The aircraft of the future

Plane truths

CAMBRIDGE, MASSACHUSETTS, AND LONDON

How to build greener planes that airlines will actually want to fly

FRUSTRATING as air travel might tie for the average punter, there is no let-up in demand. By 2014 the number of journeys made by individual passengers is expected to reach 3.3 billion, from 2.5 billion in 2009. In part, this is a consequence of the falling cost of flying: ticket prices have dropped by 60%, in real terms, over the past 40 years. But keeping prices low and finding more aircraft to cram all these people into is not the only thing the airline industry has to worry about. It must also clean up its act. Aviation is a small but growing contributor to global warming, responsible for 12% of the carbon dioxide emitted by means of transport. And even were that not so, fuel is one of airlines' biggest costs, so there is a strong incentive to burn less of it. In the case of fuel economy, then, virtue really is its own reward.

Not surprisingly, aircraft are already a lot more efficient than they used to be. The first Boeing 737 was launched in 1967 and could carry about 100 passengers 2,775km (1,725 miles). A modern version, the B737-800, can carry nearly twice as many passengers twice the distance, while burning 23% less fuel (48% less on a per-seat basis). More efficient turbofan engines, lighter structures, various aerodynamic tweaks and the development of sophisticated flight-management systems have brought about this improvement. The aircraft themselves, however, still look much like they always have done: a cigar-shaped fuselage with a big tail, powered by pod-like engines hanging from a pair of protruding wings. Some aircraft designers now believe that just about all the efficiency gains available have been wrung from this traditional shape, and that for a further big cut in fuel consumption a new type of airliner is needed.

Over the years, a number of radical redesigns have been proposed, but none has taken off. Aircraft shaped like giant flying wings, for instance, would be more efficient, but do not mesh with the realities of running an airline. Banks of seating as wide as those in cinemas would strand most passengers a long way from a window—or a door. Safety legislation requires that everyone can be evacuated in under 90 seconds from half the available exits. That would be tough in a flying wing. Moreover, aircraft design has co-evolved with airport infrastructure. Existing passenger gates, baggage-handling and aircraft-servicing arrangements are not well adapted to such novelty. And, on the level of pure comfort, a steep, banking turn in such a plane would give passengers at the edge of the aircraft an experience associated more with the fairground than with commercial aviation.

Reality check-in

Despite all these restrictions, two groups working on the future of aircraft have come up with designs that could meet the practical needs of the industry and still cut fuel consumption by half. These researchers, at the Massachusetts Institute of Technology (MIT) and Imperial College, London, rely largely on existing technologies for many of their designs.

If a B737-800 was morphed into the shape of one of the D-series of aircraft on which Mark Drela is experimenting in MIT'S wind tunnel, then it would be about the same size, could fly the same routes and would carry a similar number of passengers. But the D8.1 version (which could be built conventionally, from aluminium) would use 49% less fuel. The D8.5 (similar, but constructed from composite materials expected to be available by 2035) would burn 71% less.

Dr Drela's D-series aircraft differ from existing ones in a number of ways. Instead of having a single, cylindrical fuselage they employ two partial cylinders joined together (see above). This provides additional lift. The nose of the aircraft slants upwards, bringing still further lift. This means the wings can be thinner, saving weight. The three engines are mounted at the rear, flush with the fuselage. Placing the engines here has a number of benefits, says Dr Drela-most notably, allowing the tail to be smaller. One reason for the tall, vertical tail on an airliner is to allow the pilot to compensate with the rudder for the yaw created when a wing-mounted engine fails. Mounting the engines at the back (a design popularised in the 1950s by Sud Aviation's Caravelle, but subsequently abandoned on large aircraft) means that yaw is ▸▸

much reduced, and with it the need for a large tail. The D-series's twin tails are, in total, 70% lighter than a 737's single one.

The rear of the fuselage is also sculpted to sweep air into the engines using a process known as boundary-layer ingestion. Frictional drag means the air closest to the surface of the fuselage moves more slowly than the rest. Ingesting this slower air allows an engine to burn its fuel more efficiently while generating the same amount of thrust. However, employing boundary-layer ingestion means the airflow into the engine is not uniform. The farther the air is from the fuselage, the faster it moves. That can produce undesirable stress on an engine's components.

Pratt & Whitney, an aircraft-engine maker involved in the MIT project, is trying to overcome that problem by redesigning and strengthening the components in a jet engine. The other approach is to fly more slowly, and thus put less strain on the components in the first place. As a consequence, the D8.1 would cruise at Mach 0.72 (seven-tenths of the speed of sound) and the D8.5 at Mach 0.74, compared with about Mach 0.79 for a B737-800. But Dr Drela says the D-series's wider fuselage would compensate for that. It permits an extra aisle, which makes boarding and alighting much faster than on a single-aisle B737. On short-haul routes the D-series would still have a faster gate-to-gate journey time than a 737.

Tail away

At Imperial College, Varnavas Serghides has come up with a number of designs for lighter planes with less drag that therefore need smaller engines that burn less fuel. One of these designs has a pair of jet engines mounted aft, but positioned over and above the wing. This aircraft has no tail fins at all (see below).

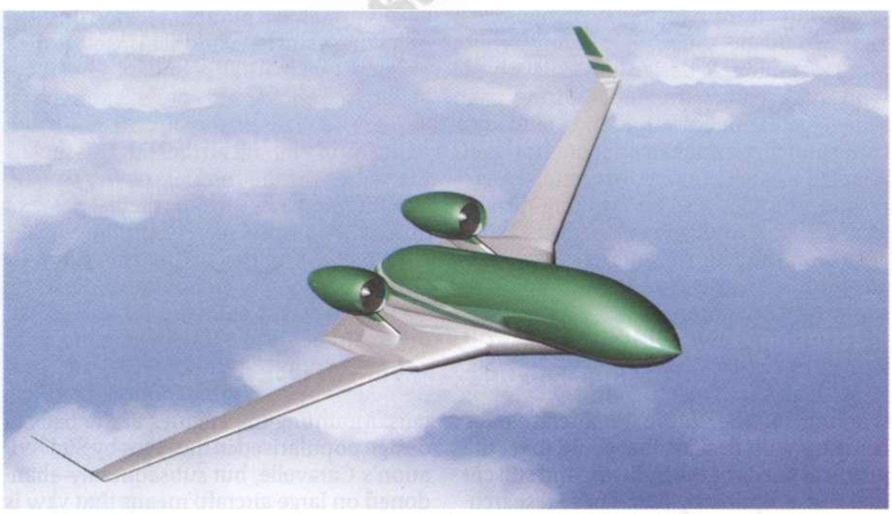
In the past doing without tail fins would have created an aircraft that is difficult to fly. But things have now changed. Mechanical systems have been replaced with electrically activated fly-by-wire controls that use computers to interpret the pilot's commands in the safest and most efficient way. Many military jets would now be impossible to fly if pilots had to rely on mechanical controls alone. So, as Dr Serghides explains, doing without the horizontal stabiliser and vertical tail is not such a radical step. Aircraft-control systems that use computers are capable of mixing the signals required to make the ailerons, flaps and other control surfaces on the wing act together to produce the same effects as the rudder and elevators on the tail would. Dr Varnavas has flown his design in a simulator and says it handles well.

Improving airflow over the wings is also crucial. Laminar (in other words, smooth) flow is preferable to turbulent flow, since turbulence creates drag. An aerodynamically perfect wing would have laminar flow from its leading edge all the way to the rear. But wings are not perfect, and at some stage the air turns turbulent. As a result, roughly half the fuel required to maintain a level cruise is being burned to overcome the drag imposed by a turbulent boundary layer.

Understanding what causes the transition from laminar to turbulent flow requires massive mathematical and computing power. But if Dr Varnavas's colleague Philip Hall and his team can work out the details, they should be able to design wings whose shape maintains laminar flow from front to back, and thus lowers fuel consumption.

Another engineer at Imperial, Dominic von Terzi, proposes to go even further than that. Instead of just redesigning the shapes of wings, he dreams of making them more active. This could be done with surfaces that change shape, or by using a system of holes and slots that can be opened and closed as appropriate to create suction that maintains laminar flow. Moreover, in some cases a pilot might wish to do the opposite and promote turbulent flow-for example, when slowing down. That might allow aircraft to do away with flaps altogether, saving yet more weight.

In an industry as regulated and risk-averse as aircraft building, introducing these changes will prove an uphill struggle. The gains in efficiency, though, make that struggle worth pursuing. Flying wings may never come to pass. But tailless, flapless, podless planes will probably land eventually at an airport near you. ■



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