Already the most reliable engine on the Boeing 787 Dreamliner, the Trent 1000 will set the performance bar even higher as the engine’s TEN (thrust, efficiency and new technology) development programme moves into its final test stages.
his latest variant of the Trent 1000 has recently completed a certification ‘Type Test’, 150 hours of hot and fast running designed to simulate conditions more arduous than those ever encountered in service and demonstrate the engine’s durability.

The Trent 1000 TEN is now being readied to begin flight testing on a Boeing 747 flying test bed (FTB) operated by Rolls-Royce. Following that, in 2016, it will undergo flight tests on a Boeing 787 test aircraft to gain full certification for powering the type.

The production version of the new engine will be rated up to 78,000lbs of thrust and will be available for all three variants of the Boeing 787: the -8; -9 and future -10.

**Improvements**

Rolls-Royce was first to power the 787-8 and 787-9 aircraft types into service. The company is hopeful of doing the same for the 787-10 aircraft with the Trent 1000 TEN engine, although agreement has yet to be finalised with Boeing on this and discussions are ongoing.

Boeing’s 787-10 Dreamliner, is the latest and longest member of the Boeing 787 family of commercial aircraft, it was officially launched at the 2013 Paris Air Show in Le Bourget, France. The new Dreamliner can reach a distance of 12,000km, covering more than 90% of the world’s twin-aisle routes, including Europe-US West Coast and trans-Pacific routes. In standard configuration, the variant is to seat up to 330-passengers in a typical two-class configuration.

The Trent 1000 engine has been subject to continuous improvements since first entering service in 2011 with Japanese airline ANA. Since then, Rolls-Royce has introduced package ‘B’ and ‘C’ improvements.

The first was predominantly to improve fuel consumption. Package ‘C’ further improved sfc but also delivered the additional thrust needed to power the new -9 version of the aircraft.

However, the TEN programme is not an improvement package, rather it is a step change in design and performance. It embodies a combination of latest design architectures in key areas drawn from the highly successful Trent XWB engine and it also features new technologies designed and developed for the Trent 1000.

“This is not a roll-up of other package improvements. The TEN is around a 70-75 per cent part change from the package ‘C’ version in service today. The LP system turbomachinery is largely unaffected but it is basically a new core and new associated systems,” says Gareth Jones, Chief Engineer Trent 1000.

“Each time we have introduced a marque of engine we have addressed the aircraft requirements and also progressively improved fuel burn – this has been an evolving story. The TEN engine is a development created to meet the needs of the future 787-10, but it has also given us a chance to use some of the best technologies and understandings of the Trent XWB programme and feed these into the Trent 1000 to substantially improve fuel burn whilst retaining our Best In Class reliability.

“Airlines need a machine that can deliver on low fuel consumption and that is completely reliable and robust. It is a balance of attributes and that is what we are going to deliver.”

Going back to the early days of the Trent 1000 it’s worth remembering that this was
to meet the high electrical demands of the 787 airframe. The 787’s systems are predominantly electrical or hydraulic and so the demand placed on the engine is two-fold: meet the necessary thrust requirements and ensure the aircraft has enough power to support the electrical architecture.

Rolls-Royce realised early in the engine’s design phase that it would be advantageous for the power offtake to come from the IP compressor, rather than from the HP spool. Doing so allows the Trent 1000 to have a lower thrust at idle and consequently lower fuel burn. On short operations, for example, the engine can be at idle for up to one third of the flight leading into the landing phase.

Elegant
The engineers also felt that using the IP spool was a more elegant solution and avoided having to compromise the design of the HP compressor. Rolls-Royce is the only large-engine manufacturer to use a three-shaft engine design, and so having the power offtake come from the IP compressor was not an option for the competition.

The challenge for the design team working on the Trent 1000 TEN programme was to ensure that the engine maintained its deserved reputation for reliability while at the same time bringing even further advantages to customers in terms of efficiency. The single biggest contributor to improved fuel burn in the TEN comes from the new compressor system. It employs a scaled version of the IP and HP compressors from the Trent XWB-84. The HP turbine architecture is shared with the Trent XWB-97 and will provide better component life results for the Trent 1000 in service.

Unique to the TEN is its modulated air system which optimises the secondary air flow within the engine. Historically an engine’s secondary air system has had to be designed to cope with the most demanding point in the flight cycle (take-off) but of course that means the system has a larger air flow circulating during the rest of the flight regime than is really required.

With the new modulating technology, the engine can regulate the amount of air it needs on demand and then when in cruise or idle, a novel valve arrangement uses air vortices (not moving parts) to regulate the amount of air flowing through the system and this helps further reduce fuel consumption.

External systems for the engine have been improved and re-designed with a greater use of composites, there is a new external gearbox and a latest generation engine control system using new-generation advanced processor technology.

During development, three technology demonstrators ran from 2013-14 to de-risk the latest developments before they were incorporated into whole engine testing which commenced in mid-2014.

Since then, four engines have run in the test programme and a further four engines are in build.

The first test engine ran to demonstrate that the core compression system would deliver the predicted benefits. The second engine had more of the new core machinery fitted. The third engine was a heavily instrumented test engine that did sea-level runs and then went to Arnold Engineering Development Center (AEDC) in Tullahoma, US, to run in the simulated altitude test bed. Here it was proving performance, functionality and stability. It also undertook an intense and very successful ice test campaign.

The fourth test engine completed the 150 hour endurance test and has now been stripped for inspection by the aviation authorities in the run up to certification.
The flight programme on the 747 is expected to be relatively light at around 100 hours of flying time because the engine is not undertaking durability work, but it will be the first time that the fuel consumption results achieved on the test bed can be proven in the air. It will also give the Boeing test pilots their first chance to work with the engine.

There then follows a more in-depth flight test programme on a 787 test aircraft during 2016. This will be a joint Rolls-Royce and Boeing effort and it will provide the data and specifications for the engine guarantees on the aircraft. It will also confirm all the software integration between the engine and the airframe systems.

**Achieved**

“This year the story has been all about base ten for Rolls-Royce. We have the Trent 1000 TEN programme going very positively, we now have 100 787s in service powered by Trent 1000s and we have just achieved one million hours in service for the Trent 1000 fleet,” says Gary Moore, Director Trent 1000.

“We are seeing customers recognise the benefits of a robust engine like ours. It is a powerful attribute. Unlike the competition, we don’t have any operational constraints in service due to high altitude icing. I think the industry looks to the Trent 1000 as a great weather vane for judging Rolls-Royce as there are not many large airframes now where there is direct engine competition. Our excellent engineering and reliability of performance is translating into great momentum in the marketplace.

“Of course, customers want lower fuel burn, but they really want reliability coupled with the ability to fly their aircraft where they want to, when they want to and how they want to. The Trent 1000 allows them to do just that.”

Author: David Howie is Director of Brand for Rolls-Royce. He joined the company from a marketing consultancy and prior to that was a press officer.