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Eureka

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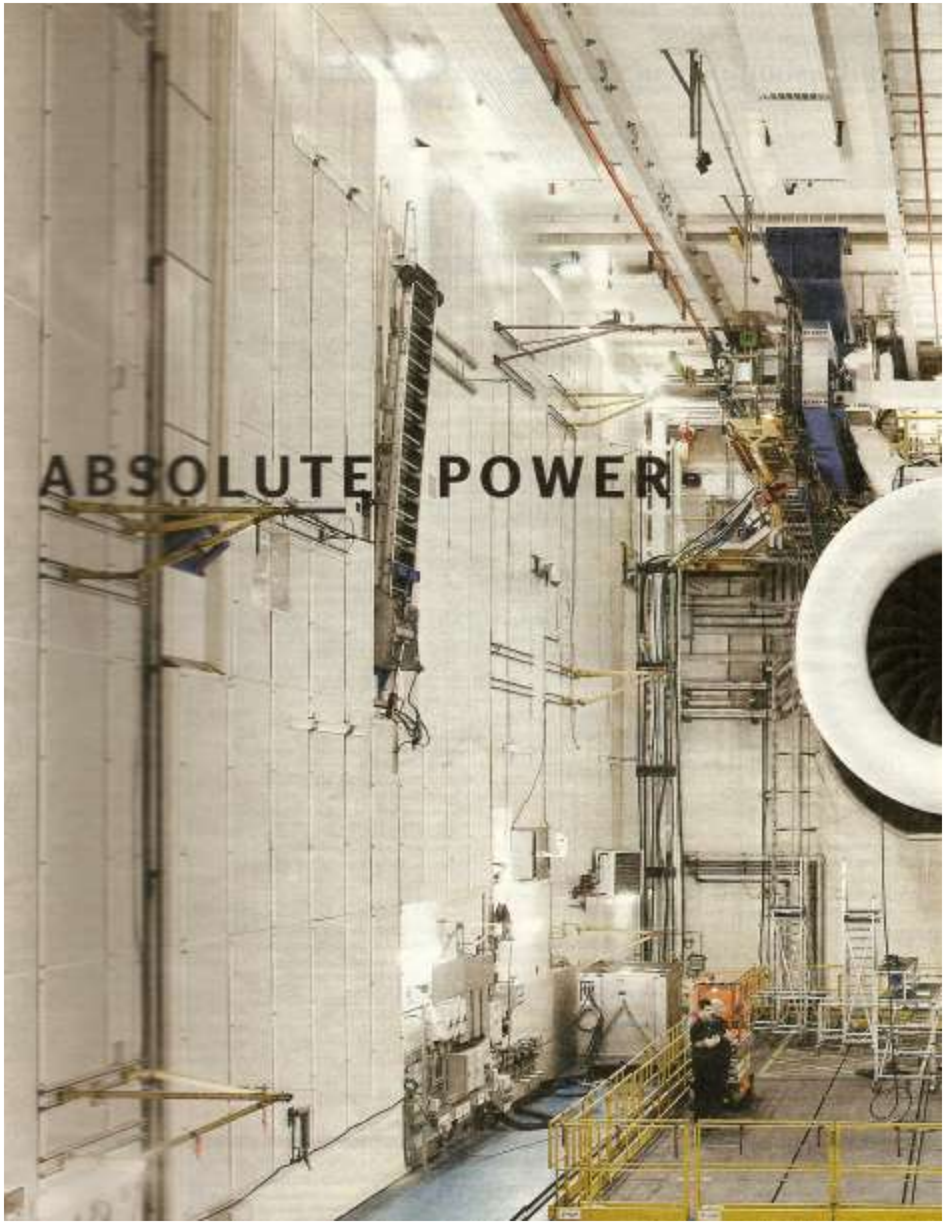
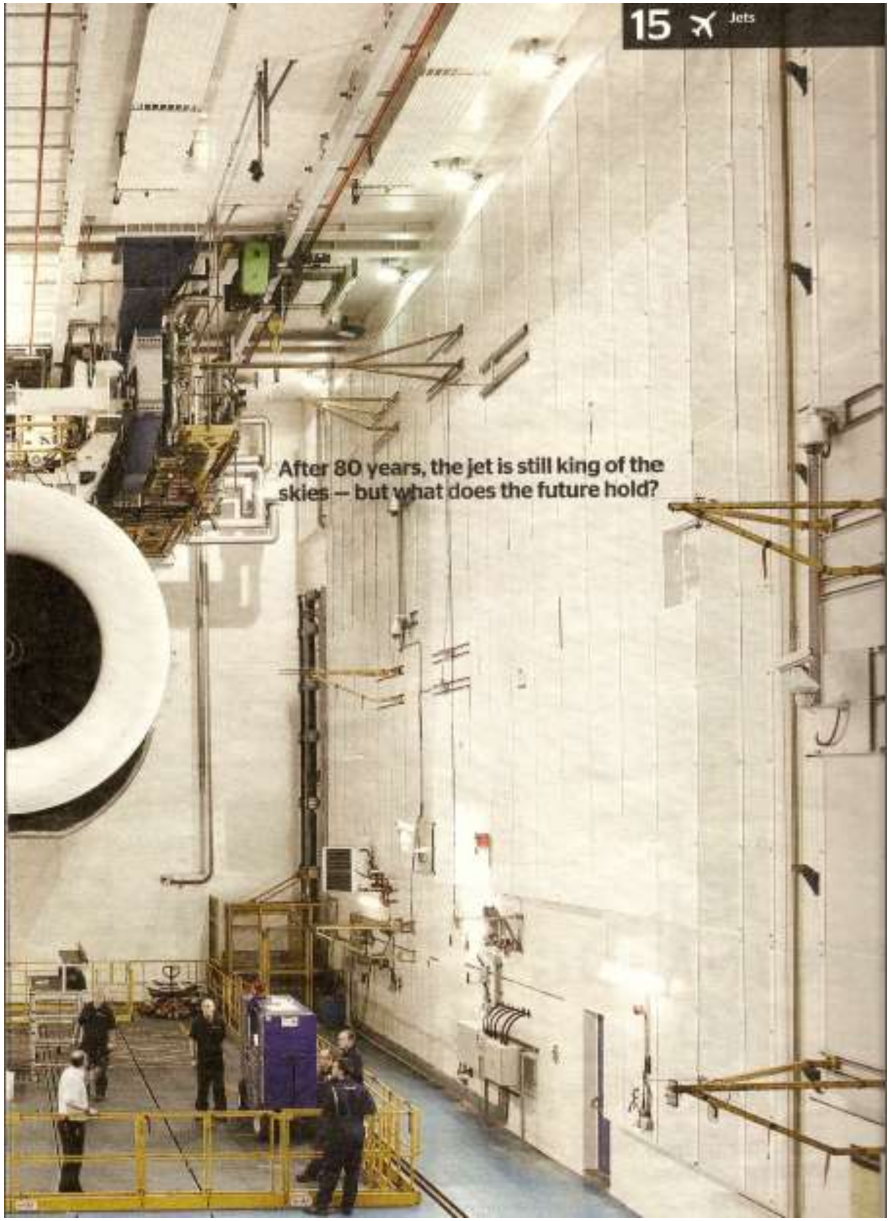
WING-NUTS

THE FLIGHT ISSUE

ABSOLUTE POWER

After 80 years, the jet is still king of the skies – but what does the future hold?





IS THE JET BEGINNING TO LAG?

Nope. It's roaring back bigger and stronger than ever

WORDS
DAVID REAY
PHOTOGRAPHS
DAVID RYLE

I am sitting beside a window three or four metres off the ground, cramped but comfortable. Outside, through a few inches of reinforced glass, dawn is breaking over a dew-covered London field. There is a faint smell of fumes. My neighbour is dozing listlessly. The only sound is of subdued chatter, and a constant, dull hum.

All at once, everything changes. The hairs rise on the back of my neck and I'm forced back in my seat as a seven-tonne monster of a machine a few metres away over my right shoulder emits a whining roar and does something truly remarkable and violent. It starts gulping up more than a tonne of air every second and expelling it at

900MPH

Its insides turn 13,500 times a minute, at twice the speed of sound, and become so hot (1,600C, or a third of the temperature of the Sun) that the whole thing should melt. Some of its components fall under a stress equivalent to having 66 double-decker buses hanging from them, generating the same amount of power as 150 Porsches.

If that wasn't enough, it can do this in air temperatures below minus 50C, and well above 50C. It can work for thousands of hours without stopping, through sand storms, ash clouds and monsoon rain, and in its life it will travel 15 million miles. It can even emerge unscathed if a large bird is sucked into it.

Perhaps its most remarkable feat is that it can launch me, several-hundred fellow passengers and the huge aircraft to which it is attached 10,000m into the sky, and keep it there.

It's safe to say that the jet engine is one of the most astonishing engineering and design achievements of the 20th century. Able to deliver passengers 10,000km across the globe in a matter of hours, it has touched the lives of most people in the Western world. It is the driving force, quite literally, of the civil and military aviation industries and has facilitated the recent low-cost flying boom. Partly because of engineers' efforts to make it more efficient it has also proved more or less immune to sporadic attempts by governments and pressure groups to de-carbonise mass travel. Indeed, for the giants of the jet engine trade — General Electric, Pratt and Whitney and Rolls-Royce (the manufacturer of the Trent 1000 behemoth that took me to Hong Kong) — business is booming.

Yet jets are an 80-year-old technology whose basic principles have changed little since the development of the first gas-guzzling brutes in the 1930s. So why is it that they have fared so well, and will they still be powering mass aviation in the next century?

The keys to the jet engine's success, as with other combustion engines, are its relative simplicity and its astonishing power-to-weight ratio. Jets are designed to create thrust, up to 115,000lbs each in modern airliners (equivalent to the downward force required to levitate a 52-tonne object). Turbofans, the first commercial versions of which were introduced by Rolls-Royce in the 1950s, are the pinnacle of efficient jet propulsion and are now used in virtually all jet airliners.

They generate thrust by sucking in air via a huge fan at their front and expelling it at a higher speed. To do this the blades of the fan must spin extremely fast, and they are spun by the turbofan's actual engine, or gas generator: once air is sucked into the jet by the fan, some of it is compressed, mixed with fuel and ignited. The hot exhaust gases expand and turn turbine blades on a disc at the back of the engine. This disc drives a shaft to which the fan and compressor are attached.

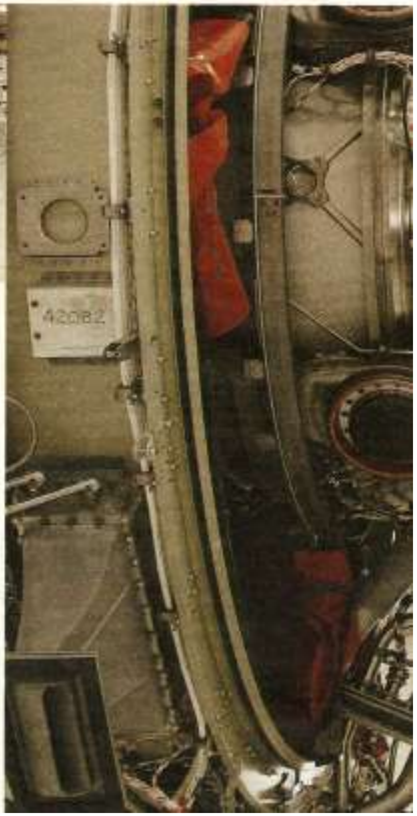
About 15 per cent of the engine's thrust is generated by the expelled exhaust gases. The other 85 per cent comes from so-called bypass. This is air that is sucked in and accelerated by the fan but that does not pass through the gas compressor core, instead passing around it — but within the jet casing — and out of a nozzle. Put simply, the turbine blades harness the power to drive the fan, which, in turn, generates most of the jet propulsion.

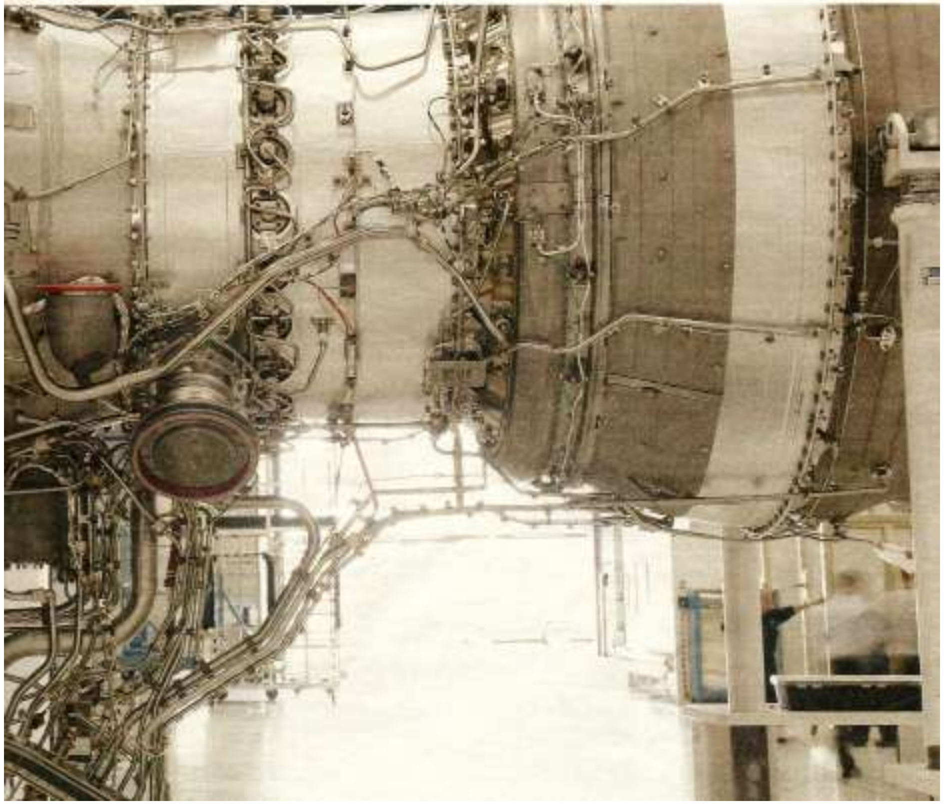
There are plenty of other variations of air-breathing jet engines (turbojet, high-bypass turbofan, low-bypass turbofan, ramjet) but the basic principles are the same.

Besides being relatively simple, the jet remains king of the skies because no other engine can match its power-to-weight ratio. Turboprop propeller engines may be more efficient, but they are not practical for long journeys. Electric motors are cheaper and produce fewer emissions than jet engines, but to power an airliner they would need such large batteries that the plane would be unable to take off.

These stark realities mean that today's attempts to improve jet engines are focused on attempts to generate more thrust from lighter engines, maximise fuel efficiency and, more recently, lower emissions. The bypass system drastically improved efficiencies, and was arguably the last major leap forward in jet-engine technology. Ever since it was introduced, attention has been restricted to fine-tuning and developing better, more precise materials and parts.

PREVIOUS PAGES
Testing a Rolls engine in a hall the size of a cathedral





BELOW LEFT AND RIGHT
Jet engines must be tested to destruction

Which is not to undersell the advances being made in the field. The culmination of this work is the Trent XWB, Rolls-Royce's new medium-to-long-range, high-thrust colossus designed for the new Airbus A350 family of aircraft — its answer to Boeing's 787 Dreamliner. When it takes to the skies in 2014, Rolls claims, the XWB will be the most efficient civil aircraft engine in the world. Its 3m-wide fan of hollow titanium blades will produce up to **97,000LBS** of thrust (four times that of a common-or-garden Ryanair Boeing 737-800 engine). Its precisely engineered turbine blades are made from a secret nickel-crystal alloy and produced to within a 6 micron margin of error to maximise power output; they will make it 28 per cent more fuel efficient than Rolls's pre-1995 jets. And it will cut carbon emissions by 16 per cent compared to the Trent 800, used in the Boeing 777, and be up to 5dB quieter.

The XWB is already the fastest-selling engine in the Trent series. Its key components and the processes used to make them are so refined that its programme director and chief engineer, Chris Young, calls them Rolls's "crown jewels" — and then there's the onboard computer. Every second, it records thousands of measurements taken from all areas of the engine, and directs it to respond accordingly. A half-knot drop in headwind — reduce thrust. Another five people turning on the aircraft's entertainment system — redirect more power to the electrical systems. All of which is done automatically. "Such a feedback system, even if the corrections are only very small, can produce huge efficiency savings," Young says.

These savings matter. The Royal Academy of Engineering has said that if, overnight, the previous generation of aircraft, for example the Boeing 767, were replaced by Trent 1000-equipped Dreamliners, airlines could save more than £1 billion in fuel costs and five million tonnes of CO$_2$ every year. More would be saved with the XWB.

But can we do better? Is the jet engine nearing perfection and, if so, what are the alternatives? "It's the best we have, and will be in service for at least the next 25 to 50 years," Young believes. "There's still room for improvement, and I think this will be driven by customer demand for greener flights, but this game-changing technology is still very much in its infancy."

And what "game-changing" technology would this be? Rolls is the world's second-largest producer of jets for the civilian market after General Electric, but is looking into other options as well. One of these is open-rotor technology, which uses a double set of counter-rotating propellers with no outer casing. The blades usually protrude from the back of the engine in a bizarre-looking "pusher" arrangement that has raised hopes of a great leap forward in efficiency in tests.

"The issue is that, like a turboprop, it is noisy and, as with all propellers, it is slower," Young says. "Ideally, it would be used on short-range flights."

Open-rotors can no doubt be refined, but they are hardly a sea change in air propulsion. There are lots of other variations on the jet theme — military jets, for example, generally use zero-bypass jets that use huge amounts of fuel and cannot stay in the air for more than a couple of hours, while ramjets are ultra-powerful but cannot work from a standing start. Ultimately, they all share the same principles and fuel source.

The simple truth is that there are few options. Electric power could be one, but, like most self-respecting engineers, Young does not think it is a serious contender for use in mass aviation. "You try getting 97,000lbs of thrust out of a battery," he says.

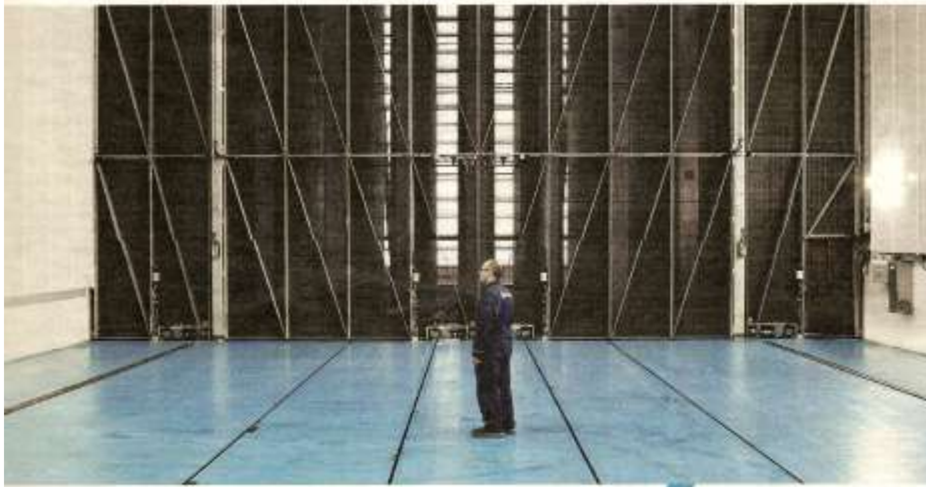
The alternatives are even more far-fetched. In theory it would be possible to power planes using nuclear reactors. Such a power source could potentially be lighter than the batteries required to drive an electric motor, but the political, safety and material costs would be too high. Rocket engines must also be dismissed — they can produce far higher thrust (the Space Shuttle created **7.8 MILLION** pounds on take off), but for relatively short periods, and at eye-watering fuel consumption of highly explosive liquefied gases.

All of which leaves the jet engine in a strong yet precarious position. Jets have proved incredibly efficient, reliable and safe. (So-called in-flight shut-downs have been cut from 40 per 100,000 flying hours in the 1960s to fewer than one today.) But in the 25 to 50-year window that Young speaks of, supplies of fossil fuels are likely to begin to dry up. Biofuels may provide an alternative, but they cannot offer anywhere near the energy density of jet fuel. More fuel will be needed and efficiencies will be lost.

So, the next time you are sitting on an aircraft at the end of a runway, waiting for the engines to blurt out enough thrust to knock over a house, give thanks that you have lived in the jet age. Because, for the time being, it's as good as air travel gets.

BELOW LEFT
The Trent XWB, for the A350 XWB, being prepared for performance tests

BELOW RIGHT
The engine test-bed screens that deliver uniform air flow



HIGH-BYPASS TURBOFAN

Launched in the mid 1960s, this has the same core sequence of compressors, combustion chamber and turbine as older engines, but uses huge front fan blades, driven by the turbine, to generate most of the thrust by forcing air backwards outside the core (hence "bypass"). Quiet and efficient at subsonic speeds, it's used in all modern Airbus and Boeing jet airliners. Future "open rotor" versions will mount the big fan blades outside at the rear.