Tougher, longer-lived engines are emerging

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Turbine-engine technology development is going in two directions. One is the development of new technology to push the envelope of performance, operational safety, maintainability and reliability. The other is to refine and update existing engines for long-term use, especially in light of more stringent Stage 4 requirements and existing Stage 3 rules.

All of the engine manufacturers are focused on producing longer lasting, lower cost, better performing and easier-to-maintain engines.

According to a Rolls-Royce spokeswoman, the company is studying future corporate aircraft engine needs. “We are focusing on the specific requirements of this market as we define our future product developments and customer-support programs,” she said.

She explained the different strategies between the company’s airline customers and their corporate aviation customers: “Aircraft utilization rates are lower than in airline use, so acquisition cost represents a higher proportion of the direct operating cost of corporate aircraft. “Furthermore, both acquisition and operating costs are becoming more of a priority in the business jet sector, with the increasing recognition of the productivity benefits of using such aircraft by a broader range of company personnel. Therefore, operators expect engine manufacturers to deliver lower-cost products and

Rolls-Royce is not only focusing on performance factors such as fuel consumption and power-to-weight ratio, but it is planning for anticipated noise and emissions regulations. The Engine 3E (efficiency, environment and economy) program is a German government-supported collaboration between Rolls-Royce Deutschland and research establishments in Germany and China. Engine 3E is performing research and development for engines that will power future business aircraft. According to the spokeswoman, the objective, is to produce technologies for a new generation of competitive, environmentally friendly and low-cost engines.

Rolls-Royce has defined a family of engines featuring a common architecture. Two

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reference engines have been identified, with the larger one targeting the airline market and the smaller version aimed at the regional and corporate sectors. A core engine test is scheduled for 2004, with a full demonstrator to run in 2008. Key activities planned include development of a weight and efficiency-optimized high-pressure compressor, a particularly low-emission combustion chamber and a high-pressure turbine for enhanced inlet temperatures.

Rolls-Royce has five-, 10- and 20-year vision programs to ensure development of the technologies needed in terms of performance, reliability and life cycle cost. To those ends, Rolls-Royce is involved with collaborative research in such areas as turbomachinery and high-temperature materials. They are partnered with some of North America's foremost academic centers of technological excellence, including Purdue, MIT, Georgia Tech, Stanford and Penn State. In Asia, several institutes in China, Japan and Singapore work with Rolls-Royce in combustion, powerplant integration, diagnostic and new material disciplines.

Any discussion of the future of aviation eventually turns to a supersonic jet. In fact, Rolls-Royce has examined three engine concepts for a supersonic business jet: a conventional turbofan (CTF), a mixed nozzle/ejector and a mid-tandem fan. The CTF concept was based on a two-spool arrangement and appears to be optimal for designs aimed at cruise speeds below Mach 2.0, which is the range favored by most of the business aircraft manufacturers studying the concept.

For economic reasons, a modified derivative of a conventional turbofan is likely to be the preferred solution should such a program proceed. Rolls-Royce continues its concept studies and is talking to interested airframe companies, though going forward into the development stage will require a strong business case.

One of the fastest-growing trends for manufacturers is the use of integrators. Historically, airframe manufacturers built the airframe at their assembly plant and essentially bought all the rest of the components and then attached them to the airframe. For example, a manufacturer might go to an engine manufacturer and buy a specific engine, go to another manufacturer and buy thrust reversers and then assemble everything at its plant. The system worked well in the early days of aviation because individual components weren't all that sophisticated, aircraft weren't all that fast and fuel efficiency wasn't as much a concern. As technology advanced it became evident that simply buying individual components and putting them together wasn't efficient on many different levels.

Eric Blickley, marketing manager for Woodward Aircraft Engines Systems, said, "Original equipment manufacturers [OEMs] have realized significant savings in development time and procurement costs by contracting major suppliers to design complete engine sub-systems and to supply all components within a specified package. This requires the system supplier to define and model the system, which can then be optimized during the initial development phase to take advantage of component consolidation opportunities. The supplier can thereby minimize total cost and weight while enhancing system performance. From the engine OEM's perspective, the development project becomes simpler and savings can be realized through fewer committed resources and management of a smaller group of suppliers."

Integration of the entire system at the design and development phase can reduce cost and weight and avoid re-engineering delays. If interrelationships between the components are not considered, possible component consolidation and optimization opportunities are often overlooked. Integration also simplifies the logistics of testing components, by enabling bench testing as a complete system before the first engine test. Testing systems, rather than components, reduces the likelihood of interrelation problems being discovered at a late stage in development.

The system integrator can subsequently “kit” and deliver a complete and convenient production system directly to the OEM’s assembly line. Kitting, when combined with an inventory pull down system, reduces the inventory levels required by the engine OEMs, ultimately lowering the acquisition cost of the engine.

Advanced Designs

Advances in engine design will most likely account for the biggest advances in corporate aircraft development for some time. Manufacturers have developed airframes capable of going any realistic subsonic speed, but it is what pushes those airframes that makes the difference.

Pratt & Whitney Canada’s PW600 family is a new series of small turbofan engines designed for the general aviation market. In August 2000 P&WC formally launched a full-scale technology demonstrator for the PW600 family, the 2,500-lb-thrust PW625. This engine is targeted at the business aircraft market, and lower-thrust variants, such as the 1,000-lb-thrust PW610, could be applied to owner-flown minijets, including the Safire S-26.

“The PW600 is being designed to offer a significant change in performance, cost and durability, similar to what the PW500 family did over the JT15D when it was introduced to the market in 1996,” said Maurice Weinberg, director of P&WC small turbofan engines. “The PW600 program achieves this by maximizing the technology built into the engine while maintaining its simplicity. For example, it offers up to a 40-percent reduction in parts count over a comparable PW500 while achieving similar pressure ratios. The compressor is designed with an innovative gas path and mixed-flow rotor design to achieve in one stage what the PW500 achieves in two. The fuel delivery system also represents technology through simplicity.”

Weinberg said instead of using a conventional system of multiple fuel nozzles supplied by an external manifold, the PW600 uses a simple internal manifold with integral nozzles fired by externally accessible torch igniters. The concept was successfully proven in a JT15D development engine before the engineers committed to using it on the PW600. The engine is controlled by Fadec, which dictates fuel flows to the engine via the fuel-metering unit.

P&WC is also developing the 10,000- to 20,000-lb-thrust PW800 in conjunction with MTU Aero Engines of Germany and FiatAvio of Italy. The project targets an engine that will burn approximately 10 percent less fuel and is much quieter and cleaner than current engines in its category, while requiring fewer parts. The PW800 series is intended for next-generation 50- to 100-plus-passenger regional jets and future large business aircraft. The engine family will also validate the technologies developed for P&WC’s advanced technology fan integrator (ATFI) demonstrator.

The PW800 program came out of a market study indicating that next-generation regional and business aircraft will be essentially driven by their operating economics and environmental concerns. Fuel consumption, acquisition and maintenance costs that are considerably better than those currently offered were identified as key objectives for the new engine family.

Honeywell remains committed to 3,000- to 9,000-lb-thrust engines to power midsize to large corporate aircraft, according to T.K. Kallenbach, vice president of engineering for Honeywell Aerospace's engines and systems division. Kallenbach said, the company is looking at what will be required of engines in the future and what it will take in terms of engineering, such as improved compressor designs and effusion cooled combustors. "This is technology we started working toward back in the 1980s and have kept pressing forward ever since," he said. "For example, we're working on a forward-swept fan blade that will help with basic fan performance and decrease the noise signature on turbofan engines.

"We're looking at the entire propulsion system, including inlets, thrust reversers, variable nozzles and so on. System integration is the future and our goal is to optimize the OEM's aircraft for maximum performance," Kallenbach said. "Part of it is how you design and build the engine, but part is also how you optimize the entire system in the aircraft. For instance, if you can minimize the amount of nacelle bleed air you can improve overall performance." He said current developments would be for next-generation business aircraft engines slated to be developed in the next couple of years.

According to Kallenbach, Honeywell is already acting as a powerplant integrator for the AS907 and will provide everything from the pylon outboard. The AS907 is a 7,000-lb-thrust-class turbofan that powers the Bombardier Challenger 300 (née Continental). It is configured with four axial-compressor stages, including two variable-geometry stators, followed by a centrifugal compressor, an effusion-cooled combustor, a two-stage high-pressure turbine and a three-stage low-pressure turbine. The discs are rated for 15,000 cycles.

AS907 engines are being delivered to Bombardier as an entire propulsion system, including nacelles, thrust reversers and all engine systems. The project began in the early 1990s and is based on the same technology used in the TFE731-20, -40 and -60 engines. The engine uses a single-stage combustor, with a liner that is precision drilled with tiny cooling holes to distribute cooling air evenly.

The AS900 series was designed to provide both low acquisition and operating cost. Honeywell estimates the engine will cost about 20 percent less per pound of thrust than current engines on the market. It is also expected to reduce maintenance costs between 30- and 40 percent per hour of operation.

A spokesman for Agilis Engines, said his company has been providing engineering services and product development since 1993. In 2000 Agilis began work on aero turbine engine design and development. Agilis is striving for an engine with "low cost and high reliability." He further said, "Agilis plans to bring to the market propulsion systems for a fraction of the current cost."

The Agilis TF1000 turbofan engine family, designed to produce 1,000 to 1,500 lb of thrust, is targeting one- to nine-seat aircraft with an mtow between 3,000 and 11,000 lb. The engine is anticipated to have a design life of 6,000 hr, with a 3,000-hr TBO and 1,500-hr hot section inspection. The engine, which is 23 in. in diameter and 56 in. long, has a dry weight of 285 lb. Its high-bypass turbofan is relatively quiet and has exceptionally low fuel consumption.

Williams, the prime mover in the field of small turbine engines, declined to elaborate on its activities for this report, but it is one of the two contenders (with its FJ33, competing against the P&WC PW615) to power the Cessna Mustang entry-level twinjet. Williams' EJ22 powered the Eclipse 500 microjet on its first flight this past August 26.

Powerplant Upgrades

Getting better performance and maintainability out of current engines is the concern of both manufacturers and equipment suppliers. Tom Memering, service and support manager for Premier Turbines of Cahokia, Ill., said Honeywell's N1 digital electronic engine control (DEEC) for the TFE731 turbofan engine is such a refinement. The company is a repair and overhaul facility that installs Honeywell's N1 DEEC system.

"DEEC reduces engine wear by enhancing exceedance protection and providing trend monitoring," he explained. "It also reduces pilot workload by providing flight crews with predictable and repeatable takeoff and climb settings and prevents fan-speed overshoot and rollback of the target N1 at takeoff."

Memering said climb-power-setting schedules are programmed into the DEEC, reducing the need for power-lever adjustments. He also said it accurately holds engine power settings, thereby eliminating drift. "Honeywell claims if you fly as little as 400 hours a year, the system will pay for itself in less than two years," he said.

The DEEC unit also automatically limits internal temperatures, providing exceedance protection during start, takeoff and climb. And because it monitors and records engine events, performance and trends, the N1 DEEC can help spot problems much earlier. As a result, the upgrade can help operators reduce maintenance, enhance engine power and improve reliability.

The unit also provides engine condition trend monitoring for performance trending, event recording, fault history and life-cycle information tracking. An optional PC data cable can be attached for easy access to stored data. The upgrade is currently available for the Hawker 400, 700, 800 and 800XP; Falcon 10, 20-5B, 50 and 900B/900C; and Learjet 31, 35 and 36.

In some cases an aircraft may be enhanced with a new engine. According to Rod Reed, engineering manager of Performance Conversions of Green Bay, Wis., the company holds an STC for replacing Pratt & Whitney Canada PT6A-20, -21 and -28 series engines on the Beech King Air C90, C90-1 and E90 with Walter M610E engines. Reed said the engine upgrade delivers increased performance, particularly for the C90 series, due to the extra reserve power inherent in the M601E-11, which is rated at 751 shp and derated to 550 shp to match the original installation.

"This allows an operator to use an extra 7,000 feet of cruise altitude [to 25,000 feet] while picking up an additional 40 knots," he explained. "Combined with the Avia five-blade propeller, the interior and exterior noise levels are greatly reduced. The STC reduces recurring maintenance costs by as much as 60 percent."

According to Reed, the cost to overhaul two PT6A-20s is about $340,000 or more. "It makes the $130,000 to overhaul a pair of Walter M601E-11 turboprops after their first 3,000 hours a welcome surprise," he said. Walter engines feature an integral engine limiter that governs operation and prevents hot starts. The upgrade also allows an increased mtow and decreased runway requirements, while reducing measurable cabin noise and vibration.

Bill Maxey, business development director for Walter and Co., said a new M601E-11 has a 3,000-hr TBO with no interim hot-section requirement. "It comes out of the container ready to run," he explained. "We are an integrator. In addition to the engine you get a starter/generator, propeller governor, fuel control, all sensors on the engine and a tool kit, in addition to all the consumables such as oil filters and O-rings to support the engine for 3,000 hours." Maxey also noted that there are no fuel nozzles to be maintained because the engine uses a slinger combustor that doesn't require maintenance.

Trend Monitoring Trends

There is also renewed interest in maintaining the health of existing engines to get more value out of an aircraft. Matthew Werner of Norwood, Mass.-based Altair Avionics said trend monitoring is gaining a wider audience. Altair, which was recently acquired by P&WC parent United Technologies, was founded in 1992 to design, develop, manufacture and distribute aviation safety enhancing products.

Altair's Automatic Data Acquisition System (ADAS), which is an avionics bay-mounted processor with three wiring harnesses and 18 sensor inputs, can monitor up to four engines and other airframe parameters. It provides an integrated aircraft data source and analysis tool for operators, maintenance personnel and fleet owners. ADAS monitors gas generator performance, turbine speeds, turbine temperature, fuel flow and engine torque. In addition, it records altitude, airspeed, OAT, bleed-valve position and ice-vane deployment, which are needed to collect accurate trending data.

Data is downloaded for analysis and report generation from the monitors to a laptop computer using Altair's Internet-based TurbineTracker (www.altairavionics.com). With each flight, ADAS logs the date, flight start time and duration. If any parameter exceedences occur during the flight, the date, start time, duration, peak and average value are also recorded and associated with the flight. Cycles are also counted and logged with each flight.

ADAS+ operates in a similar way, but logs exceedences independent of flights. It also records the date, start time, sensor minimum, average and maximum value during the event and its duration. For each flight, ADAS+ records the maximum start temperature, minimum battery voltage and the length of the start, as well as flight duration, date and start time. ADAS and ADAS+ record all sensor maximums during each flight.

Yet another area receiving increased attention is engine condition monitoring. "Advanced equipment condition monitoring (eCM) technology is designed to reduce planned downtime, eliminate unplanned downtime and maximize operating time by providing an advanced early warning of a pending problem," according to Alan Wilks, Ph.D., vice president of technology for Lisle, Ill.-based SmartSignal.

He said the core technology, originally developed at Argonne National Laboratory, is the result of a multimillion-dollar U.S. Department of Energy (DOE) research effort. SmartSignal technology has been in use by Delta Air Lines, monitoring several fleets, since January. The company's recently released Remote eCM 1.5 provides real-time monitoring, fault detection and diagnostics. In addition to lowering maintenance costs, the early warning of deteriorating conditions that Remote eCM 1.5 provides helps reduce some of the hidden costs of downtime, such as inventory and spares.

Engine operating data is captured using previously installed sensors and standard operating parameters during takeoff and climb modes, and periodically while at cruising altitude. This data is transmitted directly to SmartSignal via ACARS.

SmartSignal eCM automatically captures the data, completes a thorough analysis and posts the results in graphic format on a secure Web site.

Each aircraft engine has its own individual performance personality, so SmartSignal software maintains a separate operating model for each aircraft and engine serial number, providing the ability to compare the actual operating data to the expected performance for that specific engine on a real-time basis. Subtle differences across multiple parameters indicate abnormal operation, even if every parameter is within operating limits.

Validated indications of equipment problems are automatically posted to the "watch list," together with a diagnostic assessment for analysis and action. Customizable alerts can be sent via e-mail or pager to the maintenance control center or other key personnel. Fleet-wide management reports are available to summarize the status and health of all engines and systems, regardless of manufacturer.

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