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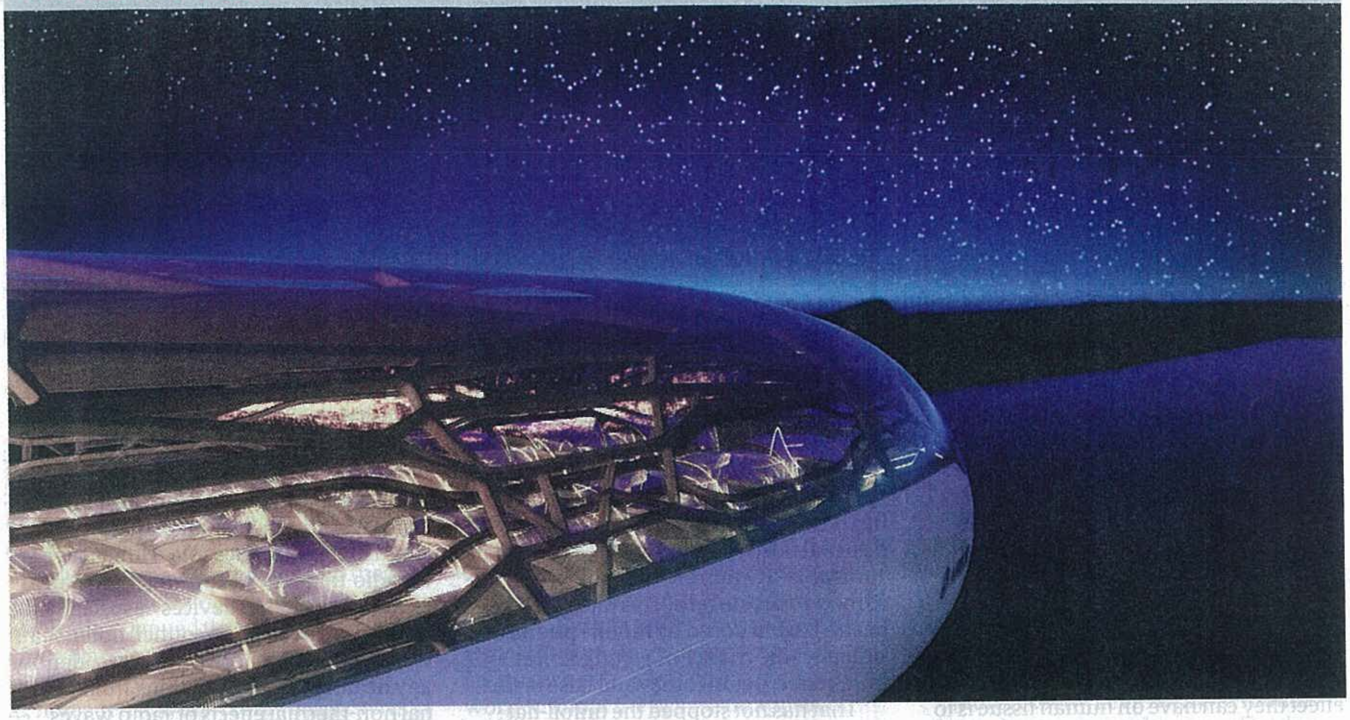
Changes in the air

The emerging technologies that will define the future of flight



Changes in the air

Aviation: Emerging technologies are ushering in more fuel-efficient, comfortable and exotic aircraft. Get ready for the future of flight

ON THE evening of July 23rd 1983, Air Canada Flight 143 ran out of fuel after a series of human errors. The new Boeing 767, lightly loaded with 61 passengers and eight crew, became a glider with only 8,686 metres (28,500 feet) of altitude to reach the nearest airport at Winnipeg, around 120km (75 miles) away. Ten minutes later it became clear that the plane was losing altitude too fast to make it.

The pilots changed course, hoping to reach a former air-force base near the town of Gimli. They were unaware that its runways had been converted into a drag-racing track. Spectators scattered when they saw the silent approach of the aircraft. As the aircraft's wheels hit the racetrack, the front landing gear collapsed and the nose slammed into the tarmac, sending sparks flying. Scraping against a guard rail that divided the track in two, the aircraft skidded to a stop. No one was killed.

Had the pilots been flying one of today's more aerodynamic airliners, they could easily have reached Winnipeg's airport, says Carl Holden, a recreational-glider instructor and head of Holden Dynamics, a consultancy based in Sydney that advises Australia's Civil Aviation Safety Authority. Today's airliners would glide about 25% farther, he says, and the next generation promises additional gains.

Gliding distance is an imperfect measure of an airliner's aerodynamic efficiency, since it is not designed for gliding. But the Gimli Glider incident, as it became known, helps illustrate the magnitude of advances in aviation technology. Improved efficiency means that Boeing's new 787 airliner consumes about 40% less fuel per passenger than its 1970s aircraft. Airbus and other manufacturers have achieved similar results.

Not all improvements in aircraft technology are incremental. As myriad technologies mature, new sorts of aircraft become possible. Unmanned aircraft have flown at more than five times the speed of sound. Last year a lightweight, piloted Swiss aircraft, *Solar Impulse*, captured enough solar energy during the day to fly throughout the night. Small drones are being developed with highly efficient wing-bottom infra-red cells that scavenge radiation energy reflected up from the ground. Boeing is developing unmanned spy aircraft capable of staying aloft using hydrogen power for five years without refuelling. Drew Mallow, the project's leader, calls *Phantom Eye*, a prototype with a 46-metre wingspan, a "poor man's satellite". The future of flight will involve gradual changes in the near term, with the prospect of more radical shifts in the decades to come.

Much research has been driven by efforts to save jet fuel. Having more than doubled in price in recent years, it now accounts for about half of airlines' operating costs. Even slight gains in efficiency quickly pay off—as a rule of thumb, a 1% improvement knocks more than $1m off a airliner's fuel bill over its lifetime of roughly 20 years, says Ihssane Mounir, Boeing's vice-president of sales for China. These savings snowball. Fuel-sipping planes are more profitable, so banks will finance them at lower interest rates.

Time to lose weight

In the push to improve efficiency, wing flaps are now operated with lightweight electrical systems instead of hydraulics. At least one airline, Australia's Jetstar Airways, is replacing in-flight entertainment kit with Apple iPads, which are much lighter. Flight Sciences International, a consultancy based in Santa Barbara, California, has found that fuselage-insulation blanketing costs airlines unnecessarily: it absorbs humidity and becomes heavier over the years. This is typical of the zeal with which savings are being sought. The only area where technologists have failed to improve efficiency is in reducing the weight of passengers, says John Corl of Flight Sciences. He is only half joking.

Aircraft engineers have for years sought to replace metal components with lightweight plastics reinforced with carbon fibres. Such materials, known as composites, are generally 20-40% lighter according ▸▸

"Changing the shape of an aircraft can be done at a microscopic as well as a macroscopic level."

to ATK, an aerospace company based in Utah that makes them for aircraft manufacturers. Composites account for as much as 15% of today's airliners, but some next-generation aircraft will be more composite than metal, including the Boeing 787 (which enters service this year) and Airbus A350 (due in 2013).

New, lightweight ceramics will further reduce the need for metals in aircraft, says Joy de Lisser, vice-president of ATK Aerospace Structures, the division developing them. Ceramic composites can also withstand hotter temperatures than metal alloys can. Accordingly, they are beginning to replace some metal parts in jet engines developed by Snecma, a French engine-maker, and General Electric, an American manufacturer. GE says it has shaved 136kg, or 3%, off the weight of an engine that propels the Boeing 787 using a ceramic-composites fan case and blade, a world first.

GE has also found a way to lighten metal components, including some for engines, by "printing" rather than forging them. Known as 3D printing or additive manufacturing, the process involves building components by zapping a succession of thin layers of powdered metals with a laser or electron beam which melts and bonds the material. Precision is measured in microns. Designers leave empty spaces inside some components, reducing their weight by a fifth. The process is less expensive than hollowing out forged parts, says Luana Iorio, head of manufacturing technologies at GE Global Research's lab in Niskayuna, New York. She reckons that GE's printed, hollow parts will be used in passenger aircraft within about three years.

In 2009 GE, working with NASA, America's space agency, picked up work it had largely set aside in the 1980s on a radically different sort of engine called an unducted fan. It combines the fuel efficiency of a propeller engine with the greater power and acceleration of a jet by using two rings of short, propeller-like rotors that spin in opposite directions in open air behind the jet housing. GE says the engine consumes almost a third less fuel than other designs. But it is loud, and if a rotor breaks it could smash into the fuselage.

Pratt & Whitney, another American engine-maker, has devised a different design that is far closer to widespread use. Called a "geared turbofan" engine, it uses a gearbox, rather than a shaft, to transmit power from the turbine (which spins as hot gases blast out of the back) to the fan (which sucks in air at the front). This allows the turbine to spin faster than the fan, which is more efficient. Called the PurePower PW1000G, it cuts fuel consumption (and noise) by about 15%, says Paul Finklestein of Pratt & Whitney, saving about $400 per flight hour. More than 1,200 of the engines have been ordered at an estimated $13m each. Deliveries begin in 2013. The firm's president, David Hess, has said the new engine could double the size of the company, which had sales of nearly $13 billion last year.

On most passenger jets, the wings and fuselage generate about 90% and 10% of the lift respectively. Working with funding from NASA, aerospace engineers at the Massachusetts Institute of Technology (MIT) have designed an aeroplane with a body so fat, and wings so narrow, that the fuselage provides about a fifth of the aircraft's lift. Its cross-section resembles that of two partially joined bubbles. The "Double Bubble", as it is called, looks awkward, but the team estimates that its design would reduce fuel consumption by about 70%. This is only partly because it would fly about 10% slower than today's airliners.

Tail wings push the back of an aircraft down, increasing drag, in order to lift its nose up. The Double Bubble sports a wide, downward-sloping nose which airflow pushes up, so its tail wings can be much smaller. Conventional airframes require heavy structural material to transfer the fuselage's weight laterally to landing gear and wheels under the wings. The MIT team reduced the plane's weight about 1% by fattening the aircraft's body—"essentially running the fuselage to the landing gear", in the words of Mark Drela, the team's leader. The engines are mounted at the back of the fuselage, rather than under the wings. Air slipping along the fuselage moves slower, so the engines ingest less oxygen and burn less fuel.


Airbus imagines in-flight entertainment in 2050

Making planes more slippery

Changing the shape of an aircraft can be done at a microscopic as well as a macroscopic level. Aircraft paint, viewed with a microscope, "looks like the Pyrenees", says Paul Booker, managing director of tripleO, a firm based in Poole, England. His firm has developed a way to reduce drag on aircraft by smoothing the painted surfaces with a very thin layer of acrylic resin that fills in tiny cracks. Britain's easyJet, the first commercial carrier to use the product, had three airliners coated about 16 months ago. The airline has since coated five more planes and two other airlines have also given it a go. Mr Booker says the extra slipperiness cuts fuel consumption by around 1%, so that the coating treatment pays for itself within a few months.

There may also be a way to cut aircraft drag by making some surfaces less slippery. In research funded by the European Union, Alessandro Bottaro of the University of Genoa in Italy has devised small keratin bristles that mimic the smallest type of bird feathers, known as coverts. Vibrating in the wind, the bristles create some drag. But they also reduce the wing's slipstream, an area of low-pressure turbulence that pulls back on the wing, and hence reduce drag. A fuzzy tennis ball flies faster than a bald one for the same reason, Mr Bottaro explains.

However perfectly an aircraft is built, its full potential cannot be harnessed without a perfectly calculated trajectory. At most airports, traffic controllers organise the approach and landing order of incoming planes in their last half-hour or

Aerion's design (top) and the Double Bubble (below)

so of flight. As a result, pilots waste fuel slowing down and speeding up as they descend in staircase fashion. This and other inefficiencies—such as circling while awaiting a landing slot—will soon be greatly reduced, thanks to a new sort of flight-management software.

Such software crunches data on each aircraft's performance and other traffic in the air or at airports to determine the optimal flight plan. The software can work out, for example, the exact rate at which a plane should rise into thinner air (to reduce drag) as fuel burn makes it lighter. Aircraft can collect and exchange atmospheric data to help each other fine-tune trajectory and speed. Crucially, the technology harnesses airliners' ability to glide. With a favourable wind, a new airliner's engines can be idled more than 150km from an airport for a gliding descent to the runway.

A single such "green approach", as it is known, saves about 100kg of fuel, says Torbjorn Henriksen, head of airline negotiations at Avinor, the operator of Norway's 19 commercial airports. Steve Fulton of Naverus, a subsidiary of GE that designs and installs such systems, likens them to a railway track: aeroplanes do not deviate more than a wingspan from their charted courses and touch down within ten seconds of the predicted time.

The airport at Brisbane, Australia, is the only one that fully uses the system so far. It has reduced delays and cut noise in surrounding neighbourhoods by nearly a third. If adopted across Europe, fuel costs (and pollution) for internal flights would drop by more than 8%, says Mr Fulton. Dozens of airports are adopting the technology, but the process requires a lot of installation and training. Avinor says it will take at least another five years to deploy the technology widely in Norway.

Saving fuel is all very well, you may be thinking, but what can technology do to improve conditions for passengers? In the run-up to this year's Paris Air Show in June, Airbus released its vision of creature comforts for the airliner of 2050. Cabin walls have been replaced with a skeletal structure and transparent membrane. "Vitalising" swivel seats mould to, and massage, each passenger's body while harvesting its heat to power individual sound pods, mood lighting and holographic entertainment units. It sounds great, even if Airbus's vice-president of engineering, Charles Champion, acknowledges that much of the kit cannot be built with today's technology. He points out that in recent years the industry has placed a far higher priority on making aircraft more efficient and comfortable than it has on making them go faster.

Yet despite the withdrawal from service of Concorde in 2003, the dream of supersonic flight has not died. Dassault Aviation, a French firm, and Aerion and Gulfstream Aerospace, two American companies, are among the firms developing technologies for private supersonic jets. Breaking the sound barrier generates a sonic boom, so supersonic travel is heavily restricted over land. Tests by NASA with a modified fighter jet have shown that novel airframe shapes can reduce the boom. But Aerion reckons that a far better approach is to abandon efforts to reduce the sonic boom and fly supersonic only over water. The company's 8-to-12-seat Supersonic Business Jet, designed but not yet built, sports thin but broad "knife edge" wings and other aerodynamic features that produce less drag than competing designs, says Douglas Nichols of Aerion.

ZEHST the job for travellers in a hurry

Around 50 potential customers have put down a $250,000 deposit for the $80m jet, which would fly at 1.6 times the speed of sound (Mach 1.6). Aerion does not yet have a manufacturing partner, however.

America's armed forces see potential in hypersonic aircraft, which fly at Mach 5 or faster using a type of engine known as a scramjet. HTV-2, an unmanned hypersonic aircraft designed to travel at Mach 20, failed during a test flight last month. Another hypersonic craft, the X-51A WaveRider developed by Boeing, has fared little better. Of the two WaveRiders tested, both for short distances over the Pacific, one failed. But Joe Vogel, the project manager at Boeing, says the technology has "crossed over the threshold" into hypersonic flight. He reckons that scramjets might one day power civilian aircraft.

Some military types have enthused that, before then, hypersonic troop carriers could be built. But Robert Mercier, a senior technology official in the Air Force Research Laboratory's aerospace propulsion division, notes with understatement that parachuting into the trailing vortices of such an aircraft would make for a rough ride. It is more likely, he says, that a hypersonic aircraft would be used as a high-speed cruise missile, to deliver a surprise hammer-blow behind enemy lines. Using a long-range ballistic missile to do the job would be risky, as its launch could be mistaken for an imminent nuclear strike.

Might the idea of near-hypersonic passenger aircraft, which has lain dormant for a few years, be coming back? At this year's Paris Air Show, EADS, the parent company of Airbus, revealed a concept design for an aircraft called the Zero Emission High Supersonic Transport (ZEHST), devised in conjunction with Japanese researchers. It has three separate kinds of engine: ordinary jet engines (running on biofuels made from seaweed or algae) for take-off, rocket engines to accelerate to Mach 2.5, and ramjets to reach Mach 4. The aircraft would carry 50-100 passengers and would travel from Paris to Tokyo in around 2.5 hours, rather than the 11 hours it takes today.

Even its designers admit that the ZEHST is unlikely to be flying before 2040. But "the future of air travel will look something like the ZEHST," declared Jean Botti, director-general for technology and innovation at EADS. It sounds fanciful. But so too, not that long ago, did rapid and routine intercontinental air travel. In aviation, what sounds outlandish today may be commonplace tomorrow. ■