**THE MARKET**

New aircraft designs boost engine demand

Demand for lower fuel consumption, more power and improved reliability keeps engine manufacturers constantly renewing their market offerings. Simultaneously, the growing number of aircraft models on the market, due to both the emergence of the very light jet (VLJ) segment and the numerous derivative designs aircraft makers are marketing, demands an ever-expanding range of engines.

In its business aviation outlook, Honeywell Aerospace forecast deliveries of as many as 745 new business jets last year, up from 589 in 2004. This year deliveries are expected to exceed 800 for the first time in industry history. Of course, that translates into record numbers of engine deliveries, too.

Williams, for example, told AIN it delivered “more than 300 general aviation turbfans” last year and plans to deliver “more than 400” this year. Rolls-Royce also delivered high numbers of corporate aircraft engines, with 133 BR710s (for the Bombardier Global and Gulfstream G500 series) and 56 Tay 611-8Cs (for the Gulfstream G350/450). GE delivered 76 CF34-3B engines for the Challenger 604 last year and expects to deliver the same number both this year and next.

P&W, which did not separate engine deliveries by category, told AIN that it delivered “more than 2,000 engines” last year. This year, it plans to double post-9/11 production—a low of 1,200 engines.

In the helicopter segment alone, Rolls-Royce delivered 334 Model 250s last year and plans to deliver 400 this year. Turbomeca told AIN that it expects to deliver 930 helicopter engines this year, up from 650 last year, when it delivered approximately 80 Makilas, 140 Arrusies and 430 Anries. “However, those figures include some military applications for our civil engines,” said Charles Claveau, Turbomeca’s director of helicopter engine programs. After deliveries of 40 CT7 turboshafts last year, GE is planning 42 for this year.

**Predictions for the Near Term**

What about market trends?

“The helicopter market is generally in good shape. The market for civil helicopters remains steady and may benefit from additional parapublic orders as a result of its high-profile roles in recent disaster-recovery operations; the high price of oil is also driving offshore demand,” according to Rolls-Royce. GE’s Harry Nahatis, director of turboshaft engine sales, agreed. “High oil prices are encouraging exploration by oil companies,” he pointed out.

Turbomeca’s Claveau sees the market growing until 2008 or 2009. “We expect this year’s orders to equal those of last year. However, our increasing delivery numbers are due to the market shares we earned, more than overall market growth,” he said. He added that the demand is strong in emergency medical services and that “India and China have huge needs.” Generally speaking, “the helicopter industry wants to bring its safety record up to that of the airlines, which implies some renewal of the world fleet of rotorcraft,” he said.

Rolls-Royce put a figure on its predictions for the helicopter can say; it is a cyclic industry depending heavily on corporate profits and overall economic growth.” Nonetheless, with its PW600 turboshaft line powering three of the in-development VLJs—the Cessna Citation Mustang, the Eclipse 500 and the Embraer Phenom 100—
Engine manufacturers bring new technology to helicopter market

Helicopter operators’ continuous demand for more power, better reliability and lower costs is spurring an infusion of new technology in turboshaft engines. All the manufacturers—General Electric (GE), Honeywell, Pratt & Whitney Canada (P&WC), Rolls-Royce and Turbomeca—are developing new models or conducting preliminary work to be ready as soon as the market requires a new engine. In fact, the turboshaft appears to be evolving faster than either the turboprop or turbofan.

French-based Turbomeca, the largest producer of civil helicopter turboshaft engines, sees a new trend in customer demand. “For three or four years, helicopter manufacturers have been asking for economy and reliability rather than lightness and performance,” Charles Claveau, director of helicopter engine programs, told AIN.

The result of this shift in emphasis is increased operating margins; in other words, the engine operates farther from its limits. In addition, the engines are more reliable and less fuel-thirsty, while component durability improves. As a result, “you can lose a bit of performance,” Claveau explained. For example, the preliminary design of the Arriel 3 (Turbomeca) has not yet fully launched the program) makes it a more powerful model in the Arriel line, which currently spans 640 to 944 shp. “But the priority is to cut direct maintenance costs, acquisition cost and specific fuel consumption [stc],” Claveau emphasized.

Sfc can be addressed by enhancing the aerodynamics of the compressor and turbine components. To prolong life and mean time between overhauls, the company is increasing the engine’s margins and is using new materials. It has modified magnesium alloys slightly, allowing them to be incorporated in the engine’s casing. “Magnesium is much lighter than aluminum, but the challenge is in the corrosion-proofing coating,” Claveau pointed out. Companies also favor titanium because it withstands higher temperatures.

Digital engine control, which Turbomeca envisions for the Arriel 3, can improve reliability and lighten the maintenance burden. However, the design of a single-channel digitally controlled engine must address the possibility of failure of the digital control. On such a turboshaft, the hydromechanical unit therefore has to be able to perform most of the control tasks. A dual-channel full-authority digital engine control (FADEC), however, can be less complicated because the second channel is independent of the first one. As a result, the dual-channel FADEC has an almost zero chance of failing completely. “A dual-channel FADEC can be much simpler,” Claveau said. Improved maintenance comes through including a health and usage monitoring system (HUMS) in the FADEC.

Turbomeca is also considering offering an Arrius 3, a smaller version of the existing Arrius. It would suit more powerful evolutions of such light singles as the Bell 206 and Eurocopter EC 120 and light twins such as the Bell 206 and Eurocopter EC 135 and Agusta A109. “We have quite precise ideas on what an Arrius 3 can be, but the market is not asking for it now,” Claveau noted. The Arrius series currently spans 479 to 716 shp.

Meanwhile, the company’s high-altitude Aridien gas turbine made its first run last October. First flight is planned for July, with EASA certification due in December. The Aridien was designed to provide the hot-and-high performance qualities required by new-generation medium twins such as the AB139, Ka-62 and EC 175. However, it will be installed first on the twin-engine Dhruv, developed by Hindustan Aeronautics in India (where it is known as the Shakti), mainly for military applications. In this role it is expected to improve power margins by 10 percent over the current TM333-B2s.

P&W is studying a new 1,000-shp-class engine, dubbed the PW210S, for the 13,000-pound-class Sikorsky S-76D. At last year’s HAI Convention, John Saabas, P&W engineering vice president, announced that the company is “starting with a brand-new sheet of paper.” He explained that the PW210S draws on technologies and materials proven in both the PW200 turboshaft line and the emerging PW600 series, of which the PW615F for the Eclipse 500 is the first production engine.

The PW210S will have a higher pressure ratio compressor—similar in design to that in the PW615F—and a higher-speed turbine with improved disc material provided by P&W’s Connecti-
GE Focuses on Variants of Current Engines

GE is studying a 3,000-shp growth version of the CT7-8, which is in the 2,600-shp class. “We see the market going to more hot-and-high capability and more range,” Harry Nahatis, director of turboshaft engine sales, told AIN.

GE engineers are working on a new three-stage power turbine (in lieu of two stages in the current engine). Further enhanced materials in the turbine will enable the use of less cooling air, which is bled from the compressor and therefore affects its efficiency. “Sfc will be reduced,” Nahatis added.

No time frame has been set yet for entry into service. “It will be dictated by the market,” Nahatis said. The engine will still hold the CT7-8 designation.

The CT7-8A received FAA certification last year. Compared with the earlier -2 and -6 variants, it features 3-D aerodynamics in the compressor for higher efficiency and stall margin, improved turbine material for increased power-to-weight ratio and an advanced inlet particle separator.

“It is an active separator that uses a blower; it is thus very effective even at idle,” Nahatis emphasized. It is therefore useful during taxi and hover. A dual-channel FADEC provides, among other functions, start management, overspeed protection, automated power assurance and HUMS.

The company is also evaluating high-temperature engine components, including ceramic parts and next-generation single-crystal blades. Rolls-Royce is also considering variable-cycle powerplants for compound helicopters.

On the current 250, recent technology introductions include an enhanced power turbine for the Series II. It provides a 3- to 5-percent increase in power and a 1- to 2-percent reduction in sfc, Rolls-Royce claims. The “R plus” upgrade for the 250-C20R has a performance improvement of operating cost reductions. “We continue to study growth derivatives of the Model 250 in response to market interest,” a Rolls-Royce executive told AIN.

Honeywell Offers Derivatives

Honeywell is also renewing its product offerings. For example, the LTS101-700 and -850 are replacing the -600 and -750, respectively. The LTS101-700D2 received its STC certification last October for the Eurocopter AS 350B2.

Design changes include an expansion of the nozzle in the gas producer section of the engine. Aerodynamics have been improved, too. A new cooling system has extended the gas producer turbine’s disc life from 6,300 to 15,000 cycles.

The LTS101-700D2 offers nearly 13 percent more takeoff power at ISA conditions than an LTS101-600A3A. In addition, the newer engine has better performance retention when the ambient air temperature gets high. At ISA+43 degrees C, takeoff power is 21 percent better, at 533 shp.

Honeywell has been ground testing the HTS900, selected for the Bell 407, since late 2004. The engine was scheduled to fly last year. Full integration of the HTS900 into the Bell 407 is scheduled for late this year.

The HTS900 uses the same system architecture as the earlier LTS101, but it incorporates new compressor technology for improved performance. In February last year, Bob Miller, head of Honeywell’s light utility helicopter engines unit, said the HTS900 will burn 3 to 6 percent less fuel than any of its earlier engines while generating 42 percent more power at ISA+5 degrees C. Honeywell did not respond. Fitted with a dual-channel FADEC, the HTS900 will provide 928 shp at takeoff on a twin; the 30-second OEI rating is 995 shp. The engine will come in both a 6,137-rpm version and a 9,598-rpm version for either single- or twin-engine applications. Miller said the low-speed model would come first, with certification scheduled for the second quarter of this year.

The compressor and turbine are designed to have a 15,000-cycle and a 25,000-cycle service life, respectively. Honeywell targets time between overhaul at 3,000 hours. Miller expects that number to increase to 5,000 hours once the product matures.

At the conceptual stage is the HTS800, a smaller derivative of the HTS900. Also available in single and twin ratings, it could deliver 807 shp on a twin. The 30-second OEI rating would be 870 shp. Honeywell claims the engine will offer improved performance retention in hot conditions compared with current-generation engines.

Honeywell did not respond to requests for information about the HTS1000. Its power is not defined yet, but its designation suggests that it would be rated at close to 1,000 shp. An application could be Bell’s modular affordable product line. The HTS1000 will benefit from the small heavy fuel engine military technology program.—T.D.
Only three engine manufacturers are active in turboprop business airplanes, and few new developments can be expected in this category. The dominance of jets in business aviation and the hegemony of Pratt & Whitney Canada (P&WC) over Honeywell, its primary competitor in turboprops, are the most likely causes for the dearth of new technology. Both P&WC’s PT6A and Honeywell’s TPE331 original designs date from the mid-1960s. One start-up company, however, has plans for a clean-sheet turboprop engine. Rolls-Royce is also a player in the field with an adaptation of its widely used helicopter turboshift; the 250-B17F turboprop powers the Extra EA-500 and the Grob G140TP singles.

At P&WC, the ubiquitous PT6A turboprop engine line has entered its fifth decade of in-service life. The first model was introduced in 1964. Since then, some 60 versions have been developed. As of the third quarter of last year, more than 13,500 aircraft powered by the PT6A turboprop were in operation around the world. The engine line has logged more than 270 million operating hours.

There is some ambiguity in P&WC’s stance on the PT6A’s future. The PT6A now covers a wide range of power, from 550 to 2,000 shp. The company has long been mulling a replacement based on the PW600 turbofan line. P&WC’s Web site refers to it as “the PW600P turboprop, in the 500- to 2,000-shp class, designed for general aviation single- and twin-engine aircraft.”

However, asked when a PW600 turboprop derivative is scheduled to replace the PT6A, P&WC answered, “It is not our intention to have the PW600 replace the PT6 engine family but rather complement it.” Market research firm Forecast International offers an explanation for that. “We do not see an immediate need for launch of the PW600P because the PT6A controls substantial market share and a turboprop variant of the PW600 would be expensive to develop,” the research company said in a study late in 2004.

Yet, a PW600P would feature much simpler architecture than that of the reverse-flow PT6A. For example, the latter’s compressor includes three or four axial stages (depending on how powerful the version is) and one centrifugal stage. The PW600P, using the same core as the PW600 turbofan series, would have only one axial and one centrifugal stage, which translates into lower maintenance costs.

Nevertheless, P&WC insists that engineers continue to inject new technology and new materials.
TURBOFANS

Jet engine designers focus on maintainability, environment

Ease of maintenance and environmental concerns increasingly are driving turbofan engine technology. Business aviation engine manufacturers—namely GE, Honeywell, P&W, Rolls-Royce and Williams International—continue to focus design efforts on thrust-to-weight ratio, specific fuel consumption and cutting costs.

The emergence of the very light jet (VLJ) segment—and increasing regulation and lobbying pressure seem to have further highlighted the importance of the thrust-to-weight ratio and sfc. Meanwhile, two new market entrants, GE Honda Aero Engines and Price Induction, are endeavoring to develop a successful small engine.

P&W’s focus on maintainability in designing the PW600 line—which has found several applications in the VLJ segment—can be seen in numerous aspects of the engine. Manufacturers have reached a lower part count and have incorporated increased durability and corrosion resistance. The PW600 design uses “one-deep line replaceable units [LRUs],” meaning that the replacement of any single LRU does not require the disturbance or removal of any other LRU.

“This, coupled with no requirement to [calibrate the control system] after an LRU replacement, results in rapid LRU replacement times,” the manufacturer said. The PW600 also includes a dual-channel FADEC.

Environmental issues become more important in engines that have more than 6,000 pounds of thrust, which is the baseline thrust to which ICAO’s committee on aviation environmental protection standards apply. The 6,100-pound-thrust PW307A, certified last spring and powering the Falcon 7X during its flight tests, has a notable environmental slant in its design. For example, the Talon combustor uses technologies from Pratt & Whitney large commercial engines. It enables the PW307A to achieve Zurich 5 emissions levels.

However, lower-thrust engines can also benefit from environmentally conscious design. For example, Price Induction’s DGEN 380 has a high bypass ratio—7.6 instead of the approximately 3.0 on other small engines such as the PW600 and the Williams FJ44. One of the main reasons for this choice is noise reduction.

“According to a preliminary study, we expect less than 55 dBA,” said company founder and CEO Bernard Etcheparre.

The Rolls-Royce Tay 611-8C is one of the engines that most recently entered service. It debuted in May last year on the Gulfstream G350/G450 and “had the smoothest entry into service of all the Tay engines,” Rolls-Royce said. Its advantages over earlier Tay variants include a 12,000-hour TBO, 2-percent better fuel efficiency and 5 percent more thrust in hot and high conditions. The G450 thus carries a higher mtof than 73,800 pounds, translating into 3,500 nm range at Mach 0.85 (a 250-nm improvement over the Gulfstream IV). The new Tay also promises better reliability, thanks to the addition of FADEC, according to the manufacturer.

FADEC Engines Proliferate

Those who are not familiar with FADEC yet probably encounter this wizardry in the near future. Every new engine is controlled via FADEC. For example, the primary change on the PW535B, which powers the Cessna Citation Encore, is the introduction of dual-channel FADEC, something that was lacking on the Encore’s PW535A. On the Cessna Citation CJ1+ and CJ2+, new FJ44 variants feature Goodrich FADEC.

A representative of Williams International told AIN, “FADEC makes for safer flying because it raises the situational awareness of the pilot, who no longer has to check and adjust engine power settings throughout the flight. This tedious, distracting chore is performed automatically and more precisely by FADEC.” This not only reduces pilot workload, but it also tends to reduce cyclic damage to the engine, reduces the risk of overtemping and extends range by optimizing fuel efficiency, Williams emphasized.

The FADEC units’ memory can be used to monitor the way an airplane is flown, as well as recording the health trends of the engine. This information can be used to adjust flying practices to improve performance or extend life, and to discover potential problems and fix them before any failures occur.

Williams is now developing the FJ44-4A, a new member in the FJ44 line. The 3,500-pound-thrust turbofan is progressing toward FAA/EASA certification by 2008, according to its designers. The first application is still unidentified.

Upgrading Older Models

Even engines that have been in production for a long time are getting some technology infusions. GE’s CF34-3B, which powers the Bombardier Challenger 604 and 605, recently received several enhancements.

“We have incorporated materials improvements in the high-pressure [HP] turbine that provide higher temperature capability for the nozzles and shrouds. In addition, an upgraded accessory gearbox incorporates increased durability gears and bearings and an optimized oil jet and scavange system,” GE told AIN. The company asserted that the result will be better overall reliability and durability.

The company is also working on an engine upgrade for the older CF34-1A/1A-3/3A-32A (powering the Challenger 601). It will allow operators to migrate to an on-condition maintenance program versus hard-time shop visits. This upgrade will be available this year.

In addition, Rolls-Royce is working on further improvements to the AE3007. “We are actively evaluating further incremental environmental performance but are not currently in a position to discuss...
at this time,” the company stated. Powering the Embraer Legacy 600 and the Citation X, more than 600 engines have accumulated almost 1.6 million hours and a little over one million cycles.

P&W acknowledged that, at entry into service, an intermittent vibration issue and various “minor” LRU issues had to be addressed on the Falcon 2000EX’s PW308C. The powerplant now meets Dassault’s overall reliability targets, P&W said. And dispatch performance, after only two-and-a-half years in service, is approaching “mature levels.”

Despite several requests, Honeywell did not provide AIN with an update on the TFE731 and the HTF7000.

Honda flew its 1,670-pound-thrust HF118 in 2003 on its developmental HondaJet but the engine has undergone major modifications since Honda formed a 50/50 joint venture with GE. GE Honda is validating design and component enhancements with early 2007 the target for running a full engine incorporating these designs. The HF118 is intended to be a 1,000- to 3,500-pound-thrust engine series.

Honda’s Japanese facilities. The company has reduced the sfc by 5 percent through engine component efficiencies. Enhancements to the HP centrifugal compressor have increased the airflow and the overall pressure ratio. Maybe the most spectacular advance is the 15-percent reduction in overall engine weight.

By incorporating lighter, higher-temperature materials and engine-cycle design enhancements, GE Honda said it has been able to reduce the size of the core engine. In the HP turbine, GE has introduced single-crystal material and 3-D aerodynamics. The U.S.-based engine maker has used GE90 technology [the GE90 powers the Boeing 777] on fan blades. They now feature a wide-chord, high-flow, swept design. “The HF118 is being designed to operate in service for 5,000 hours before the first major overhaul with no interim hot-section inspection,” the joint venture noted.

New Companies Enter Market

In Anglet, France, start-up company Price Induction (see market story on page 34) is putting together its first 560-pound-thrust DGEN 380 engine. The company expects to run its first core engine by early March. “We plan to run the first full engine two months later,” said company CEO and founder Bernard Etcheparre, who also maintained that all parts are designed with certification in mind and manufactured within the aerospace industry.

Meanwhile, State College, Pa.-based Innodyn is developing lightweight, fuel-efficient, low-cost 200- to 300-shp turboprop engines, as well as a 500-shp TwinPack that combines two 250-shp turbines via a common gearbox. The company estimates that its turboprops will burn only about seven gph per 100 shp produced.

Innodyn’s patented fuel control/management system makes its turbines so efficient and eliminates the throttle-to-power lag time. A computer monitors fuel consumption five times per rotation (300,000 readings per minute at 60,000 rpm), which allows for an optimal fuel/air mixture. The fuel-delivery system—composed of an “innovative” fuel nozzle and a “pulse width modulation” fuel pump—creates small fuel pellets that burn completely when ignited.

The company’s single-shaft turboprops have only 13 parts, with the majority being gears and the only moving part being the shaft. A prototype 250-shp engine has been flying aboard an RV-4 experimental airplane for “several years.”

Innodyn plans to certify the engines, and it is seeking a strategic partner with experience in FAA certification to undertake the process. The company said several established aircraft manufacturers have expressed strong interest in the small powerplants. —T.D.
Few technology changes on the horizon for t-props

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into the PT6As. Some newer models have electronic controls but no full authority digital engine control (FADEC).

**Beefing up the TPE331**

No in-production corporate aircraft features Honeywell’s TPE331 turboprop engine. However, the latest applications include a Cessna Caravan retrofit by Aero Twin and a King Air C90/E90 retrofit, dubbed the Kilo Alpha 290. The worldwide fleet of TPE331 turboprop engines has logged more than 106 million hours of operation since the engine entered service in 1965. Some 11,300 examples are in service around the world.

On the TPE331-10 conversion (more than 1,000 completed), a new combustor system, turbine and stator hardware, new static structure and a new fuel distribution system give “increased climb performance, cruise speed and temperature margin for hot-day operations.” Honeywell also claims lower cost of ownership. For example, the TPE331-10 conversion offered on the Mitsubishi MU-2 turbo prop twin increases power and results in better performance. A TPE331-5-powered aircraft, retrofitted with TPE331-10Ts, gets 1,000 shp on each engine (instead of 840). Cruise speed jumps from 290 knots to 305 knots and climb power is maintained to 15,000 feet instead of 6,000 feet.

Honeywell executives said they are planning further developments of the TPE331 to improve environmental performance (fuel burn, noise and emissions), but no additional details were available.

**New Turboprop Possible**

Finally, two new companies might soon have an entry for the turboprop market. French start-up company Price Induction recently unveiled a possible turboprop derivative of its DGEN 380 turbosfan, which is pegged to run in a few weeks (see market and turbofan stories page 34 and 38). “We have carried out a study but we have not launched the turboprop yet,” Bernard Etcheparre clarified.

**New engine technology**

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New technology changes on the horizon for t-props

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