THE FUTURE OF FLIGHT

2020

The four cornerstones of space-enabled UAM

Composites and their impact on MRO operations

Using technology to help reboot aviation in a COVID-19 world

ATKINS

Member of the SNC-Lavalin Group

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Foreword

These are difficult times. And there has never been a more difficult time for the aerospace industry. But out of adversity will arise a new vision for future prosperity, with the UK's advanced engineering capability at the heart of leading the aerospace industry's transformation.

With a deep heritage in aerospace and world-class digital and science capabilities, the UK industry is well placed to provide the innovative, collaborative driving force needed to tackle the grand challenges of a post COVID-19 world, net zero and sustainability.

In this magazine, we've explored some related hot topics, ranging urban air mobility, advanced material applications, next generation fuels, the criticality of taking cyber security seriously, as well as some of the immediate challenges of returning aircraft to the skies. So, read on and enjoy! We're certainly inspired to play our part in shaping the future of aerospace and keen to collaborate with you – please do get in touch to start the conversation.

Julian Fielden-Page
Head of Services,
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Julian leads Atkins' A&D Industry business and has extensive international experience helping OEM and tier-1 Aerospace and Defence companies with their most challenging business and digital transformation agendas. He is a trusted Board level advisor and leading practitioner in complex operating models, operational excellence and delivery of change.

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Working with the aerospace, defence and security markets, Jessica is responsible for raising the profile of Atkins and its experts across a range of external platforms, from press interviews and magazine articles to news announcements and social media.

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Practice Director for Advance Engineering and Technology

Andrew has 20 years of experience working in the aerospace, nuclear and rail domains. He currently leads our engineering capability that is focused on the Aerospace and Defence markets. Urban Air Mobility is becoming increasingly important as an area of focus, as it knits together our expertise across aviation and city infrastructure, transportation, civil aerospace and intelligent mobility.

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Andrew is a chartered aerospace engineer and a project manager, delivering structural analysis of composite and metallic structures across the aerospace, defence and energy industries. He leads business development for our Space Industry customers across the UK, and also for Aerospace and Defence Industry customers in Scotland.

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James is an aerospace engineering consultant at Atkins, focused on helping clients unlock the potential of the emerging Urban Air Mobility market. James looks across multiple disciplines and sectors to drive a system of systems approach to the new eco-system required beyond platform development to ensure successful integration and scalability.

Tim Edwards
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Tim has 40 years' experience as a stress and vibration engineer – principally in the aerospace industry working for British Aerospace, Astrium and Rolls Royce, but also in the rail, nuclear and defence sectors. He has a strong interest in advanced materials, having taken a leading role in the design and certification of the Airbus A400M composite wing and being actively involved in developments in the assessment of composite bonded repairs.

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James Domone is a senior engineer in aerospace design, security and technology for Atkins, a member of the SNC-Lavalin Group that is working to transform aerospace engineering for faster design, reduced downtime, and lower costs.

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Over the last 15 years Andy has worked with airports, airlines and the wider aviation industry to specify, develop, deliver and support passenger automation solutions. A former software developer and operational analyst, he is a certified SCRUM Product Owner, TOGAF Enterprise Architect and Project Manager. A member of the Biometrics Institute, Andy specialises in the application of biometrics and identity management.

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Claire graduated from Glasgow University with a BEng (Hons) in Aeronautical Engineering in 2000. Since then she's worked for various aerospace companies including BAE Systems and Lockheed Martin, focusing on fatigue of aircraft structures. Having joined Atkins in 2009, Claire now works as a Team Leader for our Advanced Engineering team and a technical specialist on fatigue and damage tolerance.

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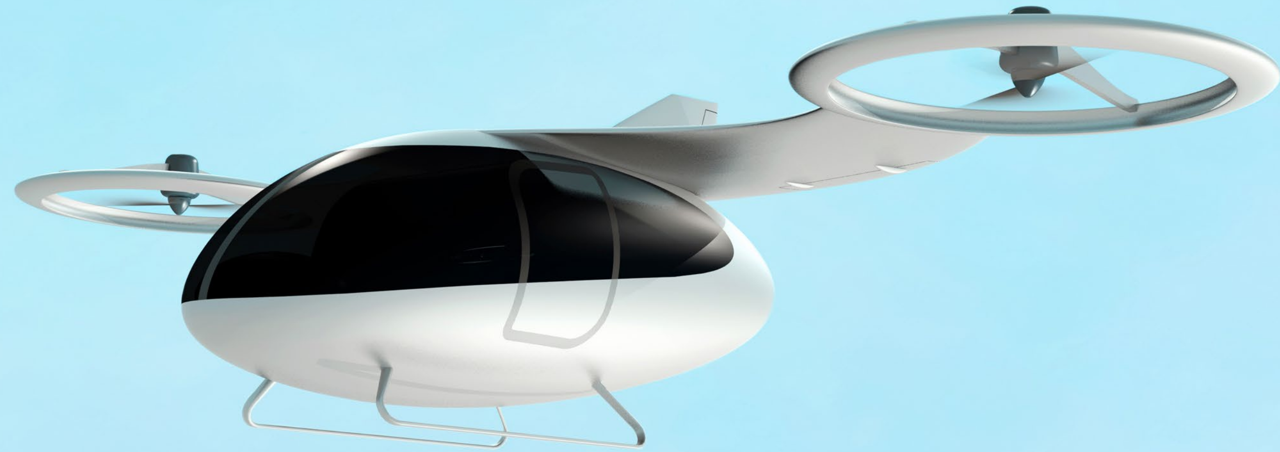
Matt has over 20 years' experience in System Engineering, Technical Assurances and Cyber Security. He provides C-Level subject matter advice to key clients on variety of topics including transport security, safety system assurance, secure SCADA architecture and Internet of Things. Matt's previously worked with the UK Government and the academic sector to produce global standards and guidance in the field of cyber security and smart infrastructure.

Unlocking the third dimension in transportation

Right now, across the globe, almost 200 companies are working on electrically powered, vertical take-off and landing (e-VTOL) flying machines. They range from inventors with rendered images seeking angel investors, to major aerospace manufacturers developing concepts and service models to address both the opportunity and the threat of the new urban air mobility market.



Behind this activity are bold claims about the future for the market, with Morgan Stanley putting the potential market size at $1.5trillion by 2039. This market – Urban air mobility – is all about the use of flying vehicles to transport people into, out of and across a city, usually as an integrated part of the ground based transport service. The concept itself is nothing new. The invention of the helicopter generated the first round of hype in urban air mobility, opening up for the first time the potential to fly into the heart of an urban area. In the 1960s you could take a helicopter from the top of the Pan Am skyscraper to any of the city's airports, with 48 flights a day and a trip costing no more than $6 ($43 at 2019 prices). Today, in many of today's megacities including Sao Paulo, New Delhi and New York, helicopters are still being used to circumnavigate the gridlock on the ground, albeit now enhanced by the technology offered by transport apps such as Uber.

Andrew Munday
Practice Director for
Advanced Engineering

The exponential increase in the investment into urban air mobility has been driven by three key factors. Firstly, the increasing urbanisation of our societies (expected to be 68% of the world's population by 2050 according to the UN) is leading to ever increasing congestion and pollution in our cities. Secondly, the incredible advances in computing processing power and the advent of 'the cloud' have unlocked the potential of artificial intelligence to enable much more complex and integrated transportation service models. And thirdly, advances in distributed electrical propulsion, battery capacity and highly automated flight controls are enabling a new breed of aircraft that can take off vertically like a helicopter and fly horizontally like a plane using cheap, clean and quiet electric propulsion – with all of the complexity of flight dynamics handled by the automated control systems. So, the problem statement is powerful and the potential solution compelling. Added to that, some of the simpler e-VTOL aircraft are reaching maturity, with demonstration flights already being carried out – notably by Volocopter who have flown in Dubai, Stuttgart and at Helsinki airport.

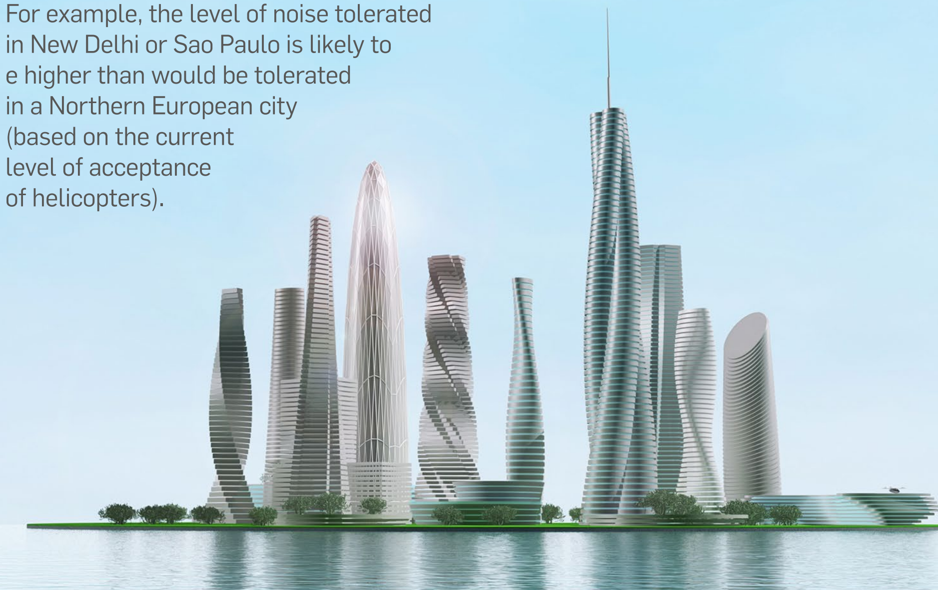
However, some big hurdles need to be resolved before vehicles can enter any kind of operational service. One of these is the battery, which is the main limiting factor on vehicle performance. Whilst there are numerous claims made about the range the different vehicles can achieve, what is clear is that the capacity to weight ratio is at best borderline adequate for the shortest distances and at worst still a number of years of development away from being truly viable.

Another hurdle is e-VTOL certification. Both the European and American regulatory bodies (EASA and the FAA respectively) have made significant progress in publishing draft regulations, but there are still no certified vehicles. Once this begins, I expect that operation of e-VTOL aircraft will commence in a similar manner to the current helicopter – i.e. using existing air traffic management technology and flying along existing routes. By operating within the existing air traffic management framework, we have the potential to get back to the kind of services that began in the 1960s. And it is at this point that I believe we'll discover if this new market is going to fully establish itself.

Looking back at the New York helicopter flights of the 60s, we can learn a valuable lesson. Operations were halted twice, and neither time because of feasibility or lack of demand. Instead, the first halt came because people living in the city (particularly near the landing sites) became painfully aware of just how noisy the helicopters were, and so formed a protest group and had flights banned. Undeterred, New York Airlines sourced a quieter helicopter and, years later, restarted operations. But on May 16th 1977, tragedy struck when the landing gear of a helicopter failed, causing the spinning rotors to strike the ground, break off and head straight into the line of waiting passengers – before falling off the roof and landing on a passer-by, 59 floors below. The service never restarted. So whilst you need the technology and regulations in place to make the concepts possible, and a high demand to create the business case, the critical hurdle is going to be whether the public will permit urban air mobility in their neighbourhoods. I consider this to be the biggest challenge facing this new industry, not because I don't consider it to be possible, but because it's the last one we will face and it's the most fragile.

The other hurdles are relatively binary (you either have certification or you don't; the vehicle can either fly a certain distance or it can't). But public acceptance can change overnight. And the public is extremely unaccepting of new technology when it causes death, even if it's an order of magnitude safer than what it replaces – as evidenced by the amount of publicity Tesla receives when its self-driving vehicles lead to a fatality. And when an accident does occur, the damage is widespread, with all players tarred with the same brush, whether or not they have the same issues. To add further complication to this hurdle, different societies will place different demands on the new service. For example, the level of noise tolerated in New Delhi or Sao Paulo is likely to e higher than would be tolerated in a Northern European city (based on the current level of acceptance of helicopters).

Given the criticality of public acceptance to the success of this market, engaging with the public to understand what will and will not be tolerated by society will enable us to greatly derisk the return on the investments that are currently being made. It will lead to user-centric design and a solution that is more likely to have a long-term future. It is clearly the case that the technology and regulation development focus needs to continue, but history teaches us that if we want to increase the chances of this new technology being successfully adopted, the public engagement needs to begin now.



The four cornerstones of space-enabled Urban Air Mobility

The industries surrounding UAM and space share several similarities. Both exist within a rapidly evolving technological environment and players in both domains are using the power of partnership to remain competitive, with some of the more traditional, established organisations seeking collaborations and investing in start-ups and early stage new entrants into the market.

Given their similarities, there are a vast number of opportunities for collaboration between the UAM and space sectors. And with decades of experience to rely on, space will undoubtedly be a crucial enabler for the UAM landscape of tomorrow.

In particular, there are four key areas where urban air mobility could build on the groundwork laid by the space sector.

Satellite communications

Satellites are already being used in the development of 5G communications, thanks to their ability to connect more remote or challenging geographies. Likewise, it could be used to enable two-way communication between ATM and UAM vehicle operators, their pilots and passengers. Beyond that, satellites have potential in machine-to-machine communications – there are already well-established aircraft health monitoring systems that rely on this method, such as the Rolls-Royce engine monitoring system.

Vehicle health monitoring enables in-flight data to be regularly communicated securely to operators and original equipment manufacturers, to provide alerts for in-flight equipment failures, to enable rapid troubleshooting and for predictive maintenance activities. Thinking about the physical infrastructure which supports UAM, satellite communications could enable remote management. For example, sensors could be embedded in facilities to indicate fuel stores, security status and the number of available parking spots.

Earth Observation

Earth observation capabilities, such as monitoring weather and high-resolution satellite imagery of fixed infrastructure assets can also play a role in optimising flight operations and maintaining the wider infrastructure that supports UAM. If weather and navigation data can be dynamically evaluated, routes could be automatically recalculated to achieve optimum passenger comfort or increase efficiency by responding to adverse wind.

Meanwhile, satellite imaging can be used to perform remote inspections, and combined with interferometric synthetic aperture radar (InSAR) to detect changes in surface deformation or movement of buildings due to the complex interactions of the urban environment, such as major construction adjacent to a launch and landing site. This will be particularly useful as the number of UAM sites increases, by reducing the need for physical surveying and inspection at numerous locations or remote vertiports.

Satellite navigation

Satellite navigation is likely to be the most widely exploited intersection between the space and UAM industries.

Automatic Dependent Surveillance-Broadcast (ADS-B) tracking of aircraft is widely adopted across the aviation sector and is increasingly mandated by the regulatory authorities. ADS-B tracking takes aircraft position data, acquired by Global Navigation Satellite Systems, and combines this with other operational data from the aircraft flight control systems.

This data is then broadcast to the local Air Traffic Management (ATM) services, enabling detailed situational and positional awareness in close to real-time.

In the future, UAM operations may cover geographies that aren't enabled for ADS-B or where there are no existing ATM services. Space-based ADS-B removes the need for ground stations, with information communicated using satellite networks instead. It can also operate at any altitude once a connection has been established, while conventional systems have specified ranges of operating altitude. In short, it has the potential to transform current ATM operations – which rely on defined flight plans, flight paths and conventional radio-based tracking systems to establish aircraft position. This may be a key enabler of fully integrated airspace for UAM.

Advanced Engineering

Beyond the technology, advanced engineering capabilities are an area ripe for collaboration. For instance, there is a long heritage of novel materials development in the space industry, driven by the need to operate in harsh environments and with mass being a mission-critical design aspect. For UAM, mass is also key to managing operating cost, as a lighter aircraft should draw a lower demand on power and propulsion systems. Composites remain a costly solution from an engineering perspective, as they can be challenging to manufacture to the standards required by regulators, and usually involve significant design input compared to metallics.

With the increase in the number of players in the new space industry, are there any innovative solutions which provide composite structures to the necessary standards at a competitive cost?

There are similar opportunities to consider around through-life sustainability of vehicles, asset management, human factors, command and control, artificial intelligence and big data analytics – it's clear that the advanced engineering skillsets employed across both industries are seeking to solve similar problems.

Mutual benefits of collaboration

As the newer of the two industries, there are multiple opportunities for UAM to learn from the ways of space. But the benefits for the space industry are also worth highlighting: the UAM industry remains in its formative stages and being able to get in front of the development of full regulations with flight-proven and trusted solutions such as space-enabled ADS-B may help shape these standards for years to come.

Maximising the opportunities to collaborate will require activity on several fronts – sharing of ideas across industries, Government-led grand challenges which enable both sectors to showcase their capabilities, and working with trusted third-party advisers who understand the breadth and depth of both domains.

Andrew Caughey
Business Development Lead,
Space Industry

MRO: A forgotten barrier to UAM

What was once a dream – the reality of aviation at large within our cities – seems closer than ever. Forming a core piece in the puzzle, the global race is on to develop a suitable vehicle platform; one that uses a green fuel source, is safe efficient and, certainly by aerospace standards, available at scale.

The realisation of this vision isn't without its significant challenges, from certification and logistics to social acceptance. That said, with the coalescing of new technologies, financial stimulus and fresh approaches by regulatory bodies, estimates of first commercial services start as early as 2023. Don't go telling your friends just yet though; the viability and sustainability of this novel urban transportation system rests on the ability to scale the solution to a point where load factors and utilisation can satisfy any prudent financial director.

A strong dependency on utilisation isn't new to the aerospace industry and we've worked hard to increase the utilisation of assets for decades. Significant improvements have largely come from better design, planning and execution of Maintenance, Repair and Overhaul (MRO) operations. But what about MRO within urban air mobility (UAM)? With so much focus on making UAM a reality, is MRO and the aftermarket an afterthought? The solution? Plan now and plan together. An effective aftermarket cannot be overlooked and the key to enabling it lies in three main areas.

James Richmond
Senior Engineer

Vehicle Design Enabled Solutions

Maintenance procedures and philosophies have developed considerably over the past 60 years. The basic approach for early operators was a time-based overhaul of components and systems. The overarching assumption being that mechanical parts wear out over time, and that the reliability of any given component was inversely proportional to its safe operating life. This 'Hard Time' approach doesn't consider the actual condition of components and therefore leads to natural inefficiencies and wasted time on the ground. With enhanced design for inspection and greater use of failure indicators, 'On-Condition' approaches were developed, leading to increased levels of acceptable operational reliability.

To maximise utilisation in a new era of aviation however, we must do more and embrace new technologies as well as new philosophies. The development of embedded sensors, for example, in both the aerospace and adjacent industries such as Formula One, provides greater real-time conditional monitoring, beyond what we use today.

Coupled with the right data infrastructure, in addition to performance and safety benefits, this can significantly decrease the need for wasted inspection. Furthermore, with the application of machine learning and AI, complex trends in maintenance events could be identified, factoring in typical mission profiles or operating environment. A natural conclusion of this is a true digital twin of each operating asset; fed with the data of each component's configuration, history and current condition. Combined effectively with a high degree of modularity, it could radically change the way we view and schedule MRO operations.

Whilst this may be a non-trivial solution, vehicle platforms considering this early in their lifecycle could reap the rewards of a scalable solution favoured by operators over an early entrant without the longevity to thrive in this highly competitive market.

Digital Tools

Whilst increased levels of vehicle automation may go some way to counter the increased demand for pilots, the same can't necessarily be said for skilled personnel given the task of safely maintaining large fleets of aircraft above our cities. The availability of suitably qualified engineers and technicians to perform maintenance present a blocker to the high utilisation required.

A leaner, more centralised approach to damage inspection and triage may provide an answer - and digital tools are at the heart of this.

The toolbox of the future will certainly contain more 1s and 0s and the ability to remotely do and share work will reduce the need for eyes on the apron. Digital maintenance aids are already being used in the aerospace industry and we must scale this to realise their full potential.

They will need to be integrated into vehicles to become the primary source of truth rather than the reliance on the human interface we have today. The ability to scan a damaged structure, for instance, and for it to be characterised digitally, allows for remote or even automated assessment. With the right digital tools to hand, centralised engineers can do the initial assessments, meaning a more focussed workforce to be efficiently deployed on the ground. These assessments also leave digital footprints, which provide input into the aforementioned digital twins. Combined with increasingly affordable virtual and augmented reality tools, it's easy to see how remote 'digital hangars' may be a key competent to the UAM system and will inform new operating models for MRO organisations.

MRO Infrastructure

Aircraft hangars, serving both line and base maintenance requirements, are commonplace at airports today. But this infrastructure solution doesn't necessarily work in an urban context, especially for those longer base maintenance related checks. There will be a clear correlation between cities where UAM could offer maximum benefit and those with the biggest premium and constraints on urban real estate. The limitations on urban space will strongly influence the configuration of a UAM facility and will therefore limit the type of maintenance activity available to operators.

From simple operational pads to stations and hubs, vehicle and infrastructure operators will need to carefully consider the movements between each to maximise maintenance planning. With space at a premium, having a vehicle held at the wrong place at the wrong time is a sure way to impact the high utilisation that underpins the UAM business model. Therefore, whilst infrastructure providers scramble to understand constraints set by high density movements and battery charging, it's important to consider where vehicles may undergo line and base maintenance activities and how this will influence both the design of the infrastructure and the vehicle.

The MRO requirements placed on infrastructure providers will be informed through a tightly coupled development with vehicle OEMs and operators. Like many aspects of UAM, this early collaboration is key to bringing to bear a winning platform and viable wider eco-system.

The Time is Now

It's fair to assume that electric propulsion will inherently present us with less complex and fewer mechanical issues than conventional means. But regardless of this, a vehicle's reliability, safety and airworthiness will remain at the centre of any aviation system, meaning MRO will be a key component. To meet the high utilisation targets that scalable UAM will demand, it must be done as effectively and efficiently as possible. Few of the options explored here are beyond the technological limitations of today, but all will require close collaboration between key stakeholders to create this new aviation system. Above all, this collaboration must happen early in the development of all aspects, signalling the way for a system-of-systems approach. For no matter how low initial movements may be, solutions that cannot be scaled to create a totally viable system will stop us from realising the great benefits that lie ahead.

Composites and their impact on MRO operations

Liam Bailey, Head of Design Organisation, speaks with Tim Edwards, Head of Engineering in Aerospace.

Operational readiness is central for commercial and military aircraft. Advances in the reliability of aero-engines, aero-systems and avionics, and improved diagnostic capability have, over 50 years, transformed availability. Structural damage remains, however, a potent hazard for contiguous operation, and its rapid detection, assessment and repair are vital components of an effective maintenance, repair and overhaul (MRO) operation.

LIAM: How do you think the environmental challenges facing civil aerospace and the introduction of military unmanned aerial vehicles changes the outlook for MRO operatives like ourselves?

TIM: Well, the business of repairing damaged aircraft and components is well established, but composite materials are emerging as the right solution for lightweight and efficient aerospace structures. Nowadays a significant proportion of an aircraft's primary structure incorporates composites, where tailored strength and stiffness characteristics satisfy the performance demands now being made of civil and military aircraft. MROs must accommodate this shift in the future.

LIAM: That's the biggest change I see, too. When metallic aircraft structure is damaged, a repair requires the defect to be removed and a doubler "patch" bolted on to restore the original strength: pretty straightforward when the damage is within the limits of a Structural Repair Manual (SRM). For composite structures, bolted repairs are far from ideal as load is not redistributed readily across the fasteners.

TIM: Quite true: there are three key challenges to repairing a composite structure over a metallic equivalent. The first is to identify the damage: composite aircraft damage can be almost undetectable by visual inspection, so you need periodic, non-destructive inspection. The second is the need to understand the underlying strength and stiffness of the original structure: ideally through reference to the Original Equipment Manufacturer's data. The third challenge is the environment in which the repair is undertaken. The form and quality of the composite repair (wet lay-up, pre-preg, pre-cured), tooling, cure process and installation environment (humidity, temperature and contamination) all influence the repair effectiveness and, currently, there are no reliable NDI techniques to confirm a bonded assembly's full strength: testing a bond's strength means destroying it.

LIAM: What about the airworthiness requirements that demand consideration of loss of a bonded repair? Doesn't that scupper bonded solutions for composite primary structure?

TIM: Oh, yes: a fourth challenge! How do you propose we overcome that difficulty: certificating a fuel tank boundary or a pressurised fuselage panel with an open hole?

LIAM: Well, during our recent campaign to gain Design Organisation Approval, I gave composite repair some thought. One thing we must do is incorporate web-based, remote damage assessments that allow rapid development of a repair procedure. This allows round-the-clock, worldwide support, to airlines and the military alike. Also, automation is critical in minimising out-of-service time and maximising repair longevity, from enabling overnight analysis to embracing automated ply-cutting techniques and lay-up and curing cycles to remove process variability. This ability to assess damage, develop repair solutions and minimise process variability is key to reducing time on the ground. Still, though, the CS 25.571 requirement on bonded repairs must be addressed.

TIM: It's a sticking point, Liam, but scarfed, bonded repairs are unreliable, so it's understandable. My own view is that primary structure bonded repairs will become a reality once 100% reliability has been established, but we're some way off that.

LIAM: I've seen technology that allows plies - or groups of plies - to be machined away using a water jet, allowing repair joints to be built up in steps rather than a scarf joint. Is this approach not much more likely to produce a reliable and compact repair than a scarf joint? Have you seen this technology?

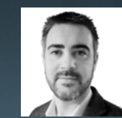
TIM: Indeed, and I think the stepped lap repair is the basis for much more reliable and compact bonded repairs then scarfed joints for which 50:1 ramp-rates are the order of the day. The technology can't be demonstrated on primary structure in the short term, however, because of that requirement on a missing repair.

LIAM: Trouble is, it's fine having exotic repair equipment, but any primary structure repair must be substantiated and that represents a big deal at present. I've seen finite element models of bonded lap repairs and their complexity is enough to make hardened analysts pale with fear!

TIM: Yes, although the building blocks of substantiation are under development, as you know. But addressing the complexity of bonded composite repairs requires cooperation between manufacturers, operators, MROs and academia. Much greater accessibility of design data and distributed availability of equipment to diagnose and remove damage and effect repair will be needed, as well as more sophisticated design analysis tools...

LIAM: ...and robust procedures for proving the integrity of the final repair, which includes demonstrating fatigue integrity – something often forgotten with bonded composite repairs. But the rewards for solving the issues will be transformative.

TIM: Growth in the aviation industry coupled with an increasing demand to reduce carbon footprints will only increase the volume of composite aerostructures in the market, so the demand for effective repair strategies for these products can only increase.



Liam Bailey
Head of Design Organisation

Tim Edwards
Head of Engineering, Aerospace

Composite aerostructures in a changing world

The goal of achieving zero net CO_2 emissions by 2050 as laid out in the Climate Change Act of 2019 is one that severely challenges aerospace engineers.

As David MacKay says, in his book Sustainable Energy – without the hot air, 2009, "planes have been fantastically optimised – there is no prospect of significant improvements in their efficiency of 0.4kWhr/tonne-km." If supporting evidence for Sir David's view were needed, it is surely that the two best-selling airliners in 2019, the Boeing 737 and the Airbus A320 family, were designed respectively 55 and 35 years ago.

Adding fuel to the proverbial flame, demand for air travel is also expected to rise. So how can aerospace engineers improve aircraft efficiency – which is already believed to be optimised – to support the net zero goal?

The Key Challenges

MacKay's view can be evidenced when considering the sources of aircraft inefficiencies: wasted kinetic energy of the air in the wake of an aircraft. Propulsion requires air to be pushed backwards, lift requires it to be pushed down, and speed causes it to be pulled forward; energy loss is unavoidable.

Structural engineering has a major role to play in the war against wasted energy. The main challenges include:

- Lowering drag
- Reduced component weight
- More efficient propulsion

Weight

Weight has always been of paramount concern to aero-structures engineers who select high strength/weight ratio materials to meet payload/range and "hot and high"/short runway performance requirements. Any reduction in airframe weight provides relief to energy consumption.

Composite materials utilising carbon fibres embedded in an epoxy or thermoplastic matrix (carbon fibre reinforced plastic, CFRP), trump the more popular aluminium alloys for both strength/weight and density, whilst their immunity to fatigue gives them a significant advantage. However, their adoption, in the form of laminates of multiple layers, has taken 30 years to progress from introduction on local structure in the A310 in 1980 to use throughout the whole airframe of today's Boeing 787 and Airbus A350. This cautious adoption of new materials has been a product of issues such as manufacturing cost, and resistance to lightning strike and impact damage, which have taken time to resolve.

There remains much potential for CFRP to be released.

Drag Reduction

Lowering aircraft speed strongly reduces parasitic drag, but there is no societal or commercial incentive to do so. Designers and engineers are therefore turning their attention towards smoothing aero-surfaces and reducing leading-edge sweep to encourage laminar flow, which offers total drag reductions of up to 15%.

Bonded composite structures lend themselves to laminar flow, as even countersunk fastener heads used in metallic assembly 'trip' laminar boundary layers to become turbulent. Composite fabrication eliminates joints; superbly illustrated by the Boeing 787 fuselage with its tape-wound barrel that removes all but a handful of circumferential joints.

Leading-edge sweep is a further destructive influence on laminar flow, caused by streamline cross-flow, which encourages turbulence. However, forward swept wings, as exemplified in the 1980s by Grumman's X29 demonstrator, allow a leading-edge sweep that is reduced compared to that of the wing overall. The X29 wing used aero-elastic tailoring to address the issue of a divergent bending moment, which arises when up-bending increases the incidence of the aerofoil to the flow, magnifying the up-bend load.

Grumman solved this using composite laminates in the wing skins that strained in shear when subject to direct stress, causing the wing tip to twist nose-down when an up-bend load was applied. This novel application of composite materials is now being explored by airliner manufacturers in their design of large-span, forward-swept wings.

Lift Efficiency

Although lift-induced drag is the lesser of the two cruise-drag components, it is in this arena that the airframe structural engineer can contribute most: notably by use of low-weight materials and processes that remove design features that constrained designers of previous generations. Composite materials have given the engineer a low-density, high-strength medium with which to work, allowing greater design freedom through, for example, aero-elastic tailoring to moderate air loads.

Concepts for future airliner design often incorporate very large wing spans of slender planform to reduce lift-induced drag and extend natural laminar flow. These features challenge the structures engineer because the long, flexible wing is more susceptible to dynamic instability (flutter), whilst the increased bending moment towards the wing root – exacerbated by the move of engines from the wing to the fuselage – demands heavier wing structure inboard.

A well-established and proven counterpoint to these concepts is the bi-plane. This eliminates the increase in bending moment and, by means of a winglet conjoining the adjacent wing tips, suppresses dynamic instability. This winglet could house a wing warping mechanism to control the aircraft: a highly efficient feature dating from the birth of powered flight.

The Future of Aerostructures

Aircraft structural engineers have a big role to play in the challenges to come. With gains from improved propulsive efficiency diminishing and current battery technology currently an inadequate power source, engineers will need to squeeze every kg from the airframe and engines; smoothen aero-surfaces to promote laminar flow; and tailor structures to match the demands of unconventional aeroplane shapes. The question is, will the efficiencies that arise from the use of composites be enough?

Tim Edwards
Head of Engineering, Aerospace

Fuelling the future: towards sustainable aviation

While the COVID-19 pandemic has brought an abrupt decline in air travel, it's likely this will only be a temporary blip; we know that growth in the aviation sector over the last 50 years has proven extremely resilient to disruption such as 9/11 and the financial crash in 2008, making a swift recovery from both. So, if and when things return to normal, what role does fuel play in the aviation sector's response to the 2050 carbon net zero target, and the future beyond?

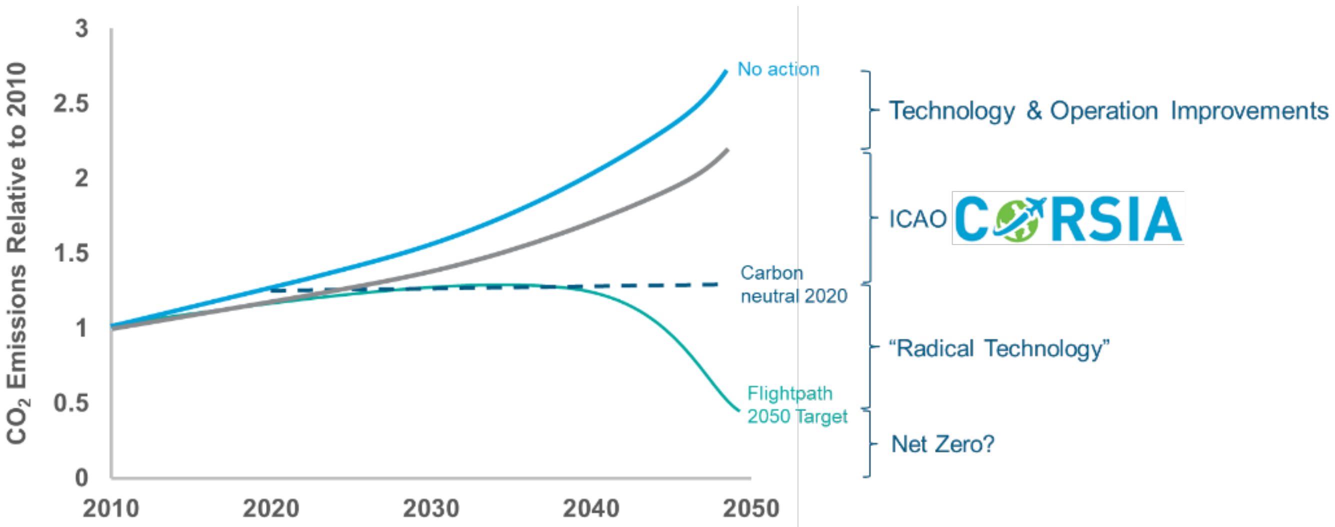
New technologies and new operations

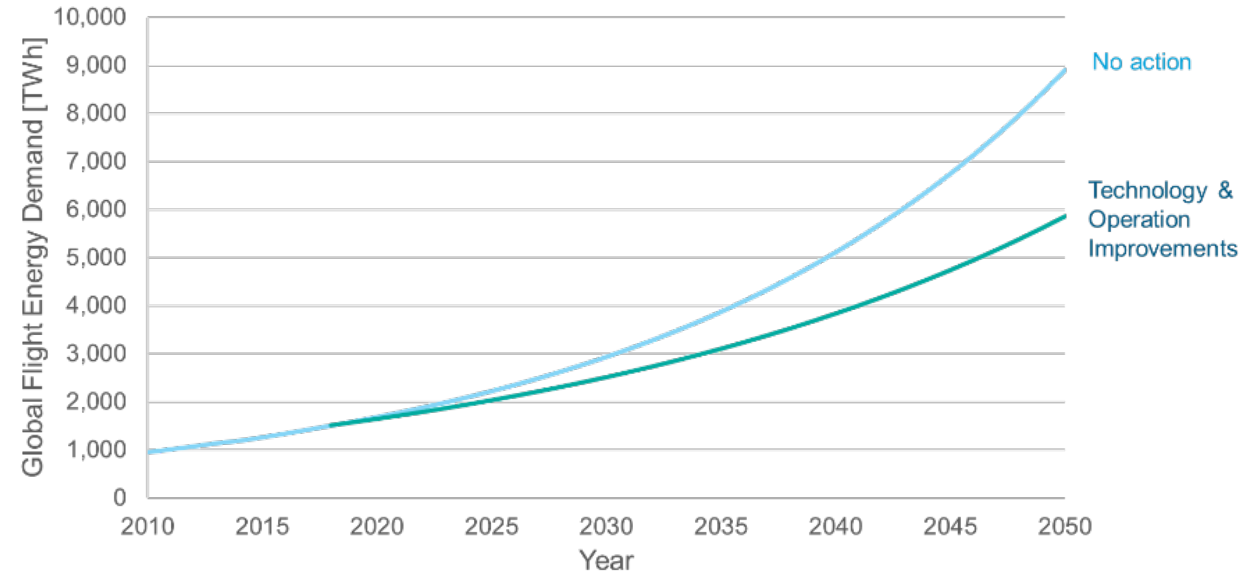
Developing new technologies and optimising existing aircraft operations are forecast to reduce CO2 emissions by around 1.5% per year. Simultaneously, the International Civil Aviation Organisation is now implementing its carbon offsetting and reduction scheme for international aviation, CORSIA, to support the use of sustainable aviation fuel. CORSIA is also aimed at providing a consistent approach to apply market-based-measures to achieve 2020 CO2 neutral growth.

But past this point there isn't a definitive answer to further reducing CO2 and many different bodies are suggesting different means to achieve it. But let's be clear: nobody has set themselves a challenge of achieving net zero CO2 emissions by 2050 – and that's where we should be aiming.

When we investigate ways to reduce emissions, while current activity is perfectly laudable, the aviation industry must be more ambitious and start targeting net zero. But where to start?

First, rather than looking at the forecasted CO2 emissions, we should be looking at the amount of energy required: that is, getting around 6,000 Terawatt-hours (TWh), stored, portable, energy into aeroplanes to sustain our demand for flying. For comparison, the total global energy supply in 2017 was 162,000 TW. Please refer to the graph at the top of the opposite page.





Hydrogen, batteries and sustainable fuel

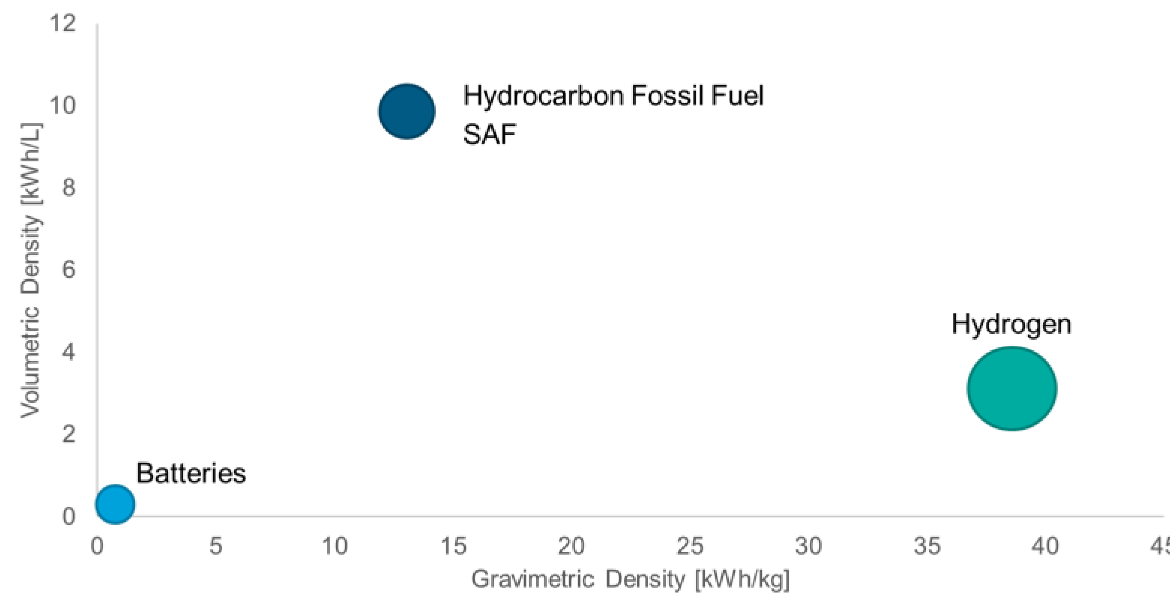
There are three proposals for storing energy needed for flight while achieving net-zero emissions: hydrogen, battery power, and sustainable aviation fuel. When looking at different energy storage options, a good starting place is to focus on relative densities.

First, sustainable aviation fuel is required by airworthiness authorities to have the same properties as traditional hydrocarbon fossil fuels, and therefore appears in the same location in the graph shown below.

Second, batteries are gaining prominence as their performance improves, mainly down to development targeting the automotive sector.

However, even for the most optimistic forecasts, energy densities will remain low until 2050.

And third, hydrogen as a storage means contains a far higher energy density per unit mass than traditional fuel, but because of its low volumetric density compared with traditional fuel, its overall efficiency is three times worse.



Technological challenges with aircraft

Where battery-powered designs are able to replace fossil fuel-powered aircraft over the use of sustainable aviation fuel, within eVTOL or small regional variants this will also reduce polluting emissions such as NOx - but other challenges for all fuel types exist, too; technological challenges with the aircraft themselves, for example. Mainly this is the case for hydrogen and batteries requiring new propulsion systems with structural mass reductions to accommodate them and their associated storage means. However, some of these could become opportunities for improved aircraft architectures.

For all options, the supporting infrastructure and supply of the fuel type presents a sizeable challenge. Hydrogen requires a complete production and supply infrastructure; sustainable aviation fuel requires far increased production capacity for feedstocks along with sustainable means of processing and transportation. All options require net-zero electricity, which is a larger global problem than aerospace and achieving net zero is completely dependent on the success or failure of the production and supply infrastructure.

Could sustainable aviation fuel hold the answer?

So, it looks like sustainable aviation fuel is the only option that has the potential to achieve the net zero CO2 target by 2050. A fuel that can be easily pumped into existing aircraft, it is probably the only option that addresses the emissions of an existing fleet, much of which will be made up from aircraft currently forming the order books of Airbus and Boeing. And beyond 2050, when exploring new designs, we should be looking to hydrogen storage rather than waiting for batteries to be developed. Hydrogen may be less efficient than batteries overall, but it's looking like the only option that will be capable of providing range commensurate with economic payload and paving the way for further increases in aerospace sustainability.

James Domone
Senior Engineer

Using technology to help reboot aviation in a COVID-19 world

COVID-19 is massively affecting airfields around the world and of every size, from the mega-hub airports to tiny airfields on Scottish islands and (potentially even) urban air mobility terminals.

Demand for passenger aviation had been growing consistently year-on-year, but passenger numbers are currently reduced by over 90%. This year the situation is likely to remain exceptional, with extremely low capacity, and adopting a "one size fits all" approach that assumes everyone has a high risk of catching or transmitting COVID-19. This affects passengers and staff alike; it applies from the moment they exit their front door to sitting in their aircraft seat, and back again.

How can technology – but not technology alone – help aviation recover, by rebuilding confidence and capacity, and reducing COVID-19 transmission risk?

Understand the passenger, personalise the journey

Let's assume airlines and airports survive the economic implications of the current lockdown so aircraft are actually flying, and people have an acceptable reason to fly. We're going to need much better information about who passengers are, where they are (individually and collectively), how healthy they are, where they're headed and when; all sensitive personal data that needs handling accordingly.

Journeys will need to be "smoothed out" in terms of both location and time, reducing bottlenecks in areas such as security, boarding and immigration. This will make best use of the limited available terminal capacity, determined by modelling the terminal and surrounding areas. Specific practical implications include the need for individuals to be able to demonstrate their COVID-19 risk status, to practise social distancing, and to minimise the need to touch shared infrastructure.

Who are you and how are you feeling?

Potential sources of COVID-19 health data could include a vaccination certificate, a health service test result, an in-terminal Elevated Body Temperature camera, a home testing kit and questions answered using a smartphone app. Most of these aren't yet widely available but will become so as medical understanding advances. Each one can contribute to an overall, combined single risk level, accessible via a standardised interface, and applicable to an individual journey.

As a traveller, how do I assert my identity to show that this aggregated health data relates to me personally? The majority of such comparisons – passport checks, for example – are still performed manually by in-terminal staff. Humans are excellent at comparing some of these characteristics (faces and voices), for people we know, occasionally. Using biometric algorithms to compare inherent physical characteristics of individual human beings is now common in daily life and starting to increase in aviation; many of these transactions could be performed on smartphones. Machines perform consistently over large numbers of these comparisons and don't get bored, tired or distracted – and can automate the process, leaving humans to deal with exception cases.

Beyond arm's length?

Strict implementation of the "two-metre rule" on an aircraft has to be relaxed; it's virtually impossible and economically impractical (requiring below 10% seat occupancy). In an interview with the Press Association news agency, John Holland-Kaye, CEO of Heathrow Airport, recently said:

> "The constraint is not about how many people you can fit on a plane, it will be how many people you can get through an airport safely. It's just physically impossible to socially distance with any volume of passengers in an airport."

In the terminal, technology solutions supporting social distancing may range from the manual (staff counting passengers with a "clicker" and halting widely-spaced queues when a given area is "full"), through automated versions of queue counting and accurate geolocation of individual passenger locations, up to biometric identification of individuals.

A typical passenger walking through an airport terminal would normally touch hundreds of objects. Exchanging documents, using a payment card, pressing buttons and touchscreens, as well as touching handrails, furniture, taps and suchlike.

A recent Atkins study suggests this number of touches can be reduced by at least 60%, by allowing passengers to interact with existing fixed infrastructure (such as kiosks) using a smartphone, reducing the short-term need for gloves, styluses and screen protectors.

Technology: necessary but not sufficient

Many existing technology "building blocks" can be used to help the aviation industry recover without taking undue health risks.

These components can be combined in innovative new ways to not only rebuild airport terminal capacity, but also to accelerate pre-COVID-19 initiatives such as linking the off-airport, in-terminal and on-aircraft aspects of passenger journeys more seamlessly. New opportunities for further automation, personalisation, collaboration and standardisation of these journeys can be delivered. Smartphones can underpin many of the required aspects, gathering data and sharing information during a personalised, contactless and low-risk journey.

Since the roadmap for dealing with COVID-19 is not entirely clear at this relatively early stage, systems need to be flexible, scalable and easily configurable. Processes must evolve along with the technology, and appropriate levels of data security and data protection must be baked in. And there's a key dependency on continued advances in the underlying medical science eventually "defeating" COVID-19.

Andy McCue-Brown
Principal Consultant

Managing aircraft fatigue is key to aviation industry's speedy return to business

It was only in February of this year that the two biggest players in the civil aerospace market, Boeing and Airbus, were showing revenue in the tens of billions of dollars. The recent situation with COVID-19 has enforced an unprecedented reduction in the aerospace industry's ability to operate. With passenger numbers plummeting and orders being cancelled, the short-term implications are being felt across airlines, manufactures and suppliers.

At some point the world's fleet will take off again, but it will take a long time for passenger numbers and revenue to return to something approaching the pre-COVID-19 figures. How long will it take? The answer to that lies, in some degree, in aircraft maintenance.

It is estimated that around 60% of the world's fleet are currently grounded.

Parking up an aircraft is not as easy as parking up a car. They are complex machines with many parts that need frequent maintenance on systems such as hydraulics and flight controls. Tyres need to be rotated and brakes to be checked. Bird nests need to be dislodged and vermin removed.

Where are the parked aircraft?

As the grounding of some planes happened suddenly, affected airlines had little choice as to where to park up. Ideally, they're somewhere warm and dry like Australia's long-term aircraft storage facility, Asia Pacific Aircraft Storage, in Alice Springs which has recently received four A380s from Singapore Airlines. The arid air of the desert is preferable for storing aircraft to the wet, humid conditions of Southeast Asia. Those aircraft stored in damp, humid conditions or close to salt-water run a greater risk of corrosion.

Metals are inherently susceptible to corrosion and prevention is the best cure. Airlines will have a series of preventative measures they need to undertake to avoid corrosion. If corrosion is found the full extent of the damage will need to be uncovered and it must be treated. Corrosion can result in a serious loss of thickness to load bearing parts, which can lead in turn to increased susceptibility to fatigue and loss of structural integrity.

Claire Jamison
Senior Engineer

Level of digital integration and utilisation

When an aircraft is to be returned to service after parking, appropriate checks and tests must be performed to ensure its airworthiness. To park up an Airbus A320 takes around 60 hours; to bring one back into service would take roughly the same again - assuming there are no issues found with corrosion or any damage to parts. This is an onerous task, but advantage could be taken of 3D damage assessment systems which provide a full aircraft scan, mapping out any areas of damage. This reduces the time taken to get the aircraft flight ready and any damage found can quickly be mapped onto a digital twin. If this digital twin is linked into the aircraft repair and maintenance manuals it becomes a simpler task to produce a route to repair. If repair isn't feasible, the digital twin can be linked into the airline's spares data and procurement of parts sped up.

Aircraft lifespan

For every aircraft that returns to the sky there will be those that do not fly again. Many of the iconic Boeing 747s now look to be on the way out with both KLM and Qantas bringing forward the retirement dates for their remaining jumbo jets. There is little appetite for maintaining an aircraft that is not likely to fly again. However, there have also been many deferrals and cancellations of orders for new aircraft. Boeing customers cancelled 150 orders for the 737 MAX in March alone. Does this mean that existing aircraft may be asked to fly for longer?

Aircraft are designed to be life limited. The life varies depending on several factors including the type of aircraft and the routes that they are flying. A life extension can bring about a huge increase in the longevity of an aircraft.

This is a complex undertaking with safety at the absolute forefront. An ageing aircraft is similar to an ageing car: the older an aircraft is the more maintenance activities need to be carried out. The scheduling of these maintenance activities needs to be backed up by analysis and extensive fleet data.

Ongoing maintenance is imperative

When the industry does begin to recover, there will undoubtedly be a need to move at speed to return the grounded aircraft to operation. There are a number of safety checks these vehicles will need to undergo to be deemed airworthy once more – and the amount of work required to achieve this will vary depending, in part, upon the preceding factors. While parking location and digital twins will give some operators a head start in this race to return to the skies, the real enabler to aircraft safety is ongoing maintenance while they are still grounded. By acting now, aircraft can be ready to answer the call when demand does climb once more.

Is the aviation industry taking cyber security seriously?

If you think cyber security in the aviation industry means merely protecting websites and online booking systems from malicious hackers, it's time to think again. The issue is much broader, in an industry that's evolving to fully embrace the benefits of going digital, where any stage along the complex maintenance, repair and operations (MRO) supply chain is exposed to potential risk and loss of service.

Do you remember the original Jurassic Park film, where the lifelong dream of an eccentric genetic pioneer – to bring dinosaurs back to life – was very quickly destroyed thanks in part to the negligence of a wayward computer programmer? Admittedly, being eaten by dinosaurs is rather an extreme example of what can happen when IT goes wrong, but it nevertheless gets to the heart of the cyber security problem: any IT system, no matter how advanced, clever and complex, will only be as strong as its weakest link.

And this issue is seriously coming to the forefront today within our industry. Sure, we know of the damage that hackers, crashed websites, and disrupted navigation systems can cause – not to mention errant drones – but bad computer security isn't just about what hits the news headlines. Poor resilience in any IT system can have the knock-on effect of infecting core business operations at any level to devastating effect, and the causes can come from many new places – from an infected USB stick plugged into a major maintenance database, to poor staff training.

Why resilience is a business-critical issue

So, operating in an industry where any aeroplane grounded at an airport beyond its scheduled time incurs cost, it makes plain business sense to take a step back and view the bigger picture and tighten any weak spots. Because resilience is a business-critical issue. And timing is of the essence. While aviation is increasingly embracing the digital revolution – and within the aviation MRO sector there is an undoubtedly a strong pull to embrace digital systems and processes and cast old-fashioned paper systems aside – that means increasingly integrated networks will need to be opened-up for users to access processes and systems. It means that potentially thousands of people along the MRO supply chain will need to have that access, as never before. And this means there will, inevitably, be weak links and exposure to risk like never before, too.

A secure airline industry is a safe one

So, there's a lot to cover. But we have to start somewhere – and there is a willingness to learn across the sector, and a general view that the only way is forward in addressing these issues. We know that security underpins safety. By failing to address emerging cyber security risks linked to digitisation and interconnectivity, you're effectively putting the entire sector in jeopardy. However, as things stand, there are no specific cyber requirements mandated by EASA. Regulation and legislation are coming – but no official date of their arrival is yet available. But cyber has been a hot topic for a while now; we need to increase the pace if we're to ensure the safety of an entire industry.

Making it happen

So, how do we ensure that regulations are put in place to cover all of the ongoing and potentially upcoming cyber threats? What's needed is:

- A broader understanding of the risks of interconnectivity to, for example, original equipment manufacturers' IT platforms
- A better understanding and awareness of the risk of integrating such platforms and opening them up to multiple users
- Clarity around how systems can recover after a cyber attack
- A better grasp of managing risk across supply chains and between companies.

Also, on the horizon, we need to know how to better manage increasing connectivity. Because tackling this issue, and its various complexities, is not a question of building new IT systems and processes with security added as a bolt-on. It's about ensuring every touchpoint of IT systems can demonstrate resilience – old and new. It's about adopting a step-change in your understanding of engineering – and not merely 'getting in cyber security experts' to deal with the problems that will, inevitably, arise later on.

There's no doubt that the issue of cyber security in the aviation industry will be a transformative one. It has to be – it's business critical after all. Now we must fully support EASA and other accountable regulators to ensure cyber security is embedded in all systems. Because if not, the results could be catastrophic.

Matthew Simpson
Head of Cyber Security,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