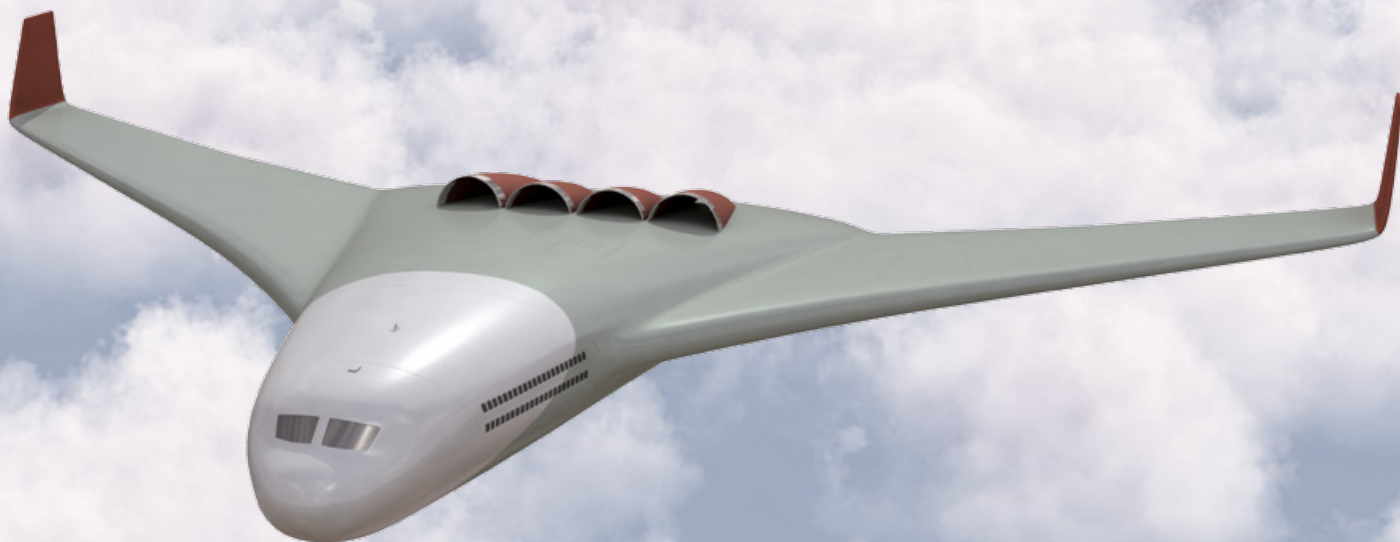


AERO 2075: FLYING INTO A BRIGHT FUTURE?

Institution of
**MECHANICAL
ENGINEERS**

**Part II:
The future of flight
2075 and beyond**



Improving the world through engineering

Do aeroplanes need reinventing? Over the next 50 years, increased demand for air travel, combined with economic and environmental pressures, will create a tipping point for game-changing aircraft designs to move from the drawing board into production.

Today, the UK is second only to the USA in the global aerospace market share. But with long development cycles for new aeroplanes, are we ready to compete in a future where aircraft design and technology will be radically different?

This report has been produced in the context of the Institution's strategic themes of Energy, Environment, Education and Transport, its 'Engineered in Britain' campaign and its vision of 'Improving the world through engineering'.

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**AERO 2075:
OPPORTUNITIES
FOR UK PLC**





Future civil supersonic transport.
NASA/Lockheed Martin.

AERO 2075: THE VISION

Aerospace engineers must navigate a turbulent zone where technology and economics combine to compete with physics. Aerospace research calls and competitions produce ever more ingenious ideas for aircraft design and technology.

While the promotional videos promising observation decks and virtual golf-ranges prompt media interest, few ideas make it from the drawing board to research, and fewer still into production reality.

This section of the report focuses on a selection of developments that do have the technological and initial research impetus to turn them into real-world alternatives for the airline industry.

The examples described below are largely US-led but crucially, the UK currently has world-leading expertise relevant to them.

If the UK is to maintain its position as the world's number two in aerospace, it needs to be an attractive technology hub for the sector. The technologies involved in taking these aircraft into production hold the long-term key to our future commercial success.

Some of the designs are not new: 'flying wings' have been around since the 1930s and 40s (Northrop Flying Wing, Armstrong-Whitworth AW-52 and Horten Ho-2), but developments in materials and computer-aided fly-by-wire control systems have started to make them economically and technologically plausible.

The concepts can be split into three groups: subsonic (slower than the speed of sound), supersonic (faster than the speed of sound) and hypersonic (more than five times the speed of sound – Mach 5), and explore everything from blended wing bodies to hybrid engines, ideas for 'Concorde 2' and scramjets.



Boeing Phantom Works
X-48B blended wing body.

BLENDING WING BODY

Boeing Phantom Works: X-48B and X-48C

Team: NASA, Air Force Research Laboratory, Cranfield Aerospace

Boeing's X-48B blended wing body (BWB) aircraft was initially developed as a study of the structural, aerodynamic and operational advantages of the airframe design (a mix between a conventional plane and a flying wing design) for potential use as a remotely controlled military vehicle.

Flying wings have no definite fuselage and only a single wing with the payload carried within the thickness of the wing. The BWB is an evolution of this design, blending the fuselage, wings and engines into a single lifting surface, producing an aircraft with increased aerodynamic efficiency while maintaining the required payload space, previously a design issue with Flying Wings.

Boeing's design integrates the engines into the rear of the aircraft, reducing the overall drag of the aircraft due to the reduction in surface area. The embedded engines can ingest the boundary layer (the slower moving air that is present in the wake of the fuselage). This technique enables the engines to use less fuel for the same amount of thrust. Furthermore, positioning the engine on the upper surface means that the body of the aircraft deflects the engine noise upwards, making the aeroplane quieter. The greatest challenge with the design is its inherent instability versus conventional aircraft designs. The wings tend to be extremely wide before they generate enough internal volume to be practical.

Two technology demonstrators were built by Cranfield Aerospace in the UK and tested from July 2007 to March 2010.

The X-48B demonstrators had a wingspan of 20.4 feet, weighed 523lb and were powered by three small model turbojet engines delivering a maximum combined thrust of about 160lb. It has an estimated top speed of 118 knots (139mph) and a maximum altitude of about 10,000 feet with a flight duration of 40 minutes.

NASA has now developed the X-48C powered by ducted fans to lengthen flight times, to enable more research to be undertaken. The full scale BWB would use turbofan engines and if NASA can prove their effectiveness it could use open rotor engines.

NACRE – NEW AIRCRAFT CONCEPTS RESEARCH – EUROPEAN COMMISSION

The European Commission's New Aircraft Concepts Research (NACRE) project is co-ordinated by Airbus and brings together 35 partners from universities, research organisations and industry, including many airline manufacturers, from 12 EU Member States plus Russia. Project funding is €30m with just under €17m from the EU.

The aim of the project is to develop generic solutions at a component level (cabin, wing, propulsion system, fuselage), rather than focusing on one specific type of aircraft.

The team has developed three concepts: the 'Pro Green' aircraft emphasising the need to reduce the environmental impact of air travel; the 'Payload Driven Aircraft' configured to optimise payload and the quality of the aircraft for its end-users; and the 'Flying Bus' focused on lowering both the manufacturing costs and the costs of ownership.

NASA N+3 PROGRAM

In October 2008, NASA asked the aerospace industry and academia to develop advanced concepts for aircraft that could meet specific energy, efficiency, environmental and operation goals in 2030 and beyond. The studies were intended to identify key technology developments to enable the proposed advanced airframes and propulsion systems.

The programme is known as N+3, because it focuses on aircraft three generations beyond today's commercial fleet. NASA uses these generational categories to prioritise its research, with each generation setting more stringent environmental targets for fuel burn, emissions, noise and field length. Equating to reductions exceeding 70% in fuel burn, 75% in emissions, and 71dB in noise relative to today's aircraft, N+3 is the most demanding because all the goals must be met simultaneously.

NASA awarded \$2.1m in research contracts for initial studies into subsonic aircraft to the Massachusetts Institute of Technology (MIT), Boeing, GE Aviation and Northrop Grumman.

In April 2010, the four teams presented their results along with a series of technology roadmaps to shape future research. While some of the designs remained relatively conventional, the technology required to meet the stringent N+3 targets did push current design envelopes.

Technology proposed included ultra-modern shape memory alloys, ceramic or fibre composites, carbon nanotube or fibre optic cabling, self-healing skin, hybrid electric engines, folding wings, double fuselages and virtual-reality windows.

Boeing: Subsonic Ultra-Green Aircraft Research (SUGAR)

Team: Boeing Research & Technology, Boeing Commercial Airplanes, General Electric and Georgia Institute of Technology.

The team explored a series of five increasingly advanced concepts, which included two conventional configurations similar in appearance to a Boeing 737 (nicknamed SUGAR Free and Refined SUGAR), two versions of a new-design, high-span, strut-braced wing aircraft (referred to as SUGAR High and SUGAR Volt) and a hybrid wing body configuration (called SUGAR Ray).

Although the team did not pick a preferred concept, the SUGAR Volt aircraft with hybrid-electric propulsion had the greatest potential to fulfil all NASA's N+3 goals.

Extract from NASA feature: *"The SUGAR Volt is a twin engine aircraft with hybrid propulsion technology, a tube-shaped body and a truss-braced wing mounted to the top. Compared to the typical wing used today, the SUGAR Volt wing is longer from tip to tip, shorter from leading edge to trailing edge and has less sweep. It also may include hinges to fold the wings while parked close together at airport gates. Projected advances in battery technology enable a unique, hybrid turbo-electric propulsion system. The aircraft's engines could use both fuel to burn in the engine's core, and electricity to turn the turbofan when the core is powered down."*

Short missions for the SUGAR Volt would be flown on electric power, while for longer flights jet fuel takes over. The result is a predicted fuel-burn reduction exceeding 63%, not far from NASA's 70% target, but at the expense of carrying 20,900lb of batteries.

For noise reduction, the best-performing concept was the hybrid wing body (HWB) configuration, SUGAR Ray, which reduced noise through the airframe shielding the advanced turbofans. The design would achieve a fuel-burn saving of 44%, with noise reduced by 3dB, but this is still well short of NASA's N+3 goal.

Boeing: Awarded a three-year contract (\$8.8m) for its Subsonic Ultra-Green Aircraft Research (SUGAR) concept. The research is funded for further studies into the truss-braced wing and hybrid-electric propulsion.

**MIT: D8 'Double Bubble'
& H-Series Hybrid Wing Body**

Team: Aerodyne Research,
Aurora Flight Sciences and Pratt & Whitney

Extract from NASA feature: *"MIT designed a 180 passenger aircraft fusing two aircraft bodies together lengthwise and mounting three turbofan jet engines on the tail. Important components of the MIT concept are the use of composite materials for lower weight and turbofan engines with an ultra high bypass ratio for more efficient thrust. In a reversal of current design trends the MIT concept increases the bypass ratio by minimizing expansion of the overall diameter of the engine and shrinking the diameter of the jet exhaust instead. The team said it designed the D8 to do the same work as a Boeing 737-800. The D8's unusual shape gives it a roomier coach cabin than the 737."*

The D8.5 configuration narrowly beat NASA's 70% fuel-saving target, exceeded the NO_x goal with an 87% reduction, but fell slightly short on noise, coming in at 60dB lower.

The team also proposed the 350 passenger H 'hybrid wing body' (HWB) series to replace the Boeing 777 class aircraft now used for international flights. The H3 is an evolution of the HWB design developed by the Cambridge-MIT Institute under the Silent Aircraft Initiative. The design features include a lifting body with cambered leading-edge and a wing with no leading-edge slats or flaps. The engines are embedded in the upper fuselage for boundary-layer ingestion and noise shielding and have variable-area thrust-vectoring nozzles. The results are a 54% decrease in fuel burn and 46dB noise reduction.

MIT: Awarded a three-year contract (\$4.6m) to conduct further studies with partner Pratt & Whitney of their D8 'Double-Bubble' configuration.

Northrop Grumman: Silent Efficient Low Emissions Commercial Transport (SELECT)

Team: Northrop Grumman, Rolls-Royce, Sensis Corp, Spirit Aerosystems and Tufts University

Although Northrop Grumman has no background in building civil airliners, they are experts in the technologies that can increase range (bombers) and extend endurance (UAVs).

Extract from NASA feature: *"The Northrop Grumman team foresees the greatest need for a smaller 120-passenger aircraft that is tailored for shorter runways in order to help expand capacity and reduce delays. The team describes its Silent Efficient Low Emissions Commercial Transport, or SELECT, concept as "revolutionary in its performance, if not in its appearance." Ceramic composites, nanotechnology and shape memory alloys figure prominently in the airframe and ultra high bypass ratio propulsion system construction. The aircraft delivers on environmental and operational goals in large part by using smaller airports, with runways as short as 5,000 feet, for a wider geographic distribution of air traffic."*

The team came closest to achieving NASA's goals – a 69.6dB reduction in noise, 63.5% in fuel burn and NO_x emissions of 90.6%.

Northrop Grumman: Awarded a 14-month contract (\$1.2m) to study a multi-function wing leading edge that will enable cruise laminar flow while reducing airport noise by eliminating the slat. The company will build and test models of several leading-edge concepts.

GE Aviation:

Team: Cessna

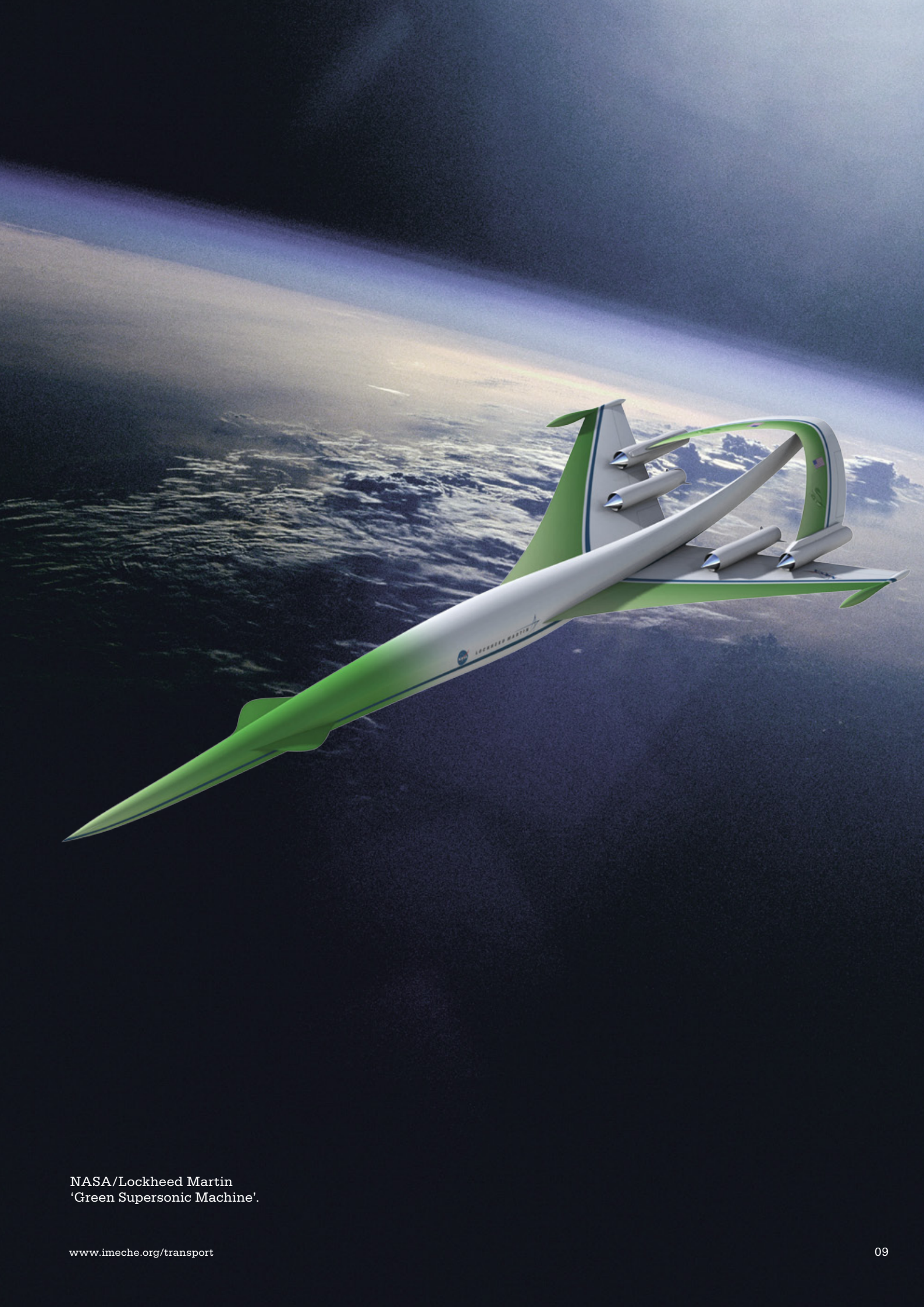
Extract from NASA feature: *“The GE Aviation team conceptualizes a 20-passenger aircraft that could reduce congestion at major metropolitan hubs by using community airports for point-to-point travel. The aircraft has an oval-shaped fuselage that seats four across in full-sized seats. Other features include an aircraft shape that smoothes the flow of air over all surfaces, and electricity-generating fuel cells to power advanced electrical systems. The aircraft’s advanced turboprop engines sport low-noise propellers and further mitigate noise by providing thrust sufficient for short takeoffs and quick climbs.”*

The team achieved 69% reduction in fuel burn, 75% in NO_x and 54dB, either meeting or approaching NASA's goals.

Cessna: Awarded a 27-month contract (\$1.9m) to design a protective skin that could enable lighter structures by protecting composite materials from impact damage, humidity, high temperatures and lightning strikes. The skin would combine foam or honeycomb layers for impact absorption and acoustic insulation with an outer film providing a smooth surface for drag-reducing natural laminar flow.

NASA has now awarded follow-on contracts to advance some of the ideas proposed by the four teams, to identify new technologies that could become available within a new extended horizon of 2040–2045.

Contracts to the value of \$16.5m have been awarded to Boeing, Cessna, MIT and Northrop Grumman.



NASA/Lockheed Martin
'Green Supersonic Machine'.

In parallel with the NASA N+3 subsonic research, Boeing and Lockheed Martin conducted similar studies for N+3 supersonic (faster than the speed of sound) aircraft. In what could be considered the next generation of Concorde, both teams produced aircraft concepts that carry more than 100 passengers at cruise speeds of more than Mach 1.6 and a range of up to 5,000 miles.

BOEING: ICON II

Team: Boeing Research & Technology, Boeing Commercial Airplanes, Pratt & Whitney, Rolls-Royce, General Electric, Georgia Institute of Technology, Wyle and M4 Engineering

Extract from Boeing feature: "The team focused on four concepts that include a low fuel-burn/low-boom swing-wing "arrow" configuration, a low sonic boom concept with a V-tail to shield noise and control the sonic boom, a joined wing alternate concept and an oblique "scissor" wing alternative concept. The team recommended a fixed wing configuration called Icon II with V-tails and upper surface engines as the technology reference concept plane for N+3. The Icon II can carry 120 passengers in a two-class, single-aisle interior, and can cruise between Mach 1.6 and Mach 1.8 with a range of about 5,000 nautical miles. The study acknowledged that supersonic aircraft inherently have less fuel efficiency than subsonic aircraft, but that it offsets productivity benefits because of speed. The study concludes that advanced technologies can reduce fuel burn enough that a supersonic aircraft could be viable, economically and environmentally, in multiple markets."

LOCKHEED MARTIN: SUPERSONIC GREEN MACHINE

According to NASA, the team's simulation for the Supersonic Green Machine shows the possibility for achieving overland flight by dramatically lowering the level of sonic booms through the use of an 'inverted-V' engine-under-wing configuration. Other revolutionary technologies help achieve range, payload and environmental goals.

The critical market lever for these aircraft is to solve the issue of sonic-boom overland. While no funding has been allocated to Phase Two research for these aircraft, NASA is conducting research to solve the sonic boom issue.

AERION SUPERSONIC BUSINESS JET (SBJ)

This SBJ builds on the aircraft manufacturer's natural laminar flow (NLF) expertise. Aerion teamed with Pratt & Whitney to adapt its JT8D-200 series engine. The jet will cruise at a maximum altitude of 51,000 feet with a maximum speed of Mach 1.6. The Aerion NLF wing will be constructed using a carbon epoxy with a coated metal leading edge to provide resistance against erosion. The remaining fuselage will be a combination of aluminum and composite materials.^[42]

Ref 42: <http://aerioncorp.com/jet>

E-5 NEUTRINO SBJ

The success of this design was that it reduced the sonic boom characteristics to enable supersonic flight over land. The cruise speed has been designed to be that of Mach 1.8 with the fuselage using the same manufacturing processes and techniques as the Boeing 787 – modular assembly barrels, using integral stiffeners that reduce the number of parts and improve the aerodynamic shape. It was estimated that the unit cost of this SBJ would be £48.4M (US\$79M).^[43]

Ref 43: www.cranfield.ac.uk/soe/postgraduatestudy/aerospacedesign/e_5_supersonic_business_jet.pdf

SUPERSONIC COMBUSTION RAMJETS: 'SCRAMJETS'

The commercial aviation world benefits from advances not just in military technology but also space technology. Designed to withstand huge extremes in temperature and turbulence, and using advanced remote operating systems that are rigorously tested to ensure their longevity, technology certified for space is hugely valuable.

As the 'shuttle' programme is now closed, NASA and the European Space Agency are pushing the boundaries to find solutions for delivering cargo and people into space. In addition, space underpins the global communications industry, using rockets to launch satellites is expensive, and space agencies and industry are looking at how to develop viable alternatives.

One alternative may be the scramjet-powered space plane, which has moved from the drawing board to testing stage. Huge leaps forward have been made in the scramjets, which could see these space planes eventually launch straight from the ground into space – so-called, single stage to orbit.

In 2005, NASA achieved the longest combustion ramjet-powered hypersonic flight with the X-51A air-breathing scramjet engine built by Pratt & Whitney. The engine burned for more than 200 seconds to accelerate the US Air Force's X-51A vehicle to Mach 5 and an altitude of 70,000 feet. And in 2006, the Australian Air Force tested the British-designed Hyshot III from QinetiQ, reaching Mach 7.6 (9,000km/h).

Charlie Brink of the Air Force Research Laboratory said about the ground-breaking X-51A flight, "We equate this leap in engine technology as equivalent to the post-World War II jump from propeller-driven aircraft to jet engines."

Scramjet engines provide propulsion at speeds above Mach 5, by capturing atmospheric air to mix with on-board fuel. The scramjet has no moving parts, it simply takes all the oxygen it needs to burn hydrogen fuel from the air. This makes the payload more efficient as it does not need to carry its own oxygen supply.

The greatest challenge in their development is that the method works only at high velocities – scramjets start working at Mach 5. So they have to be attached to rocket boosters and then launched once the rocket has reached high speed. At this speed the air passing through the engine is compressed and hot enough for ignition to occur. Rapid expansion of the exhaust gasses creates the forward thrust.

Even further gains have been made in the last five years. In April 2011, NASA's X-43A scramjet-powered research vehicle, attached to a Pegasus rocket booster and tucked under the wing of a B-52B launch aircraft, reached nearly Mach 9.8, flying at 110,000 feet.

TECHNOLOGY AND OPERATIONAL CONCEPTS

ON-BOARD ELECTRICAL GENERATION

While it is unlikely that solar or hydrogen fuel cells alone will provide enough energy to fuel a 300-seat passenger plane across the Atlantic, researchers are exploring the opportunities for on-board electrical generation from renewable sources.

Two key solar power projects under way are the OMEGA – Solar Impulse and the Zephyr developed by QinetiQ.

Solar Impulse, fronted by round-the-world hot air balloonist Bertrand Piccard, had a successful test flight out of Switzerland in July 2010, proving it can run both day and night on the power of the sun. The team will attempt to fly it around the world in 2014.

The unmanned Zephyr broke records in July 2010, by flying continuously for 14 days and 21 minutes above the US Army's Yuma Proving Ground in Arizona. For the Yuma trial, Zephyr carried a communications payload configured to meet the needs of the UK Ministry of Defence, but civil applications could include environmental and agricultural monitoring, surveying disaster zones and providing mobile communications in remote areas.

The aircraft flies by day on solar power delivered by paper-thin amorphous silicon solar arrays that cover the aircraft's wings. These are then used to recharge the Sion lithium-sulphur batteries that power the aircraft by night.

Although significant developments would need to be made in battery technology, especially weight, for large-scale passenger aircraft, on-board electrical generation is a key future technology.

FORMATION FLYING, AIRCRAFT CARRIERS AND FLYING FUEL STATIONS

In October 2010, the EU-funded CREATE project 'Creating innovative air transport technologies for Europe' published a report which set out a series of bold visions for the future of air transport. While none of the ideas were scientifically assessed, the project, co-ordinated by the Aerospace & Defence Industries Association of Europe, delivered some exciting concepts. Elements of these concepts could make it past the drawing board given current developments in technology, specifically within the military (Unmanned Aerial Vehicles) and space sector (ATV docking system).

Formation Flying

Aircraft require much less power at cruise than they do for take-off and landing. The group considered whether this relatively low need for cruise power could be extended by turning off the power of some aircraft and using the power of others more efficiently.

Aircraft could be configured in a V-shaped, echelon formation when at cruise with following aircraft enjoying a drag reduction and lift advantage from the airflow generated by the aircraft in front. Taken directly from nature, the concept is akin to the aerodynamic nature of a flock of geese.

The aircraft could join the flight mass through mechanical docking to form a semi-rigid body of several aircraft. The automated docking would allow aircraft to join the flock in a computer determined best flock position which it would approach on automatic control and then latch to the flock. Aircraft leaving the flock would need to have pre-programmed their sequence of departure so that they were not locked into the centre of the flock when they needed to leave.

This is a software and systems engineering challenge, but some of the technology already in development could form the building blocks. The Unmanned Aerial Vehicle (UAV) industry is the hotbed for 'collision avoidance' and 'terrain avoidance' warning systems, and 'wake vortice' solutions including "a souped up version of lidar, a laser-based sensor rather like radar, which can measure air turbulence" (*New Scientist*, Aviation, The Shape of Wings to Come, 29 June 2005) was being explored five years ago by both EADS and Michigan Aerospace.

In addition to these navigations, the 'automated docking technology' already exists. ATV is a fully automated cargo space plane that delivers supplies to the space shuttle. Developed by EADS, the project had significant input from EADS Astrium in the UK.

Aircraft Carrier and Flying Fuel Station

As highlighted earlier in the report, current airframe developments have been built around a hub-and-spoke or point-to-point transport model. While industry is split over which will dominate, the CREATE report delivered some exciting new ideas on how point-to-point could be taken to the next stage.

One very radical idea proposes a system that would "deliver the individual passenger at or near the front door". This might be achieved by means of "a large aircraft carrying individual units that can be released over the destination and float down to the designated area where the passenger needs to go" – a sort of Ark Royal for the skies.

Another idea involving a similar docking station model, was to build a flying fuel station so that future aircraft did not have to take off with full tanks. A design study was conducted by Cranfield University into the future possibilities of air-to-air refuelling. The report assumes that the future aircraft would use advanced avionics systems which would include automatic refuelling boom docking. The report concludes that air-to-air refuelling of civil aircraft may have economic advantages on routes beyond 4,500 nautical miles (8,334km), with fuel costs above £1.8/G (\$3US/G). However, for this to become reality there would be a requirement for a global network of tanker fuelling hubs to be established, and there would need to be the psychological acceptance by fare-paying passengers that in-flight refueling of civil aircraft is a safe procedure.

While in both cases the size of the 'mothership' presents huge engineering challenges, the concepts rely on the technology outlined for formation flying.



Solar impulse project which aims to be the first piloted aircraft to circle the earth using only solar power.

AERO 2075: OPPORTUNITIES FOR UK PLC

The UK has the engineering talent to drive forward many of the disruptive and emerging technologies that will help shape the future of aircraft design, systems and operations.

Leadership will come from our ability to invest in collaborative research and validation projects, and the speed with which we can move 'across the chasm' into production.

Cross-fertilisation will be pivotal to our success: the aerospace industry needs to have access to the talent and technology of the UK's other leading and emerging industries: automotive, digital, data mining and bio-tech.

ADDITIVE MANUFACTURING: HOW TO MAKE AN AEROPLANE IN 2075

By 2075, the UK could be the world leader in the technology that can create advanced components and structures using a printer.

Additive Manufacturing (AM) is the use of 3D printers as production tools, and the UK is a world leader in the development of this ground-breaking technology.

Objects are grown one at a time from either plastic or metal compounds, using a computer-controlled laser that builds up the material in tiny layers to create a completely formed component or product.

"The whole process unlocks design freedom," explains expert Dan Johns, from EADS Innovation Works in the UK.

"Additive Manufacturing breaks the design rules. Historically you design for machining, creating a rectilinear (straight lines, flatsides) product from a block of raw material, creating lots of waste. With Additive Manufacturing in your design space you create the environment the component has to satisfy and it automatically adds layers of weight in exactly the right spots – creating less waste across the whole structure. Nature only puts materials where they are needed – Additive Manufacturing is finally able to mimic the same super-efficient process."

As 3D printers are driven by software, each item can be made differently without costly retooling, producing ready-made objects that require less assembly.

While AM has generally been used to create small-scale products, it could be scaled up to transform manufacturing. EADS Innovation Works has started to make aircraft components using AM and has the ambition to create an entire aircraft wing. With industry looking to the blended-wing body and hybrid-wing body to transform aircraft efficiency, AM is the transformative technology that could make this happen.

The UK currently has a lead in the industrialisation of Additive Manufacturing. We have been faster to create a network and community of knowledge, adopt and use the technology, and drive the research agenda to a stage where the technology can be applied across industrial sectors en masse.

What started out as a group of academic visionaries in UK universities in the 1980s and 1990s has become a network of knowledge and experts, many of whom are still working in UK industry, turning knowledge and technology into real-world applications.

Government has also been quick to see the benefits of AM. It meets the need for a low-carbon economy and has applications across the spectrum of UK manufacturing, medical devices, automotive and aerospace, sports equipment – the list is endless.

To stay ahead of the game, the UK needs to keep pressing ahead with large-scale validation projects. For example: Bloodhound, the UK's world land-speed record attempt, will be using AM to create a 1,000mph car. Dan Johns, who is heading the project, believes that it is this kind of open-source technology demonstrator that will allow a range of industries to make leaps forward in the application of AM.

Back in 1943, the US Army's Air Tactical Service Command met Lockheed Martin Corporation to discuss its urgent need for a jet fighter to counter a rapidly expanding German jet threat. Just one month later, a group of engineers led by Kelly L Johnson delivered the XP-80 Shooting Star jet fighter proposal. The go-ahead was given and 143 days later, seven less than required, Kelly's team designed and built the XP-80.

What enabled Kelly to deliver so quickly was his unconventional approach – he broke the rules, challenging the bureaucracy of innovation, creating 14 simple rules and practices. Giving the UK supply chain, this level of innovation freedom will be essential for success.

SPACE RACE

By 2075, the UK could have developed the first re-usable space plane that forms the basis for global passenger 'hypersonic jets'.

A small company in Oxfordshire could hold the key to developing the hypersonic scramjet of the future.

Skylon, produced by Reaction Engines, is a re-usable space plane designed for single-stage-to-orbit (ie can take off and land on the ground) transportation of cargo and satellites into space.

In May 2011, the European Space Agency (ESA) delivered its verdict on the Sabre engine technology developed by Reaction Engines that would power the aircraft into space. It wrote: "ESA has not identified any critical topics that would prevent a successful development of the engine."

With the approval of some of the world's leading experts in the field, Reaction Engines can now move on to create a larger demonstration of the technology on an experimental rig at its Oxfordshire home. If the results from this demonstrator get the green light, then the company is hoping that £220m of private investment will see a sub-scale version of Sabre for ground demonstration running by the end of 2013/2014.

If the vehicle makes it to full production, the investment required will probably be in the region of £5.5–£7.5bn. To make it to take-off, there will be a number of regulatory barriers to leap from licensing and certification to airspace management.

SENSE AND AVOID: INTELLIGENT FLYING FOR 2075

With the UK's expertise in space docking, earth observation technology and UAV autonomous navigation systems, could we hold the key to formation flying by 2075?

Three areas of UK expertise could merge to create the intelligent navigation systems required for formation flying: sense and avoid, environmental observation and autonomous docking.

According to the UK Trade & Industry Authority, the UK currently ranks fourth in the development and production of Unmanned Aerial Vehicles (UAVs) after the USA, France and Israel. While UAVs are predominantly used for military purposes, and although there is interest in using the sense-and-avoid technology for future freighter aircraft, passengers may not embrace the thought of a completely unmanned civilian aircraft.

But UAV autonomous navigation technology, combined with our expertise in space docking from the development of the ATV cargo ship, and instrumentation for earth observation (EO) missions could lead to the development of the systems and data required for automated formation flying by manned civilian aircraft.

The UK is a world-leading expert in earth observation instrumentation. UK scientists developed the 'super-radar' for the Aeolus mission to accurately measure wind speeds across the globe. In addition, the Space Innovation & Growth team report in 2010 highlighted our expertise in collating and analysing EO data, and the potential to create a new industry based on the commercial application of EO data.

Is the combination of these UK engineering skills the key to air traffic control technology for the next century?

The future of the aviation industry looks to real time or intelligent traffic management.

Data mining is a new growth industry for the UK and is a relatively young sector that will mature over the next 20 years. Data mining may be used within the aviation industry by being integrated into a complex modelling and decision-making processes. Currently in London there is a cluster of these entrepreneurial firms focused at Old Street, which has been renamed 'Silicon Roundabout'.

McLaren Applied Technologies, which is renowned around the world for working within the Formula One business, has begun working with National Air Traffic Services. Their aim is to help predict air traffic movements up to two hours ahead at Gatwick airport, turning data into clear visualisations.

The Single European Sky initiative has found that delays cost airlines between £1.2bn and £1.7bn (€1.3–€1.5 billion) a year. Improved traffic management, aircraft positioning and communication technology such as the European Galileo positioning system, which offers huge opportunities and improvements.

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