The McGraw-Hill Companies

www.AviationWeek.com/bca FEBRUARY 2009

The McGraw-Hill Companies

Business & Commercial Aviation

Betting Big on Business Aviation

With three small turbine engines in development, General Electric is targeting the business aviation market as never before.

By David Esler

General Electric Aviation's much-heralded eCore advanced gas generator may see its introductory application not in an airliner engine but in a business jet powerplant — the long-awaited "10K," or 10,000-pound-thrust class turbofan the company has promised for several years amid an aura of super secrecy.

Now ready to talk about the project, the Cincinnati-based engine maker sees three scaled applications of varying thrust for the new core: narrowbody airliner, regional jet and business jet. In the last — which may be the first to market — the engine would power large-cabin business jets in what is developing to be a highly competitive segment, with Cessna's Pratt & Whitney Canada PW810-powered Columbus and Dassault Falcon Jet's Rolls-Royce RB282-equipped (and so-far unnamed) super midsize aircraft already announced. According to GE's Brad Mottier, vice president and general manager, business and general aviation, the company is working with at least two airframe manufacturers to size and match potential airframes to the 10K engine "to help make their aircraft the best they can be and to differentiate them from their competitors."

GE Aviation

With more than 18,700 in service, the GE-Snecma CFM56 turbofan is the most successful commercial jet engine ever built, mostly due to its berths on the Boeing 737 and Airbus A320 and A340 jetliners. Shown here at GEs Peebles, Ohio, test facility, is an example of the latest variant, the CFM56-7, rated between 18,500 and 34,000 pounds thrust and currently powering the entire "Next Gen" B737 line, including the Boeing Business Jet.

GE is choosing to launch the eCore — again, possibly — in the business aviation market because the segment represents more OEMs and development activity and tends to move at a faster pace than the airline field in which new aircraft emerge roughly once a decade.

Mottier claims that GE commits $1 billion a year toward research in new engine technologies and that the business jet market provides the company with an opportunity to introduce these developments in products sooner that every 10 years.

"That's one of the attractions of this market," he said, "as there are a lot of platforms, more shots on goal, as it were. Boeing and Airbus come out with a new model every decade or 15 years, and, meanwhile, in that period, we're developing technologies trying to anticipate what they will require. Because there are more airframe manufacturers in the business jet arena, we can take those technologies and place them in that market. And that's where we're orienting the 10K engine."

At the upper end of the thrust spectrum up to 25,000 to 30,000 pounds the eCore will serve as the basis for an eventual replacement for the CFM56 turbofan, which GE developed and continues to manufacture in partnership with Snecma of France under the CFM International banner. Arguably the most successful commercial jet engine ever built, thanks to its berth on Boeing's 737 narrowbody airliner (itself the most successful jet-powered commercial airliner in history), as well as variants of Airbus's A320 and A340 jetliners and the B737-based BBJ large business aircraft, more than 18,700 CFM56s have been produced in both the United States and France. Snecma will again partner with GE in the development of the follow-on engine, and the pair are scheduled to run a technology demonstrator christened the "Leap 56" in 2010.

First New In-House Business Jet Engine Since CF34

The 10K, which has been christened with the engineering designation "TechX," is

GE's Cincy Business Jet Center

As an integral part of its business and general aviation division reorganization in 2008, General Electric Aviation added a business jet component to its existing customer operations center at its Cincinnati headquarters.

Named the Business Jet Operations Center, the enterprise is essentially a 24/7 call center staffed by three specialists overseen by Karl Kasparian, customer support program manager, business jets, and Michael Harris, a field-service engineer, and reflects the growing importance of business aviation that GE sees as part of its overall business plan. "We wanted to have a single point of contact for business jet customers, and we wanted to assure that we understood what their needs were, that the necessity for responsiveness and relationships were met," Kasparian said during our recent visit there. "When you call in, a real live human being answers the phone — you don't get a recorded menu with a bunch of selections to make just to get to an operator or arrive back at the beginning of the menu."

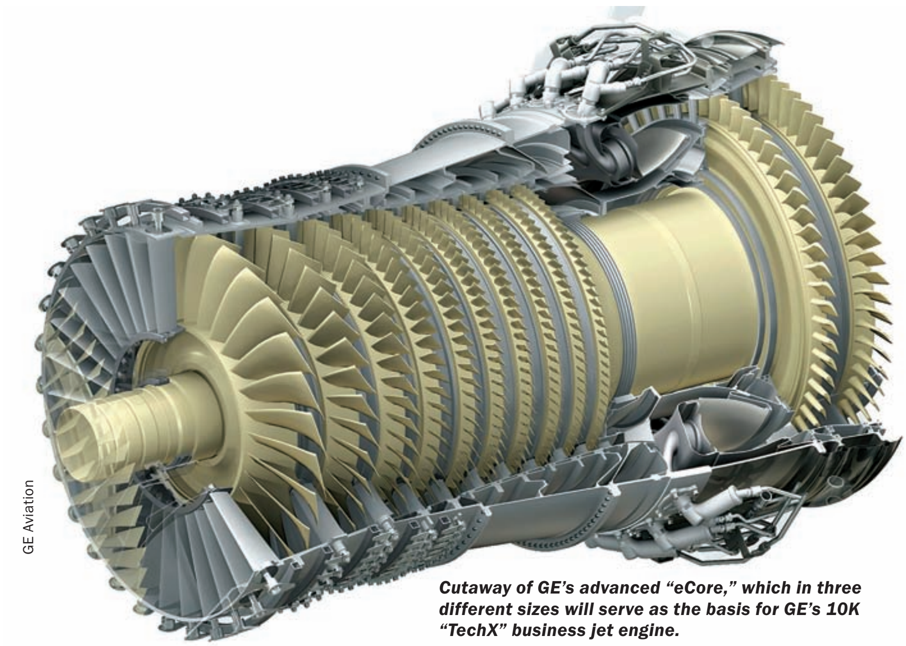
GE's product support begins at purchase of a new or used business jet equipped with the OEM's engines. "We have an 'entry-into-service' process for new customers," Kasparian said. Currently, GE's business jet applications are confined to CF34 turbofan-equipped Challengers, but as HF120, M601H-80 and, ultimately, TechX engines enter service on their airframe platforms, the service will be extended to cover their operators, as well. To support the Challenger application, GE maintains a team of field service engineers at Bombardier who meet new owners at point of sale.

"We provide them with their technical publications, inform them of who the field service engineer is in the area where they operate, give them the warranty terms and training offerings, and provide them with customer Web site access, which is not in the public domain," Kasparian said. Once the aircraft is in service, the operator is backed up by a customer contact plan, where the field rep is to contact the customer at least quarterly irrespective of whether there has been an engine problem.

"For existing airplanes changing hands, we collaborate with the airframer, and review any transfers that occur so we can, in turn, make contact with the customer," Kasparian continued. "The entitlements might be different, but the service is the same. We treat every call or contact as an AOG."

Overflow and after-hours support of the Business Jet Operations Center is provided by the larger Airline Operations Center, staffed by more than 30 specialists, so that a customer always has access to expert assistance. "This is the front end of he product service group," field engineer Harris said. "In the 'back room,' we have a product support engineering team, or PSET. About 95 percent of the cases that come in are handled in the Operations Center, while the more deeply technical ones that need engineering support go to the PSET. Our approach is customer-centered and data driven — for example, inflight shutdown causes, shop-visit causes, delays and cancellations. So typically, we find out what the customer needs, rally the team to deliver it and then measure the success." Scorecards are actually used to track reliability items and, when necessary, proactive programs such as SB campaigns are conceived to address the problems. (The Operations Center's engineers are constantly inputting information into the Fleet Data Management Program, a common database used by both the airline and business jet groups to track potential problems.)

Another key element of GE's product service program is diagnostics, or trend monitoring. "Unless you're enrolled in OnPoint [GE's maintenance service plan], the diagnostics program is purchased," Kasparian said. Some models of the Challenger business jet automatically capture the trending data, which can be downloaded and e-mailed to the Operations Center. "We sole-source on our business jet applications, unlike the airlines, so we have an obligation to help the airframers, as well," Kasparian said. "We want the customer to know who their GE points of contact are."



GE Aviation

Cutaway of GE's advanced "eCore," which in three different sizes will serve as the basis for GE's 10K "TechX" business jet engine.

the first totally in-house business jet engine GE has developed since the CF34, which itself was a civil spin-off from the military TF34 conceived in the early 1970s for the Republic A-10 Warthog ground support fighter. The company's new HF120 entry-level turbofan and forthcoming M601H-80 turboprop, both based on existing engines, are joint ventures with, respectively, Honda Aviation and Walter Aircraft Engines, the latter, based in the Czech Republic, acquired by GE in 2008. With the ongoing CF34 program, these new additions considerably flesh out the GE Aviation business and general aviation product line that hitherto consisted of only the venerable CF34 — with its single Bombardier Challenger application — and support for the 1960s-era CJ610 and CF700 engines long out of production.

The TechX will be "the next generation beyond the CF34 for the 10,000- to 20,000-pound-thrust market," Shawn O'Day, leader, business and general aviation marketing, said. "We are talking to the large-cabin OEMs about this engine and what it can do for them. We could be in service as early as 2015, dependent on a launch customer. It is leveraging technology already developed, building off architecture and a lot of experience in this thrust class."

That's where the eCore comes in, plus considerable trickledown from the GEnx commercial turbofan GE developed for Boeing's forthcoming 787 and 747-8 widebody airliners. According to Chet Fuller, GE's chief marketing officer, the exact architecture of the eCore will vary depending on the application size. An artist's rendering of the core, actually lofted from digitized engineering blueprints, depicts a 10-stage high-pressure compressor driven by a two-stage HP turbine. Noteworthy are the smaller number of airfoils normally seen on rotors of a conventional gas generator, characteristic of advanced designs produced with sophisticated 3-D and computational fluid dynamics (CFD) software.

(Because it is now possible to design more efficient airfoils with these tools, fewer of them are necessary to produce a given pressure ratio, allowing significant weight decreases in the engine. The same advantages can be had on the low-pressure spool. In ducted fan configurations, as the TechX business jet powerplant will more than likely reflect, fans with significantly fewer blades will be possible, although the blades will feature much wider chord and almost artistically curved silhouettes than conventional fan-type propulsors.)

The advantages in fuel economy and emissions reduction GE hopes to harvest from its next generation of 10,000- to 20,000-pound-thrust turbofans are more than anything else dependant on the eCore, Fuller claimed. What type of propulsor the builder hangs on the core engine — and in addition to the advanced fan, GE is seriously considering reviving unducted "propfans," or open-rotor propulsors, for the larger variants — drives installation issues and sets a bypass ratio, but the inherent efficiency of the engine is set by the compressor's efficiency and the pressure ratio and temperature produced in the core.

"So if you don't have the most efficient compressor, turbine and combustor," Fuller said, "it doesn't matter what you put on it in terms of a propulsor. That's why we have run an advanced compressor core every year of the last decade, because it sets the level of entitlement in regard to operating efficiency of the engine."

Accordingly, GE engineers are studying a variety of advanced technologies for the eCore:

➤ Ceramic matrix composites (more on CMCs later), for their unique cooling characteristics, durability and cost advantages;

➤ Other, more conventional, composite media, like carbon fiber, applied to the cold section to fabricate fan blades and case ring, a la the GE90 and GEnx engines, for weight control;

➤ Titanium aluminide for low-pressure turbines, to exploit its extremely light weight;

➤ Active clearance systems that control the gaps between rotating parts and stators for improved efficiency;

➤ Advanced airfoils, thanks to the aforementioned use of 3-D design software; and

➤ GE's TAPS (twin, annular, premixed, swirl) combustor, developed initially for the GEnx.

The company claims TAPS provides a better than 50-percent NOX reduction below CAEP 6 (Committee of Aviation Environmental Protection) emissions standards and, according to Fuller, is able to deliver an NOX level 60 to 80 percent below today's technology. "In general," he said, "if you pump up the temperature and pressure ratio, you would normally increase NOX, but what we have been able to do is characterize and manipulate the way the fuel is burned with TAPS so that actually we create significantly less NOX in a higher pressure regime."

Addressing off-the-shelf technology advancements like TAPS shared by multiple platforms, O'Day added, "A lot of our dollars go to GE's Global Research Centers — there are three of them: Germany, India and Niskayuna, New York — to develop technologies for next-generation engines. We are always looking out 40 years."

Striking Pay Dirt With Fiber Reinforcement

Going back 40 years, in their quest for ever greater efficiency, reliability, durability and lower component cost and weight, engine manufacturers have been experimenting with ceramic components for the hot sections of gas turbines, mostly with limited success.

But now GE claims to have struck

pay dirt with composite media, strengthening ceramic resin fabrications with imbedded silicon carbide fibers in what it describes as a "highly sophisticated process." The resulting ceramic matrix composite parts, made at GE's Newark, Del., facility, are then enhanced with proprietary coatings. Parts fabricated of the material are touted to be one-third the density of comparable metal ones, thus reducing engine weight and allowing a commensurate decrease in fuel consumption.

An enthusiastic proponent of the technology, Fuller described the composite media concoction like this: "If you picked up a piece of it, you'd think you were holding a broken coffee cup, but you can drive a nail into it without cracking it. It's light and has a ceramic feel to it." Another advantage of CMC media, Fuller emphasized, is superior durability and "extraordinary resistance" to heat compared to metals, requiring less — or, he claimed, in some gas turbine installations literally no — cooling air, thereby allowing higher thrust, as less bleed air has to be picked off the compressor flow.

Robert Schafrik, GE's general manager of materials and process engineering, foresees CMCs being used for many applications within engine hot sections, such as high- and low-pressure turbine blades and vanes, turbine shrouds and combustor liners. Several years back, GE ran a government-funded demonstrator engine equipped with a CMC combustor liner and LP turbine blades, and the aforementioned CFM International Leap 56 demonstrator will feature several CMC hot section components.

But the first production application of CMCs could occur in the F136 military turbofan that GE and Rolls-Royce have partnered to develop as a second-source powerplant for the F-35 Lightning II Joint Strike Fighter. Later this year a prototype of the F136 with CMC third-stage LP turbine vanes will be operated in a test cell. The engine will begin flight tests on the F-35 in 2010. Additionally, an advanced derivative of GE's T700 turboshaft engine (which powers the Sikorsky Black Hawk military helicopter, among other rotary-wing platforms) now in development may see some CMC hot section parts.

CMC components are touted as a "key feature" of the eCore, which was designed to reflect a 16-percent improvement in fuel efficiency over GE's best contemporary engines,

Creating the Intelligent Airframe

General Electric's acquisition of Smiths Aerospace in May 2007 marked an expansion from engine building into aircraft systems. No sooner than the ink had dried on the purchase contract, the Cincinnati-based OEM was busy developing a strategy integrating cyber-based aircraft systems with its engine products.

"When you see how successful we were on the engine front, you understand that in order to grow, we had to expand the scope and offer more than engines," Frederic Daubas, chief marketing officer for the renamed GE Aircraft Systems, said in explaining the Smiths acquisition. "Smiths was covering cockpit to actuation systems and power systems and represented a nice fit to expand the value proposition."

The marriage of airframe systems to the engine goes beyond cockpit controls to the fully integrated power system of today's digital "electric airplanes." As Daubas explained, "Today when you consider aircraft are becoming more electric — on the Boeing 787, for example, the total installed electrical system is 1.45 megawatts, or the equivalent power needed for 400 homes — in order to provide this electricity there is only one place to get it, the engines. Each engine has two generators and an electrical power distribution system. But it is a huge dilemma on how I am going to optimize the electricity all over the aircraft. This includes the emergency power systems, too, the batteries, the APU or a RAT [ram air turbine]."

GE Aircraft Systems' solution is to offer claimed superior optimization, or better integration of the generator with the engine. "A generic modular power 'tile' can be placed near where the application is and programmed for the specific function intended," Daubas said. "Think of the tile as a distributed microprocessor. It is a fully digital system. Gulfstream will use this system on the G650, the first business jet application." In addition to improved performance and heightened efficiency within the aircraft's power grid, the system saves weight over conventional power distribution and control systems.

The next step beyond this is centralized systems control. "For example, the centralized control system, or CCS, on the core computer system of Boeing's new 787 is the backbone of the aircraft," Daubas said. "Each application in the past had its own box, but in the 787, we used one computer to host all the apps, built by GE Aviation Systems." This configuration, in which GE partnered with Rockwell Collins to design, provides improved access to the applications and simplicity, as the operator can simply add more cards and memory for upgrades. Centralization is also claimed to simplify software upgrades and maintenance. "All over the aircraft we have RDCs — remote data concentrators — built by GE Aviation Systems," Daubas said. "It's all open architecture, redundant, easy to upgrade."

Another GE Aircraft Systems project addresses aircraft "health management," interfacing the FMS with sensors throughout the airframe. "We are working with OEMs to offer a system that will not only detect faults but will predict a failure and transmit it to a centralized maintenance monitoring facility," Daubas claimed. "This facilitates preventive maintenance." Meanwhile, the division's avionics engineers are utilizing the FMS to calculate constant-rate descents (CRDs), and the company is working with selected airlines to test what Daubas termed "green approaches."

"If you have one team of engineers walking together," Daubas said, "you can improve the optimization and integration of the systems and the engines. The goal is to achieve higher reliability, lower maintenance cost, less fuel burn and emissions, and reduced noise."

i.e., the CFM56s. However, Mottier cautioned that forthcoming eCore tests, *e.g.*, in the Leap 56, are actually part of "tradeoff studies" regarding the viability of CMCs. "All these technologies have a cost," he said. "If you think about an engine today, it doesn't have the same materials throughout, so you choose the appropriate material for a certain region within the engine. You may use a high-temp material in only one part of the engine. What CMCs do is allow you to select a higher temperature margin that you can use in certain areas of the engine, and so that will give you some additional efficiency or durability."

But the big advantage is durability. "The objectives of the [TechX] engine are better fuel efficiency, lower emissions and longer TBO, and CMCs might promote that," Mottier continued. "It is one of the technologies in the eCore, but we have not made a decision whether to incorporate it into the 10K, which is still in the conceptual development stage . . . [and] has not been completely defined. You can go in a lot of different directions: bladed disks or segmented blades, different fuel and exit nozzles. It won't be frozen until we have a launch customer. Do you want titanium or composite fan blades, swept or straight leading edges? It's a big tradeoff study."

It is likely, then, that the initial production version of the engine won't contain CMC parts, but that later variants could. Another possibility, Mottier said, is that CMC diffusers, turbine rotors and vanes, and coated

All About Fuel Burn

To Chet Fuller, GE Aviation's chief marketing officer, the recent decline in fuel prices is temporary because pressures from global warming and energy demands from growing economies will eventually push them up again. "That's why we are working hard on open-rotor technologies for narrowbody applications that will be based on the eCore [GE's next-gen gas generator for business jets, regional jets and single-aisle 130-to 150-passenger jetliners now powered by the GE/Snecma CFM56 and IAE V2500 turbofans]," Fuller said in an interview late last year.

GE is "extremely serious" about its revived interest in open rotors, or "propfans," Fuller claimed, and has teamed with Snecma and NASA researchers in testing a one-fifth scale set of counterrotating unducted fans this quarter on a component rig mounted in a wind tunnel at the Glenn Research Center in Cleveland. GE flirted with large unducted fans 25 years ago when the engine manufacturer built, tested and flew the GE36 propfan that was claimed to have demonstrated fuel savings of up to 30 percent below then-contemporary turbofans in the 20,000- to 30,000-pound-thrust category. The engine featured aft-mounted open rotors with large, wide-chord curved blades installed on free turbines in the exhaust path of the engine's core.

The GE36 was flown first on GE's Boeing 727 test bed and later on a McDonnell Douglas MD80 jetliner, as the Long Beach, Calif., airframe manufacturer was considering using a propfan engine on its planned MD90. Allison Engines (now Rolls-Royce) and Hamilton Standard also built and demonstrated a propfan on a Gulfstream II test bed, later flying it on the MD80, as well. Both efforts were partially funded by NASA.

Even through the propfan demos were lauded as a great success and the wave of the future, the programs were abandoned in the early 1990s when an oil surplus sent the cost of fuel to the cellar, and the cash-strapped airlines, just emerging from the recession of the previous decade and faced with high acquisition costs for new equipment, as well as an untried, radical engine concept, shunned the propfans (and McDonnell Douglas wound up powering the MD90 with the wholly conventional IAE 2500 turbofan). The engines also faced blade-pitch, vibration and noise issues that would have had to be resolved before certification and entry into service. (While meeting Stage 3 standards, the quality of their noise emissions was radically different from that of conventional ducted turbofans.)

Now, with computational design technology available that didn't exist in the 1980s, GE is considering the renamed "open rotor" concept again for its next-gen airliner engines. While the propfans were ahead of their time a quarter century ago, their potential to facilitate a quantum leap in fuel economy presents a logic for this era that is hard to ignore. "Regardless of what fuel costs in the future," Fuller mused, "you're still going to have . . . continued pressure to improve efficiency, because for every pound of fuel you burn, you produce 3.1 pounds of CO_2. . . ."

Nevertheless, the challenges of blade pitch, as they related to complexity and reliability, and noise control for the big fans remain to be solved. These engines generate their efficiency the same way as turboprops, by moving large quantities, or masses, of air in what could be considered huge virtual bypass ratios. To do this, the fan diameter, like that of the turboprop, must be larger than that of a ducted turbofan, and the open fan must be spun at speeds much higher than the propeller on a turboprop. Furthermore, there is no conventional nacelle-mounted thrust reverser mechanism, as the braking function is accomplished by reversing blade pitch. The engine-out dynamics presented by the huge windmilling propfans must also be accommodated.

"There is a large blade-angle range for reversing and feathering, the latter in the event of a failure — up to 94 degrees — so you have to be able to accommodate that," Fuller explained. "It is a large technical challenge, considering all the appropriate safety mechanisms that are necessary. Think of open rotors as variable-pitch N1 rotors, or unducted fans. As such, they're spinning faster than a conventional turboprop, and because of that, they have to be counterrotating [for torque damping and to straighten out the thrust flow for greater efficiency, as there are no stators for that purpose]. Also, it looks like the blade diameters will fall in the 12- to 14-foot diameter range."

Then there is the noise challenge. "Our ever-expanding combustors could be offered as later upgrades to the launch engines.

The New Paradigm: 'Integrated Power Packages'

"Then we're studying how we package the engine into an integrated propulsion system, a low-drag nacelle and target-type thrust reverser as part of a long-duct, mixed flow exhaust," O'Day said. Using the target-type reverser as opposed to a cascade type is a "weight hit," he admitted, but a good tradeoff in terms of performance and noise.

To promote the slimmer nacelle — already dubbed the "Slimline" — GE is considering a core-mounted accessory gearbox for the TechX, as opposed to one driven by the fan and mounted on the fan case. "This also allows greater accessibility of components and thus lower maintenance cost and turnaround times," O'Day said. In addition to range and getting to altitude fast, he observed, "in business aviation, it's all about . . . aircraft availability — the operators don't measure delays or cancellations, they go when the CEO wants to go."

GE's 2007 acquisition of aircraft systems designer Smiths Aerospace (see sidebar) opens up the possibility for the engine builder to "do stuff" it couldn't before in terms of approaching the propulsion system and its integration with the airframe in what O'Day called "a holistic manner."

Accordingly, GE is studying, among other aircraft systems, an integrated

envelope around acoustics is leading us to a path of noise-reduction techniques," Fuller said, implying the possibility of some sort of active noise control technology. "At the end of the day, we think we see a line of sight that is quieter than today's [Airbus] A320. That's what this research effort is all about."

It should be noted here that Pratt & Whitney has taken a different route to next-gen fuel efficiency, emissions reduction and noise control with its PW8000 geared and ducted turbofan (see "The Greening of Business Aviation, Part II," June 2008, page 54), citing the blade-pitch issue and contending that open rotors are impractical because of their size, as they present mounting challenges. We asked Fuller about that. "Three years ago," he responded, "the issue around next-gen propulsion was noise; now it is clearly efficiency. So if you invested heavily in a noise machine but woke up in a carbon-conscious world, you would try to sell it as best as you could.

"If you think about it," he continued, "the one thing we could never argue with is that the GTF [PW8000], as opposed to a conventional engine of the same diameter, gives you better noise control. But if you then consider the world today, the big players spending big money believe there is a play here [for the claimed advantages of open rotors], and the size of the brass ring available for unducted fans is worth the investment." In any case, the TechX 10,000-pound-thrust business jet engine that GE will extrapolate off the eCore will sport a conventional ducted fan, while open rotors — if GE and Snecma indeed decide to go with the concept — will be reserved for the partnership's CFM56 successor and, possibly, a regional jetliner engine. Meanwhile, Rolls-Royce is also exploring open rotor technology.

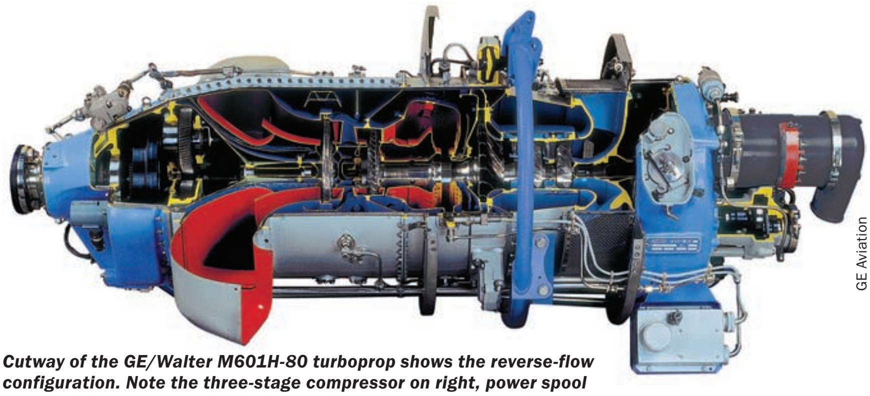
GE Committed to Alternative Fuels Research

Again, despite the recent decline in fuel prices, GE is continuing its research program in alternative fuels. "We are very serious about alternative fuels," Fuller said, "and if you think about them, you have to consider two issues. First, fuels for energy independence, that is, coal, because we have a lot of it and know how to [make liquid hydrocarbons from] it. To the extent that you want to create a hedge against fuel dependence [but not be concerned about CO_2 emissions], that's clearly the answer. We have the coal to do it." What has slowed down coal liquefaction in the past, however, Fuller maintains, "is that fuel from oil is a pretty efficient system and so the production costs are well understood and the economies of scale are enormous." Approaching fuel from the standpoint of carbon reduction presents a different set of priorities. "The first impact is the end result of burning it," Fuller said. "But you have to look at it from the lifecycle of not only burning it but how you produce it [as this releases carbon into the atmosphere, as well]. The resultant fuel, from whatever source it comes, per unit of energy when you burn it, will have the same carbon footprint. But the way it is made will have a further impact on the footprint. So if you make fuel out of algae, it will respirate CO_2 as it grows. Alcohol isn't good for aviation because it absorbs water. Non-food stocks, however, are good."

The turbine can burn "all of that stuff," Fuller said, referring to biofuels from various sources, "but for aviation, the challenge is energy density because we have volume and weight issues carrying it. We also want to distribute it to the aircraft in an efficient system. We [GE] are participants with the [U.S.] Air Force on alternative fuel testing."

And standards are an issue, too, i.e., how these new fuels will be evaluated. "We have to get the international community to create the standards that make it possible to blend alternative fuels in a system where they are 'indifferent,' in other words, 'drop-in fuels' that are recognized across the international industry. We have tested either in our labs or on aircraft most of the known available fuel types in the appropriate quantities necessary — when we can get them, as it takes a lot of fuel to do a demonstration." (For example, when Virgin Atlantic did its Boeing 747 biofuel demonstration flight in 2007, 5,500 kilograms of blended biofuel and Jet-A-1 were used out of a total of 22,000 kilograms of fuel on board. Prior to this flight, GE ran two four-hour ground tests of the fuel, which was a blend of 80 percent Jet-A-1 and 20 percent coconut oil from the Philippines and babassu oil from Brazil.)

"So it won't be the engines or the standards that hold us up but the creation of a system to refine sufficient quantities of drop-in fuels to be practical," Fuller concluded. "Plus the costs will be high, and so probably there will have to be a government-sponsored program."



Cutway of the GE/Walter M601H-80 turboprop shows the reverse-flow configuration. Note the three-stage compressor on right, power spool and reduction gearbox on left.

engine electric power generation and distribution system. While there is "a huge focus" on the engine itself, Mottier said, "for the airframes that will use it, we are putting a lot emphasis on the systems, as well, like an integrated vehicle health monitoring system [IVHMS, both a real-time and trend-monitoring system].

"With our engine and systems divisions working together," Mottier continued, "we can provide an integrated power package, which includes the electric power as well as the engine and bleed air sources. We call these 'integrated powerplant systems,'" he said.

"Another area we're looking at is remote diagnostics," O'Day injected, adding that eventually, "we will have the capability to extend this technology to the entire aircraft. Thus this will be available to business aviation in a smaller and more compact architecture."

Enumerating the various GE R&D yields incorporated into the eCore — CMCs, bladed disks ("blisks"), the business jet engine follow-on to the TAPS combustor, etc. — Mottier pointed out that GE can bring "a technology suite" to the business and general aviation product lines that the OEM either already has in commercial service or is developing for it. "In fact, that's what we're doing with the Walter turboprop," he said. "We ran the CFD numbers on the engine, and we have tweaked the flow path of the core and are now building parts and running them through component tests." Out of that effort, GE will certify the improved Walter M601H-80 turboprop in the fourth quarter of this year.

Timeframe for definition of the 10K TechX is 2012 to 2013, Mottier estimated.

Renewed Commitment to Business Aviation

The 10K engine program is the centerpiece of a renewed commitment by GE to business and general aviation that includes the Honda partnership and acquisition of Walter Aircraft Engines. Both initiatives place GE in markets where it previously had no presence, the HF120 turbofan in the entry-level business jet segment and the M60lH in the smaller business turboprop arena (supplementing GE's 1,800-shp CT-7 turboprop, a T700 variant, seen on the Saab SF340 and CASA CN235 regional airliners). Thus, in less than three years, the manufacturer has broadened its engine product line to embrace nearly the full breadth of turbine-powered business aviation activity. (Remember, too, that the CFM56 turbofan it builds with Snecma powers both the BBJ and Airbus 319CJ.)

Topping this aggressive expansion has been a complete reorganization of the business aviation division, with an emphasis placed on customer service and support. All of this has derived from a premise that the business aviation market is as established, profitable and economically viable as that of the airline industry, long GE's bread and butter in terms of civil sales. Within the context of the current economy, the expansion is, in its most fundamental sense, a multi-billion-dollar gamble on — and a vote of confidence in — the future of business aviation.

As O'Day put it, "We have always been in business aviation but we're accelerating and formalizing it with a new division in the company targeted specifically at [this segment]. We have dedicated emphasis on it, as exemplified by the GE-Honda partnership, the Walter acquisition and [creation of] the Business Jet Operations Center. And this business aviation venture and the TechX are leading how we are integrating systems and engine technologies through our acquisition of Smiths Aerospace in 2007."

The recent partnership and acquisitions also reflect a synergy between divisions in terms of design and manufacturing. As O'Day has pointed out, the enfolding of Smiths — now GE Aircraft Systems — into the operation opens an opportunity to think of an engine application as more than just propulsion, but as a component in a larger chain of integrated activities like electrical power management and airframe and engine diagnostics. Not only does this advance the state of the art in aircraft design, reducing crew workload and facilitating easier and more proactive maintenance, but it expands the OEM's market and, thus, its profit potential.

The Honda joint venture is interesting in this regard, not just as an entrée into a new market segment for GE, but as an injection of new culture from a disparate outside source — one of the world's most innovative and successful automobile manufacturers. First and foremost, Honda is more than just a car company; as GE-Honda President Bill Dwyer points out, it's no coincidence that the Japanese mega-firm is named Honda *Motors.* After all, it designs and builds motors — for cars, trucks, boats, various industrial applications like electric power generation, championship racing cars and, now, airplanes. In six decades of existence, Honda has turned out literally millions of engines. And because it functions in a highly competitive marketing climate, it has been forced to master the balance between manufacturing a quality product and controlling production costs sufficient to turn a reasonable profit. This talent is especially useful in building entry-level business jet engines where acquisition cost is a major concern, both of the engine and the complete aircraft.

On the other hand, GE, like its competitors in the heavy airframe jet engine business, is very good at manufacturing low volumes of large engines that are very expensive in order to cover long and costly development periods, pricy materials and production techniques, and a rigorous certification regimen . . . big engines for airframe applications with relatively small productions runs, where these costs can be absorbed by an acceptably large sales price compared to automobile manufacturing. The entry-level jet market comes with a whole different set of financial considerations.

Dwyer claims that GE studied the entry-level jet market for 15 years but avoided committing to it "until the right partner came along," and what Honda brought to the table was an expertise in controlling production costs that was complementary to small jet manufacturing. In conceiving an entry-level engine, Dwyer said, "There are four fundamental forces you're trying to optimize: fuel efficiency, the cost to produce, maintenance cost and weight. You have to balance the price of the engine, you have to weigh the different factors. And you have to find affordable technologies."

Engine architecture drives a lot of the cost, and the material selections and sophistication of machining and surface finishes all play a role, he explained. "So does the size of the core." In developing the HF120, derived from Honda's original HF118 prototype engine dating from the 1980s, Dwyer said, "a lot of work went in up front to optimize the architecture to make it practical at a competitive price."

Holding Down Production Costs by Design

The reality with this class of airplane, Dwyer continued, is that "you fly fewer hours a year, so we have to build the product at a cost where we can make a profit because we can't make it on the service end. We have to make our profit up front when we sell the engine, so if we can make it at less production cost, we can make money on it."

GE hopes to learn a lot from the partnership with Honda, Dwyer said, adding that "there's a lot of potential synergy between the two of us in terms of how to make a vehicle lighter, more efficient, at lower cost, more reliable and more electric, and what have I just described? A car or an airplane?" Furthermore, it is expected there will be blowback into GE's larger engines from the Honda relationship.

The HF120 will be rated at 2,100 pounds of thrust, giving it a thrust-to-weight ratio of greater than 5.0. Its bypass ratio is roughly 3.0. The engine's turbomachinery consists of a single high-pressure centrifugal compressor driven by a single HP turbine on the core spool and a two-stage low-pressure axial compressor (or core booster) and two low-pressure turbines on the fan spool.

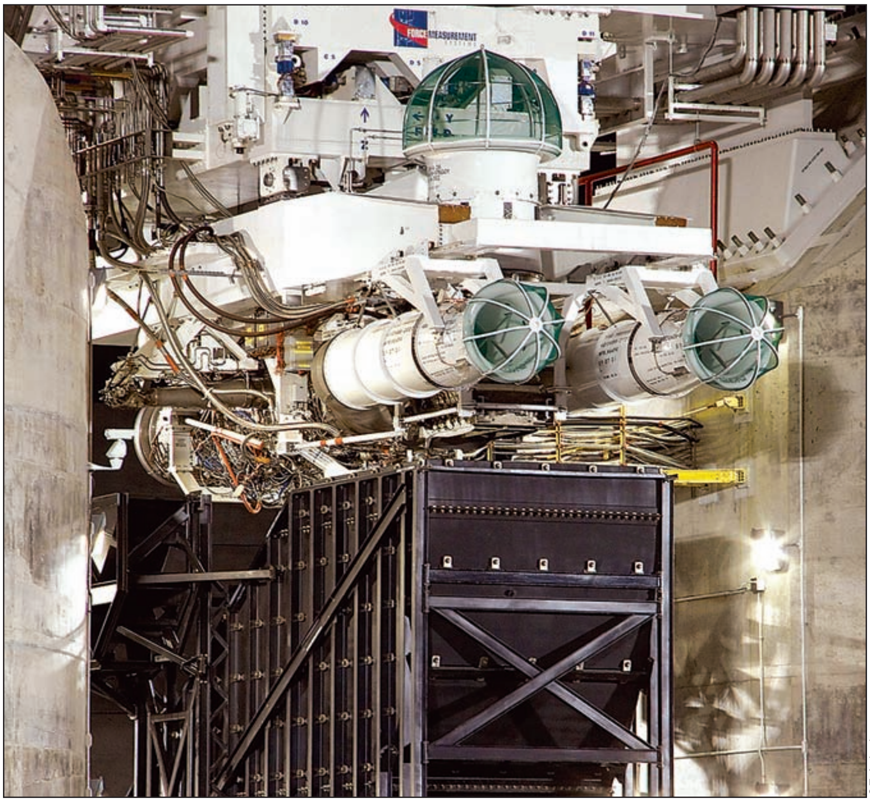
"We believe we have a better thrust-to-weight ratio than the competition, as well as better SFC and durability," Dwyer said. "We *have* to be better going into an established market. The TBO will be set at 5,000 hours, and there will be no hot section inspection. The fact that you don't lose downtime for inspections means there will be savings on maintenance. Our value proposition is very compelling for charter and fractional ownership operators."

GE's first task following the formation of the Honda partnership was to massage the compressor airfoils to increase airflow after the HF120 had been redefined from the smaller HF118 prototype. Then, most of 2008 was devoted to refining and validating the design in preparation for certification trials this year. "In terms of program status, we have hardware on the dock and are building our first conformity engine," Dwyer said late last year.

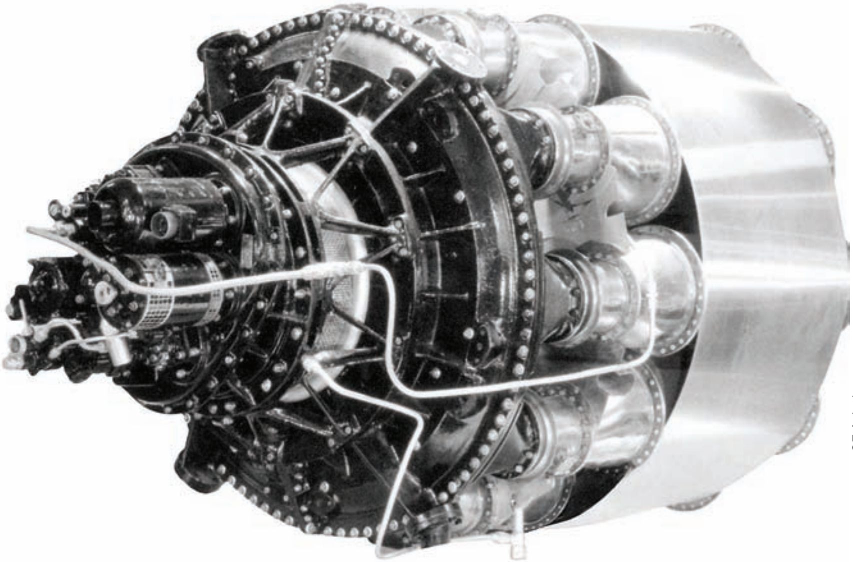
Thanks to Honda's ability to rapidly design and produce prototype hardware, a spin-off from its Formula 1 and Indy racing efforts, the partnership was able to quickly move through 10 iterations of the HF120 core and 11 builds of complete engines in 12 months. (The combined development and racing center in Tokyo is even equipped with its own foundry. Honda is one of the few car manufacturers that actually uses its racing program as an integral part of its R&D activities, running all of its automotive engineers through a stint in the operation before assigning them production car divisions. With Honda Motors' announcement in December that it was considering abandoning Formula 1 racing due to the downturn in auto sales, this practice may end.)

The multiple builds and runs tested for vibratory modes to assure all components in the engine were within design specifications. "We wanted to confirm the basic aeromechanics of the engine, the natural frequencies, so we wouldn't see failures during the certification program," Dwyer said. "These tests proved out the design."

At this stage in an engine's development, the builder will customarily confine tests to cores, but GE-Honda chose to run multiple builds of full engines to ensure the design was producing "macro performance," *i.e.*, making its design thrust, fuel specifics


GE Aviation

The F136 turbofan GE is developing with Rolls-Royce as a second-source engine for the Lockheed Martin F35 Lightning II Joint Strike Fighter, seen here on an elaborate test stand.

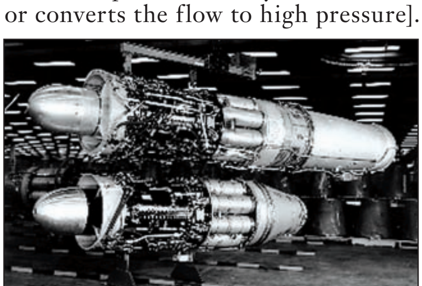


GE Aviation

The World War II-era GE I-A (pronounced "eye-eh") was the first jet engine produced in the United States. Based on Frank Whittle's 1941 design, it had an improved compressor and produced 1,200 pounds of thrust. Two of the engines, upgraded to 2,000 pounds thrust each, powered America's first jet fighter, the Bell P-59 Airacomet.

and efficiency targets. "Within the efficiency metric, an engine has a lot of cavities," Dwyer said, "and you have to purge them. What I mean is that there is a secondary flow through the engine providing pressurization for the bearing sumps [to keep the oil inside the sump] and an appropriate airflow to cool the hot parts, like turbine disks. Because those secondary flows are complex through the engine, we wanted to optimize them to reduce risk downstream."

The demo program proved the transient stability of the engine, or its resistance to stall margins in the fan and compressor. "When trying to make air flow uphill to higher pressure, you can get disturbances that can cause stalls," Dwyer said. "Are we keeping everything cool? Are we keeping the sumps healthy? So a lot of systems integration validation had to be done, like optimizing the compression system diffuser [which is the opposite of a nozzle, since it slows down compressor velocity and increases or converts the flow to high pressure].



GE Aviation

The most all-up successful jet engine ever produced was GE's late 1940s-era J47 turbojet.

We wanted robust stall margins, an essential ingredient for success of the engine. It is possible to over-optimize the compressor for efficiency and lose stall margin, so these two parameters have to be balanced."

At the end of 2008, the program was focused on fine tuning adjustments and preparing to release design definitions to suppliers, which were ramping up parts manufacturing to support the certification program. "Thus, we have essentially released the engine for certification," Dwyer said. Certification is scheduled for the fourth quarter of this year with entry into service during the second half of 2010, whereupon the engine will be cleared for flight testing on GE-Honda's two customer launch aircraft, the HondaJet and Spectrum S-40. Early this year, however, the HF120 will be tested in an altitude chamber to simulate flight conditions through its full operating envelope. This is also intended to verify engine endurance and clear the 5,000-hour TBO.

Then it will be flown on a Citation CJ1 test bed early this spring. By certification, some 15,000 cycles will have been completed on the test engines. Testing will be done at seven sites, five in the United States: altitude chamber, both full engine and core runs, in Evendale, Ohio; fan blade-out and crosswind tests at Peebles, Ohio; customer-compliance tests at Lynn, Mass.; test flights at Greensboro, N.C.; and engine endurance tests at Honda's plant at Burlington, N.C. Meanwhile, icing tests will take place at Maribel, Canada, and LPT stress tests at Honda headquarters in Tokyo. Initially, the engine will be produced at Lynn, with production eventually transferred entirely to Burlington.

Dwyer described product support as "a token to play in this market, in other words, a key requirement for this customer base. That's a given." Private ownership is based on "a distributive business model," Dwyer pointed out, "not like an airline where the fleets are concentrated, so we have to be responsive. Accordingly, we have a business jet call center established here [in Cincinnati]. We have that infrastructure in place because we have 50,000 engines flying today. The phrase we use to describe this segment is the 'VIP fleet of one,' which reflects the uniqueness of this market. We can leverage some aspects of the commercial product support infrastructure, but we have to supplement that with customer service oriented toward the individual operator."

The GE-Honda joint venture is a 50/50 partnership supported by the infrastructure of both parent companies. "What this is all about is economics," Dwyer said. "In other words, the cost of ownership. Both companies are committed to reliability. You design to fuel consumption, maintenance cost, weight and acquisition cost — those four parameters dictate the performance and the burden of cost of ownership and require a proper balance. This is our challenge."

Leveraging Synergy for Increased Market Share

Synergy and expansion of the product line also drove GE Aviation's purchase of Walter Aircraft Engines in the Czech Republic in July 2008. Following establishment of the Honda joint venture, GE was looking to further expand the bottom end of its general aviation market share, "learning about the materials channels required and how to motivate customers," Mottier said. In that regard, Walter seemed like an ideal fit, especially in the upgrade and retrofit market in which GE had no presence. "We want to leverage the strength of GE beyond the acquisition, so with our product support and supply chain, we saw a huge opportunity to not only improve the Walter, but through the scale and resources of GE, we could bring a viable choice to the marketplace where none has existed for some time [read: against P&WC and the PT6A turboprop]."

Since we've already reported in depth on the Walter turboprop and GE's evolution of it (see "Engine Retrofits: Something Old, Something New," December 2008, page 28), we won't go into detail on the hardware here. Suffice it to say, GE and Walter are engaged in upgrading the 777-shp M601F to the 800-shp (at 36°C) M601H-80, providing improved hot-and-high and altitude performance. One of the first tasks GE undertook was to apply a 3-D aero treatment to the M601's compressor airfoils to increase flow. Flow path tests were scheduled to begin at Walter's Prague headquarters in January. "We are continuing to move forward on an aggressive schedule to certify the H-80 in 2009," Mottier said. "The hardware has been built, the development engines are being assembled, and we are on schedule."

The simple and robust base engine, designed during the Soviet era, has had a long and successful production run. Some 1,500 of them labor in service today, mostly in Eastern Europe and South America, where they power the Czech LAT 410 regional airliner, as well as military trainers and crop dusters, and GE will assume support of these engines.

Fuller said that the Walter acquisition owes its origins to "the premise that all the smartest people in the world don't necessarily work for you, so we started to survey the world to find a long-standing aviation culture and what areas of the planet might hold the potential for an engineering design or manufacturing center." Fuller, who led the initiative to grow GE's general aviation product line through a suitable acquisition, began his search in the Czech Republic "because, more than most other countries, it has had a long-standing aviation heritage. Think of the number of platforms they've created. Prague Tech University is huge. So it looked like there might be an opportunity there, and that's how we found Walter."

The executive described the Walter organization as "innovative engine guys, caring about reliability and safety and knowing how to interact in a global aviation safety system." What they lacked, he claimed, was cash, resources and access to Western markets. "We will fix those things and bring Western product support to them," Fuller promised.

Visually, the Walter engine looks a lot like a PT6A. Is the Walter M601 a reverse-engineered copy of the PT6A? "The only thing comparable to the PT6 is that it is a reverse-flow engine; everything else is different," Fuller answered. "Yes, it has a centrifugal compressor, but then most engines in this size class do. We think there is room in this market for a choice. We intend to deliver a great performing engine at a lower unit and operating cost in a product network that is world class. We are staking our reputation on it." ■

For additional information about Business and General Aviation at GE Aviation, contact:

Shawn O'Day
+1 513 552 4319
shawn.oday@ge.com