Air Mobility Ecosystem Consortium (AMEC) Report:

NATS Services: Recommendations to enable growth of advanced air mobility industry



Contents

Executive Summary	3
The air traffic management challenge of advanced air mobility	4
Identifying the key stepping-stones to the future	6
Simulations informing industry readiness for the future	9
AMEC Project Key Findings	12
Recommendations and next steps	15



c. Skyports

Executive Summary

Many will know NATS from our decades of work managing the complex and highly congested airspace over London and the UK. On the ground, in the UK and internationally, our teams also excel in conducting cutting edge research and development: by design, through technology and partnerships that optimise efficiency from airport to airspace. This expertise is particularly relevant to Advanced Air Mobility (AAM) operations, which inherently aim to function within these challenging settings.

In this space, NATS Services – the commercial arm of the NATS group - has developed air traffic management (ATM) technology and services needed to prepare for the integration of AAM vehicles into today's airspace. AMEC is one of our Future Flight projects that has helped validate this capability for both Beyond Visual Line of Sight (BVLOS) and AAM operations. It has given us a clear vision of the next steps to implement concepts of operation, technology and infrastructure that will expand the existing transport network and enable growth of the associated economies.

Our concept-of-operations (CONOPs) describes the operational method for safely integrating AAM eVTOL operations within low-level UK airspace. It introduces new automation and digital services into the existing ATM environment and a Master Control Room to provide coordination with traditional air traffic control when required. The CONOPS considered not just airspace integration but also the broader aspects of the overall AAM service and allows for increasing levels of automation into the AAM eco-system.

This work has enabled us to develop a concept that evolves through distinct time horizons from today through to the far future, from piloted electric vertical take-off and landing (eVTOL) vehicles to remotely piloted and autonomous aircraft operations. The CONOPs lays out the associated progression in technology, processes, rules, standards and policies needed for safe, integrated operations. The CAA have collaborated with us throughout the CONOPs development journey, helping us align with the regulatory vision and develop and inform what changes will be required to achieve it.

And through the insightful expertise within the AMEC consortium, we also have a much better holistic understanding of the business case challenges for all stakeholders within an AAM ecosystem.



This was not just a technical feasibility study - the work went straight to the heart of the business case for AAM.

The AMEC project culminated in recommendations to enable commercial operations to be established. These included conducting live flight tests in a safety critical, operational environment to further validate the CONOPs and establish the digital services and Master Control Room operations. It signals the urgency of investing in, and developing, infrastructure to support this expanding transport network.

For regulators around the world, the lower airspace traffic management system, including the underlying data exchange platform, are critical enablers of the industry's development plans.

Through collaborative projects such as this and our experience in managing some of the world's busiest airspace, NATS Services is playing a key role in supporting AAM operations scale safely and efficiently in the UK and internationally.

Richard Ellis, New Airspace Users Director, NATS

The air traffic management challenge of advanced air mobility

Very shortly, travellers around the world will be able to take a ride from the city centre to the airport in an electric air taxi, or electric vertical take-off and landing (eVTOL) aircraft. Soon, cargo and passenger-carrying eVTOLs and other electrically-powered aircraft will criss-cross the urban sky linking towns, cities and regions in an entirely new transport mode called "Advanced Air Mobility", delivering environmentally responsible, fast and cost-effective travel services in the airspace up to 5,000 feet.

In several countries, regulators are in the final stages of certifying these new aircraft for flight, with the first commercial services expected within the next couple of years. Meanwhile, research agencies, industry and regulators are also working to develop the infrastructure, such as vertiports and traffic management systems, which will allow these aircraft to fly safely and efficiently in the increasingly busy low altitude airspace.

Developing the technologies and operating concepts for efficient low level airspace air traffic management is a vital element in the AAM eco-system. New ways will be needed to safely and efficiently integrate eVTOLs with other low level airspace users such as drones and small aircraft. New digital services will be needed to ensure eVTOLs can reach their destinations with a healthy reserve of battery power. There will be limits on the landing and take-off space available at vertiports, so the demand-and capacity performance of the entire AAM network has to be carefully managed to ensure safety and equity for all airspace users.

AAM aircraft operations will have to be fully integrated into the current airspace management system if they are to access busy commercial airports - a key use-case. AAM traffic management systems are being designed with scalability built-in from day one. As eVTOL operators scale their operations from one or two flights an hour with a single aircraft to potentially hundreds of flights a day with fleets envisioned to ultimately fly autonomously, without human pilots.

"AAM aircraft developers want to introduce increasing levels of autonomy into their vehicles; they will be flying aircraft based on a set of routes based on autopilot control, with digital airspace management oversight."

Mark Balsdon, Head of New Airspace Users Accounts and Partnerships, NATS Services



Fundamentally, there are several vital questions which the AAM industry and regulators around the world urgently need to answer for these services to commence. Can we operate eVTOLs today into commercial airports using current technology and procedures? How, when and where should we introduce more automated, digital systems to allow the industry to scale? What kind of new regulations and standards are required to increase flight frequencies? What are the major capacity bottlenecks and how can they be overcome?

These were some of the key questions that NATS Services has been investigating over the past two years. Working with other AAM industry stakeholders in strategic research programmes, many of these questions have been answered identifying, along the way, the most important technology development steps that will need to be taken to evolve today's air traffic management system to a fully digitalised, automated management network to support high-density AAM operations.

A definition of Advanced Air Mobility

Advanced air mobility (AAM) is a new aerospace industry sector that uses advanced aircraft to transport people and cargo. AAM aircraft are often highly automated and electrically powered, can take off and land vertically or on short runways, with different flying characteristics than helicopters. These are the core elements in an AAM eco-system:

- Aircraft: AAM aircraft include electric or hydrogen powered aircraft, electric vertical take-off and landing (eVTOL) aircraft, short take-off and landing (STOL) aircraft and flying cars or personal transport vehicles.
- Infrastructure: AAM infrastructure includes uncrewed aircraft systems (UAS) – aspects of air traffic management, airports, heliports, vertiports (a mulit-eVTOL station incorporating charging mechanisms) and vertistops (single-eVTOL stations used only for passenger access), short runways as vertiports, charging, and security.
- Operations: AAM operations include urban air mobility (UAM), regional air mobility (RAM), cargo delivery, public services and private vehicle travel.

Project AMEC encompassed urban air mobility and regional air mobility aspects of this new way of flying.



c. Vertical Aerospace



c. Vertical Aerospace

Identifying the key stepping-stones to the future

NATS Services, working with AMEC consortium partners, based their work on four major evolutionary steps, or "horizons", to evolve AAM operations from a few occasional eVTOL flights in today's airspace environment to a future where hundreds of fully automated eVTOLs will operate in a densely packed network, supported by a range of new digital technologies.

The AMEC project developed an airspace management concept-of-operations (CONOPs) for all four time horizons, based on the principle of full airspace integration, including using a target time for arrival as a focal point for demand-capacity balancing and trajectory planning. While the emphasis was on how to enable the coexistence of this new type of airspace user in the airspace, the CONOPs also considered the broader aspects of the overall AAM service. The wide pool of expertise within the AMEC consortium was leveraged to understand and account for the requirements of other stakeholders in this ecosystem. This included the location and capacity of landing sites, or vertiports, and the impact of variable turnaround times for eVTOL aircraft charging on the overall network.

The project team built and tested a technology framework for operators and airspace managers to support the CONOPs evolution across the horizons.

"We started with low traffic levels, with only a few tactical, human interactions, which is likely to be further reduced over time with the introduction of artificial intelligence and automation. A key challenge was understanding precisely where those interactions would be needed, especially in emergency situations--for instance, when battery power is limited or during interactions with other types of traffic. As these systems continue to evolve, human interactions will inevitably become increasingly exceptional."

Dr Anthony Rushton, R&D Senior Researcher, NATS



Concept of Operations – The Foundation

In aviation, a concept of operations is a blueprint describing a new operational method and how it will work. An effective CONOPs identifies and addresses a key problem, or set of problems, with the current operational method and proposes a solution that adheres to and prioritises the core tenets of aviation: safety and efficiency.

Within the New Airspace User domain, a CONOPs needs to address the challenges related to the operation of new vehicles alongside conventional air traffic, setting out the operational, technological, regulatory and standards-related requirements to achieve airspace integration.

A CONOPs is a fundamental building block which facilitates the process of turning ideas into reality. It provides the theoretical requirements that scope the real-world validation exercises. These, in turn, prove the feasibility of the solution, as was the case within the AMEC project.

Horizons are indicative timescales for the anticipated development of AAM.

- **Horizon 1** is the demonstration phase with very low-density of piloted AAM operations operating in existing airspace structures and leveraging existing procedures. Many consider this to be the Horizon in which we are operating today.
- **Horizon 2** is the industrialisation phase with low-densities of piloted AAM operations utilising existing airspace structures as defined by the existing regulatory framework.
- **Horizon 3** is the scaling phase with medium densities of AAM operations, piloted or remote, enabled by new airspace structures and highly digitalised and automated ATM services.
- **Horizon 4** is the service-based phase where high densities of AAM operations, piloted and remote, are fully integrated with potentially AI-based ATM services.



Horizon 1

Human-centric UTM operations in segregated airspace, using largely **traditional ATM**

~ 20 Aircraft

- Low density
- Low-medium complexity traffic
- High tactical intervention



Horizon 2

Technological aircraft, technology-derived separation (ground-based and remote), **humans monitoring** and intervention where necessary

~ 70 Aircraft

- Medium density
- Medium-high complexity
- Low tactical intervention



Horizon 3

Semi-automated aircraft, technology-derived separation (ground-based and remote), **humans monitoring** and intervention where necessary

~ 100s Vehicles

- High density / high complexity / high autonomy
- Minimal tactical intervention
- Network level management & oversight



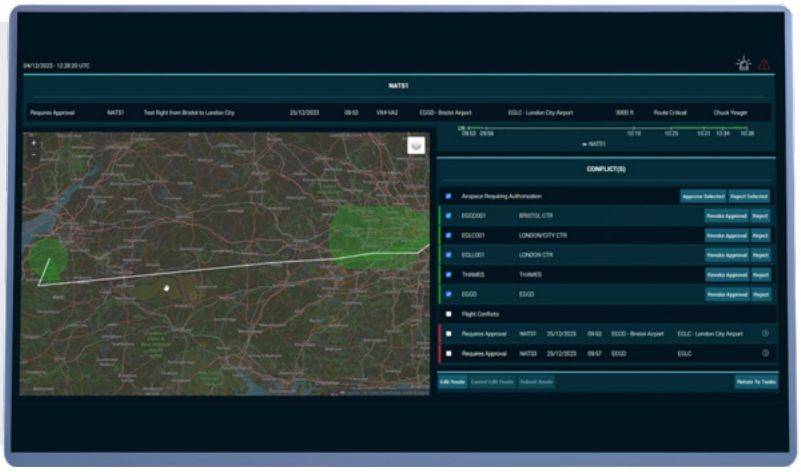
Horizon 4

AI-based aircraft, self-separation, **no humans** in the loop, fully integrated airspace

~ 1000s Vehicles

The Master Control Room Interface

Within AMEC, NATS Services refined the Master Control Room. The Airspace Manager has the capability to manage all phases of flight from origin to destination and can connect directly to the traditional air traffic management (ATM) systems.



A key part of the CONOPs was the identification of an "Airspace Manager" role. This role, working within a Master Control Room, an interface already trialled within Project CAELUS[i], another Future Flight initiative, acts as a focal point for managing low level airspace traffic.

The MCR is an agnostic platform, equipped with digital airspace management tools that adhere to latest technology standards while allowing for drones and eVTOLs to be tracked in a way that maintains privacy, ensures cyber security and allows for compliance with future Remote ID requirements.

MCR functionalities include an automated flight plan request and authorisation system, integrated with a slot availability-based flow-control function, ensuring there is always ground capacity that can be accessed for AAM vehicles with limited battery reserves. The MCR also allocates airspace corridors for AAM operations, with traffic management data transferred between the ground and the air using emerging industry standards.

The AMEC project team developed a National Aviation Planning Portal to understand how the MCR worked from the points of view of both the operator and the Uncrewed Traffic Management Service Provider (UTMSP) service provider, demonstrating how the system could be integrated with eVTOL fleet operations management tools. This stage of development has already been implemented in several airports through digitised flight approval services for AAM operators.

A human-machine interface (HMI) was also designed to inform traditional air traffic controllers of eVTOL movements, with only exceptional controller interventions required.

"What we have done for both drones and eVTOLs which I haven't seen anywhere else, is integration – developing the technical interfaces with the legacy air traffic management domain which are aligned with the airspace modernisation strategy of the Civil Aviation Authority."

Gareth Bowen, New Airspace Users Solutions Consultant, NATS Services



Simulations informing industry readiness for the future

Inspired by the output of the CONOPs, we developed a series of simulations[ii], starting with a real-time flight from Bristol to London City. Would the CONOPs scale to support a network of eVTOLs flying high-density operations?

The simulations explored in detail how an electric vertical take-off and landing aircraft (eVTOL) can transit through controlled and uncontrolled low level UK airspace safely to and from new vertiports and existing airports, using current technology and procedures. Simulations were also run to see what happened when more automated traffic management functions were introduced – with hundreds of eVTOLs flying through the lower airspace simultaneously and in tandem with commercial traffic.

The simulation provided an end-to-end view of what AAM could look like in the future. This allowed the project to better understand how approvals could be arranged across multiple sectors and airspace types, from class G to class D. It was more than just an airspace exercise – for AAM to work safely and efficiently the entire ecosystem needs to be carefully managed so the availability of staff, chargers, landing areas and maintenance areas were also included in both the planning and tactical stages of the simulation. It was important, too, to see how the aircraft operators were involved as soon as possible in any decision that involved overall system capacity.

During the simulation, controllers successfully managed commercial aircraft flights into and out of London City Airport alongside eVTOL operations. To support this, the team built an eVTOL flight strip display to activate controllers' awareness of incoming, departing and transiting eVTOL traffic. The team ensured the simulations were as realistic as possible by incorporating expected and unexpected situations. During the eVTOL's journey, a blue light situation had to be accommodated, and as the eVTOL approached London City Airport, a digital communications failure was incorporated into the simulation. The system immediately reverted to voice communication between the pilot and the controller until digital communications were resumed.



During the eVTOL's journey, a blue light situation was accommodated. The air traffic controller created a segregated space for the vehicle and traditional traffic was notified through normal procedures. The Airspace Manager received the information, the eVTOL was notified digitally, and appropriate deconfliction was immediate.

The project concluded that it will be possible to safely operate eVTOLs in some of the world's busiest airspace corridors and into commercial airports without distracting traditional air traffic controllers from their main tasks.

Several other scenarios were trialled using fast-time simulations, looking at how many eVTOLs the London network – one of the busiest and most complex pieces of airspace in the world - could accommodate if current aircraft separation criteria were maintained and what would happen if separation criteria were reduced or had to be increased. Currently, radar separation criteria are three nautical miles apart and 1000 ft vertically separated – but in poor weather conditions these may have to be increased; the project measured how that might impact demand and capacity balancing.



"We simulated an eVTOL landing, a departure and a transit flight and I was easily able to remain focussed on controlling the rest of the traffic; the eVTOL was visible to me but not significant in my workload"

Philip Terry, Senior Consultant and Air Traffic Controller, NATS Services

Real-time and fast-time simulations

The Bristol to London City simulations allowed the AMEC partners to understand in detail how an eVTOL can be integrated with existing air traffic and transit through controlled and uncontrolled low level UK airspace safely.

Different types of simulations – real time and fast time – were used to test the CONOPs and technology spanning horizon one and horizon three. The simulations accommodated moving to and from new vertiports and existing airports, using current procedures, new technology and the newly developed CONOPs.

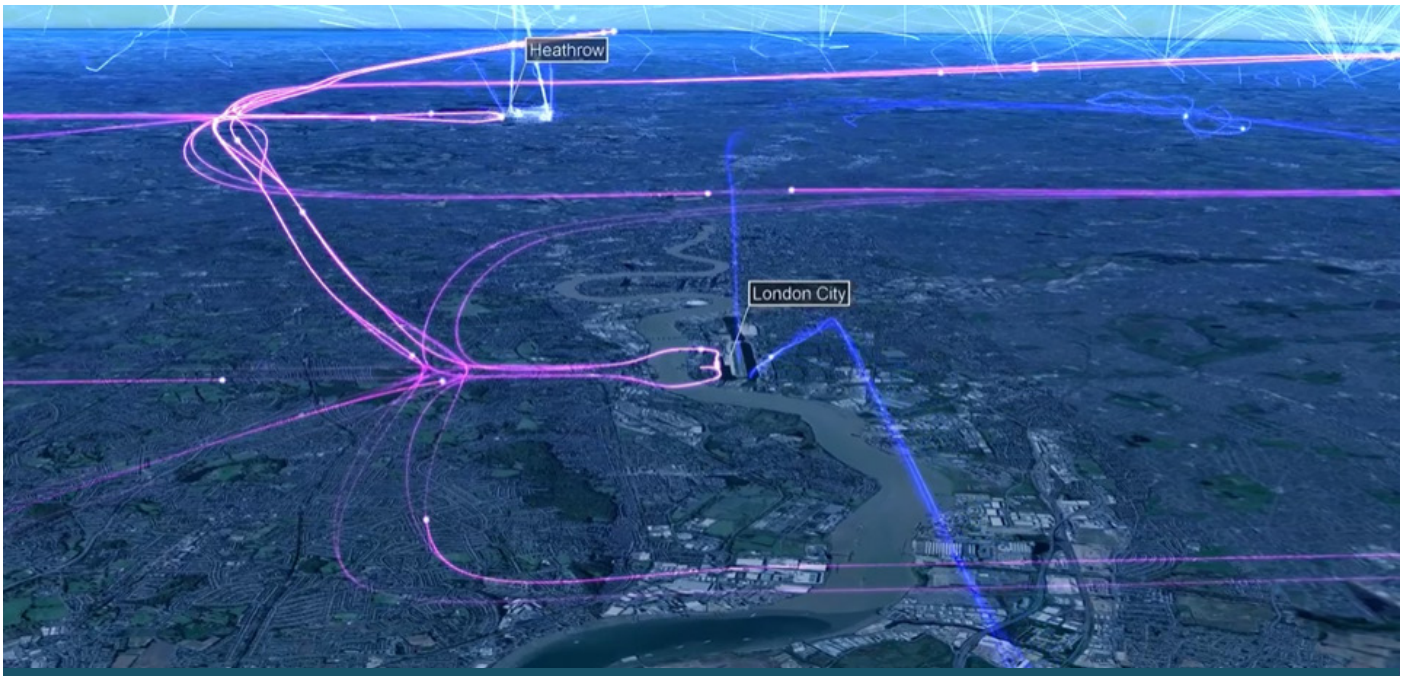
Real time simulations were conducted to understand the impact of an eVTOL on the existing ATM ecosystem and the respective actors involved in safely managing the flights. Both routine and non-nominal situations were simulated.

Fast time simulations were used for the rapid assessment of complex scenarios and processes as envisioned up to horizon three, which provided a better understanding of the future impact of eVTOLs.

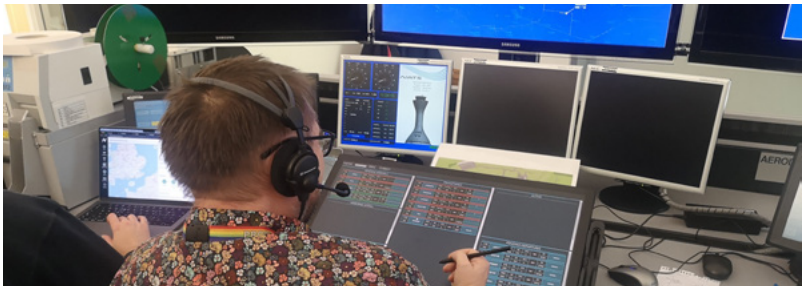
The fast-time simulation primarily aimed to understand whether the CONOPs could be applied to a network of eVTOLs flying high-density operations, with hundreds of vehicles flying simultaneously in an integrated airspace. It was also able to confirm that, with some changes to existing Instrument Flight Rules, the network has the capacity to support the business cases that eVTOL manufacturers and operators are planning for the future.

We looked at all aspects of the flight, the vertiport operator, the pilot, the aircraft and created an end-to-end flow map for every step in how an eVTOL would move from one place to another. And then we did exactly the same for Horizon 2, understanding how that would change with some of the digital interactions we developed.

John Holmes, Head of UTM Concept Development, NATS



By using demonstration vertiport locations and flight paths, fast-time simulations indicate that the airspace network can support growth of the AAM industry. Future operations would be subject to detailed airspace design outcomes.









c. Vertical Aerospace

AMEC Project Key Findings

NATS Services roadmap of how eVTOL operations can be launched and start to scale across horizons has been validated. There is a clear understanding of the impact of adding new capacity to existing networks, from airspace to runway operations and controller workload, and what key technologies, procedures, regulations and standards will be required to implement more automated functions that will enable scalability.

The AMEC work has highlighted several important elements which will be vital for the launch and evolution of AAM operations, many of which apply to the integration of these operations globally.

The project concluded that in controlled airport environments, particularly if they were capacity constrained, it was advantageous to decouple the flow of AAM operations from the conventional traffic and manage them through routes that are procedurally separated from other traffic flows. Conversely, for aerodromes in uncontrolled airspace, in the initial time horizons it may be beneficial to integrate AAM traffic with the existing traffic to reduce airspace complexity.

The project also highlighted the related issue of the critical importance of time management within an AAM ecosystem. The use of electric powertrains in AAM aircraft imposes limitations on vehicle performance, limiting the range and ability to hover. To enable the aircraft to transit the airspace efficiently, the Airspace Manager and aircraft operator both need to be able to predict landing times and gate availability accurately and dynamically adjust the speed of the eVTOL in flight to meet those times.

"AMEC has proven that eVTOLs can safely coexist with the current air traffic by using our existing infrastructure; initially, procedural separation is a viable method for integration. However, without change, growth will be limited. Digitalisation of traffic management systems and an underlying data exchange platform are essential to create the ecosystem that will support predicted levels of new traffic."

Alex Burlacu, New Airspace Users Consultant, NATS Services



"It's not just a case of the missed landing slot. The extra time in the air isn't just a couple of extra seconds refuelling, it could be 10 of minutes on a charger, which will be in limited supply at some vertiports. And so a decision which effects an aircraft in the air could then disproportionately ripple around the network in a high utilisation scenario. AMEC has helped us to identify what kind of interaction there needs to be between the digital airspace manager, the controller and the aircraft to manage these issues."

John Holmes, Head of UTM Concept Development, NATS



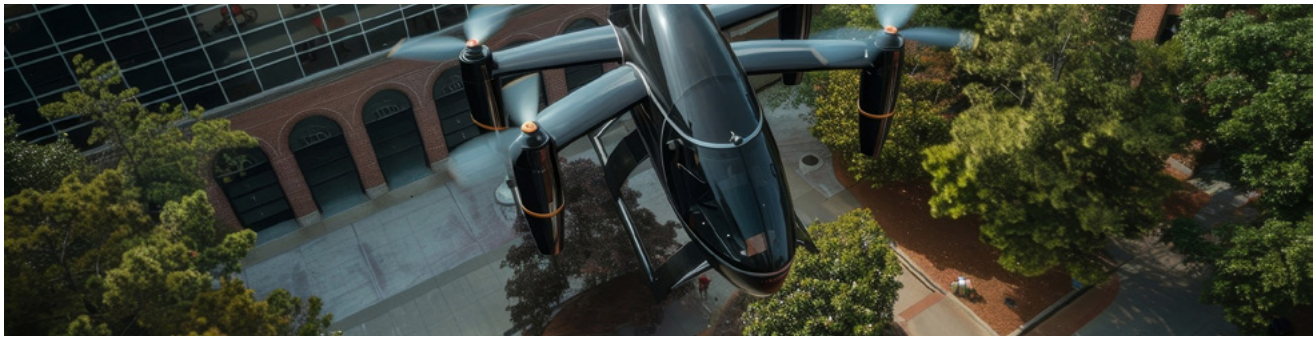
Headwinds and temperatures could severely restrict the range of an eVTOL, and therefore the operation of the entire network. Accurate weather data which can be shared via open standards to aircraft operators, vertiports and the Airspace Manager is particularly important, especially for high density operations. More work needs to be done on understanding micro weather impact on eVTOLs, such as wind-shear events close to high buildings. Testing the resilience and robustness of the connectivity protocols is needed to develop multiple ways of validating the location of the eVTOL as well as communications between air and ground.

Then there is the challenge of understanding the performance of different types of AAM vehicles. Within aviation, there is increasing diversification of aircraft design and performance. This is especially true within the eVTOL space where research shows a multitude of multirotor, tilt-rotor, vector-thrust and other vehicle designs are emerging, all of which have differing capabilities and limitations. From an airspace management perspective, this broadens the set of requirements that need to be accounted for in the operational procedures and digital services that are employed to ensure all airspace users are integrated safely and efficiently.

Another key aspect for the project was understanding the critical demand-capacity balancing throughout the network. Simulations looked at a network in which 240 eVTOL movements per hour could be accommodated. It was clear from this work that one of main constraints was the physical and time-based capacity of vertiports to handle large amounts of traffic, rather than available airspace. Through collaborating with experts across the consortium representing different aspects of this ecosystem, the project has developed an understanding of the standards and operational procedures needed to move to more digital management of the system.



AMEC Consortium member, Vertical's VX4 eVTOL is designed to meet the same stringent safety standards required of commercial passenger airliners.



Future Flight 3 – the foundations to accelerate the integration of new vehicles into lower airspace

NATS Services is actively engaged in Future Flight 3 projects, aimed at accelerating the integration, at scale, of drones and eVTOLs into existing UK and international operations.

These include developing concepts of operations, leading to our Master Control Room interface, Airspace Manager tools, Fleet Management tools, conducting vertiport location assessments and Live Communication tools envisioned for future adoption by aspiring and future UTM service providers and airports globally.

In Project CAELUS, NATS and its project partners created and validated a revolutionary new Concept of Operations (CONOPs), which lays the groundwork for routine drone operations in the UK. It included the development of the "Master Control Room" interface as a bridge between crewed and uncrewed air traffic operations, something NATS considers essential to achieving a fully integrated airspace.

Through both simulated and live flight trials, NATS was able to demonstrate how digital and automated services developed for the Master Control Room could be used to safely integrate uncrewed traffic in controlled and uncontrolled airspace, while minimising disruption to current air traffic operations.

In Project AMEC, NATS demonstrated the feasibility of a UK Advanced Air Mobility ecosystem. The project culminated in a simulated flight of an eVTOL from Bristol to London City Airport, and a concept of operations validated in today's environments as well as anticipated skies of the future – populated with a range of new types of vehicles. NATS further refined a technology platform to manage eVTOL flights via new applications, including flight plan authorisation apps, which can be approved, rejected or amended in just minutes. Through this technology, flights are entirely deconflicted from other aircraft before even taking off, with the 'Airspace Manager' function monitoring the airspace from a digital 'Master Control Room' interface, capable of exchanging data smoothly and securely with existing ATM systems.

This technology strikes a balance between ensuring safety and providing airspace access without adding to the workload of air traffic controllers or pilots. It also opens the door to existing regional airports to become mixed-use 'vertiports' with eVTOLs operating seamlessly alongside existing traffic, offering a valuable new source of income, diversification, and services to their customers.

These solutions unlock the door to an industry in waiting, expansion of the existing transport network and an active part of an estimated £60 billion global economy[iii].

Recommendations and next steps

NATS has developed and refined the technology and operating concepts needed to prepare for the integration of advanced air mobility vehicles into today's airspace architecture and to scale and commercialise the industry, anywhere in the world.

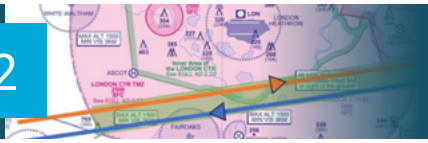
Main findings and recommendations include:

1



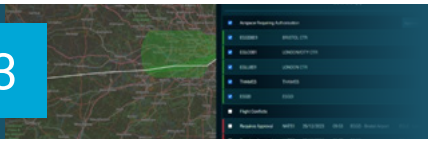
Conduct live flight tests in a safety critical, operational environment to further validate CONOPs and digital services

2



Invest in and develop infrastructure (see page 5) to lead in expansion of the transport network

3



Implement technology platforms to provide digital services and automation for the management of an integrated airspace at scale

4



Establish 'rules of the sky' appropriate to a new age of digital, integrated lower airspace traffic management

5



Implement the provision of statewide Common Information Services

The lower airspace traffic management system is a critical enabler of the industry's development plans and through collaborative projects and operational expertise. NATS Services can play a key role in supporting AAM operations that can scale safely and efficiently.

Sources:

i: Project CAELUS - Research & development - NATS

ii: Project AMEC - Research & development - NATS

iii: Global Forecast Report on Advanced Air Mobility Market, 2024-2034 | satsearch

Through projects such as AMEC, The UK Research and Innovation (UKRI) Future Flight Challenge is helping build the ecosystem needed to accelerate the introduction of advance air mobility, drones, and zero-emission regional aircraft in the UK.

Working with industry, academia, government and regulators, and stakeholders across the country, the Future Flight Challenge is co-funded by industry and the UK government to support the development of future flight services and enabling technologies such as AI and autonomy, digital communications, and electric propulsion.

The AMEC consortium members are:

AtkinsRéalis

CATAPULT Connected Places

Heathrow

Skyports DRONE SERVICES

Bristol Airport

LONDON CITY AIRPORT

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