Aerospace

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Keep calm and fly on despite EU vote

UK is under pressure to show its support for the sector at key trade fair, writes *Peggy Hollinger*

New delivery: the RAF's F-35B Lightning II stealth jet is expected to fly at Farnborough
Matt Cardy/Getty Images

When the Farnborough Airshow opens its doors today, less than three weeks will have passed since the UK voted to leave the EU. While the shockwaves are still being felt politically, the government is under pressure from industry to use this gathering of global aerospace and defence companies to send a reassuring message about the UK's commitment to a sector that is one of its most important export engines.

"Farnborough is where global aerospace and aviation industry comes to talk business," says Paul Everitt, chief executive of ADS, an industry lobby group. "The referendum was a major disruption to the way in which both countries and businesses look at the UK. It is important that we are seen to be coherent."

Mr Everitt says the government has to "send some important messages about stability, and particularly stability of intent". He argues that initiatives are needed to encourage investment now as the aerospace industry gears up for a level of production not attempted by many companies since the second world war. Research and development incentives, a reduction in UK business rates and other measures would mean more to aerospace than the recent cut in corporation tax rates, he says.

Britain's aerospace industry is second only to the US, with roughly 17 per cent of the global market and annual turnover of £55bn. It has also been a leader in air travel, with London's Heathrow until 2014 the world's busiest airport for international passengers.

But the vote to leave could threaten some of that dynamism, argue many in the industry, in particular at a time when aircraft orders already show signs of slowing down after a six-year boom.

Iata, the airline industry trade group, estimates that air travel to and from the UK will grow more slowly, by up to 1.5 percentage points a year. The effect of slower growth could mean that by 2020 the UK's aviation industry will be 3 to 5 per cent smaller than it would have been without Brexit *(see column, bottom right)*.

In defence, too, the prospect of the UK's exit has sparked fears of a retreat from the UK's recent commitment to buy urgently needed US-made equipment — such as maritime patrol aircraft from Boeing — as the decline in sterling raises already hefty price tags. However, the need for the P-8 submarine hunting aircraft — which will protect the UK's new aircraft carriers — is so pressing that industry experts are confident this deal and others will be announced at the airshow, whatever the exchange rate.

"The trade-off may be that Boeing should pledge a greater level of investment in the UK," says Howard Wheeldon, an aerospace and defence analyst.

People close to Boeing suggest there will be an announcement showing the company's commitment to the UK in return for an agreement to buy the P-8. Dennis Muilenburg, Boeing chief executive, says the UK will continue to be an important base for the US aircraft maker. "We constantly have to manage major changes in political circumstances around the world. And that's exactly what we will do now as the situation continues to evolve in the UK and in Europe," he told the FT. "The UK is an important base of our operations . . . and we have an important network of suppliers and technology partners there."

UK companies are just as keen to stress that they will adapt to the new environment, although it could take years before the final shape and form of Britain's relationship with Europe is decided.

Certainly, businesses such as BAE Systems, the world's third-largest defence company by sales, will benefit in the interim from any continued weakness in the pound. While BAE says it expects no immediate effect to its business before the outcome of the UK's negotiations with the EU, the company urges that strategies already laid out — at least for the defence industry — should not be meddled with.

"The result of the EU referendum will lead to a period of uncertainty for all businesses but our industry is not in the same position as companies in sectors that sell directly into the single market," a BAE statement said. "The Strategic Defence and Security Review [announced last autumn] was a definition of the UK's defence requirements as a sovereign nation, it was not related to membership of the EU. We would expect the UK to maintain its posture on defence and security and to have a continued focus on UK exports."

For BAE, the appearance at Farnborough of Lockheed Martin's fifth-generation stealth jet, the F-35, will be a chance not only to put paid to doubts over the cost of buying the US aircraft, it will serve to remind ministers of the substantial export revenues the UK business earns from its 15 per cent share of the joint strike fighter's sales.

Mr Everitt of ADS believes the fears over Brexit — at least in the short term — may prove to be exaggerated. In the meantime, there will be other pressures to preoccupy exhibitors at Farnborough, such as the race by Boeing and Airbus to accelerate production to unprecedented rates and at ever lower cost. "If you flip to what the big issue will be, it will still be 'ramp up and cost down'," he says.

With orders slowing — and likely to be even more muted this year than at last year's Paris Airshow — there are fears that a turn in the cycle could be imminent. But Sandy Morris, veteran aerospace analyst at global banking group Jefferies, is sceptical that either Farnborough or Brexit will mark a definitive turning point for the aerospace industry. In the end, global demand for air travel is rising so steadily that such fears risk clouding judgment, he says.

"These are just more excuses for everyone to be looking for problems rather than solutions. What does it matter if the UK ploughs its own furrow?" he says. "And we had a period of above average growth [in orders] and now it might settle back to the long-term trend. That is just fine."

> 'These are just more excuses . . . What does it matter if the UK ploughs its own furrow?'

Inside

Acronyms engage in aerial battle to attract attention

Digital

Disruptive technologies are making a bigger blip on Farnborough's radar, writes *Paul Sillers*

A battle of acronyms linked to developing technologies will be taking place in skies above Hampshire this week as the Farnborough International Airshow gets under way. UAVs (unmanned aerial vehicles), AR (augmented reality) and ALM (additive layer manufacturing, or 3D printing) are three of the many technologies on display at the biennial aeronautical show.

The word that links these innovations is not "aerodynamics" but "digital": UAVs rely on satellite and ground station data for navigation; AR is the realm of superimposing digital data on to visors to add contextually relevant information that helps people to handle complex tasks; and 3D printing translates digitised information into products that are built up layer by layer.

Developments in technology have also led to a change in the type of talent the aerospace industry is looking for. John Schmidt, who leads consultant Accenture's global aerospace and defence practice, says that "70 per cent of executives believe that the employee of the future has to be more adept at adopting new technologies". What do these three innovations bring?

Augmented Reality

AR has been around since 1990, pioneered by a Boeing researcher who used a head-mounted display to see computer-generated assembly instructions while installing wire harnesses on aircraft wings. But it has only been with the more recent advent of high-definition smart glasses that the technology is really catching on. "AR is being selectively introduced to support the rapid diagnosis of systems and objects in need of service, and to reduce risk of errors in unfamiliar procedures," says Christine Perey, founder of the Augmented Reality for Enterprise Alliance.

The rising demand for digital technologies in the aerospace sector has also coincided with skill shortages. But Chris Freeman, head of digitally assisted assembly at the University of Sheffield's Advanced Manufacturing Research Centre, says AR can improve rather than merely replace work on the production line.

One such AR application is designed to check structural brackets that hold wiring, pipework and hydraulics while also flagging up damaged and wrongly positioned brackets, "reducing inspection time for the 60,000-80,000 brackets in the [Airbus] A380 fuselage from three weeks to just three days", Mr Freeman says.

> 'Imagine eliminating the [need for parts] sitting idly on shelves around the world'

Unmanned Aerial Vehicles

Accenture's Mr Schmidt has calculated that "the commercial UAV market is expected to reach $2.8bn [by annual sales] by 2020 — growing by 14.1 per cent year-on-year — and the defence market is expected to amount to $6.6bn".

The UK government sees drones as an essential platform for the nation's future military needs. It has invested £185m in Taranis, an advanced unmanned combat demonstrator aircraft designed and built by BAE Systems in collaboration with Rolls-Royce, GE Aviation, and Qinetiq, alongside the Ministry of Defence.

Taranis is being designed to test technologies that could be used to further develop drones capable of carrying out attacks as well as surveillance. Martin Rowe-Willcocks, head of future programmes and services at BAE, describes Taranis as "the most advanced air system ever conceived, designed and built in the UK, with the capability to work alone, under the continuous command of a pilot, or in co-operation with manned combat aircraft".

Additive Layer Manufacturing

Another technology we are likely to see across the industry is additive layer manufacturing, the industrial-strength version of 3D printing. And it is not just used for minor components — Rolls-Royce has already flown the world's largest 3D-printed structure, consisting of aerofoils, in its Trent XWB-97 engine.

ALM has developed into an economic manufacturing platform which enables designers to leapfrog tooling processes and jump straight from design to finished product. The savings in cost, time and waste-reducing environmental benefits make it an attractive manufacturing option for the aerospace industry. Airbus says ALM produces "only 5 per cent waste material instead of up to 95 per cent from machining".

Scott Sevcik, director for aerospace and defence business development at 3D printing company Stratasys, says that in addition to enabling the aerospace industry to make lightweight components more efficiently, the potential of print on demand allows for new supply chain savings. "Imagine eliminating the tens of billions of dollars in inventory sitting idly on shelves around the world. When you can print a part, those tools and parts can be stocked digitally and produced on demand. Stocking 20 years' of spares for a part going out of production will become a thing of the past."

Fresh aviation agreements must come first in a post-Brexit world

COLUMN

Tony Tyler

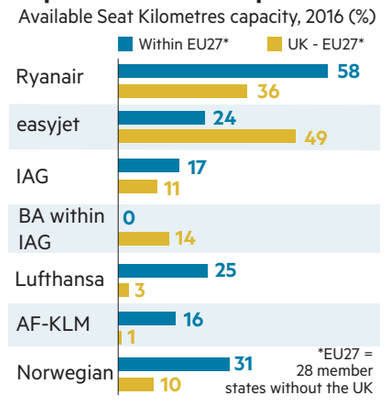
The UK's vote to leave the EU has triggered enormous uncertainty. The shockwaves of Brexit instantaneously extended worldwide and the fallout will clearly affect the air transport industry, which plays a critical role connecting our world.

The most apparent effects on aviation are twofold: economic and regulatory. On the economic side, exchange rates and markets have already moved. This will undoubtedly change travel plans and shipping needs in both the short and long term. Experts have developed scenarios for how Brexit might unfold. Using these, our best estimate is that travel to and from the UK will grow more slowly — by up to 1.5 percentage points a year. Airlines are well placed to deal with that challenge. They are experienced and adept at adapting to economic shocks. Demand can fluctuate for many reasons.

By 2020, slower growth could mean that the UK's aviation industry will be 3 to 5 per cent smaller than it would have been without Brexit. That is a significant and unfortunate gap that will have its own economic consequences. I would be remiss if I did not remind the government that some of this could be mitigated by eliminating air passenger duty. But even if growth is slower, the aviation sector will still be a vital part of the UK economy.

Today there are 1.3m UK jobs tied to aviation. And the industry contributes nearly $100bn annually to the UK's economy. A small portion of UK aviation activity serves domestic markets, but the vast majority of the demands that they meet are for international connectivity to continental Europe and further flung places. Specific air services agreements — outside of normal trade arrangements — make this possible.

Share of intra-EU air capacity exposed to Brexit implications
Available Seat Kilometres capacity, 2016 (%)



Sources: OAG; Morgan Stanley research; Iata

Last year saw about 160m air trips to and from the UK. About two-thirds of those were linked to the EU. Whatever political framework exists between the UK and Europe, the fundamental demand for travel between the two will remain.

And facilitating these links should be at the top of the priority list for the government's negotiators.

There is a lot at stake on the regulatory side. The world-leading regulatory framework of the single EU aviation market has produced safe, efficient and economical air connectivity across Europe and beyond. As a result of growing air links, businesses are stronger, people are more prosperous, and the quality of life for Europe's citizens has been enhanced.

Looking more broadly, the agreement between the EU and US is similarly important. Allowing carriers from either market unlimited access for international services has seen the web of connectivity between the continents expand with economic benefits accruing on both sides of the Atlantic.

What should aviation agreements look like in a post-Brexit world? Some suggest that the UK should remain part of the European Common Aviation Area, or negotiate a bespoke EU-UK agreement as Switzerland has. Whichever framework is chosen, the best outcome would be an essentially unchanged operating environment. We cannot step backwards. And in the face of potentially very difficult adjustments across the economy, any solution that compromises aviation's contribution to social and economic development is simply not acceptable.

The task ahead is big and it is complicated. It should not be underestimated in any way, including the negotiating skills that will be required. That is particularly true for the UK which has little recent experience of negotiating air service agreements. Close co-ordination with industry will be critical to achieving a practical agreement.

People want to explore their world. Businesses need to work with global partners. Supply chains rely on worldwide access. And the best ideas are supported by real experiences. There are myriad reasons why aviation is a force for good in our world. Brexit changes none of them. It is paramount that, when the negotiations between the UK and Europe turn to air services, the focus is firmly on maintaining the benefits of connectivity.

Tony Tyler is the director-general and chief executive of the International Air Transport Association (Iata)

All aboard: Boeing 737 fuselages are delivered by train to a Boeing manufacturing site in Renton, Washington state — Reuters/Jason Redmond

Rise in aircraft demand forces supply chain to modernise

Delivery problems

Delays have long bedevilled the industry, writes *Ross Tieman*

At the perimeter of Toulouse-Blagnac airport are rows of airliners, their wheels covered and doors taped over. An empty space beneath their wings betrays the supply chain hitch that caused this stockpile of aircraft, valued at more than $2bn. For some, the Airbus A320neo (new engine option) became a no-engine option.

As the inflow of geared turbofans accelerates in coming weeks, these aircraft will soon be on their way to airlines around the world. But the scene demonstrates the kind of delays in assembly that have long afflicted aircraft programmes and still do.

Patrick Daher of French aerospace industry association Gifas says aerospace is at last in the throes of a fundamental transformation in the way it operates. "In the old supply chain, not just in France but everywhere, we worked like artisans," he says. "Now we have to become a manufacturing industry, with automation, robotics and standardisation."

Asian economic growth, the development of new Gulf airlines and the expansion of low-cost travel have boosted demand for airliners. That has encouraged new entrants to challenge the long-standing dominance enjoyed by Boeing of the US and Airbus, its European rival, over large passenger aircraft. Bombardier of Canada, Embraer of Brazil, Irkut in Russia and Comac of China are all now competing to sell single-aisle jets.

Many of these manufacturers rely upon common suppliers, which are thus racing to increase volumes to satisfy competing customers.

Some are shifting capacity from production lines serving weaker sectors, notably business jets and helicopters, towards manufacturing parts for airliners. To do so, they must install new equipment and continue to hire and train workers.

In 2015, aerospace companies in France, which with the US and UK has one of the biggest aerospace clusters, hired 11,000 additional workers. This year they will take on 10,000 more.

In recent decades the industry has pioneered new technologies on warplanes and transferred them to civil jets. Yet each programme has had delays caused by complex supply chains. Wiring problems delayed the Airbus A380 superjumbo, outsourcing snared Boeing's 787 long-haul aircraft, and software bedevilled the Airbus A400M military transporter.

Aircraft makers have worked hard to avoid further problems in meeting delivery schedules, so delays to the A320neo are doubly frustrating for Airbus and its clients.

Pratt & Whitney spent two decades and more than $1bn developing its innovative geared turbofans, one of two engine types available on the A320neo. Scheduled to enter service last autumn, commercial use was delayed until January. Software glitches gave false warnings and the engine was slow to start. Only now are enough fault-free engines arriving in Toulouse. Greg Gernhardt, president of commercial engine programmes at P&W, says his company is working closely with Airbus to ensure timely deliveries for the rest of the year. But, he says, the problems overshadow success in developing an engine that matches or exceeds performance goals.

"I've been at Pratt 26 years, and I can't remember the last time anybody's done a programme where we have actually hit the performance guarantees at entry into service."

> 'In the old supply chain, not just in France but everywhere, we worked like artisans'

Deliveries of Airbus's new wide-body A350 have been delayed by late arrival of lavatories and business class seats from Zodiac Aerospace factories in the US. In the first half of this year, Airbus completed only nine A350s, yet hopes it can still reach its 50-aircraft full-year target in the remainder of the 2016.

Zodiac's problems have stemmed from poor operational control and difficulty in producing complex composite components to the required quality, as well as delays in safety certifications. Zodiac has begun making seats at a second plant outside Montreal, Canada, and found two external suppliers of the composite seat shells. According to the company: "We are working hard on both ramp-up and quality issues."

Yet as Boeing forges ahead with production of its upgraded single-aisle 737 Max and development of the enlarged 777X wide-body, its executives are focused on avoiding similar hiccups.

Boeing Commercial Airplanes buys $40bn of components and services a year from 1,500 suppliers, whose inputs account for 65 per cent of an aircraft's cost.

"It's vital to collaborate closely with suppliers on a continual basis," says the company, "and for Boeing to be proactive in assessing and addressing any concerns."

Increased volumes of orders and price pressures are beginning to deliver an overdue modernisation of supply chain in the sector, says Mr Daher of Gifas. An industry-wide programme aimed at improving dealings between manufacturers and main suppliers has delivered big improvements, he says, adding: "In the automotive industry they achieve 100 per cent [on time and quality]. We are moving forward fast to get close to this level. Nothing else is acceptable."

Efficient practices get the green light

Environment

New European aerospace technologies address environmental concerns, writes *Paul Sillers*

Big fan: a carbon and titanium engine

Global air traffic surged over the past year and is expected to more than double over the next two decades.

Worldwide airborne travel, measured by the total number of kilometres travelled by paying passengers, grew 7.4 per cent last year. That was well above the past decade's average annual growth of 5.5 per cent, according to Iata, the global industry trade body. Data from Iata also show more than 3.5bn passenger journeys were flown in 2015. The number is expected to exceed 7bn in 20 years.

European manufacturer Airbus anticipates worldwide demand of 32,585 new aircraft over the next 20 years — a figure not too different from estimates by US rival Boeing that 38,050 aircraft will be required. While this could only be good news for aircraft makers, engine manufacturers and their supply chains, there are also environmental considerations.

"Manufacturers are investing in producing cleaner, quieter aircraft, but the industry growth rate always outpaces the improvement in the efficiency of new aircraft," says Tim Johnson, director of the Aviation Environment Federation (AEF).

The organisation represents communities living around the UK's airports and whose immediate concerns are noise and air quality. Mr Johnson says this growth is already hampering decision-making on large UK aviation infrastructure, such as Heathrow's proposed third runway in London, which he believes is "being delayed only by uncertainty about how to manage the environmental consequences".

Aviation produces 2 per cent of carbon dioxide emissions globally and 12 per cent of the transport sector's CO2 emissions. This compares with 74 per cent from road transport, according to the Air Transport Action Group, which lobbies for the industry.

Following demands from campaign groups, as well as from airlines seeking to cut fuel costs, manufacturers have been under pressure to produce cleaner, quieter and more fuel-efficient aircraft.

Such pressure, building over the past 15 years, has resulted in action to convert these demands into quantifiable goals.

The Advisory Council for Aviation Research and Innovation in Europe, an EU research network, has set out a road map for European aircraft to achieve by 2020 a 50 per cent reduction in fuel consumption, CO2 emissions, and noise levels, as well as 80 per cent less nitrous oxide, compared to 2000.

New technologies, many on display at this week's Farnborough Airshow, are on course to achieve such goals.

The principal body responsible for funding these efforts is an initiative called Clean Sky, a partnership between the European Commission and the EU's aerospace sector. Stakeholders include Airbus, the UK's Cranfield University, engineering group Qinetiq and Rolls-Royce, which is attempting to improve efficiency through initiatives such as the introduction of engine fan blades made out of carbon and titanium (CTi).

"In the future we want to go to engines with larger diameter fans, as these burn less fuel," says Phil Curnock, chief engineer of future programmes at Rolls-Royce. But the way to do this is to replace titanium with CTi fans on the company's two new aero-engines Advance and UltraFan that will enter service in 2020 and 2025 respectively, trimming 1,500lb off the weight of a twin-engined aircraft.

In another venture backed by the Clean Sky programme, Airbus Helicopters in 2019 will start flight tests on a high-speed vehicle named LifeRCraft. Looking like a helicopter with added aircraft wings and two forward-facing propellers, it combines hover capability with fast forward flight, enabling it to offer increased speed, at a lower cost, with reduced emissions and noise compared with conventional rotorcraft.

Airbus Helicopters' Tomasz Krysinski, head of research and innovation, says that in a medical evacuation role, "50 per cent more speed than a conventional helicopter" will enable the LifeRCraft to reach offshore oil platforms and wind farms within the "golden hour", the time after a traumatic injury when treatment is most likely to be successful.

While Clean Sky has a successful record of pan-European collaboration, the UK's vote to leave the EU could affect future projects.

> Aviation is responsible for 12 per cent of the transport sector's CO2 emissions

"The UK is an important player with a high number of participants including many British SMEs as well as universities," says Eric Dautriat, Clean Sky's executive director.

"It is far too early to speculate on the implications of the UK referendum. That will be addressed in due course, once negotiations with the UK begin [on new arrangements with the EU] . . . For the time being, nothing changes."

Helicopter projects balance speed with safety

Rotorcraft

The advantage of cutting overall journey times is often undone by limited top speeds, says *Rohit Jaggi*

The search for speed is a risky business. For rotorcraft, immutable laws of physics provide limits on the speed of a helicopter.

But a desire for faster travel remains strong, and drives development work particularly in the world of helicopters and related vehicles.

Rotorcraft — which depend on rotor blades for lift — may be able to take off and land vertically, but the advantage of cutting their passengers' overall journey times from point A to point B — without the need for airports — is often undone by limited top speeds.

The market for rotorcraft to reach offshore oil and gas rigs may have slackened in the wake of the fall in the oil price. But new designs continue to be pursued, and analysts point out that the market for emergency medical and search helicopter still has room for growth.

Military buyers, understandably excited by the idea of aircraft that are both fast and can land vertically, have funded the best-known combination of helicopter and aeroplane, the Bell-Boeing V-22 Osprey tilt-rotor. Its transition from concept to working product was costly, both in dollars and lives lost in crashes in testing, but the technology is now proven, and the V-22 has a speed capability of 275 knots (509kph).

The civilian version, the much smaller nine-seat AW609 tilt-rotor, is still in development and the timetable for first deliveries has slipped from 2007 to 2018. The project started as a collaboration between Bell of the US and Agusta of Italy, but was taken over completely in 2011 by AgustaWestland, which is now known as Leonardo Helicopters.

Much like the V-22, the project has also suffered setbacks. Preliminary findings of an inquiry into a fatal crash in Italy during high-speed testing in 2015 were released last month and indicate a conflict between pilot input and the logic of the fly-by-wire software. Leonardo has said it has a solution to the problem and has resumed flight tests.

Airbus Helicopters, the European consortium, has a more elegantly simple solution to wringing more speed out of vertical-lift craft. Its X3 technology demonstrator replaced the anti-torque tail rotor of a conventional helicopter — which stops the aircraft body turning in the opposite direction to the main rotor — with two forward-facing rotors on stubby wings alongside the cabin. The combination produced the necessary anti-torque effect, generated forward thrust and eased the workload of the main rotor by the stub wings generating lift.

The X3 set a speed record of 472kph in level flight in 2013. Last month, Airbus announced that a rotorcraft building on the X3's architecture, the LifeRCraft high-speed demonstrator, has had its initial layout validated by wind tunnel tests.

The rotorcraft's increased speed results in "less fuel and smaller noise footprint for the same mission", according to Tomasz Krysinski, head of research and innovation at Airbus Helicopters. Flight testing of a prototype could start as early as 2019.

As a project backed by a pan-European company with a substantial presence in the UK, this aircraft development could be affected by the UK referendum vote at the end of June to leave the EU. However, Airbus says that with contracts not due to be awarded until around 2020, it is too early to make any firm predictions of any Brexit fallout.

Leonardo Helicopters says it is considering development of the tilt-rotor.

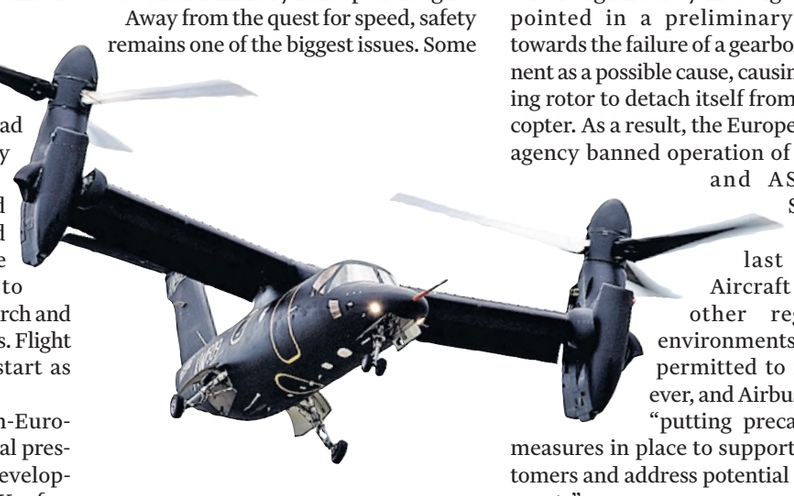
Other manufacturers have their own solutions to speed. Sikorsky of the US, bought by defence company Lockheed Martin at the end of 2015, also funded its own high-speed demonstrator, the X2. That used a rearward-facing propeller for thrust and twin coaxial, counter-rotating main rotors for lift and it achieved a speed of 460kph. The technology has been used for the company's proposed S-97 Raider military helicopter design.

Away from the quest for speed, safety remains one of the biggest issues. Some variants of an Airbus heavyweight helicopter have been grounded by regulators in the wake of the crash of a Super Puma in Norway in April, killing all 13 aboard.

Norwegian safety investigators have pointed in a preliminary finding towards the failure of a gearbox component as a possible cause, causing the lifting rotor to detach itself from the helicopter. As a result, the European safety agency banned operation of H225 LP and AS332 L2 Super Pumas last month. Aircraft in some other regulatory environments are still permitted to fly, however, and Airbus says it is "putting precautionary measures in place to support our customers and address potential initiating events".

Some North Sea operators have drafted in Sikorsky S-92 helicopters, which are a similar size, as they did after the 2012 grounding of Super Pumas. Airbus's re-engineering of a component, a bevel gear shaft, allowed the Super Pumas to return to service in 2013.

Keeping even conventional helicopters in the air means juggling competing forces such as lift and weight. Add pushing the envelope on speed, and the task becomes much more complex.



Lofty ambitions: the AW609 tilt-rotor

> Military buyers have funded the best-known combination of helicopter and aeroplane: the V-22

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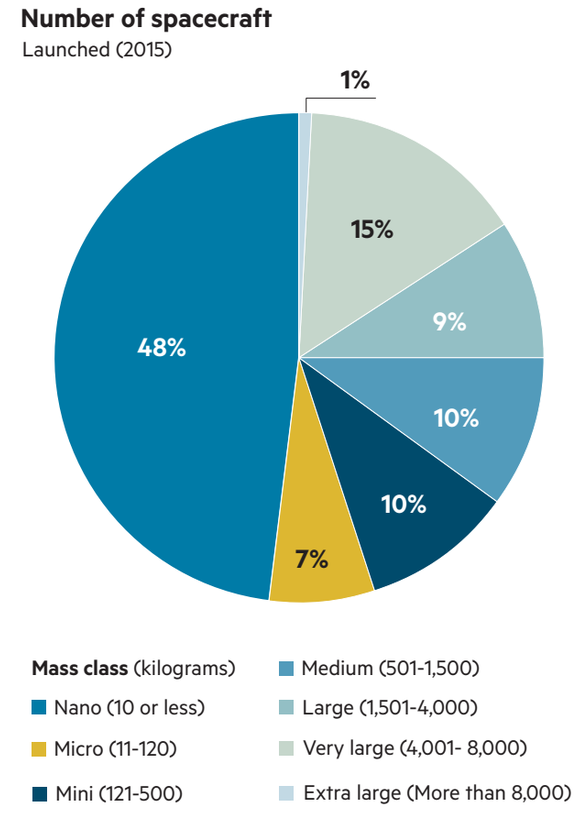
Aerospace

Nano-satellites help spread spies in the skies

Space Start-ups race to establish networks of smaller satellites, writes *Clive Cookson*

Small package: nano-satellites can offer more frequent and reliable imagery
Reuters



FT graphic Sources: Eurospace; Space Foundation

Small satellites are normally designed to operate in low orbits just a few hundred kilometres up. In contrast, geostationary orbits of 36,000km above the Earth enable satellites to maintain the same position above the equator by rotating at the same speed as Earth — a position that is advantageous for broadcasting, communications and remote sensing.

The International Space Station, in orbit 400km above Earth, is turning out to be a useful launch platform for small satellites. They are brought up in batches and later released into somewhat lower orbits where they could not collide with the ISS. The ISS deployed 49 satellites in 2015 and 36 so far this year, according to the Space Foundation. Most are launched from a special CubeSat deployment device developed by NanoRacks of the US for the ISS. "There is a tremendous backlog of small satellites waiting to be launched," says Mr Walter-Range. "For example, Rocket Lab have 18 months of solid bookings even though they haven't flown yet."

With small satellites going into space at an ever-increasing rate, there is a danger of some orbits becoming overcrowded and a risk of collisions.

"It is important to find ways of managing that environment," says Mr Martin, "but the low orbits of most satellites have the advantage that they will automatically decay and burn up in the atmosphere after a few years, without creating permanent space debris."

Small is becoming beautiful in the world of satellites. Miniaturisation of electronics and components means you no longer need to send a tonne of metal into orbit for telecommunications or Earth observation. Small satellites promise to provide more comprehensive coverage at much lower cost.

India's Polar Satellite Launch Vehicle mission last month carried 20 spacecraft into orbit. Alongside its primary load — a 727kg mapping satellite called Cartosat — the rocket carried another 19 payloads weighing a total of just 560kg between them. Twelve of these were a flock of Dove satellites from Planet Labs, a US-based Earth-imaging company.

The largest number of small satellites launched at the same time to date was the 33 sent into orbit in June 2014 by Russia's Dnepr Cluster Mission. A new record is scheduled for later this year when Sherpa, a satellite deployment system from US-based Spaceflight Industries, carries 87 small payloads into orbit for a variety of scientific and commercial customers, alongside Taiwan's large Formosat 5 satellite, on board a SpaceX Falcon 9 rocket.

Stuart Martin, chief executive of the Satellite Applications Catapult at Harwell in the UK, says there are advantages for Earth observation in going small. "By having a large number of small satellites rather than a few big ones, you can fly over the same piece of ground much more frequently to obtain images.

"A conventional constellation of satellites might take a detailed image of a particular place every week or two," he says. "Now we are talking about being able to observe everywhere on Earth every 15 minutes." That would make a big difference for monitoring crop growth or an unfolding natural disaster.

According to common industry usage, a "small satellite" has a mass below 500kg. There are various ways of classifying small satellites. One puts "mini-satellites" at between 500kg and 120kg, "micro-satellites" at 120kg and 10kg, and "nano-satellites" at below 10kg.

A term often heard in discussions of small satellites is CubeSat — a 10cm cube based on standard nano-satellite design. These modular units can effectively be packaged together in larger clusters, of up to six times their original size, which allows for efficient multiple launches.

Small satellites are not a new idea. In the late 1970s, an engineering team at the University of Surrey was a pioneer in building small, inexpensive satellites from off-the-shelf components, rather than the costly special components favoured by the aerospace industry.

The success of the 72kg UoSat-1 led the university to spin out Surrey Satellite Technology Ltd in 1985 to commercialise the technology.

Today SSTL remains an innovative small satellite developer, although it now nestles within the giant Airbus space group.

Small satellites, meanwhile, have moved from being a niche sector for research and special missions, such as disaster monitoring, and into the industrial mainstream.

There are two very different ways of looking at the penetration of small satellites into the market — by number launched and by mass — says Micah Walter-Range, director of research and analysis of the Colorado-based Space Foundation.

In 2015, 262 spacecraft were launched, of which 64 per cent fell into the small category and 48 per cent were nano-satellites below 10kg. But by mass, small satellites accounted for just 2 per cent.

Several companies based in the US are developing innovative schemes involving global networks of small satellites for communications or Earth observation. OneWeb plans to have 648 satellites weighing 150kg each, circling the world to provide worldwide affordable internet and mobile telecoms. Planet Labs is establishing a similar network of more than 100 satellites to image the world for applications from agriculture and forestry to energy and mining.

> 'We are talking about being able to observe everywhere on Earth every 15 minutes'

Robots at work let humans do more creative jobs

Automation

Increasing demand is driving the need for efficiency gains, but machines cannot do it all, writes *Ross Tieman*

It may be the 21st century, but an aircraft final assembly line still has many hallmarks of a cottage industry. Workers use hand-tools to connect assemblies and fit wiring and components in a process that seems to have changed little since the 1940s.

But soaring demand for aircraft and production volumes are beginning to offer opportunities for efficiency gains through automation that have eluded much of the aerospace industry for half a century.

Robots are making their debut at both Airbus and Boeing and at their suppliers. By the end of May, Airbus had secured 4,568 orders for its upgraded A320neo family of short-haul airliners. Strong demand underpins plans to raise output from 40 a month in 2016 to 60 a month by 2019. And after building just nine big A350 twin-jets in the first half of this year, the European company's Toulouse plant aims to turn out 10 a month by the end of 2018.

It is a similar story at Boeing, where bulging order books are driving adoption of robots to help assemble the 737 Max short-haul plane and its impending big sister, the 777X.

In the supply chain, Pratt & Whitney (P&W) has developed a new kind of jet engine, a geared turbofan, which will power many of the single-aisle aircraft and their rivals from Canada, Russia, Brazil and Japan.

Greg Gernhardt, president of commercial engines programmes at P&W, expects annual output of this engine to multiply sixfold to 1,200 motors by 2020. That will probably be the highest production rate since P&W was turning out its Wasp piston engine in the second world war, he says.

The airframes of the latest airliners, notably the B787 and A350, make extensive use of composite materials, prized for their strength and lightness. Manufacturers such as GKN Aerospace make extensive use of robots to produce these in sufficient volumes and to the required accuracy and consistency.

At the company's Bristol plant in the UK, automated fibre placement machines lay the carbon fibres of the 27 metre rear wing spar. Automated guided vehicles carry wing structures through dedicated work stations for machining and drilling by robots. On other assemblies, the company has also introduced robots for tasks such as welding and installing fasteners.

Chris Gear, chief technology officer at GKN Aerospace, says the use of robotics is becoming more prevalent "to meet demands for increased rates of production along with even finer manufacturing tolerances and higher levels of consistency".

As aircraft production rises, investments that make sense for suppliers increasingly make sense for aircraft makers too. Kuka Robotics, in Augsburg, Germany, has been developing some of its robots for aerospace applications for more than a decade. Its platforms are used to position aerostructures and tools. Its robots work on drilling, riveting, polishing, welding and fuselage assembly.

> Investments that make sense for suppliers also do so for aircraft makers

At Boeing they are used to drill and rivet fuselage sections together, reducing the need for workers to undertake tedious repetitive tasks that can cause injuries. The US aerospace group has installed an automated robotic production line from Kuka at its Everett plant in Washington state to assemble fuselage sections of its 777 twin-aisle aeroplane.

The robots work concurrently, one inside the fuselage and one outside, to drill and countersink holes, insert the tens of thousands of fasteners, and complete the riveting. Other robots are used for spray painting.

Wolfgang Meisen, a spokesman at Kuka, says that automation is not necessarily driven by costs. Rather, robots can undertake harmful, strenuous or dangerous jobs that require high precision. That frees humans "to focus on tasks the human is much better at due to his or her extreme flexibility, cognitive abilities, adaptability and ability to make decisions".

The development of the internet of things is expected to accelerate the use of robots as machines communicate more with each other, and become more mobile. Airbus is working with researchers in France and Japan to develop collaborative robots, or cobots, to work alongside assembly staff. A French supplier, Daher, has been experimenting with the use of exoskeletons to augment the muscles of employees engaged in physically demanding tasks.

Another more radical idea is to "3D print" aircraft assemblies and components where they are needed, using a cluster of robots to build awkward shapes or one-off items.

Some fear staff may lose their jobs, but Mr Meisen notes: "If you look at the three countries with the highest density of robots — Japan, Germany and South Korea — those three also rank among the countries with the lowest unemployment rates worldwide. The rise in robotics goes along with innovation, productivity and economic success."

GKN's Mr Gear says that "use of robots is creating new types of jobs focused on their effective maintenance, which is vital to consistent and sustained production levels".

Robots, it seems, can be almost as challenging to manage as their human counterparts. And that makes companies think before swapping an expensive robot for a flexible human. "Where maintenance, repair and overhaul of state of the art robotic technology is not practicable, robotics may not be an effective solution," says Mr Gear.

Rising demand: robots take on tasks