrust with a propeller," Arndt said. In fact, a turbofan jet engine, the sort used on today's jetliners, is a series of multi-bladed fan-like propellers under a cowl. But cowling adds both weight and drag to an aircraft.

The best turbofan jet engines today convert only about 65 percent of the fuel energy into thrust. A propeller

Prop-fans look wildly different from conventional straight-blade propellers. From left to right in the painting are Hamilton Standard's single-rotating prop-fan, its counterrotating model, and General Electric's counterrotating UDF (unducted fan) design. GE is building a revolutionary engine-prop package (see text); Hamilton Standard's prop-fans will be mated with engines and nacelles made by others. Prop-fans are particularly suited for 80-to-160-passenger planes and military airlift planes that fly short hops—300 to 500 miles. Here the Hamilton Standard single-rotating prop is shown as a wing-mounted tractor design on a twin-engine airliner and on a four-engine Air Force airlifter. The counterrotating prop is shown aft-mounted, as a tractor in the painting and on the model (above). The cover painting shows it as a pusher. A single GE UDF engine powers a remotely piloted vehicle, and four of them, wing-mounted, power a military assault-transporter. Whether prop-fan engines will be wing- or aft-mounted on airliners depends primarily on results of noise tests to come: If prop noise is propagated through the air, mounting the engines aft, behind the rear cabin bulkhead, might reduce cabin noise. If it is propagated through the plane's structure, aft-mounting might not help. And wing-mounting offers some aerodynamic benefits.
converts at least 80 percent. Those numbers give propellers a real edge in fuel economy.

Then why do jets dominate modern air transport? The answer is twofold. When the airlines introduced jets, fuel was cheap. The trade-off between high speed and fuel cost made jets economical. Today, fuel accounts for at least 30 percent of airline operating costs.

More important, traditional propellers with thick, straight blades run into a physical barrier at about Mach 0.6. (Mach 1 is the speed of sound at any given altitude. At typical jet altitudes, it is about 690 mph.) Above that speed, air passing through the propeller begins to compress. The added impact of compressed air on the blades causes shock waves, turbulence, and rapid pressure changes. These and the increased air density increase drag. In effect, the barrier has limited propeller aircraft to about 400 mph.

"To move beyond that you must maintain a smooth airflow above Mach 0.6," said Alfred L. Weisbrich of Hamilton Standard's Advanced Propulsion Systems. That's impossible with conventional propeller blades.

Enter the prop-fan, with blades that bend, lean, and twist from root to tip. Their fiberglass shells encase a foam core and an aluminum central spar. At Hamilton Standard's huge Connecticut plant, surrounded by acres of noisy machines, I ran my hand over a prop-fan blade nearing completion. Its airfoil shape not only tapered sharply toward the tip but varied in thickness over its entire length. I traced its trailing edge, where the blade slims to almost knife-like sharpness. Conven-

Wind-tunnel tests of Hamilton Standard's counterrotating prop-fan (top) indicate an efficiency of 89 percent at Mach 0.8. GE's UDF (unducted fan) engine-propeller design (center, left) has no gearbox; half of the turbine's fans will turn the leading propeller directly while the other half drive the rear prop (in the opposite direction) through a central shaft. Tests are to begin later this year. Hamilton Standard's single-rotation prop-fan (center, right) is to be flight-tested on a Gulfstream II business jet modified by Lockheed. The strange-looking result—with the prop-fan on the plane's left wing and nothing on its right wing—will fly in 1987 (left). In the air, test pilots will power down the jet's own aft-mounted left engine, allowing the prop-fan to take over. A 6,600-hp Allison turbine engine will provide power. A modified gearbox taken from a Lockheed F-3 will reduce the engine's 11,000 rpm to about 1,100.
passengers won’t tolerate noisy propellers"

Blade thinness and curvature translate directly into smoother airflow at high speeds, Weisbrich said. “It avoids the drag buildup and concurrent lift loss.” Wind-tunnel tests prove that the new prop-fan, in a single-rotating prop design, operates at 80-percent efficiency at Mach 0.8, a speed that matches jets in commercial service.

Hamilton Standard is also developing a counterrotating prop-fan (cover) — one propeller behind another, turning in opposite directions—that shows even greater efficiency at jet speeds. The reason: Air flowing through a single propeller develops a swirl effect that wastes energy. “In counterrotation, the swirl that comes off the front blade is recovered by the second blade,” Weisbrich said, “increasing efficiency from 80 to 89 percent.”

Long in coming

Hamilton Standard began developing the prop-fan blade in 1975, splitting costs with NASA. An eight-bladed propeller, dubbed SR-1 (for single rotation), reached the wind-tunnel-test phase in 1976. Its relatively thick two-foot blades were only slightly swept, yet still achieved a 76.2-percent efficiency above Mach 0.7. But the noise was too great.

Computer analysis showed that curved blades don’t maintain their shape in motion. They bend and deflect as centrifugal force and power loading increase. That meant future designs and calculations had to start with the blade shape in motion, then work backward to determine its shape on the manufacturing line.

The designers returned to their computers to search for the right set of curves and dimensions. “It went back and forth between the aerodynamicists and the structures guys,” said George G. Walker, prop-fan business-development manager. “One side wanted the blades super-thin. The other side said they had to be thicker, or they’d fall apart.” The solution: Add more curve and width. As the blade got wider, it could also thin without losing strength. When the SR-3 completed wind-tunnel testing in 1978, performance was up and noise was down.

Hamilton Standard settled on eight blades for its single-rotating prop-fan and refined the SR-3’s dimensions and twist distribution. The company now is fabricating a nine-foot-diameter prop-fan with eight blades for wind-tunnel testing and actual flight tests by Lockheed. Prop-fans for commercial airliners of the future would be 11 to 13 feet in diameter.

Flying the prop-fan

Lockheed joined the prop-fan program last August and will add $6.1 million of its own to the NASA funds. At the company’s Georgia plant, an enthusiastic Bill Arndt took me through detailed plans for prop-fan testing. “The next round of improved turbofan jet engines should add 10 to 12 percent in fuel efficiency,” he said.

“But when you combine any engine with the prop-fan, you add another 18 to 20 percent for single rotation and 30 percent for counterrotation.”

After wind-tunnel tests in 1986, Lockheed will mount the prop-fan on a Gulfstream II business jet for flight testing in 1987 (see photo). The program will evaluate the prop-fan’s structural integrity and its noise.

Noise is a real concern. Airline passengers won’t tolerate propellers if noise levels are uncomfortable. “All the noise data so far come from wind tunnels,” Arndt said, “the worst possible place to measure it.” To get accurate noise data in the air, Lockheed will install a long microphone boom next to the prop-fan on the Gulfstream II. Tests so far indicate that while perceived noise on the ground during takeoff and landing will be less, the prop-fan will noisier inside the aircraft than turbofan engines.

Until more is known about how the noise is propagated to the cabin, aircraft designers don’t know whether prop-fan engines should be mounted on the wings or on the rear of the plane.

Gearing down

General Electric calls its prop-fan an “unducted fan,” or UDF. It’s a jet engine with twin counterrotating propellers mounted at the rear. What makes it unique is the lack of a gearbox. The props are driven directly off the central turbine stages. The concept immediately attracted interest from aircraft manufacturers, many of whom have a fear of gearbox problems dating back to the 1950s.

GE literally stumbled into UDF development. Engineers, searching for a breakthrough to improve turbofan engines, found none to be had at a reasonable cost. “That led us to prop-fans, where there was a much larger payoff in fuel economy,” said program manager Bruce Gordon.

The GE team quickly opted for a counterrotating system to recover energy lost to swirling air. And, Gordon said, they decided to combine the turbine fan with the propeller to reduce gearbox complexity.

“The next step was to make it a pusher prop to reduce noise and vibration,” he said. “That gave us a geared pusher.” Finally, engineers began to increase the loading, or force, applied from the turbine to the propeller blade to reduce gear ratios. “One day we got to a ratio of 1:1,” Gordon said, “and that meant we didn’t need the gearbox at all.”

The UDF engine’s core has six stages, or turbine fans, which turn on a rotating frame. That drives the leading propeller’s eight curved blades, which are mounted on the frame. What happens next gives the UDF its unique characteristics. In a typical turbofan, guide vanes, or stators behind each fan, straighten the swirling air, smoothing the flow to the next row of blades. But GE replaced the stators with counterrotating turbine stages. They drive the rear propeller through a central shaft.

“The whole thing doesn’t take any more length than a six-stage turbine,” Gordon said. “We limit the propeller-blade-tip speed through variable pitch control to keep the noise low.”

A full-size demonstration engine developing about 25,000 pounds of thrust now is being built at GE’s Cincinnati plant. Gordon expects to run the engine through a series of tests in mid-1985. Then he plans to team the Hamilton Standard-Lockheed team into the air by mounting it on a Boeing 727 and flying it in 1986. For now, the UDF engine is strictly experimental. “By the end of ‘86, we should have everything we need to make a go-ahead decision,” Gordon told me.

The competition in prop-fan development might have no losers. Different aircraft manufacturers might like either concept, or both. If the GE decision is “go,” Gordon expects to see a new generation of short-to-medium-range commercial airliners flying in the early 1990s with after-mounted UDF engines. Weisbrich and Walker at Hamilton Standard see the same future for their prop-fan, either wing- or aft-mounted.

And at Lockheed, Bill Arndt expresses the view now widely held by newly alert aircraft manufacturers. “It’s a healthy situation for us to have the industry people working on two concepts,” he said. “We’re in a good position to let them slug it out.”

Then, depending on each new aircraft’s design or application, he said, “We’ll use the best.”
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