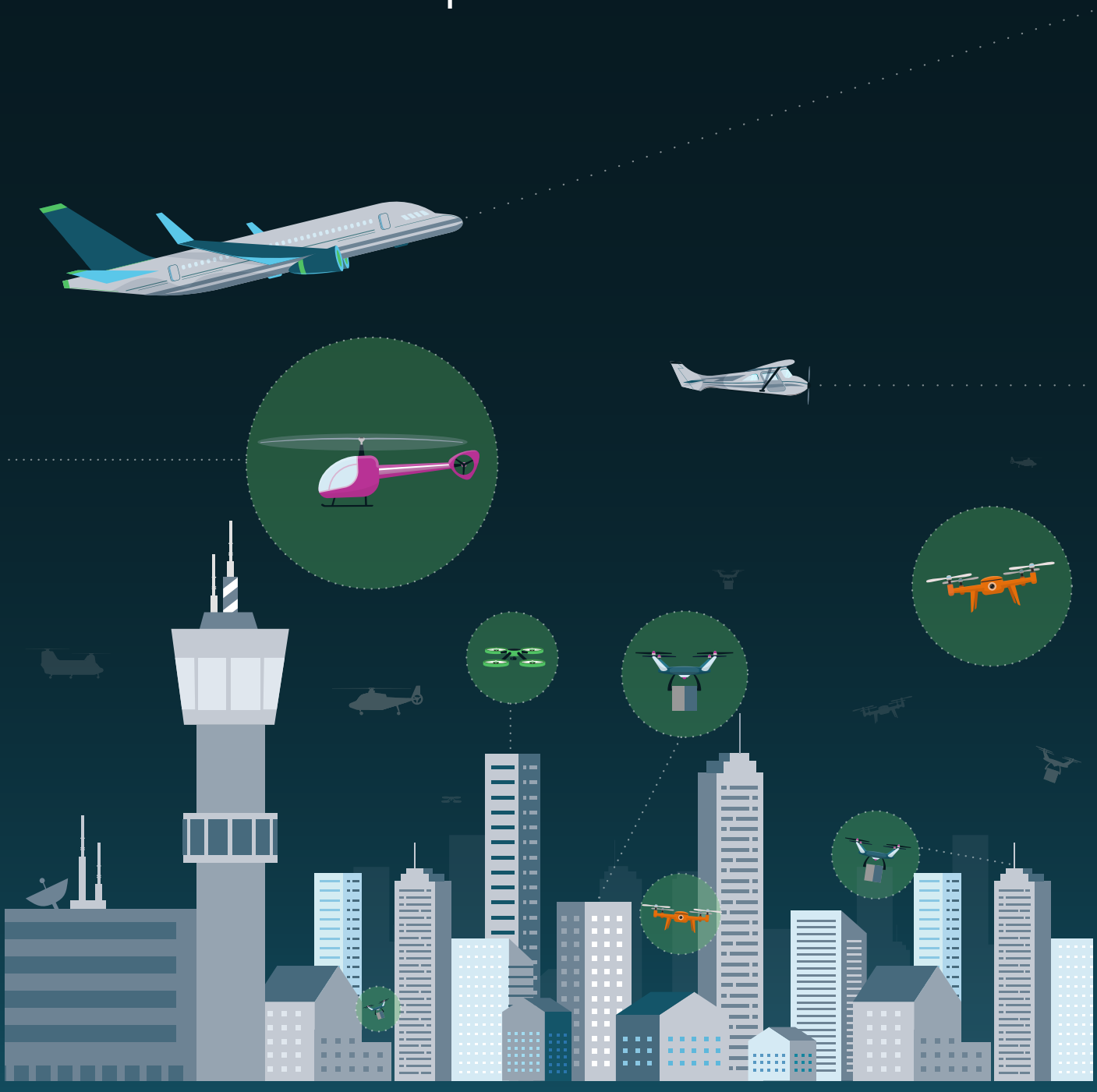
NATS

Project CAELUS:

Advancing Aviation through Integration of Drones into the UK's Low Level Airspace



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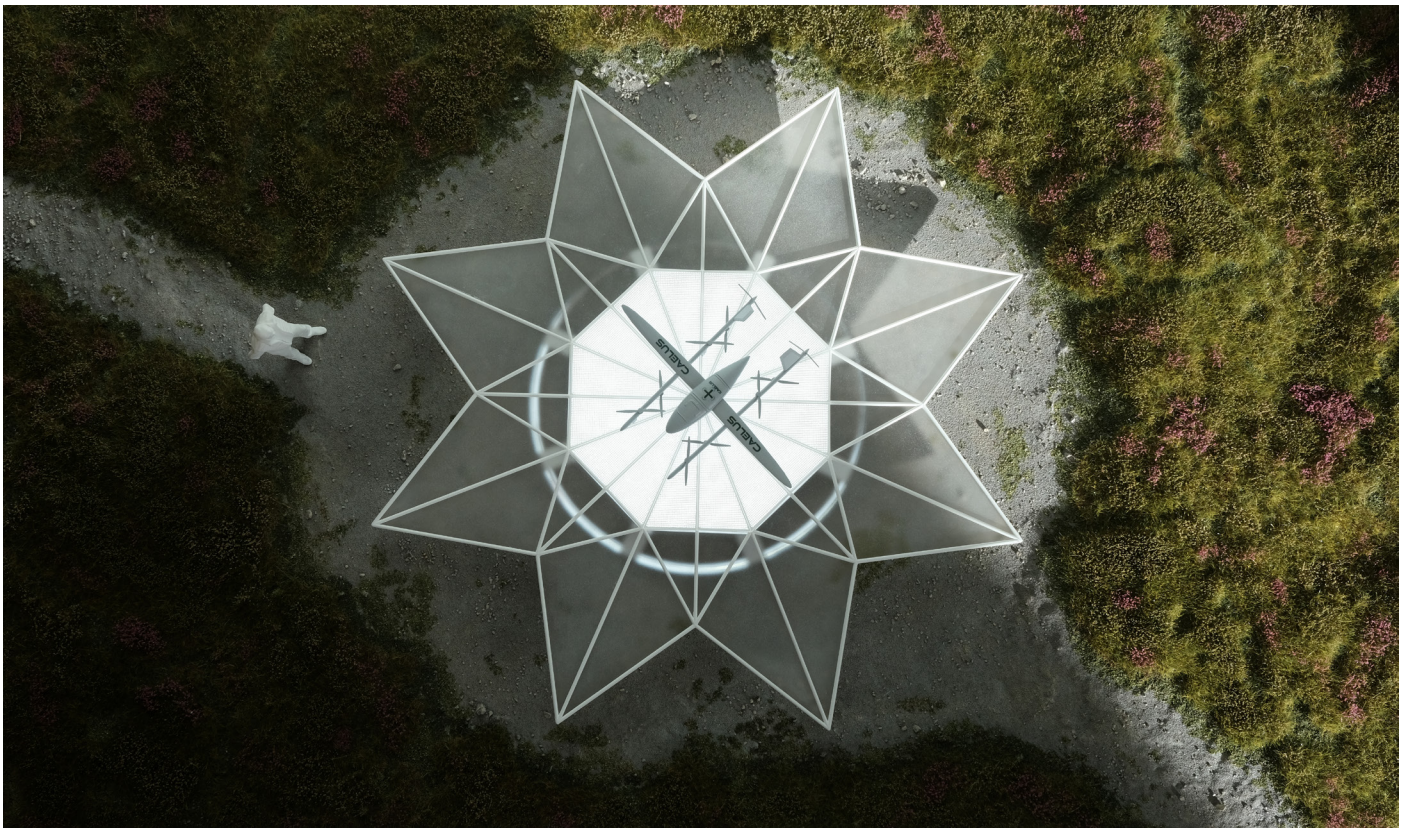
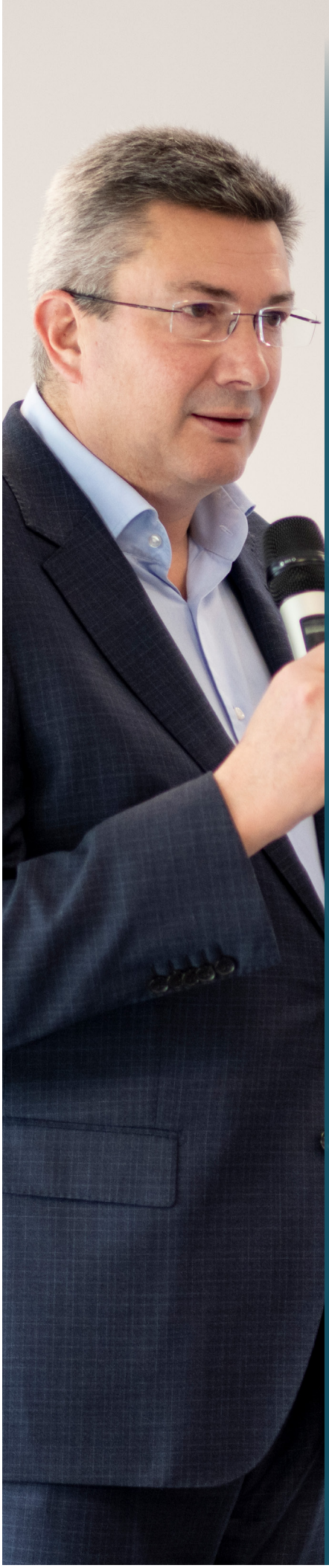




Executive Summary

The UK Civil Aviation Authority (CAA) has targeted 2027[1] for the establishment of beyond visual line of sight (BVLOS) drone flights. Over the last four years, Project CAELUS[2] has brought together 16 partners[3] to deliver the UK's first national drone network equipped to transport essential medicines, bloods, organs and other medical supplies to both urban and rural communities across Scotland. The project has become a vital stepping stone along the path of evolving regulations and operations to allow the drone sector to fully realise its commercial potential, developing a safe, profitable, and world-leading, low-level airspace economy in the UK.

The CAELUS flight trials successfully established that safely managed medical drone flights between NHS Scotland sites could be done using Temporary Danger Areas (TDAs). But it was also a test bed for the Future Flight Challenge to develop a clearer understanding of how BVLOS operations could be evolved into full integration with commercial traffic. Evidence from the trial flights in TDAs will build the safety case for using other types of more flexible airspace, leading to full integration.

NATS is committed to engaging and collaborating with regulators and industry to develop a fully integrated low-level airspace in the UK. Our specialist core operational and technological expertise, along with initiatives and advances made in BVLOS flight, has been combined with that of consortium partners to support the integration of drones into the airspace in the UK and beyond. CAELUS helped validate the concept of operations and technology and define a progressive roadmap that documents the evolution to full integration.

Through the Future Flight Project, NATS has derived the following important conclusions from the programme:

- Partnerships across the industry will be key to creating an end-to-end ecosystem with a single organisation acting as a systems integrator to streamline processes and services.
- This systems integrator foundation lends itself to the development and deployment of cloud-based technology to support the high-fidelity data transfer required to ensure all stakeholders are operating to a standard approach in real-time.
- The use of a 'Master Control Room' (MCR) is essential for future integration to ensure appropriate data sharing, swift authorisations, and the monitoring and managing of nominal and non-nominal situations to ensure the safety of airspace users.
- The MCR technology is an integral tool in enabling a new 'Airspace Manager' role to safely realise integrated airspace.
- The regulatory framework now needs to develop to move ahead with the integration of programmes such as CAELUS into real-world operations.

The time has come to move beyond research and head towards full integration and commercialisation. As the Future Flight Challenge Programme comes to an end, there needs to be a clear pathway for industry and regulators to move from advanced trials to routine commercial operations.

Richard Ellis, New Airspace Users Director, NATS

A low-level airspace revolution

The aviation industry is on the edge of a global revolution. A recent PwC study Skies without Limits[4] forecasts that up 900,000 drones could be flying across UK skies by 2030, with over a fifth used by the public, defence, health and education sectors.

While the number and variety of drones taking to the skies around the world has been steadily growing over the last few years, the industry has not yet been able to reach its full commercial potential. There are still considerable regulatory barriers preventing drone operators from scaling their operations, so one operator can manage many autonomous drones at one time, flying beyond visual line of sight (BVLOS) over people, at night and in congested airspace.[5] At the same time, new types of electrical vertical take-off and landing (eVTOL) vehicles could soon be ferrying passengers in, or close to, the space where drones are planned to fly – the low-level airspace below 5,000 feet is set to become extremely busy.

The low-altitude economy has the potential to transform many people's lives with new services and transport options. But before the drone and eVTOL industries can scale to meet the wishes of communities and the market, aviation safety regulators will need to be assured that the technologies, standards and procedures for flying these new aircraft are safe and sustainable.

The UK aviation regulator, the Civil Aviation Authority (CAA), has targeted 2027 for routine BVLOS drone flights and has supported several trials within the Future Flight Challenge Programme to test drone technologies and procedures in increasingly complex environments. Project CAELUS is one of the most comprehensive of these. It brings together each element required for successful end-to-end service delivery.

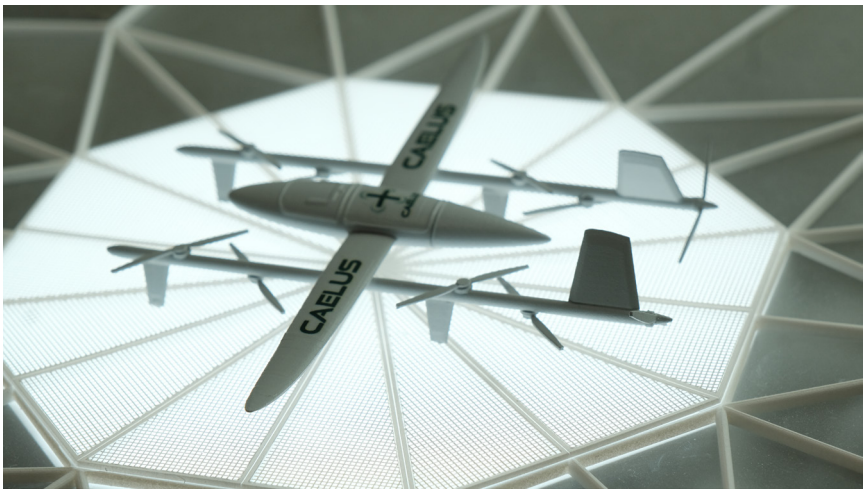
"Working with NHS creates a real sense of urgency in the project. We're acutely aware of the challenges they are facing and the limitations to their resources….Drone technology will benefit society immensely in the future and move medicine and treatment closer to individuals in their communities. As an airport operator we need to use our expertise to support them."

Fiona Smith, AGS Airports, Project Director for CAELUS

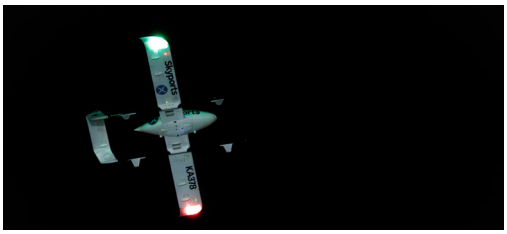


As well as trialling the use of drones to improve the way NHS services can be delivered, Project CAELUS has become a vital stepping stone along the path of evolving regulations and operations to allow the drone sector to fully realise its commercial potential, developing a safe, profitable, and world-leading low-level airspace economy in the UK.

For NATS, Project CAELUS has provided invaluable opportunities to develop and test how complex low-level drone flights can be safely managed within the airport airspace environment, where drones and passenger carrying aircraft will soon have to share the same airspace. It has provided valuable insights into the way the management of complex low-level traffic can safely evolve from segregated to integrated airspace in line with the CAA's Airspace Modernisation Strategy (AMS).









Airspace integration within Project CAELUS

Uncrewed aircraft systems traffic management (UTM) is the key to unlocking safe and scalable drone and eVTOL operations. NATS, as the UK's largest air navigation service provider, has an important operational role to play in developing UTM concepts that ensure BVLOS drone operations can be seamlessly integrated into the current and future airspace environment, developing robust safety submissions for the regulator along the way.

The first phase of Project CAELUS was the development of the concept of operations (CONOPs) which describes the characteristics of how the operations would work and evolve across a number of time horizons. Servicing the NHS' medical delivery needs requires two types of drones - a smaller multi-rotor uncrewed aircraft for point-to-point operations and larger, fixed wing remotely piloted aircraft for transporting supplies in bulk between aerodromes. Separate operating methods were derived for these two types of operations. While the project and the concept was primarily focused on the NHS medical delivery use case, the concept was purposefully constructed with broader applicability in mind, addressing the wider challenge of how to safely integrate drone flights across both controlled and uncontrolled airspace.

The second phase of the project involved validation of the CONOPs through a set of simulations and flight trials. This was supplemented by a study to determine the potential NHS Scotland medical network including hospitals, pathology laboratories, distribution centres and GP surgeries. The output of this study informed the locations of the subsequent live flight trials in Greater Glasgow and Clyde, Lothian, Borders, Ayrshire & Arran and Grampian NHS boards.

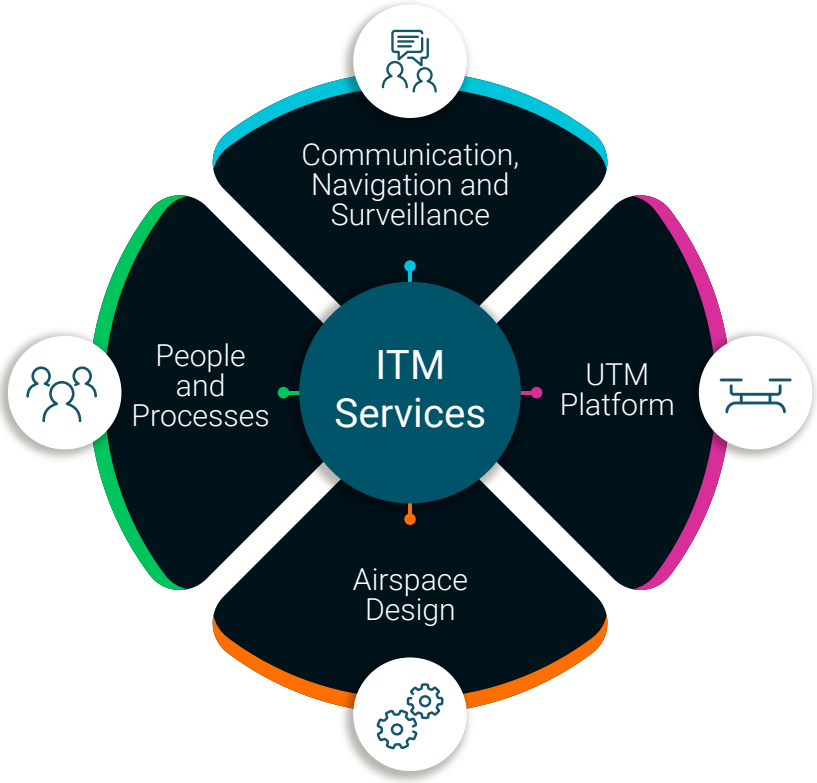
The project partners enabled creation of an end-to-end solution, including the development of a digital twin[6] of the proposed delivery network, the design and prototyping of drone landing stations, the development of a delivery management system for the NHS, installation of surveillance technology and noise perception studies. Live flight trials were operated by Skyports Drone Services, an experienced provider of drone delivery, survey and monitoring services with experience operating medical drone deliveries, and data was integrated from various sources[7].

Underlying the programme has been the development of NATS UTM digital infrastructure, which enables drone flights to take place safely in different types of airspace.

The CAELUS digital infrastructure roadmap

CAELUS' published roadmap[8] illustrates the key developments associated with each milestone, charting the journey from initial operations as part of a minimal viable delivery service to full airspace integration of scaled BVLOS drone operations as part of a comprehensive, nationwide medical supply delivery service for NHS Scotland.

The airspace integration component of the digital infrastructure roadmap has several key threads, as illustrated below:



A number of airspace integration-related goals were achieved in Project CAELUS, including:

- Developing the CONOPs for the drone operations which informed the airspace-related strands of the roadmap;
- Validating aspects of the CONOPs through the development of a validation strategy, plan and report;
- Reconfiguring the NATS simulator to incorporate an integrated UTM system working alongside the ATM system;
- Providing a standard interface to a simulated UTM service provider to support pre-flight authorisations and in-flight monitoring and control services;
- Drawing up an integrated airspace design to enable digital traffic management;
- Working with the regulator to define Temporary Danger Areas (TDA) and Temporary Segregated Areas (TSA) for the trial drone flights;
- Developing safety assurance protocols, and;
- Working with the CAA and the Department for Transport (DfT) on identifying operational challenges and achievements to inform future 'rules of the sky'.

The NATS simulator capability proved instrumental to demonstrating how drones could be efficiently integrated alongside other air traffic in a full range of scenarios with minimum tactical interventions by ATC, with the involvement of a new role, the Airspace Manager. This included drone operators filing flight plans, flying in and out of a busy airport and being safely deconflicted with other aircraft, including non-nominal emergency aircraft.

Multiple scenarios were simulated demonstrating the dynamic activation and deactivation of airspace to support the uncrewed and crewed aircraft integration. A cooperative environment was created that simulated the management of non-cooperative crewed aircraft and drones in the same airspace. This environment involved drones equipped with multiple sensors capable of detect-and-avoid communications with all operators.

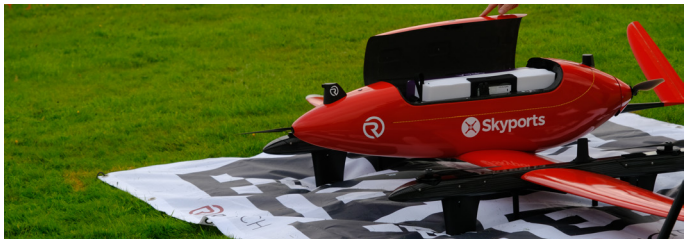
Dronamics' fixed-wing drone was used to simulate the movement of larger aircraft types capable of moving bulk supplies. This type of aircraft required runways for take-offs and landings.

The simulations also trialled rare cases where drones carrying defibrillators might have to be prioritised over crewed traffic on survey missions, which opened discussions around the challenges that the regulator would need to address when considering the current rules on prioritisation of aircraft.

"The CAA has a philosophy of 'crawl, walk, run' and CAELUS absolutely aligned with that. Through the simulations we were able to show how we could move from managing drone flights within segregated environments to flying in fully integrated airspace, at an airport for example."

Gareth Bowen, New Airspace Users Solutions Consultant, NATS









Implementation of Uncrewed Traffic Management

Project CAELUS proved to be an important step towards realising a truly integrated airspace where both BVLOS drones and commercial traffic can co-exist. The CONOPs provides clarity on how the concept is expected to evolve to reach this goal and the simulations provided an opportunity to validate aspects of that future vision. From the perspective of the live flight trials, due to the constraints of current regulations, these focussed on validating the nearer term concept of operations, safely managing medical drone flights between NHS Scotland sites using temporary danger areas (TDAs), with findings that could apply to a future recognised traffic environment such as a Transponder Mandatory Zone (TMZ)[9] also noted.

TDAs have limitations which mean they, and the drone operations within them, cannot be scaled or applied to on-demand missions. They impact other airspace users and severely restrict the potential for on-demand drone services. Evidence gained from the trial flights within TDAs is supporting the safety cases for using other types of more flexible airspace, such as Temporary Restricted Areas and Transponder Mandatory Zones, as the next steps to full integration of airspace. Furthermore, through simulations and live trials, it has been established how drone take-off and landing sites can co-exist safely with airports with minimal disruption to traditional air traffic.

► The CONOPs as a bedrock to UTM development

Developing and validating the CONOPs through simulations and live trials allowed early risk mitigation, improved collaboration, enhanced quality, identified cost savings and gave greater adaptability in the development process. The CONOPs primarily focussed on airspace integration but also considered the broader aspects of the overall medical delivery service, including the location of landing sites, interactions with NHS staff, a delivery management system and the medical payloads themselves.

> "The project has set the context of the framework of how the different actors, stakeholders, systems, data flows, decision making processes could be coordinated to provide safe integration. There were no clearly defined regulations or set of rules to say exactly what was needed so the CONOPs provided a baseline. It became a living document and was progressively matured throughout the programme, so the flight trials were closely aligned to the CONOPs."
>
> **Nick Stevens, Head of Integrated Traffic Management Solutions, NATS**

External input into the CONOPs proved to be invaluable. Engagement with the CAA throughout the development of the CONOPs was key to ensuring alignment with the regulatory vision and the third-party scrutiny helped identify aspects that needed refining, improving the quality. Throughout the concept development process, NATS was also able to enhance CAELUS' work with research from parallel programmes.

"NATS is actively involved in many threads of complementary research and development in this domain, tackling challenges associated with safe, scaled integration of new airspace users. We leveraged our knowledge of state-of-the-art concepts and actively sought to incorporate the latest developments as we led the consortium partners in the creation of the Project CAELUS CONOPs and the validation process,"

Jacob Blamey, Senior Research Analyst, NATS



The validation of the CONOPs involved identifying over 120 specific requirements and testing them during the simulations and trials. As an example, there was a requirement for the Airspace Manager to be able to approve flight plans and send the approval message via the MCR to the UTM service provider. This was performed successfully on multiple occasions spanning several flight trials to ensure the system integration was accurate, robust and reliable. Another example came from an unplanned landing when the weather deteriorated unexpectedly in flight. This enabled the contingency landing procedure to be tested using a pre-arranged, alternative landing site. The trials also provided an opportunity to document findings that were not associated with the requirements. For instance, it was observed that data (e.g. MET) needs to be sourced from a common reference to mitigate the risks of ambiguity or inconsistency between data users. This finding supported the functional architecture proposed within the CONOPs.

In addition to ensuring drone flights can be safely managed, there are a number of other 'non-airside' aspects that are critical components of, and more bespoke to, the NHS Scotland medical delivery service. These aspects cover questions such as: How does a clinician request a drone delivery? What training do they need? How can the physical security and in-depth chain of control for the medical items being transported be assured? How can there be assurance that nothing has been tampered with? How do the packages fit onto the drone? Who is responsible for loading and unloading them? Has the payload been kept within its physical limits (e.g. temperature) throughout its journey? An holistic approach to the validation activities was taken to ensure these 'non-airside' aspects were also considered and tested in a live trial environment.

From a Future Flight Challenge Programme perspective, 27 of the high-level demonstration objectives were linked to requirements that have been partially or fully achieved in Project CAELUS. This highlights the extent and magnitude of what has been achieved. Coverage at the programme level is likely to be even higher when combined with the successes of the other projects. One such project is the Advanced Mobility Ecosystem Consortium (AMEC) in which NATS has also led the CONOPs development work on advanced air mobility infrastructure to support eVTOL flights in the UK[10].

Outside the Future Flight Challenge Programme, the CONOPs learnings from Project CAELUS are already starting to be leveraged by NATS in other regions – including Asia Pacific and the Middle East.

"We won't be successful because of one organisation's contributions; collaboration and transparency across the industry including competitors is needed,"

Richard Ellis,
New Airspace Users Director, NATS



► A Master Control Room Interface to enable scalable operations

The NATS Master Control Room (MCR) Interface prototype provided an agnostic platform on which to integrate traditional ATM with drone traffic. The MCR has been equipped with airspace management tools that adhere to existing technology standards while allowing for drones to be tracked in a way that maintains privacy, ensures cybersecurity and allows for compliance with any future Remote ID requirements.

The CAELUS trials succeeded in integrating the live drone telemetry from an UTM service provider into the MCR prototype for the first time. NATS prototyped and demonstrated a range of enabling UTM/ATM integration technologies: messaging interfaces for data exchange, human-machine interfaces and control and automation systems. This meant developing a fully homogenous information flow throughout the network to understand the status, demands and requirements on the airspace at all times.

The MCR demonstrated that technology can be used to safely incorporate uncrewed traffic into existing air traffic systems without disruption[11]. It allows an Airspace Manager, a new role which is envisioned to one day be automated, to authorise low-altitude flight plans, provide deconfliction advice and instructions, monitor notifications related to airspace restrictions and specific missions and maintain oversight to ensure safe and efficient operations. The role of the Airspace Manager is an integral component of the concept for realising an integrated airspace where both drones and other airspace users share the airspace at scale. The ATC role ensures the drones are safely managed in both nominal and non-nominal situations.

The Master Control Room proved to be an essential tool to support the Airspace Manager. It ensured appropriate data sharing, in turn providing the capability to authorise, monitor, and track the drone flights. The technology makes it possible to overcome the limitations of relying on traditional ATC by minimising controller workload whilst maintaining safety assurance.

Realisation of the MCR concept marks another step toward enabling scaled, on demand operations to take place through real-time flight monitoring and authorisation for new airspace users.

"Electronic conspicuity is key. It allowed us to work out all the procedures to see and understand the airspace situation. We want to integrate from day one but you have to integrate on the basis of information,"

Alex Burlacu, New Airspace Users Consultant, NATS



► Airspace digitalisation as a catalyst for integration

"Today aviation is people-based; there is a pilot in the aircraft and a controller in the tower. But future traffic will be comprised of a combination of crewed and uncrewed aircraft and part of the fabric of a new, digital airspace,"

Nick Stevens,
Head of Integrated Traffic Management Solutions, NATS



Another important take-away has been a greater understanding of how digitalisation of services can drive airspace integration and utilisation efficiencies. Different airspace users need to fly at different altitudes; drones rely on expedient access to lower airspace. Digitalisation offers a way to support airspace integration, which is viewed as a precursor to enabling the scaled use of drones.

Digital flight rules have been a major topic for the evolution of aviation and Project CAELUS has added to the raft of evidence that sees this as an urgent issue to be resolved. As part of this process, flight plan formats will need to be translated into new data packets to allow for the allocation of the appropriate separation distances between multiple flights.

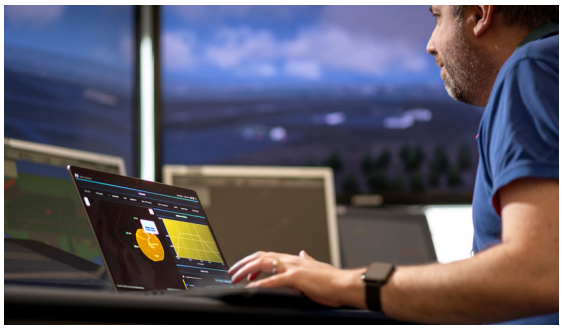
The project also highlighted the potential for drones themselves to help Airspace Managers by providing traffic information. Smaller drones operate closer to the ground and might only have low bandwidth connectivity, but larger drones which fly at a higher altitude with better bandwidth could gather information on the location of aircraft around them and possibly use this information to deconflict.











Beyond CAELUS: What's Next?

NATS is committed to working with regulators and industry to develop fully integrated low-level airspace in the UK. The shift towards commercialisation has already begun, with drone digital flight approval services now taking place in a number of airports across the UK, routine offshore drone inspection flights in the North Sea and implementation of the next generation of Master Control Room technology underway.

Working closely with the UTM service provider, NATS gained a granular understanding of the content and format of data used and how this could be aligned with traditional ATM systems for full integration. It was not just data that was explored in bridging the two worlds – the required levels of competency of all stakeholder groups were also made clear.

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By the end of the programme, NATS had achieved a close understanding between ATM and UTM personnel of the need for further cooperation. Routine, unsegregated crewed and uncrewed aviation is coming and all participants recognised the need to accommodate these new technologies and concepts within the traditional ATM environment.

"NATS has considerable ATM experience in understanding air risk and through exposure to the uncrewed aircraft world we were able to gain a quick understanding of what ground risk is and where the risk ownership lies. Knowing where the risks lie, from both an operational and regulatory standpoint, is vital. We also have a much better understanding of the junctions of responsibility among all stakeholders as a result of CAELUS."

Gareth Bowen, New Airspace Users Solutions Consultant, NATS

The learnings from Project CAELUS can now help to accelerate the integration of drones into the airspace in the UK and beyond. CAELUS helped validate NATS' Integrated Traffic Management concept of operations and define an evolutionary roadmap of technology, processes and procedures which can lead to full integration. Other important conclusions derived from the programme include:

1



Partnerships across the industry are essential to create a synchronised, commercially viable ecosystem supporting the end-to-end, order-to-delivery process with a single organisation acting as a systems integrator. Users such as the NHS perceive benefits in interfacing with a single organisation; there are drawbacks and inefficiencies when considering how to coordinate all the different organisations needed to make their drone deliveries possible. During long distance drone flights, there could be several different UTM service providers to work with along the way.

2



Development and deployment of an interoperable, cloud-based tool would keep all stakeholders up-to-speed and in communication with each other in real-time and enable provision of a seamless, safe, and timely service for drone operators.

3



The technology, CONOPs, and safety evidence is available to support the regulatory framework to progress programmes such as CAELUS into real-world, on demand, scalable operations.

Today there are 30,000 registered commercial drone pilots in the UK. The time has come to move beyond research and development and head towards full commercialisation. And as the Future Flight Challenge Programme comes to an end there needs to be a clear pathway for industry and regulators to move from advanced trials to commercial operations.

"The Future Flight activity has helped us identify where we can draw on existing NATS' resource and what new capabilities are required. We are developing a wide range of services for new airspace users in the UK and beyond, so CAELUS is part of a pipeline of activity that is running in parallel. We now have a baseline that we believe can work and scale. The next step is to put it into commercial operation."

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

NATS is a leading partner in the Future Flight Challenge, a £300 million R&D programme co-funded by government and industry, which is helping to build the ecosystem needed to accelerate the introduction of advanced air mobility, drones, and other new aircraft types in the UK.

NATS has been a part of several projects through the course of the programme, during which there has been collaboration with industry, academia, government, and regulators to develop new ways of connecting people, transporting goods, and delivering services in a safe and sustainable way.

The Project CAELUS Consortium partners are:

ags Three airports. One journey.

ANRA TECHNOLOGIES

ARUP

AtkinsRéalis

CATAPULT Connected Places

boldyn NETWORKS

Commonplace

Delivering Today DRONAMICS

INTELSIUS A DGP COMPANY

NATS

NHS SCOTLAND

planefinder

Skyports DRONE SERVICES

THEDRONEOFFICE

Trax

University of Strathclyde Glasgow

Sources

[1] Delivering Scalable UAS BVLOS in the Specific Category

[2] Care & Equity – Healthcare Logistics UAS Scotland

[3] The CAELUS consortium partners are AGS Airports Limited (Aberdeen, Glasgow & Southampton Airports), NHS Scotland, NATS, University of Strathclyde, Connected Places Catapult, ANRA Technology, Atkins, Arup, Cellnex Telecom, Commonplace Digital, DGP Intelsius, Dronamics, Planefinder, Skyports Deliveries Ltd, The Drone Office, Trax International.

[4] pwc.co.uk/issues/technology/drones/the-impact-of-drones-on-the-uk-economy.html

[5] egis-group.com/projects/advancing-uas-bvlos-and-airspace-concepts-design-and-regulation

[6] University of Strathclyde

[7] Anra Technologies

[8] CAELUS Roadmap, published 12.2024: Have Your Say Today - Deliverables - CAELUS

[9] 'Known traffic environment' means the flight plan intent is known for all the airspace users in that environment; 'recognised' means that all the airspace users are electronically conspicuous with a rule set to be followed to ensure safety of users in this space.

[10] nats.aero/about-us/research/n/project-amec/

[11] nats.aero/blog/2022/06/another-step-on-the-journey-to-next-generation-aviation/



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