There's little question that Pratt & Whitney's new PurePower PW1000G family of geared turbofan engines represents a remarkable technological achievement and many pundits are touting its potential as a major contender in tomorrow's narrowbody-propulsion market.

The PW1000G has already been chosen to power the Bombardier CSeries, Mitsubishi MRJ and Irkut MC-21 narrowbodies, and — as rumours proliferate that Bombardier intends to stretch the CSeries into a 150-seat design — analysts see the PW1000G as a strong candidate to power any re-engined A320 or 737 that Airbus or Boeing might respectively offer.

However, few observers have noted that the geared turbofan (GTF) concept is already highly proven in the civil aviation market — albeit in the form of engines rather less powerful than Pratt & Whitney's new offering. As do all GTFs, these engines employ planetary gearboxes — driven by the low-pressure spool — to decouple the low-pressure turbine (and low-pressure compressor) from the fan. This allows both the...
fan and the low-pressure spool to revolve at their optimal rates — fast for the low-pressure spool, quite slowly for the fan.

Geared turbofans already in service

Both the LF502/LF507 and the TFE731 engine families (now made by Honeywell, but originally developed by Avco Lycoming and Garrett respectively) are geared turbofans that have clocked up many millions of hours of flight time — and new versions of the TFE731 in particular continue to sell well, according to Bill Storey, founder and president of aerospace research firm Teal Group. While the LF502 suffered serious reliability problems — which led to the development of the LF507 — these weren’t to do with its geared fan, says Storey, and the GTF concept has proved reliable in service.

So why all the fuss about the PW1000G? The answer is that it’s a much bigger, more powerful GTF than any previously designed. Storey says that where Pratt & Whitney (P&W) has made a breakthrough in bringing to market a new GTF family is in managing “to get the weight of the gearbox down to a scale where it makes the concept viable” for large-aircraft applications. P&W duly patented this new gearbox technology, “so competitors can’t jump on it,” he notes.

The PW1000G’s fan and core

In pursuing the narrowbody propulsion market, P&W chose to develop a GTF rather than a more conventional turbofan because it believed its GTF design could offer the best “value proposition” in two ways, says Paul Adams, P&W’s senior vice president of engineering.

First, because the PW1000G’s fan rotates 30 per cent more slowly than that of a conventional turbofan, P&W could make the engine’s 18-blade fan diameter very large without running into the blade-tip shockwave problems that destroy a conventional engine’s efficiency above about 80 per cent of maximum thrust. The large fan diameter allows a much higher bypass ratio than would be possible with a conventional turbofan, increasing the PW1000G’s propulsive efficiency. The slower-turning fan also minimises the chances of blade damage from bird ingestion, since most ingestion dam-

“We think we have the most durable blades, in combination with [operating] temperatures more conservative than the competition. The PW1000G will run at lower temperatures than we think the competitors are going to run at.”

—Paul Adams, senior vice president of engineering, Pratt & Whitney
age is caused by the speed at which the fan is turning, not the speed at which the bird is flying.

In developing the PW1000G, P&W also designed in a new, very durable core — based on a core it developed with MTU, one of P&W’s partners in A320 supplier International Aero Engines — optimised for the high-cycle narrow-body operating environment. Because the low-pressure spool in the GTF can run at its optimal speed without affecting the propulsive efficiency of the fan, P&W was able to remove several low-pressure turbine (LPT) stages: The PW1000G has three, rather than the six or seven normally needed. Similarly, P&W could do away with two low-pressure compressor (LPC) stages, using three in the PW1000G rather than the conventional five.

Dropping five or six LPC/LPT stages produced an engine with less than 50 per cent of the low-pressure stages in a conventional turbofan, and 1,500 fewer blades, says Adams. At the same time, P&W introduced into the PW1000G a new eight-stage high pressure compressor, each stage of which is a single-piece, integrally bladed rotor (or “blisk”).

The PW1000G’s core also has an advanced combustor based on P&W’s low-emissions TALON-X design. This features a “floatwall” of inner-lining panels — which can expand and contract independently, reducing lining wear — as well as a rich-quench-lean combustion cycle to prevent nitrogen oxides forming. Behind the combustor, P&W has employed new turbine cooling technologies, including advanced thermal-barrier coatings, powder-metal blade alloys, new cooling-air-path geometries within blades, and turbine-casing active clearance control.

Above: Pratt & Whitney is hoping that should either a re-engined A320 or 737 appear, the PW100G would be selected to power it.
“We do think we have the most advanced combination [of cooling technologies],” says Adams. “And we think we have the most durable blades, in combination with [operating] temperatures more conservative than the competition. The PW1000G will run at lower temperatures than we think the competitors are going to run at.”

Other key technologies

Two other technologies are important in the PW1000G, says Adams. One is the composition of the engine’s fan blades, still largely secret. Adams says the PW1000G has “a hybrid metallic fan blade” that P&W has developed over the past two years. “It is actually lighter and higher-efficiency than a composite fan blade” the same size would be, he claims. “We think we have got a concept that meets all structural criteria and is significantly better than a composite fan blade. We have done full-scale, full-speed birdshots and we’re in extremely good shape. We don’t see any significant risks with the fan blade.”

Another key technology is the PW1000G’s gearbox. P&W expects the gearbox, which is made of high-strength gear steels, to be “very low-maintenance”, says Adams. “We’re expecting the gear will be less than two per cent of the maintenance cost of the product. It’s designed to be full-life without any additional maintenance outside normal maintenance periods.”

Combining “a very efficient core designed specifically for the high-cyclic narrowbody market” with the propulsive efficiency created by the PW1000G’s large fan and its high-strength gearbox will create “a step change” which will provide “the best value proposition” for the market, he says.

That market includes aircraft “up to the A321 or the large-737 class”. P&W has already run demonstrator GTF engines at 30,000lb, is developing a 30,000lb PW1000G for the Irkut MC-21 — with a 12:1 bypass ratio, like the CSeries powerplant — and Adams says P&W sees the PW1000G’s competitors as being engines offering “more than 30,000lb”.

The company has been running a full PW1000G core since late 2009, and reportedly
has scheduled the first CSeries engine to run in August and the first MRJ engine in October. With the CSeries expected to enter service in 2013, P&W will bring the PW1000G to market significantly before 2016, when CFM has said its LEAP-X will be ready for its first application, China’s COMAC C919 mainline narrowbody.

The PW1000G’s market and its competition

This could help P&W in winning a position on a re-engined 737 — and a re-engined A320. “Whether or not it proves to be a competitive advantage, it gives [P&W] good reason to think they have a head start on the single-aisle war,” says Storey. “They may even stumble in by the back door if Bombardier builds a 150-seater.” Bombardier might well do so, he thinks: “There has always been a gulf from the regional jets into the single-aisle widebodies [such as the A320 and 737]. The CSeries might be a spanner between the two, if they were to stretch it.”

CFM International’s new LEAP-X engine is P&W’s most obvious medium-term competition. “LEAP-X has been by far the most vocal in there,” says Adams. But he believes CFM is trading away some of the vaunted maintainability of its existing CFM56 engine family to meet customers’ fuel-efficiency demands for a re-engined A320 or 737.

LEAP-X is “more like a widebody engine”, claims Adams. “The interesting thing here is, in order to compete with the GTF product, the LEAP architecture has had to change significantly from the CFM56 architecture to a widebody architecture,” optimised for fuel-efficiency and low-cycle operation rather than high cycles and durability. “We think the competition has had to compromise maintenance cost,” he says.

Meanwhile, Adams thinks that the open rotor’s noise, installation and blade-containment challenges, along with the need to provide a variable pitch mechanism for each of its two contra-rotating blade rows, will rule out an open-rotor design in the medium term. “Variable pitch is 10 times less reliable than a gearbox,” he says. “And square that” for two rows of blades.

Phased improvements

Some have pointed to the apparent gap between the 12 per cent fuel-efficiency improvement P&W is promising from 2013 with
the PW1000G and the 15-16 per cent benefit CFM says it can offer from 2016 — and the 30 per cent improvement Rolls-Royce is claiming from 2018-2020 with an open rotor. However, Adams says that, “apples to apples,” all three engine manufacturers are essentially talking about the same levels of benefit being available at the same dates.

P&W’s initial 12 per cent benefit with the PW1000G is only a starting point, he explains. In developing the new engine, P&W has adopted a programme to introduce “technological injection” packages at phased intervals to keep the programme “fresh”, both for new-build engines and upgrades to in-service PW1000Gs: “We think we get to the same number at the same point in time” as the other manufacturers.

Generally, “turbomachinery [efficiency] improves at 0.75-1 per cent a year” through manufacturers’ continuing research, says Adams. “The reason we stepped to the geared turbofan was that we saw we were actually getting nearer to the limit ... with traditional concepts. We had to work harder and harder to get the improvements. The GTF-style architecture allows us to continue that rate” more easily.

“In 10 years the geared turbofan can be 7.5-10 per cent better than it is now. We think that for at least the next 15 years we can continue to run that out at the historic trend or better.”

**Will the 737 or the A320 use the PW1000G?**

If a re-engined A320 or 737 appears, it will be important to P&W to be on it, Storey believes. P&W was the sole provider for the first generation of 737s with the JT8D, but subsequently “Pratt & Whitney played themselves out the game and they’re keen to get back in, in a big way, and to be at least one of the engines on the Airbus or Boeing plane. It would mean a lot for [P&W’s] bottom line.”

The PW1000G’s large fan size - the diameter of the CSeries fan is 73in, compared with the CFM56-7B’s 61in, the IAE V2500A5’s 63.5in and the CFM56-5B’s 68.3in — will create challenges if it is chosen to re-engine the 737. “It certainly fits pretty easily with the A320, even now,” says Storey. “At the time the A320 was designed [Airbus] probably anticipated larger and larger engines” being used. But the same isn’t true for the 737, whose design started life some 20 years earlier.
However, Storey says senior P&W executives have assured him the PW1000G could fit under a 737 wing. “I think the possible road to that is a somewhat lengthened nose gear,” says Storey. “It’s probably not feasible to lengthen the main gear on the 737 — you might as well redesign the plane.” He declines comment on how much longer the 737’s nose gear would need to be. But reports suggest that, assuming the nacelle design was flattened like that of the CFM56-7B, a four-inch nose gear extension would produce about a two-inch clearance for a PW1000G.

IAE and the PW1000G

A320 re-engining presents a different problem: P&W is, along with Rolls-Royce, one of the two largest partners in IAE, which has won more than a 50 per cent market share on the A320 family with the V2500. Airbus has stressed it wants any P&W path to market on a re-engined A320 to be through IAE.

Asked for comment, IAE responds: “We intend to offer an engine solution that meets our customer’s needs and we’re in ongoing discussions with Airbus and our shareholders to determine the right approach to meet those needs. We are considering all available technology options and will offer the best solution once Airbus has clearly defined the aircraft’s requirements.”

Presenting P&W’s view, Adams says: “We both clearly state we like IAE and it’s a good channel to market, and we continue to work with Rolls-Royce to see if there’s a resolution to the problem. There are some philosophical differences and we’re not sure where it will come out.” He confirms “we have done studies with both airframers” and notes “a 737 approach wouldn’t necessarily have to be through IAE”.

What this means, says Storey, is that “Rolls-Royce obviously hasn’t jumped on the bandwagon. It’s always been a triple-spool proponent and possibly also of an open rotor. I can’t see Rolls-Royce coming out [for an A320/737 re-engining] with its own 25,000-30,000lb engine ... so I would think [Rolls-Royce’s presence] would be either through IAE or nothing. That would lead me to believe Pratt & Whitney thinks it is bringing the most to the table and would want a bigger share” of a new GTF-based IAE engine for the A320 than the 32.5 per cent it now has on the V2500.

Ultimately, says Storey: “I think both Boeing and Airbus are going to prefer two engine options, and if they’re not both open rotors, I think they will be the LEAP-X and P&W. It seems Rolls-Royce is the one not in lockstep.” While Boeing might not be actively favouring two engine options, “if the LEAP-X doesn’t deliver as advertised and Airbus has options with both the LEAP-X and the geared turbofan, Boeing would be at a disadvantage. My assumption now is that both manufacturers will offer two engines, and they’ll be the same two engines”.

The GTF as a widebody engine

Adams confirms Embraer is also considering the PW1000G in its “studies of what its next product would be like”. But even more interesting is Adams confirmation that “the overall concept of the geared turbofan is scalable up to pretty much any size”, including a potential 100,000lb-thrust engine for a 777-300ER replacement — or perhaps for the A350XWB-1000.

“Pratt & Whitney played themselves out of the game and they’re keen to get back in, in a big way, and to be at least one of the engines on [a re-engined] Airbus or Boeing plane. It would mean a lot for [P&W’s] bottom line.”

—Bill Storey, founder and president, Teal Group