CFMI LEAP-X: Initial assessment

CFMI has opted to develop a conventional turbofan engine that delivers a high bypass ratio that is delivered through a wide, slow-turning intake fan driven by a core producing a pressure ratio of 20:1. The engine is expected to be 15% more fuel efficient that its predecessors.

The development and launch of several new narrowbody and large regional jets in recent years and over the next decade has only been, and will continue to be, possible with the development of new engines. CFM International has launched its LEAP-X project as its next generation of narrowbody engines. These are due for certification in 2014.

The efficiency and performance of conventional turbofan engines has steadily improved. A particularly important criterion has been fuel burn. Steadily lower rates of fuel burn have been achieved through higher engine bypass ratios, which in turn are a consequence of wider-diameter intake fans.

Further gains in fuel burn efficiency through wider intake fans and higher bypass ratios are arguably limited by conventional turbofan configurations. Moreover, there is the increasing difficulty of engine installation with wider fans. This issue coincides with steadily rising fuel prices and the need for the aviation industry to reduce carbon emissions.

This has therefore prompted engine and airframe manufacturers to give consideration to the configurations that the next generation of jetliner engines need to have. Pratt & Whitney (PW) has launched its PW1000G geared turbofan family to power a variety of narrowbodies and larger regional jets. One series of the PW1000G will be used to power the A320neo. This engine will have a fan diameter of 81 inches and a bypass ratio of about 12:1. This compares to a fan diameter of 68.3 inches and a bypass ratio of 5.5-6.0:1 for the CFM56-5B, which is the current engine powering the A320.

PW has followed the path of developing a geared fan to achieve a higher bypass ratio than a conventional turbofan could achieve. Conventional turbofan architecture arguably limits further increases in fan size because: larger low pressure turbines (LPTs) with more stages are required, which add weight; as well as larger fans requiring more power from the core, which ultimately results in higher combustion temperatures. The problem here is that higher temperatures lead to high pressure turbine (HPT) blade deterioration, which generally increases engine maintenance costs.

LEAP-X configuration

CFMI analysed as many as 18 different engine configurations, before selecting the path of the LEAP-X. The LEAP-X will provide thrust ratings at similar levels to those of the CFM56-5B, and will be the alternative engine choice for the A320neo. The LEAP-X is scheduled to enter service on the A320neo in 2016. It will also power China's Comac C919, which is also due to enter service in 2016.

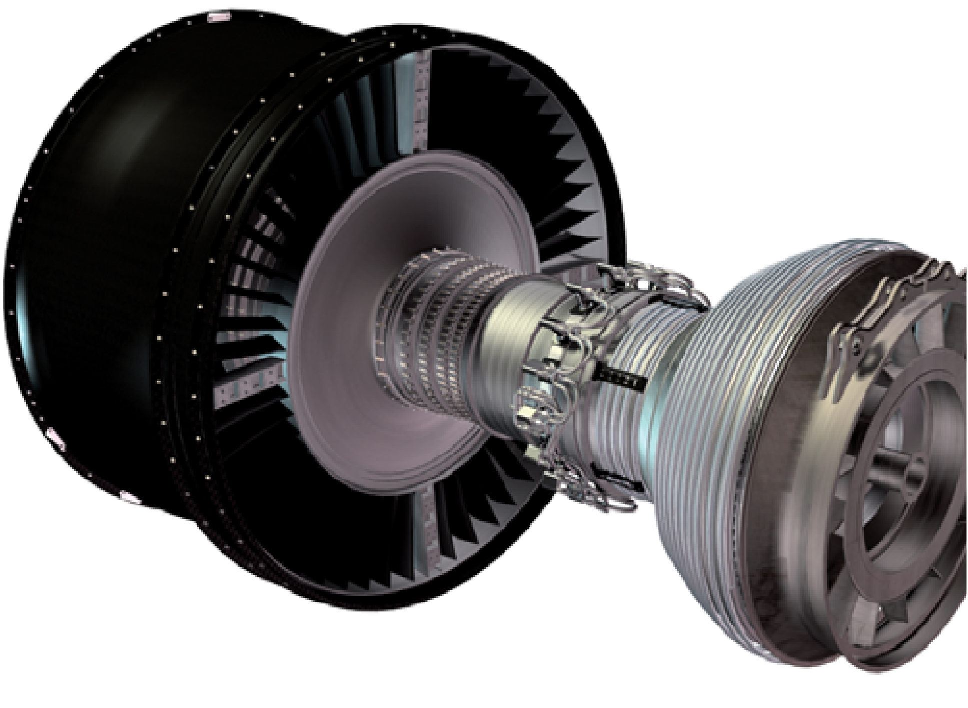
The main requirements that CFMI's new engine had to meet were: lower fuel burn; similar or better reliability than the CFM56-5B; predictable maintenance costs; lower noise emissions; and the ability to use alternative fuels.

The top four engine configurations that CFMI considered were: a conventional turbofan with a single-stage HPT; an open rotor engine, which had counter-rotating, rear-mounted fan blades; a geared turbofan; and a high bypass ratio ducted fan powered by a dual-stage HPT.

The LEAP-X's configuration is a dual-stage HPT, ducted turbofan. It is designed to achieve an ultra-high bypass ratio of between 10 and 12:1 so that a 15% improvement in fuel burn can be achieved. The engine will have a wide-chord bladed fan with a diameter of about 76 inches. This high bypass ratio for a ducted turbofan of conventional configuration will be achieved through the use of a high core pressure ratio of 20. This compares to the CFM56-5B's core pressure ratio of 11.

The LEAP-X's high pressure compressor (HPC) will have 10 stages, which is just one more than the CFM56-5B's nine stages. Each stage in the LEAP-X's HPC will therefore provide almost twice as much pressure as those in the CFM56-5B's HPC.

Increasing the core's pressure ratio will give it the power to turn a larger fan, which in turn will increase bypass ratio and lead to the desired fuel burn efficiency. A high pressure ratio core is an alternative to having a larger core with more stages. A high pressure ratio from the core, however, is only possible through the expenditure of more energy. This comes from a higher combustion temperature and the utilisation of a two-



The small diameter of the LEAP-X's core engine is illustrated by this computer representation of the engine, and demonstrates how the engine's bypass ratio of 12:1 will be achieved.

The LEAP-X will have four more stages than the CFM56-5B/-7B. This will include an additional HPT stage. These features raise concerns that the LEAP-X will have higher maintenance costs than its predecessors.

stage HPT.

The use of a higher combustion temperature means that the core will be required to compress a smaller volume of air. The LEAP-X's HPC and core overall will have a smaller diameter than those of the CFM56-5B's. This smaller diameter core is one contributing factor to the LEAP-X's high bypass ratio. In other words, the smaller volume of aircraft used by the core is a key feature of a high bypass ratio. A larger fan and volume of bypassed air are another element contributing to the higher bypass ratio.

The higher combustion temperature required, however, means that the HPT blades will need to be capable of withstanding the LEAP-X's higher combustion temperature. A core with a high pressure ratio was demonstrated in the Tech56 project.

While a core with a high pressure ratio and wider intake fan are the main configuration factors that contribute to the LEAP-X's high bypass ratio of up to 12:1, another is the fan's design. Although it is eight inches wider than the CFM56-5B's fan, the LEAP-X's fan will have the same weight. This is because the LEAP-X fan will have 18 wide-chord fan blades. This compares to 24 fan blades on the CFM56-7B, and 36 on the -5B engines.

The LEAP-X's wide-chord fan blades are half the weight of the -5B's fan blades. This is possible because the fan blades are constructed of composite materials and fibres that are woven together to provide a 3-D aerodynamic and lightweight blade. The low weight and wide-chord design will provide a fan that is aerodynamically more efficient than those found on current CFM56 engines. Low weight will also contribute to improved efficiency.

One configuration issue that has to be taken into consideration here, particularly in relation to fan diameter, is the interaction of the engine with the airframe. The LEAP-X, however, achieves a bypass ratio of 12:1 with a 76-inch diameter fan, while a similar bypass ratio is only achieved by the PW1000G with an 81-inch diameter fan. It is therefore expected that the LEAP-X should have fewer installation problems than the PW1000G.

In addition to fan diameter and blade design, fan speed is another contributing factor to engine efficiency. The LEAP-X will have a slow turning fan, which means that it will make fewer revolutions per minute (RPM) than current turbofan designs. This lower speed and wide diameter intake have been designed to achieve a small acceleration of a large mass of air in order to increase propulsive efficiency.

A lower speed (RPM) fan is achievable through the use of a lower speed LPT. A slower LPT is only possible, however, because the LEAP-X has two more stages than the -5B and -7B, and one more stage than the -5C. CFMI prefers this architecture to the gearbox between the fan and the LPT, citing efficiency losses that arise from a gearbox.

Economic characteristics

Apart from propulsive efficiency and fuel burn performance, these engine configuration characteristics dictate other performance parameters and the engine's operating economics.

The LEAP-X's core is four stages shorter than that of the -5B/-7B, which could have negative consequences on the removal intervals of engines, because of increased flexing and blade tip erosion. As a result, CFMI has introduced technology to improve engine durability, which includes rigid structure for the HPC.

Another major issue that will affect both the engine's durability and its maintenance costs is the higher combustion temperature. CFMI is using new HPT blade materials to deal with these higher temperatures, with the aim of maintaining an exhaust gas temperature (EGT) margin that is similar to that of the -7B. EGT margin is the difference between the temperature in the engine's turbine and the temperature that the material in the turbine can withstand. This temperature is influenced by the materials and coatings that are used in the HPT blades. The new materials and coatings, which were originally used in the Tech56 project, combine to allow a higher combustion temperature. The LEAP-X's HPT blades will also have improved cooling.

The higher combustion temperature will contribute to leaner fuel burn, thereby lowering CO2 emissions. This higher temperature, however, will have negative consequences for NOx emissions. CFMI will therefore utilise a twin-annular pre-swirl (TAPS) combustor to offset these. The new engine is expected to benefit from: 15% lower CO2 emissions; a 15% lower fuel burn; 50% lower NOx emissions, which will make the engine compliant with CAEP VI regulations; and noise emissions that are 10-15 decibels lower than Stage 4 requirements.

The use of a dual-stage HPT is likely to increase the LEAP-X's maintenance costs. CFMI has therefore used several design features to counter the potential causes of higher maintenance costs. These include the use of a smaller number of new 3-D, woven fan blades; and improved materials, coatings and cooling systems in the HPT blades. Nevertheless, the engine's higher combustion temperature, dual-stage HPT, and two additional LPT stages will all remain major causes of higher maintenance costs, so it seems unlikely that these will be avoided altogether, despite CFMI's efforts to address the problem. AC