Integration of advanced propulsion engines makes headway

In its quest to nurture environmentally-friendly technologies for aviation’s next two generations of aircraft (also known as N+1 and N+2), one of the focal points of the Large Passenger Aircraft (LPA) platform within Clean Sky is the integration of energy-efficient new engines.

The challenge is to reconcile the increased diameter of newer engines with airframe and wing architectures which have remained relatively unchanged for the past five decades. Engines are getting bigger as a consequence of the trend towards larger bypass ratios, which is the ratio between the mass flow rate of air, drawn into the engine via the fan, that goes around the engine core – relative to the mass flow rate of the air that goes through the engine core.

With a higher bypass ratio, engine propulsion is more efficient, resulting in fuel savings in line with Clean Sky’s objectives and the European Commission’s Green Deal ambitions. It’s an evolution that has transitioned through successive eras of the jet age – for example, back in 1967 a turbofan engine typically had a bypass ratio of one. By 1987, the A320 engines had a bypass ratio of 5.5, whereas the world’s largest airliner, the A380, has a bypass ratio of eight. Today’s state-of-the-art single-aisle A320neo was launched with an engine bypass ratio of 12, while the Rolls-Royce UltraFan®, currently in development and one of Clean Sky’s flagship Engines ITD demonstrators, has a bypass ratio of 15.

‘The Rolls-Royce UltraFan® (Ultra High Bypass Ratio) engine is designed mainly for long range aircraft, such as the A330 and A350 type, but due to its larger size the pylon (the structure that connects the wing to the engines) and the nacelle (the engine housing) have to be reconsidered to cope with this specific new engine,’ explains Clean Sky project officer Pierre Durel.

‘Clean Sky’s D10 demonstrator supports this integration path, with activities and technologies developed to facilitate flight testing. Concurrently, engine manufacturer Safran is working on a similar (UHBR) type of engine, but aimed more for short and medium range aircraft like the A320, where the integration of a similar size engine but on a smaller aircraft is a bit different, and that’s the aim of the Clean Sky D13 demonstrator,’ says Durel.
In D10 the main partners are Rolls-Royce, Airbus, Liebherr, and ONERA, while for D13 they are Airbus, Safran, ONERA, NLR, and DLR.

These projects aren’t just about the physical and aerodynamic integration of UHBR engines on long and short/medium haul aircraft. Larger engines also mean extra weight and more drag. Therefore, the D10 and D13 demonstrators are also tasked with compensating for these factors using new innovative technologies in order to address the ambitious environmental targets: the D10 is aiming for a 7-12% reduction in CO₂, a NOx reduction of 35-40%, as well as an EPNdB (Effective perceived noise in decibels) of between -4 and -8. While the Rolls-Royce UHBR demonstrator has also been developed in the framework of Clean Sky’s Engine ITD, flight testing will be carried out within Clean Sky’s Large Passenger Aircraft Platform 1.

For the short-medium haul D13 demonstrator, the aim is to cut CO₂ by 2% and lower noise by 2 EPNdB. Both demonstrators are targeting TRL5/6 by the end of Clean Sky 2, with potential entry into service of the technologies developed under D10 and D13 by around 2030.

‘Going for a bigger engine diameter generates integration complexity, because we need to keep the clearance from the ground, but we do not have much room for locating the engine on the wing in an optimum manner, and this is why the technologies we’re developing are key to ensuring the success of the exploitation route for the technologies we’re developing in the D10 and D13 demonstrators,’ says Xavier Hue, Advanced Engine and Aircraft Configuration Platform Leader for Clean Sky 2 at Airbus Group in Bremen.

UltraFan® development

Key challenges within the D10 Rolls-Royce UltraFan® demonstrator are designing the pylon, investigating and optimising thermal management, and developing nacelle solutions. It’s also necessary to analyse the coupling effect of the engine on the wing, and carry out aerodynamic and aeroacoustic tests in order to characterise the engine.

‘The associated analysis of the jet noise for prediction on optimisation is also essential in order to reach the Clean Sky environmental targets,’ says Hue. ‘Another top objective is to deliver an integration solution for flight test demonstration of the Rolls-Royce UltraFan® engine which will be carried out on Rolls-Royce’s test aircraft to verify the predicted benefits.’

The area of the engine inlet is also a focal point for a number of opportunities for optimisation. For example, a titanium lip skin forming technology is being developed in order to manufacture the lip of the engine inlet in one piece, so as to improve the natural laminar flow (NLF) over the nacelle in order to reduce drag.

‘If the flow is not laminar it causes friction and this drag penalises the efficiency of the overall system,’ explains Hue. ‘The idea is to come up with a physical solution that will allow us to increase the laminar airflow length in order to reduce drag, and this means looking at anti-contamination surface treatment technology coatings, spot weld splicing technologies and titanium/composite hybrid co-bonded junction technology.’

The D10 demonstrator also encompasses optimising the bleed and precooler integration – both for optimising the air into the engine itself for combustion purposes, but also to allow more air to be ingested into the air conditioning system from the bleed. ‘It’s a tricky juggling act to maximise both objectives. ‘We want to improve the architecture especially for take-off and climb. We also want to optimise the high engine energy and we need to meet the air consumers’ requirements with a minimum of energy. So it’s basically understanding how we need to master the technology to be able to provide a supply of air into the passenger cabin with the optimised energy level without penalising the engine itself,’ says Hue. ‘And we’re also looking at some concepts around innovative precooling using additive layer manufacturing.’

SA²FIR and techno-bricks

For the D13 demonstrator project the centrepiece is the Clean Sky SA²FIR (Simulation of Aerodynamic and Acoustic Fan Integration) test rig. Designed specifically for evaluating small/medium range aircraft/engine integration, the SA²FIR can be fitted with small and large diameter fans which can be tested using an array of sensors for measuring a variety of parameters. The rig will enable engineers to learn more about physical phenomena such as acoustics and aerodynamics in order to optimise fuel burn and reduce engine noise.

‘We also have various techno-bricks supporting the D13 that we are developing that are essential for the maturation of various technologies including nacelle acoustic liners, close coupling, and a short thrust reverser unit/shutter,’ says Hue. ‘All of this combined package will enable us to make a step change in the next generation of engine integration.’

Nacelle acoustic liners are another innovation being developed to reduce engine noise. ‘The idea is to have air inlet acoustic panels just behind the lip of the interior of the engine nacelle,’ says Hue. ‘We’re also looking at placing acoustic panels a bit further inside the engines. And for this, we’re trialling concepts to reduce the low frequency on the broadband noise using a combination of resonators.’

Integration demonstrator progress

The D10 UltraFan® demonstrator is advancing, the engine having completed its Critical Design Review (CDR) in 2019 and the nacelle its Preliminary Design Review (PDR) in 2020. Additionally, some of the first engine components were manufactured and delivered at the end of last year. If all goes to plan, engine testing will start next year, culminating at the end of the engine development programme with flight testing.

Regarding the D13, Hue reports that ‘on the techno-bricks for the D13, we will increase the technology readiness level of the nacelle acoustic liners with wing close coupling and short thrust reverser unit/shutters.’

The SA²FIR demonstrator opened its Critical Design Review (CDR) in April 2021 with a CDR closure planned for around October 2021. Actual testing using the rig is scheduled for the end of 2023.