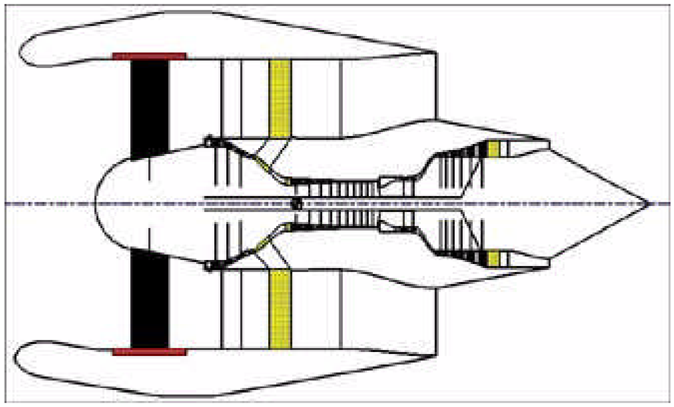
Advanced Engine Cycles Analyzed for Turbofans With Variable-Area Fan Nozzles Actuated by a Shape Memory Alloy

Advanced, large commercial turbofan engines using low-fan-pressure-ratio, very high bypass ratio thermodynamic cycles can offer significant fuel savings over engines currently in operation. Several technological challenges must be addressed, however, before these engines can be designed. To name a few, the high-diameter fans associated with these engines pose a significant packaging and aircraft installation challenge, and a large, heavy gearbox is often necessary to address the differences in ideal operating speeds between the fan and the low-pressure turbine. Also, the large nacelles contribute aerodynamic drag penalties and require long, heavy landing gear when mounted on conventional, low wing aircraft. Nevertheless, the reduced fuel consumption rates of these engines are a compelling economic incentive, and fans designed with low pressure ratios and low tip speeds offer attractive noise-reduction benefits.

Another complication associated with low-pressure-ratio fans is their need for variable flow-path geometry. As the design fan pressure ratio is reduced below about 1.4, an operational disparity is set up in the fan between high and low flight speeds. In other words, between takeoff and cruise there is too large a swing in several key fan parameters--such as speed, flow, and pressure--for a fan to accommodate.

One solution to this problem is to make use of a variable-area fan nozzle (VAFN). However, conventional, hydraulically actuated variable nozzles have weight, cost, maintenance, and reliability issues that discourage their use with low-fan-pressure-ratio engine cycles. United Technologies Research, in cooperation with NASA, is developing a revolutionary, lightweight, and reliable shape memory alloy actuator system that can change the on-demand nozzle exit area by up to 20 percent. This "smart material" actuation technology, being studied under NASA's Ultra-Efficient Engine Technology (UEET) Program and Revolutionary Concepts in Aeronautics (RevCon) Program, has the potential to enable the next generation of efficient, quiet, very high bypass ratio turbofans.

NASA Glenn Research Center's Propulsion Systems Analysis Office, along with NASA Langley Research Center's Systems Analysis Branch, conducted an independent analytical assessment of this new technology to provide strategic guidance to UEET and RevCon. A 2010-technology-level high-spool engine core was designed for this evaluation. Two families of low-spool components, one with and one without VAFN's, were designed to operate with the core. This "constant core" approach was used to hold most design parameters constant so that any performance differences between the VAFN and fixed-nozzle cycles could be attributed to the VAFN technology alone. In this manner, the cycle design regimes that offer a performance payoff when VAFN's are used could be identified.



Analytical NASA model of low-fan-pressure-ratio advanced turbofan with a variable-area fan nozzle.

The NASA analytical model of a performance-optimized VAFN turbofan with a fan pressure ratio of 1.28 is shown in the preceding figure. Mission analyses of the engines were conducted using the notional, long-haul, advanced commercial twinjet shown in the following figure. A high wing design was used to accommodate the large high-bypass-ratio engines. The mission fuel reduction benefit of very high bypass shape-memory-alloy VAFN aircraft was calculated to be 8.3 percent lower than a moderate bypass cycle using a conventional fixed nozzle. Shape-memory-alloy VAFN technology is currently under development in NASA's UEET and RevCon Programs.

Notional long-haul advanced commercial twinjet using a high wing design to accommodate large, high-bypass-ratio engines.

Find out more about this research:
UEET (http://www.ueet.nasa.gov/)

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