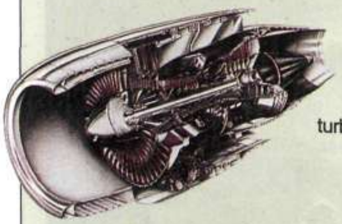
1960s

1963 Pratt & Whitney J58 – first sustainable Mach 3 engine

1964 Pratt & Whitney JT8 – most produced commercial turbofan

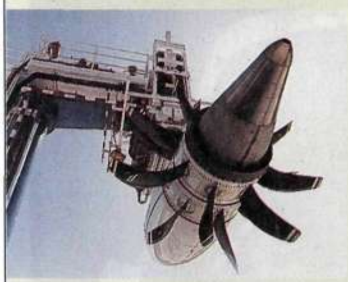


1966 Pratt & Whitney JT9D – first high bypass-ratio turbofan

1970s

1974 First GE/Snecma CFM56 demonstrator runs

1980s



1986 General Electric GE36 unducted fan flies

1990s

1990 Pratt & Whitney YF119-powered Lockheed YF-22 supercruises

1994 Progress D-27 prop-fan flies on An-70

1998 Tests start on STOVL F119 variant with lift fan for JSF

2000s

2002 Revolutionary Turbine Accelerator contracts issued

2003 Pratt & Whitney hypersonic scramjet reaches Mach 6.5 in ground tests

General Electric GE90-115B reaches record thrust level of 127,900lb

First Pulse Detonation Engine-powered aircraft flight attempted

CLOCKWISE FROM TOP: PRATT & WHITNEY, MARK WAGNER, G P&W

combustion engine. They are also "green" because they are powered by hydrogen and exhaust only water as a by-product.

Working with NASA on the ultra-low-emissions air vehicle demonstrator (a converted Diamond Katana Xtreme motor-glider), are Advanced Technology Products, Aerlyper of Spain, Boeing and Sener, together with Intelligent Energy, a UK-based developer of the proton exchange membrane (PEM) fuel cell. Boeing aims to demonstrate a fuel cell-based auxiliary power unit (APU) on a 737 as part of possible plans to use the technology in future commercial aircraft from 2010, as well as paving the way for potential retrofits.

Unlike the hydrogen-based PEM technology used in the demonstrator, the parallel advanced APU development will be based on a solid oxide fuel cell (SOFC). Boeing hopes big gains can be found with a 45% efficiency improvement. This equates to savings of about 340,500kg (750,000lb) of fuel a year on a typical 777 cycle, but would save up to 1,360,000kg per aircraft a year for a typical 737 operation.

The technology will be sufficiently mature for incorporation from "around 2010", which means Boeing's planned 7E7 will, initially at least, not be offered with an SOFC APU. In the meantime, Boeing expects to test an experimental unit in a 737, possibly from 2005 to 2008, in which the APU will power the DC bus only. But there seems little doubt that hybrid fuel cell-based propulsion and eventually all-electric powered aircraft will appear.

By its very nature, fuel cell technology also allows designers to play with unconventional powerplant and airframe configurations. Distributed vectored propulsion, distributed exhaust and distributed engine concepts are being studied in which mini or micro engines can be clustered or spaced around the airframe. Another concept involves several smaller fans being driven by two or three main power units. In some concepts, namely highly efficient shapes such as the blended wing body, large sections of the wing become, in effect, giant fuel cells.

In the nearer term, engine makers are developing technologies to keep the hydrocarbon-fuelled jet engine environmentally acceptable. Targets for emissions established by the Advisory Council of Aeronautical Research in Europe (ACARE) suggest fuel consumption and carbon dioxide should be cut by up to 10% by 2007-2010 and by 50% (including contributions from the airframe) by around 2020, compared with emissions from a current turbofan. Notional targets set by the US Aerospace Technology Enterprise (ATE) are a 25% cut in fuel burn and CO_2 by 2010 and a 50% cut by 2025. ACARE also targets noise for a 40dB cutback by 2020, and the ATE says reductions of up to 75dB are obtainable by 2025. Emissions of nitrous oxides, now around 30% below International Civil Aviation Organisation standards in many current engines, are targeted for an 80% cut by ACARE and ATE.

One option being studied is a derivative of the geared turbofan concept championed for so long by Avio, MTU, Pratt & Whitney and P&W Canada. The intercooled recuperated aero engine (IRA) is being developed in a pan-European research programme rivalling NASA's Ultra Efficient Engine Technology initiative. Dubbed the Efficient and Environmentally Friendly Aeroengine project, it is split into two main thrusts. The first is the short- to medium-term Affordable Near Term Low Emissions (ANTLE) validation vehicle led by Rolls-Royce, and the longer-term Component vaLidator for Environmentally-friendly Aero Engine (CLEAN) programme.

ANTLE will provide the technology basis for future 50,000-110,000lb-thrust engines, while CLEAN is aimed at new narrowbody engines. R-R, which provides a Trent 500 as the baseline validation platform, has outlined a "Vision" plan for the next 20 years that embraces several ANTLE features. Electric starter-generator technology, for example, will feature new offerings for more-electric aircraft such as the 7E7. Gone will be the conventional gearbox, replaced by internal starter motors, active magnetic bearings, intelligent sensors and shaft-mounted generators. Further off, R-R's 20-year study is examining more exotic advanced cycles, tip-driven fan and contra-rotating aft fan concepts.

Nestled within CLEAN, the IRA concept has potential to maximise thermal efficiencies and reduce nitrous oxides by modifying the thermodynamic cycle through a heat exchanger or recuperator. The recuperator will sit in the hot gas exhaust while a system of collectors, splitters and tubes will deliver compressed air to the heat exchangers and then return it to the burner inlet. MTU, leading the project, believes the result will be a 200°C rise in compressor air temperature. Combined with a geared fan, the IRA concept, compared with current generation turbofans, is expected to generate up to