U-space

SUPPORTING SAFE AND SECURE DRONE OPERATIONS IN EUROPE

A preliminary summary of SESAR U-space research and innovation results (2017–2019)

SESAR JOINT UNDERTAKING

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JOINT UNDERTAKING

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About the SESAR Joint Undertaking

As the technological pillar of the Single European Sky (SES) to modernise Europe's air traffic management (ATM) system, SESAR is now making significant progress in transforming the performance of Europe's ATM network. The SESAR Joint Undertaking (SESAR JU) was established in 2008 as a public-private partnership to support this endeavour. It does so by pooling the knowledge and resources of the entire ATM community in order to define, research, develop and validate innovative technological and operational solutions. The SESAR JU is also responsible for the execution of the European ATM Master Plan, which defines the European Union (EU) priorities for research and development (R&D) and implementation. Founded by the European Union and EUROCONTROL, the SESAR JU has 19 members, who together with their partners and affiliate associations represent over 100 companies working in Europe and beyond. The SESAR JU also works closely with staff associations, regulators, airport operators, airspace users, the military and the scientific community.

Horizon 2020 and Connecting Europe Facility

The projects outlined in this publication were co-funded by the European Union, through the following programmes*:

Horizon 2010 research and innovation framework programme
Connecting Europe Facility

* With the exception of the GEOSAFE project, which was funded by the EU on the basis of a delegation agreement

FOREWORD

Drones are disrupting 'business as usual' in air traffic management

As the drone service market continues to grow and take shape in Europe, the pressure is on to make sure that these air vehicles are safely and securely integrated into our already busy airspace.

Transforming infrastructure to support such operations is critical to harnessing the potential of the sector, unlocking market growth, jobs and services to EU citizens. But a simple adaptation of our current air traffic management system is not enough; accommodating these air vehicles in the numbers forecasted requires a new approach.

In 2017, the European Commission mandated the SESAR JU to coordinate all research and development activities related to U-space and drone integration. This brochure reflects the work that we have conducted over the last two years, and specifically the results from our 19 exploratory research and large-scale demonstration projects that addressed all aspects of drone operations, as well as the enabling technologies and required services.

The results from these projects show that we have made progress on the building blocks of U-space, with project partners already reporting plans to start work now in their respective countries to deploy some elements of U-space. At the same time, the projects also identified important gaps in terms of the performance of certain technologies or where more research is needed, especially in the area of urban air mobility operations and the interface with manned aviation.

Another important outcome of the research and innovation has been the building up of the drone stakeholder community, with projects bringing together an unprecedented number and range of actors from traditional aviation, but also new entrants, including start-ups, small and medium enterprises (SMEs), research institutes, universities, drone operators as well as service providers, airports, local/city authorities, law enforcement agencies and civil aviation authorities.

With the involvement of the European Union Aviation Safety Agency (EASA) and the European aviation industry standards-developing body, EUROCAE, the projects have also ensured that their results can be taken further within ongoing drone standardisation and regulatory work.

I hope you enjoy the read!

Florian Guillermet
Executive Director
SESAR Joint Undertaking

Background on U-space

Drones represent a rapidly growing sector of aviation in Europe and worldwide – offering potentially a myriad of services to business and citizens, but placing new demands on the airspace around us. Estimates vary on the volume and value of the drone industry in the future. However, the European Drones Outlook Study([1]) estimates as many as 400,000 drones will be providing services in the airspace by 2050, and a total market value in excess of EUR 10 billion annually by 2035. Recognising the huge potential available, the European Commission launched U-space in 2016 - an initiative aimed at ensuring the safe and secure integration of drones into the airspace. With it, the Commission set in motion a series of activities across Europe directed towards the development of appropriate rules and regulations, as well as technical and operational requirements capable of supporting future autonomous operations. This included tasking the SESAR JU to coordinate all research and development activities related to U-space and drone integration.

> ***U-space is a set of services and procedures relying on a high level of digitalisation and automation of functions to support safe, efficient and secure access to airspace for large numbers of drones. It provides an enabling framework to support routine drone operations and addresses all types of missions including operations in and around airports. Ultimately, U-space will enable complex drone operations with a high degree of automation to take place in all types of operational environments.***

U-space Blueprint

The SESAR JU started with the publication of the U-space Blueprint([2]), setting out the vision and steps for the progressive deployment of U-space services from foundation services, such as registration, e-identification, geo-awareness, to more complex operations in dense airspace requiring greater levels of automation and connectivity. Building on the blueprint, the SESAR JU then went further into detail with a roadmap for the safe integration of drones into all classes of airspace(3) . This embeds not just the timeline for U-space, but it also outlines the steps to be taken to ensure a coordinated implementation of solutions to enable remotely piloted aircraft systems (RPAS) to fly alongside commercial aircraft. The roadmap has been included in the 2020 edition of the European ATM Master Plan(4), which is the main planning tool shared by all stakeholders for air traffic management modernisation in Europe.

([1]) European Drones Outlook Study https://www.sesarju.eu/sites/default/files/documents/reports/European_Drones_Outlook_Study_2016.pdf

([2]) U-space Blueprint. https://www.sesarju.eu/u-space-blueprint

([3]) Roadmap for the safe integration of drones into all classes of airspace https://www.sesarju.eu/node/2993

([4]) European ATM Master Plan. https://www.sesarju.eu/masterplan

Research and innovation portfolio

In 2017, the SESAR JU launched[5] a set of exploratory research projects addressing everything from the concept of operations for drone operations, critical communications, surveillance and tracking, and information management to aircraft systems, ground-based technologies, cyber-resilience and geo-fencing. Seeing is believing when it comes to securing acceptance and accelerating market take-up of the U-space services and capabilities. To this end, in 2018 the SESAR JU launched demonstration projects 5[6] aimed at showing the readiness of U-space services to manage a broad range of drone operations and related applications, and their interaction with manned aviation. These range from parcel deliveries between two dense urban locations, medical emergencies and police interventions, as well as air taxi trials in an airport controlled airspace. The leisure user was also catered for, with projects demonstrating how private drone operators too can benefit from U-space services. The operations also aimed to demonstrate different levels of automation that are possible, as well as seamless information exchange between multiple service providers in the same geographical area at the same time.

Strong multi-stakeholder participation

The research work brought together an unprecedented number of actors from traditional aviation, start-ups, research institutes, universities, drone operators, service providers, airports, local/city authorities, law enforcement agencies and civil aviation authorities. Altogether 125 entities, including 25 European airports, 25 air navigation service providers, 11 universities, more than 65 start-ups and businesses, as well as 800 experts, shared their knowledge, skills and resources. The projects were conducted in close coordination with the EASA, tasked by the Commission with drafting rules to govern the safe integration of drones into manned airspace, to help identify the operational requirements needed for this regulatory

(5) Co-funded by the EU's Horizon 2020 Research and Innovation Programme.
(6) Co-funded by the EU's Connecting Europe Facility.

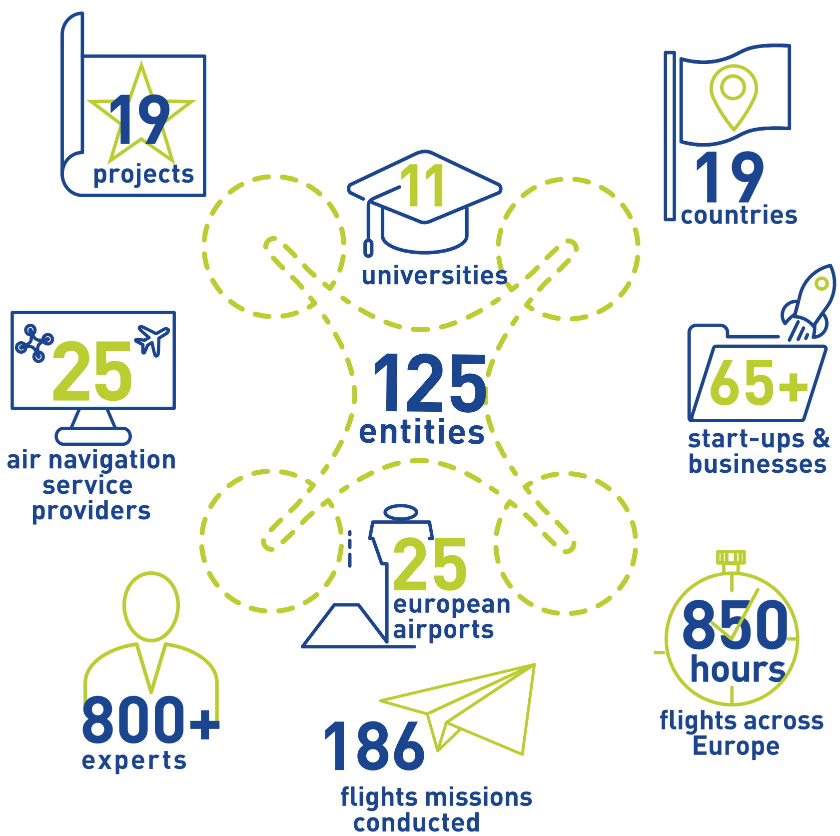
U-space CONOPS and Research Dissemination Conference, 1 October 2019, Brussels

framework. In addition, the SESAR JU also ensured close cooperation with the European aviation industry standards-developing body, EUROCAE, and supported wider standardisation work by the International Civil Aviation Organisation (ICAO), in particular ICAO's Standards and Recommended Practices (SARPS) for drones operating in manned airspace due for implementation in 2023. Recognising the need to have a broader view on U-space, the projects also involved organisations representing new entrants, such as the Global UTM Association (GUTMA) and Drone Alliance Europe, as well non aeronautical bodies from the telecom industry.

The SESAR JU research and demonstration projects have forged new relationships. A good example of this is the collective support gained through a series of workshops and involvement of hundreds of stakeholders to develop a Concept of Operation for EuRopean Unmanned Air Traffic Management Systems (CORUS), which was published in 2019. The U-space Community Network (UCN) grew to over 500 members over the course of the project and resulted in the release of a detailed and widely accepted initial concept of operations for U-space.

To ensure even broader engagement, the Commission launched the European Network of U-space Demonstrators in 2018, a forum to share knowledge and support the work of research bodies such as the SESAR JU and regulatory agencies including EASA. The network serves to extend the community and to involve more actors in the important task of developing a robust framework for unmanned and manned vehicles to share the airspace.

U-SPACE RESEARCH & INNOVATION IN NUMBERS



What is in this publication?

Two years on, SESAR JU partners have completed 19 research and demonstration projects, the results of which are summarised in this brochure. The projects map progress on development of the technological capabilities and all services required for making U-space a reality, starting with foundation services (U1) before progressing to initial services (U2), advanced services (U3) and finally full services (U4) – read definitions of services in Annex 1.

U-space services

U1	Foundation	Registration Registration assistance e-identification Geo-awareness Drone aeronautical information management	
U2	Initial	Tracking (Position report submission) Surveillance data exchange Geo-fence provision (includes dynamic geo-fencing) Operation plan preparation /optimisation Operation plan processing Risk analysis assistance Strategic Conflict Resolution Emergency Management Incident/ Accident reporting	Citizen reporting service Monitoring Traffic information Navigation infrastructure monitoring Communication infrastructure monitoring Legal recording Digital logbook Weather information Procedural interface with ATC
U3	Enhance	Dynamic Capacity Management Tactical Conflict Resolution Geospatial information service Population density map	Electromagnetic interference information Navigation coverage information Communication coverage information Collaborative interface with ATC
U4	Full	Integrated interfaces with manned aviation Additional new servicesw	

SOURCE: Based on list from U-space concept of operations – Edition 3 (see annex 1 for the full description)

How mature is U-space?

In order to assess the maturity of U-space technologies, the SESAR research programme created two basic assumptions: the first assumed that U1 services are ready and available now; the second assumed that U2 services are technically possible and can be realised today. SESAR JU projects were then designed to test the two assumptions and report on the extent to which they were true.

Whilst the projects provide plenty of examples where U1 (foundation) services, such as geofencing and identification are already available, they also clearly showed that a lack of standardisation has led to variations in performance. In addition, there are gaps in capability, for example in sharing information with other stakeholders or operating multiple drones. Similarly, while advanced technology supports many U2 (initial) services, including tracking and monitoring, flight planning and communications, delivery of these services was characterised by under-performance in connectivity and interoperability.

Results coming from this first round of SESAR exploratory research and demonstration activities allow, for the first time in Europe, conclusions to be drawn from a series of projects that address the full range of issues that need to be covered to implement U-space. This permits a rigorous analysis of both where we stand and how

U-space technological capabilities

Aircraft systems	Higher levels of air and ground automation	Concept of Operation and procedures
Datalink and spectrum	Drone information management, including geoawareness and interfaces with manned aviation	Ground based technology
Multiple service providers	Security, including physical security, & cyber-resilience	Sense & avoid and separation provision

U-space environments

- Urban environment
- Sub-urban environment
- Rural environment

to focus further work to enable U-space to reach a higher level of maturity. For example, many business models have the need for drones to safely carry out long-distance operations known as beyond visual line of sight (BVLOS). These include reliable two-way communications during flight and the means to identify and track drones while in the air so that the flight can be safely managed and deconflicted from manned aircraft and from other drones.

Supporting the standardisation process

In addition to providing a breakdown of development work still required, the results feed directly into the standardisation process underway in Europe, as well as in other world regions. Research findings and operational trials provide valuable performance data to support coordinated and common standards for drone operations. For example, only by testing the performance of geofencing technology on board drones can appropriate minimum standards be drawn up. U-space demands a risk-based and performance-driven approach when setting up requirements for safety and security. This demands comprehensive understanding of the performance of drones in operational scenarios.

SESAR JU and its partners work closely with EUROCAE and the European UAS Standardisation Coordination Group (EUSCG) to ensure that parallel standardisation activities – vital to the implementation of U-space – can benefit from reliable data coming from the projects.

KEY MILESTONES AND FINDINGS

CONCEPT OF OPERATIONS FOR U-SPACE

The CORUS project received broad consensus for the U-space Concept of Operations (CONOPS). It provides an initial U-space architecture and detailed definition of the airspace types to be used for very low-level drone operations and the services within them so that operations are safe and efficient. It describes U-space from a user's perspective, showing how it will be organised and detailing the rule-making that is under development. The CORUS CONOPS shows, for the first time, a complete picture of U-space that can be easily understood and that can form a foundation on which U-space implementation throughout Europe can be based.

SHOWING THE FEASIBILITY OF MULTIPLE SERVICE PROVISION

A key aim of the development of U-space in Europe is the promotion of an open drone market, enabling operators and service-providers alike to build this new eco-system without having to adopt the structure of more traditional ATM. This will support the operation of multiple simultaneous service providers operating in both cooperation and in competition. The SESAR JU projects provided an opportunity to progress from demonstration flights to introducing drone services in the future. The Port of Antwerp, for example, explored inspection technology which was demonstrated during the Safe and Flexible Integration of Initial U-space Services in a Real Environment (SAFIR) project, extending over 120 square km. The port authorities found the drones "an immense addition to safety" as they were able to "manage, inspect and control a large area in a swift and safe manner." SAFIR succeeded in interconnecting multiple UTM systems and supported a variety of drone types and established Antwerp as one of the key locations in Europe where U-space is advancing in a real operating environment. It also recommended further research into interaction with air traffic control and performance requirements for satellite mobile connectivity. The project showed how technology can support multiple service providers, a core requirement for complex future applications.

SUPPORTING STRATEGIC DECONFLICTION

Among key capabilities, foundational U-space services (U1) such as e-registration,

Visit by then European Commissioner for Transport, Violeta Bulc, to SAFIR Droneport demonstration, 5 September 2109

e-identification and geofencing were successfully demonstrated by the D-flight Internet of Drones Environment (DIODE) project. Flights conducted in real-life environments, including precision agriculture, parcel delivery, road traffic patrolling, surveys and search and rescue showed that capabilities on board drones can manage containment. The project also showed how a U-space service provider (USSP) can provide a safe operational environment by exchanging information with drones and air traffic management. This supports strategic deconfliction for a limited number of operational drones, allowing initial trials in Italy in 2019.

Advanced conflict detection is essential for multiple drones to operate simultaneously, and this was tested by the Demonstration Of Multiple U-space Suppliers (DOMUS) project. DOMUS used a federated architecture to show how several U-space service providers can support drone operations using key functionalities including dynamic geofencing and tactical de-confliction to deliver dynamic flight management in real-time. The project integrated already developed technologies to support optimum operation profiles and fleet management while ensuring safety, security and privacy. A principle service provider, called the Ecosystem Manager, provided a single point of truth and an interface with air traffic control. DOMUS investigated the full range of U1 and U2 services, and demonstrated solutions, for example, enabling a controller to create a geofenced area around a manned aircraft, in addition to interoperability between different U-space services.

↘ INCREASING SITUATIONAL AWARENESS THROUGH INFORMATION EXCHANGE

A basic function of U-space is to bring situational awareness to all actors, and information exchange is fundamental to achieving this. Safe drone integration in the Gulf of Finland (GOF-USPACE) trial established an interoperability architecture to integrate existing solutions and used this to support operations ranging from parcel delivery, inspection services, police operations and search & rescue in maritime and city environments. The architecture relies on standard protocols to exchange data and serves as a flight information management system (FIMS), which disseminates information about manned and unmanned vehicles to a wide range of stakeholders including local and national authorities, ANSPs, U-space service providers, etc. By using an open platform and system-wide information management (SWIM), the solution manages collectively and cooperatively all drone traffic in the same geographical region. In the real-life demonstrations, the platform enabled manned and unmanned aircraft to safely share the same airspace by providing operators and pilots access to common flight information.

↘ FOCUSING ON TRACKING AND MONITORING

GOF-USPACE also showed the importance of reliable tracking data for all airspace users. Flight tests assessed the performance of multiple collision avoidance and tracking systems (e.g ADS-B, FLARM) and, whilst these technologies could all support surveillance, experience revealed inconsistencies in performance. Project results thus highlighted the need for interoperability and for further work on standardising such technologies. Similarly, the reliability of data communications is key to timely delivery of information, so U-space services need to be resilient to loss of mobile network coverage.

Another project that tested secure tracking and identification of drones was USIS. During long-distance flights in Hungary and France, SESAR JU partners relied on advanced flight planning, authorisation and tracking services and successfully used cloud-based platforms to manage multiple numbers of unmanned operations. USIS validated the integration between the UTM platform and e-identification and tracking of drones; it also showed how flexible flight planning supports multiple drone operations and recommended more research involving more participants.

Meanwhile partners in TERRA assessed whether machine learning can help monitor very low-level operations, including early detection of off-nominal conditions such as trajectory deviations. They found that artificial neural networks modelling could be used for predicting and classifying drone trajectories in urban scenarios.

↘ ADDRESSING THE INTERFACE WITH MANNED AVIATION

The interaction with manned aviation proved to be among the most challenging of areas of research. For unmanned and manned vehicles to share the same airspace, flights need to be visible to other airspace users. This is especially important in the lower airspace where general aviation accounts for over 100,000 users in Europe.

Maintaining the safety of air operations when drones and conventional aircraft share low-level air space, close to an airport for example, will require a high degree of digitalisation and automation. This was one of the key areas addressed by partners in the SAFEDRONE project. Over the course of two years, the project partners looked at the increased levels of autonomy necessary to operate in non-segregated airspace and to carry out dynamic in-flight activities such as on-board re-planning trajectories within the U-space approved flight plan, and autonomous generation of coordinated trajectories within an approved U-space area of operation. It assessed the viability of using 4G networks for communication during BVLOS flights and GNSS technologies for drones to report an accurate altitude so that the UTM system can use it.

The interface with manned aviation was also addressed by the GOF-USPACE, whose demonstrations marked the first time that general aviation aircraft, drones, and recreational remote-controlled model aircraft shared controlled airspace above and around an operational airfield. The project showcased the core vision of U-space, increasing transparency for all users, including drones, general aviation and other airspace users, who are able to access digital tools that the current UTM solutions provide in order to create situational awareness for everyone. Mobile 4G networks were used to relay situational awareness data

to both ground crew and general aviation flying up to 2 000 feet, tracking targets using transponders, FLARM, and mobile network-based position trackers.

An important finding from all the projects that looked at the interactions with manned aviation was the need for a common altitude reference. Different drones used different mechanisms for measuring and reporting their altitude, but there was no harmonised approach that could support the management of a vertical profile with regard to other drones or manned aircraft. This is one of the key findings from the technologies tested that have been passed to EASA and standardisation bodies, EUROCAE and GUTMA, to help develop standards that will enable safe integration of drones in the airspace.

HARNESSING RESULTS FROM NON-U-SPACE SESAR RESEARCH PROJECTS

Thanks to its broader mandate, the SESAR JU has a comprehensive and integrated view of the air traffic management, and the operational needs of all airspace users. This means that insights drawn from one area of its research and innovation activities can be fed where relevant into other areas of the programme. This is the case of a number of research projects from SESAR JU's core innovation portfolio, the results of which are providing valuable additional findings about cost-efficient solutions that may be of interest to the drone community. In the area of surveillance, for example, the General Aviation Improved Navigation and Surveillance (GAINS) project used low-cost, low-power ADS-B transceivers to show that electronic conspicuity helps general aviation pilots integrate with other airspace users without incurring high cost or requiring additional certification. The results showed general aviation pilots were able to avoid potentially hazardous situations as a result of improved traffic situational awareness before visual acquisition.

Reliable communications are essential to support safe operations, prevent mid-air collisions and enable dynamic flight planning. The EMPowering Heterogenous Aviation through cellular Signals (EMPHASIS) project examined affordable cooperative surveillance that is available using a low-power automatic dependent surveillance – broadcast (ADS-B) transceiver – which could be carried on board each drone and are becoming readily available. However, further work is required to ensure that such developments do not impact the critical 1090 MHz spectrum. The research also found general aviation could interact successfully with unmanned vehicles using 4G/5G datalinks and justifies further research and development.

U-SPACE EXPLORATORY RESEARCH COVERAGE*

* The map illustrates the geographical coverage of all U-space exploratory research projects, taking into account the location of each project partner headquarters. Project names are displayed according to where the project coordinator is located.

SERVICES

U2 U3 U4

TECHNOLOGIES

ENVIRONMENT

CORUS:
Concept of Operation for EuRopean UTM Systems

CORUS

Partners

ENAV
EUROCONTROL (Coordinator)
Deutsche Flugsicherung (DFS)
Deutsches Zentrum für Luft- und Raumfahrt (DLR)
HEMAV
NATS
The direction des Services de la navigation aérienne (DSNA)
The Polytechnic University of Catalonia (UPC)
Unifly

A set of easy-to-use rules for low-level airspace operations

A harmonised approach to integrating drones into very low-level airspace is vital if the rapidly growing drone industry is to fulfil its economic and social potential. Gathering experts from aviation, research and academia, guided by a 21-member stakeholder advisory board, the CORUS consortium developed a Concept of Operations (CONOPS) for U-space. It proposes an initial architecture for this airspace with a detailed definition of the airspace types to be used for very low-level drone operations and the services in them, so that operations are safe and efficient. It balances the needs of the drone sector with those of society as a whole.

The activity of the CORUS project centred around three workshops held in January and June 2018 and April 2019, each attended by 100 stakeholders of widely varying backgrounds. Each workshop discussed a new iteration of the CONOPS, allowing the project to refine and validate them, leading to a U-space concept of operations (edition 3), providing the latest baseline for the U-space services.

CORUS developed a concept of operations for drone operations in very low-level airspace

Broad acceptance of the CORUS CONOPS has been essential to its success, with interested parties invited to join the "U-space Community Network" (UCN) that grew to over 500 members during the course of the project. These UCN members received information about the progress of the project, were invited to attend the workshops, and provided input on a number of questions to guide the project's work. Well over 1 000 written comments were received that informed the drafting of the CONOPS. CORUS also communicated and cooperated with more than 70 organisations involved in other related projects looking at specific drone and U-space technologies.

The initial architecture description identifies airspace type, services and necessary technical developments

The CONOPS details drone operations in uncontrolled very low-level airspace, and in and around controlled and/or protected airspace such as airfields. It also describes an initial architecture that identifies the airspace types, services and technical development necessary for implementation of the CONOPS, quantifying the levels of safety and performance required. It includes use-cases for nominal scenarios such as contingencies and emergencies; and proposes a method to assess the safety of service provision (MEDUSA). Finally, it proposes solutions for easing social acceptance of drones by examining aspects including safety, privacy, noise and other societal issues.

The CONOPS is a living document and so the expectation is that updates will be required in order to take into account the evolution towards urban air mobility (UAM) operations.

SERVICES U2 U3 U4

TECHNOLOGIES

ENVIRONMENT

Security is key to safe operations in very low-level airspace

SECOPS: an integrated SECurity concept for drone OPerationS

Given the highly automated nature of drone operations, cyber security is particularly important and security risks in U-space need to be assessed and mitigated to an acceptable level. Secure drone operations need to be supported by a combination of different security functions at different levels in the drone end-to-end system, managed by a dedicated set of procedures and supported by clear regulations. By establishing an integrated security concept, drones can operate in accordance with appropriate procedures and regulations, while any drones that divert from their flight plan can be detected and acted upon.

To this end, SECOPS defined an integrated security concept for drone operations, including addressing resistance of drones against unlawful interference, protection of third parties and integration of geo-fencing technology. The research reviewed technological options for both airborne and ground elements, considered legal, as well regulatory and social aspects.

A preliminary cyber security risk assessment was performed to determine the risks concerning confidentiality, integrity and availability (CIA) of the U-space information flows. By assessing and prioritising potential security risks, the SECOPS Integrated Security Concept defines requirements and proposes potential security controls. An experimental proof of concept integrating common-off-the-shelf technologies of the consortium partners was executed in order to prove the feasibility of parts of the integrated security concept and co-operability of the more mature technical solutions, including detection of rogue drones and air defence solutions.

Among critical issues, SECOPS found the trustworthiness of drone track and position information to be important. A key priority is knowing where data comes from and assuring data integrity of global positioning and geofence information for example, as are the timeliness of reactions to events to ensure law enforcement is informed.

SECOPS concluded drone counter measures are likely to be a combination of different technologies and suggests further research to identify appropriate solutions for various applications. It also recommends a legal framework setting out the roles and responsibilities of enforcement agencies.

Partners

Delft Dynamics

NLR- Royal Netherlands Aerospace Centre (Coordinator)

Sensofusion

Unifly

- **U-space that incorporates security is needed to facilitate the secure, safe and efficient growth of drones**
- **Drones which fail to operate in accordance with the regulations need to be detected and acted upon**

SERVICES U2 U3

TECHNOLOGIES

ENVIRONMENT

IMPETUS:
Information Management Portal to Enable the inTegration of Unmanned Systems

IMPETUS

Partners
Altitude Angel
Boeing R&T-E
C-ASTRAL
CRIDA (Coordinator)
INECO
Jeppesen

New technologies to support U-space information needs

Microservice-based architecture supports flexible and rapid information updates

A scalable and federated architecture is possible to meet consumer demands and facilitates billing according to the use of resources

Many of the differences between ATM and U-space have to do with scale. Drone information services will be significantly more detailed, diverse and dynamic than those used by aircraft today. Safety critical information, for instance, will be needed at a much higher fidelity than in today's solutions, and will include geospatial information services to ensure surface clearance, local weather information to calculate drone trajectory uncertainties and non-conventional navigation sources (such as signals of opportunity and vision-based navigation) to allow for more precise navigation on a local scale. Services of this level of fidelity will require the movement and provision of massive amounts of data to a wide array of users spread out over a large geographical area.

When IMPETUS looked at what information is needed and how it will be used by drones in very low-level airspace, researchers proposed an information management architecture based around microservices. This contrasts with legacy monolithic applications which are centralised, uniformly packaged and single-language-based programmes that quickly reach overwhelming complexity as they grow to meet consumer demand. Microservice-based applications avoid this issue as the entire application is split into small, independent but highly interconnected services.

The framework of the IMPETUS solution is based on a federated architecture with a layered distribution of responsibilities. It is made up of a central actor that provides a single point of truth of the airspace situation, an intermediate interface composed of multiple U-space service providers, and an external layer for the end users (drone operators). The IMPETUS platform supports testing of various U-space services.

IMPETUS replicated aspects of this architecture and concluded it can meet relevant U-space challenges. For example, one experiment explored how a drone deconfliction service can interact with other services in the system to maximise the airspace capacity for drones based on dynamic volumes. Impetus looked at whether this is not only technically possible, but also a viable option when realised in coordination and conjunction between services. This approach fully supports U-space objectives of flexibility, availability and scalability, and is an enabler of high-density operations requiring agile responses and adaptability to change.

SERVICES U2 U3

TECHNOLOGIES

ENVIRONMENT

Drones need essential aero nautical information to fly safely

Much like manned aviation, unmanned flights rely on accurate aeronautical information to stay informed about the weather, airspace restrictions and regulations during a flight. The variety and complexity of drone operations requires a different approach to managing this aeronautical information.

The DREAMS project set out to identify gaps between existing information used by manned aviation and new needs coming from U-space. Unmanned aviation will require a comparable level of information with the same level of integrity and reliability as manned aviation. In this respect, DREAMS assessed the present and future needs of aeronautical information to support the growth of unmanned aviation and ensure the safety of operations.

The gap analysis carried out by the DREAMS partners analysed operational and technical aspects, environmental scenarios, technologies, safety and security impact in order to identify possible U-space data - including airspace structure, drone data, flight plan, obstacles and weather - and related service providers and facilities required by drones. The work was validated through simulations and examined how information might be sourced, managed and disseminated. It also looked at technologies needed to support remotely piloted flights, such as geo-fencing and flight planning management functionalities. It recognised the importance of information quality for drone operators and the need to provide sufficient information on active drones for other airspace users.

The project concluded aeronautical information available today is insufficient to support U-space operational needs without some extension or tailoring and additional research. It confirmed, for instance, that U-space will need new aeronautical features such as geofencing and geo-caging (to instruct a drone where it can fly), geo-vectoring (how to fly) and speed vectors. Several data formats were identified – for example AIXM and GeoJSON – which will be needed to ensure data quality and performance. Similarly, several protocols will be necessary to enable data exchange with different client capabilities. DREAMS also concluded that the aeronautical data exchange service should provide data querying capability in terms of feature type and attribute, and any data suppliers should include data sources in keeping with the open-data environment. In terms of preferred development, the research partners concluded that a microservice approach would be the best option and fully compliant with SESAR JU and CORUS CONOPS architecture principles.

DREAMS:
Drone European Aeronautical information Management Study

dreams

Partners

EuroUSC
IDS AirNav (Coordinator)
Topview
TU Delft

- **DREAMS delivered a stronger understanding of data items and services that are important for U-space users**
- **The variety and complexity of drone operations in the future require an extension of aeronautical information available today when at the same time, existing data and format can be used and completed to fulfil the needs**

SERVICES

U2 U3

TECHNOLOGIES

ENVIRONMENT

CLASS: Clear Air Situation for uaS

CLEAR AIR SITUATION FOR UAS

Partners

Airbus D&S (Coordinator)

Aveillant

Ecole Nationale de l'Aviation Civile (ENAC)

Norwegian University of Science and Technology (NTNU)

Unifly

Safe drone operations require reliable tracking and monitoring

Reducing the risk of conflict between airspace users becomes more important as more drones enter the airspace. The Clear Air Situation for uaS (CLASS) project examined the potential of ground-based technologies to detect and monitor cooperative and non-cooperative drone traffic in real-time. The consortium fused surveillance data obtained using a drone identifier and tracker, and holographic radar, to feed a real-time UTM display.

CLASS tested tracking and display of cooperative and non-cooperative drones in six operational scenarios, ranging from an out-of-control leisure drone, conflicts with emergency operations, and incursions by rogue drones. Various scenarios were carried out by project partners to benchmark the surveillance and data fusion technology and achieve the lowest rates of false alarms. The functionalities provide the basis for a real-time centralised UTM system, which can be used by all stakeholders, from drone operators to air navigation service providers, authorities and airports. The functionalities were also designed to support advanced services, such as geo-fencing (where the drone pilot is warned automatically if he trespasses into an unauthorised zone), geo-caging (where the drone pilot is warned that he is leaving a pre-defined zone), conflict detection and resolution.

Data from dozens of field flights have improved drone detection and tracking

Sensitive categories of airspace need higher performance tracking services

As a result of the demonstrations, CLASS was able to define and detail the functional and technical requirements for tracking, monitoring and tactical deconfliction. For example, tracking requirements will vary from statically managed to dynamically managed airspace where real-time decisions are necessary because of conflict, or new dynamic geo-fenced volumes. CLASS also found variations in the performance of tracking technology and recommended the drawing up of standards for different U-space services. For example, there is a difference between tactical deconfliction services and on-board detect and avoid systems, which means these must operate effectively to manage the wide range of drone types and sizes.

Further research is recommended to scale up the operational scenarios to simulate surveillance in denser environments, initially involving tens of drones.

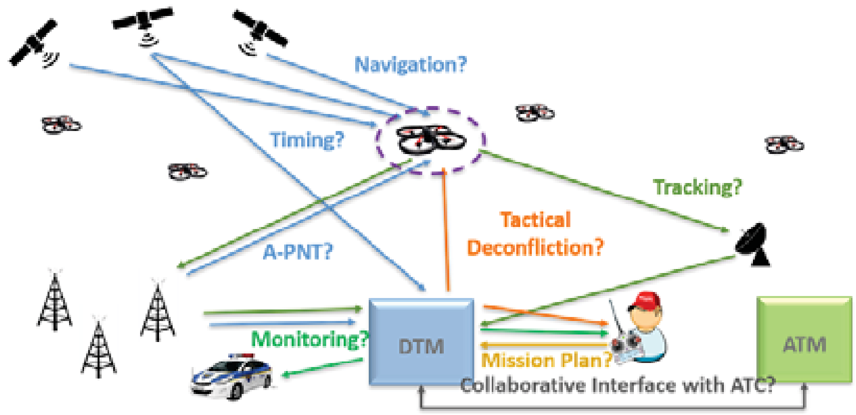
SERVICES

U2 U3

TECHNOLOGIES

ENVIRONMENT

U-space relies on existing and new ground infrastructure technologies



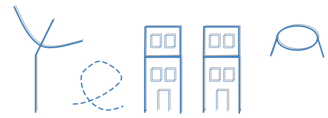
The current communications, navigation and surveillance (CNS) infrastructure is designed to support the needs of manned aviation. The requirements of the emerging drone sector are different and will rely on new and existing technologies to perform effectively. The TERRA project set out to identify relevant ground technologies and to propose a technical ground architecture to support drone operations.

TERRA started by defining the performance and functional requirements of ground-based systems for drones, analysing in particular the strengths and weaknesses of CNS technologies to support safe, effective and efficient very low-level operations. Three business cases were selected - agriculture, infrastructure inspection and urban delivery – and small-scale trials were conducted using new and existing technologies. A qualitative evaluation was performed for all the presented technologies using a set of performance characteristics, together with an assessment of their pros and cons for drone operations. Additional work was carried out to assess whether machine learning can help monitor very-low-level operations, including early detection of off-nominal conditions such as trajectory deviations.

The research considered different sizes and types of drones operating visual and beyond visual line of sight, in urban and rural environments. In terms of the applicability of technologies, the research examined continuity of service, coverage, data security, bandwidth, latency, update rate, integrity and availability. The research also applied artificial neural network (ANN) modelling to demonstrate successful conflict prediction in urban environments and used rule-based reinforcement learning to mitigate against frequent follow-on conflicts with other traffic. The analysis showed that machine learned application of traffic rules performed relatively well under higher traffic densities.

TERRA concluded that in environments with a low density of drones and a low level of complexity the current CNS technologies are sufficient to support U-space services. However, existing technologies present some drawbacks, which limit their application for complex scenarios such as urban environments and high drone densities. To allow full U-space deployment, improved technologies are required. These include making use of 5G wireless communications, technologies enabled by Galileo and EGNOS such as augmented satellite positioning data, to cover gaps. Additionally, artificial neural networks modelling has shown the potential benefits of machine learning for use in predicting and classifying drone trajectories in the urban scenarios.

TERRA: Technological European Research for RPAS in ATM



Partners

C-Astral
CHPR BV
CRIDA
INECO (Coordinator)
Leonardo
NLR- Royal Netherlands Aerospace Centre

- **Existing CNS technologies are sufficient to support U-space in simple environments**
- **New technologies like 5G, Galileo and EGNOS v3 will be needed in complex environments**

SERVICES

U2 U3 U4

TECHNOLOGIES

ENVIRONMENT

PercEvite:
Percevoir et Eviter – Detect and Avoid

Partners

KU Leuven
Parrot
TU Delft (Coordinator)

Developing an autonomous sense and avoid package for small drones

Collaborative separation is possible using novel WiFi-based communications solutions

Project provided insight into novel perception methods including depth-perception in still images and aircraft detection based on sound

Given the number of drones forecasted to take to the skies in the coming years, a key priority will be to ensure they stay clear of other airspace users, people and property on the ground. A solution is needed that allows drones to detect and avoid other obstacles autonomously, and it would be beneficial if this solution is also suitable for large groups of small drones.

To address this challenge, the PercEvite project focused on the development of a sensor, communication, and processing suite for small drones. The main requirement was that the chosen solution could detect and avoid ground-based obstacles and flying air vehicles without necessitating human intervention.

The work centred around developing a low-cost, lightweight, energy-efficient sensor and processing package to maximise payload capacity. The package features a mixture of mature concepts like collaborative separation and less mature but high-potential technology like hear and avoid.

The work started with designing the hardware and software to support these functionalities before combining the technology into a single unit capable of operating on small drones. Activity then transitioned to live demonstrations using innovative concepts to test the different functionalities. For example, cameras were used to identify objects such as cars, people and obstacles, while embedded microphones were used to differentiate between objects in the airspace and identifying an aeroplane as opposed to a helicopter. The tests looked at different methods of communication ranging from software-defined radio to long term-evolution (LTE) 4G wireless broadband. The aim was always to find low-cost, light weight solutions suitable for use by small drones.

The PercEvite partners developed two systems: one designed for extremely small drones weighing as little as 20 grams; and a more comprehensive solution weighing 200 grams suited to drones commonly used in commercial activities like inspection services, photography, surveillance and package delivery. Development work continues in 2020 as the research partners endeavour to produce integrated solutions for these applications.

SERVICES

U2 U3

TECHNOLOGIES

ENVIRONMENT

Reliable communications are central to safe drone operations

DroC2om: Drone Critical Communications

Drones rely on a high level of digitalisation to operate autonomously and depend upon datalink communications to achieve this. Command and control (C2) information needs to be reliably transferred in support of functions and specific procedures, enabling drones and manned vehicles to operate safely in the same airspace. The DroC2om project reviewed the capability of the existing cellular and satellite infrastructure that supports C2 datalink communications, using live flight trials and simulations to test availability and performance. The research led to the definition of an integrated communications concept incorporating cellular and satellite datalinks, which is contributing to EUROCAE and 4G/5G standardisation work.

Project partners assessed the reliability of the combined cellular – satellite radio network architecture and radio mechanisms. One of noted challenges is the operating conditions for drone radio channels, which are reasonably known for the satellite communication channel commonly used by large drones, however limited investigation has been carried out on the cellular channel and the operating conditions which prevail at drone heights up to 150 metres. The Droc2om project included experimental investigations to bring further clarification on this in order to design radio technology that will make the C2 link operate with specified reliability with specific reference to service level compliance and latency. Based on DroC2om initial investigations, the project partners found that interference management presents a challenge to the reliable operation of the C2 datalink and proposed solutions for further simulation and research.

Proposals to address connectivity issues include: Increasing the number of antennas on the drone, with a simple selection mechanism; and adding different networks connections and operators. The solutions are moderately complex and designed for when density of drones increases.

The project provided solid empirical evidence on the drone to cellular networks channel in urban areas and validated dual LTE C2 performance using live trials. It also tested multi-link connectivity and beam switching to ensure drone C2 link quality is maintained in highly loaded cellular networks. It concluded a hybrid cellular-satellite architecture, combining low latency and coverage of cellular with reliability of satellite communications, contributes to robust C2 performance.

DroC^{2}om

Partners

Aalborg University (Coordinator)
ATESIO GmbH
Nokia Bell Labs
Thales Alenia Space

- **DroC2om validated dual LTE C2 performance in an urban environment**
- **The results feed into EUROCAE standardisation work and 4G/5G specifications on LTE usage by aerial vehicles**

SERVICES
U2 U3
TECHNOLOGIES
ENVIRONMENT

AIRPASS:
Advanced Integrated RPAS Avionics Safety Suite

Partners

Avular B.V.

Deutsches Zentrum für Luft- und Raumfahrt e.V. (Coordinator)

Israel Aerospace Industries Ltd.

Nationaal Lucht- en Ruimtevaartlaboratorium

Università degli Studi di Napoli Parthenope

SAAB Aktiebolag

Technische Universität Braunschweig

The Central Aerohydrodynamic Institute TsAGI

NLR- Royal Netherlands Aerospace Centre

Assessment of technologies on-board drones reveals solutions and potential gaps for some U-space applications

AIRPASS has defined a functional architecture for on-board drone systems to enable the use of U-space services

Identifying on-board technology necessary for drones to share the airspace

Drones of all shapes and sizes will provide services in the future, ranging from small medical deliveries, inspection services, and package deliveries, to larger urban taxis and remotely operated systems. To interact safely with all other airspace users and services, AIRPASS partners defined a high-level architecture for the on-board equipment they need to carry. This architecture considers communications, CNS systems, as well as technology specific to drone operations such as autopilot and detect and avoid systems.

AIRPASS carried out an analysis of available on-board technologies and identified gaps between these systems and technologies necessary to operate drones. The project matched every U-space service to the main avionics components of a drone; specifically communications, navigation, automated flight control and databases. This was used to compile over 60 basic requirements for an on-board system concept for drones in a U-space environment.

The research enabled the partners to develop different subsystems relating to specific activities and define a general functional architecture, which can be applied to different missions. Among key technologies, the project addressed pre-tactical, tactical, and dynamic geo-fencing; tactical deconfliction; e-identification in communications systems; emergency management; and tracking and monitoring. Due to the variety of drone types and airspaces, AIRPASS defined a general functional architecture which can be applied to multiple applications and which has no implications for hardware. These findings are now being used by standardisation groups to develop a standardised on-board architecture available for use by every drone using U-space services.

In summary, the AIRPASS functional architecture supports the development of U2 services in simple environments and paves the way for the integration of every drone into U-space. The project identified some gaps in currently available on-board technologies, especially when it comes to scalability and operations in high drone densities, underlining the importance of the quality of U-space services and CNS capabilities. Certification will be a critical part of implementing U2 services, especially for the all-important BVLOS, which is expected to become the standard way of flying in U-space.

U-SPACE DEMO COVERAGE

SERVICES
U1 U2 U3

TECHNOLOGIES

ENVIRONMENT

DIODE:
D-flight Internet Of Drones Environment

Safe and secure drone operations in each and every environment

Partners

Aiviewgroup
e-wGEOS
ENAV (Coordinator)
EuroUSC
IDS Ingegneria Dei Sistemi
Leonardo
Nextant Applications & Innovative Solution (NAIS)
Poste Italiane
Techno Sky
Telespazio

DIODE validated U-space technologies to enable strategic deconfliction

Adopting a risk-based approach supports step-by-step growth of U-space service

Drones operate across multiple sectors including medicine, agriculture, mapping, deliveries, inspection and emergency services. They range over different terrain and display different characteristics. The DIODE project focused on demonstrating capabilities to safely manage multiple drones flying in very low-level airspace at the same time, while accomplishing multiple tasks and missions. The project worked on the assumption that each aircraft (manned and unmanned) will report its positions. In other words, the whole traffic is cooperative and its complexity is therefore reduced.

A consortium of Italian companies conducted 11 missions in Rieti, a small province close to Rome, with several different geographical situations, including rural, mountain and remote territories, industrial, urban and semi¬-urban. The demonstrations covered a wide range of operations: parcel delivery; road traffic patrol; professional photography; railway and power lines surveillance; search and rescue, airport operations; interaction with general aviation; and firefighting. The flights were carried out in combination with manned flight and took account of third parties on the ground.

The demonstrations adopted a risk-based approach to the provision of initial and advanced U-space services aligned with the expectation of drone operators. The drones were monitored using D-Flight, a dedicated platform which provides e-registration, e-identification and static geofencing in compliance with European regulations due to be introduced in 2020. The risk assessment followed the specific operations risk assessment (SORA) methodology used for complex drone operations and looked at new competences and technology to support the growth of drone services.

DIODE demonstrated emerging and mature capabilities on-board drones, which support the deployment of a risk-based and an operation-centric concept of U-space. The project considered a huge range of drones and highlighted opportunities where the drone market can also contribute to development of more advanced U-space services.

SERVICES U2 U3

TECHNOLOGIES

ENVIRONMENT

Putting multi-service provision to the test

Ensuring drones operate safely alongside all other airspace users calls for advanced conflict detection between flight paths and reliable communications with the air traffic management system. By integrating already developed technologies and concepts around a federated architecture, members of the DOMUS consortium showed that initial and some advanced U-space services, including tactical de-confliction, are possible.

DOMUS demonstrations involved three service providers interacting with one ecosystem manager, and several drone operators using drones from different manufacturers, during tests in Andalucia, Spain. In this approach, the ecosystem manager is the principal U-space service provider and provided data integrity to the system as a single point of truth: Ensuring safety, security, privacy and secrecy, and easing the entrance of new service providers to the system. It also provided the single interface with air traffic management. The service providers operate in parallel to deliver U-space and added value services to the various drone operators, who need to exchange data to carry out their operations. Such data includes optimum operation profiles, fleet management, log records and addition flight information. During the flights conducted by DOMUS partners, three service providers connected to the ecosystem manager and simultaneously provided services to five different drone operators in close proximity, and at distance, in two different locations: Lugo and Jaen, Spain. In one example, integration with manned aviation was also demonstrated.

Thanks to the ecosystem manager, DOMUS demonstrated some of the initial services detailed in U1 and U2 definitions of U-space, including e-registration, e-identification, geo-fencing, flight planning, tracking, dynamic flight management and interfaces with air traffic control. Some U3 services, such as tactical deconfliction between two drones, and dynamic geofencing – for example around manned aircraft – in collaboration with air traffic management, were also tested. Activities included mapping, normal and urgent deliveries, building inspections and integration of recreational flights. The project also demonstrated the feasibility of connecting U-space operations to the smart city platform.

The live trials showed how a federated architecture can support multiple service providers under the management of an Ecosystem Manager for efficient deployment of U-space services. This is possible using current technology and interoperable U-space services provided by different service providers and different drone operators.

DOMUS: Demonstration Of Multiple U-space Suppliers

Partners

AirMap
Correos
CRIDA
Earth Networks
Enaire (Coordinator)
Everis Aerospacial y Defensa S.L.U.
FADACATED
FuVeX Civil SL
GMV Aerospace & Defense S.A.U
Indra Sistemas
INECO
Ingeniería de Sistemas para la Defensa de España (ISDEFE)
Pildo Consulting
SCR
SOTICOL Robotics Systems
Vodafone España

- **Drones can respond to emergency situations, including recreational flights without flight plans**
- **Drones can conduct strategic and tactical conflict resolution in real-time**

SERVICES

U2 U3

TECHNOLOGIES

ENVIRONMENT

EuroDRONE: A European UTM Testbed for U-space

Partners

Aslogic
Cranfield University
Dronsystems Limited
Hellenic Civil Aviation Authority (HCAA)
Hellenic Post S.A.
Romanian Post
University of Patras (Coordinator)

Identifying key criteria necessary for fully autonomous operations

The safe integration of drones into manned airspace requires a universal platform connecting various stakeholders (drone operators, regulators, law enforcement agencies and product developers) and providing interoperability between different systems in a unified environment. EuroDRONE tested different concepts, technologies and architectures to promote the cooperation of the relevant stakeholders in an U-space environment. By using cloud software and hardware, the research experimented with U-space functionalities ranging from initial services to more advanced services such as automated detect and avoid. A series of demonstration flights in Missolonghi, Greece, helped to identify technology, architecture and user requirements necessary for U-space.

First end to end U-space demonstration in South East Europe/ Mediterranean Region

EuroDRONE conducted highly automated unmanned flights using a cloud-based UTM system connected to a miniature, intelligent transponder processing board on drones fully capable of flight mission planning. The tests used an innovative vehicle to infrastructure link (V2I), integrated to a self-learning UTM platform, with a capability to share flight information in real time. The flights demonstrated end-to-end UTM applications focusing on both visual and BVLOS logistics and emergency services. Among the main activities, the project identified key user needs and regulatory challenges, and compared the results with the CONOPS. The findings were used to define a practical, automated cloud-based UTM system architecture, and to validate this architecture using simulation and live demonstrations.

EuroDRONE is helping to define a practical, highly automated cloud-based UTM system architecture

In conclusion, the project demonstrated robust end-to-end UTM cloud operations, including beyond visual line of sight medical deliveries over 10km in coordination with air traffic control and commercial operation. It also demonstrated innovative vehicle to infrastructure and vehicle to vehicle (V2V) communications, equipped with operational detect and avoid algorithms. The flights were able to demonstrate high levels of autonomy using cloud-based infrastructure envisaged for an advanced UTM environment. The demonstrations ranged from sea areas to countryside and urban environments, and tested LTE communications links.

SERVICES U2 U3

TECHNOLOGIES

ENVIRONMENT

Avoiding no-fly zones in busy low-level airspace

To prevent drones straying into protected areas, for example around critical infrastructure such as power plants or airports, geofencing and geo-caging technology are used to contain drone operations. Geofencing solutions prevent drones from entering forbidden areas and geo-caging does not allow drones to fly beyond a set boundary. Both measures are critical to keeping complex low-altitude airspace safe for all by ensuring drones avoid any designated no-fly zones and adhere to rules put in place by EU Member States. Geofencing solutions are therefore key safety enablers and form part of the foundational services for the development of drone operations.

The GEOSAFE research set out to establish state-of-the-art geofencing U-space solutions and to propose improvements and recommendations for future geofencing system definition. The project was based on a one-year long flight-test campaign, which assessed a number of commercially-available geofencing solutions in order to propose improved geofencing systems for tomorrow and technological improvements for drones. The research included 280 flight tests in France, Germany and Latvia, which tested representative situations that a drone will face in urban and rural areas. They covered a range of missions including agricultural operations, inspections, emergency events and deliveries.

The flights tested foundational and advanced geofencing services with reference to pre-tactical flight (a core competency required for entry level U-space, U1); tactical operations (required for slightly more advanced U-space U2); and dynamic situations (necessary for U3). Project partners considered issues such as technology performance, pilot warnings, communication failure, weak satellite positioning signals, restricted area updates during flights, tracking and drone navigation system performance. The results were used to identify ways in which the technology can be used to support safe interaction with all airspace users.

The project concluded most drones meet the requirements for pre-tactical geofencing and demonstrated that existing technology is ready for initial U-space services even though no one solution is aligned with regulations in different countries. Solutions are also available to support tactical geofencing necessary to deliver advanced U-space services despite the lack of standardisation. However, technology capable of supporting dynamic geofencing is not sufficiently mature to meet full U-space service levels, although this is expected to develop rapidly in the near term, not least because dynamic geofencing is a key function for unmanned vehicles operating beyond the visual line of sight.

The results are helping to inform the European Commission, EASA and EUROCAE of best practices for integrating drones into European airspace; in particular the development of performance requirements will be useful for the ongoing standardisation process.

GEOSAFE: Geofencing for safe and autonomous flight in Europe

GEOSAFE

Partners

Aeromapper
AirMap,
Air Marine
Atechsys
SPH Engineering
Thales AVS (Coordinator)

Geofencing prevents drones straying into protected areas, for example around critical infrastructure such as power plants or airports

Flight tests found a lack of standardisation in the case of tactical geofencing activity, a key safety enabler for U-space services

GOF-USPACE: Safe drone integration in the Gulf of Finland

Partners

Altitude Angel
AirMap
Air Navigation Services Finland
Avartek R. Lindberg Ky Kb
BVdrone Oy
Cafa Technology
Estonian Air Navigation Services (EANS) (Coordinator)
Estonian Police and Border Guard Board
Finnish Transport and Communications Agency
Finnish Air Rescue Society
Fleetonomy.ai
Frequentis
Helsinki Police Department
Hepta Airborne
Robots Expert Finland Oy
Threod Systems
Unifly
VideoDrone Finland Oy
Volocopter

Mixing manned and unmanned aircraft relies on reliable data exchange

The safe operation of multiple drones in the same airspace relies on collaboration and data exchange between many different actors. A basic function of U-space is to bring situational awareness to all users and bridge the gap between manned and unmanned aviation by linking air traffic management information with unmanned traffic information, thus allowing operators and pilots access to common flight information. A flight information management system (FIMS) makes this possible by creating an interoperability architecture using standard protocols to exchange data.

The GOF-USPACE partners established a pre-operational authority FIMS by creating an interoperability architecture for integrating existing solutions from three U-space service providers to showcase U-space in all phases of drone operations. Specifically, the GOF U-SPACE architecture enabled data exchange between two air navigation service providers (in Finland and Estonia), several U-space service providers, eight drone operators and two manned aircraft operators. The technology was demonstrated in seven flight trials during summer 2019 involving parcel deliveries, police operations, flights in dense urban airspace, forestry inspection beyond visual line of sight, airport operations, maritime search and rescue, and a manned taxi demonstration in Helsinki International airport.

Common standards are required for communication between information systems

A basic function of U-space is to bring situational awareness to all users

The GOF U-SPACE architecture integrated U-space service provider microservices that enabled a collective and cooperative management of all drone traffic in the same geographical region. A microservice-oriented data exchange layer provided standard protocols to connect various U-space services from different service providers and the capabilities of service provision was demonstrated during the trials. Integration between FIMS and U-space service providers, FIMS and FIMS, and U-space service providers to ground control services was established with a link to receive data from the ATM systems, demonstrating interoperability between systems.

The demonstrations showed commercial off-the-shelf UTM components to be fit for purpose to demonstrate all phases of drone operations with a focus on pre-flight and flight execution. The exercise proved that service providers and operators were able to connect to the open platform to access FIMS and ATM data, while noting the need for additional work to develop tracking solutions and improve resilience to poor mobile network coverage. The project demonstrated the need for single truth - where all airspace users can access one source of reliable airspace and aeronautical information – and common standards for communication between systems.

SERVICES

U1 U2 U3

TECHNOLOGIES

ENVIRONMENT

Putting U-space services to the test in operational scenarios

PODIUM carried out demonstrations at five operational sites in Denmark, France and the Netherlands during 2018 and 2019. The project tested the performance of pre-flight and in-flight services using different scenarios ranging from airport locations to beyond visual line of sight. The results were used to draw up recommendations on future deployment, regulations and standards.

The project collected and analysed validation data from 41 post demonstration questionnaires completed by participants; five facilitated de-briefing sessions; and observations from validation experts and partners. The partners considered the maturity of services and technology and analysed the impact on flight efficiency, safety, security and human performance metrics.

Today, drone operators must perform a number of manual processes before they can fly. All this takes extra time and effort which can affect the commercial viability of drone operations. PODIUM looked to reduce the risks inherent to the operational and industrial deployment of U-space by demonstrating a web-based UTM system – including an open cloud-based solution and a secure gateway solution - using tracking systems based on ADS-B 1090 MHz, UNB-L-Band, and mobile telephony networks.

Drones operate in low-level airspace where they need to comply with local restrictions and regulations while take account of changing circumstances such as the weather. The PODIUM web-based platform enables drone operators and authorities to follow drone operations in real-time and connect with the pilot where necessary.

PODIUM concluded that there is a very strong demand from all stakeholders for U-space solutions that can ease the burden of obtaining flight authorisations for drone flights, and that increased situational awareness enables safety and efficiency benefits during flight execution. It found U-space services for the pre-flight phase almost ready for deployment, but concluded that significant action is needed to ensure that U-space services can really take off in the flight execution phase. In particular, PODIUM made recommendations relating to tracking, the human machine interface for drone pilots, and the access to trustworthy data – with implications for standardisation and regulation, and further research and development.

PODIUM:
Proving Operations of Drones with initial UTM

PODIUM

Partners

Airbus
DSNA
DELAIR
Drones Paris Region
EUROCONTROL (Coordinator)
Integra Aerial Services
Naviair
NLR- Royal Netherlands Aerospace Centre
Orange
Unifly

- **There is strong demand for U-space solutions that can ease the burden of obtaining flight authorisations for drone flights**
- **Significant work is needed to ensure that U-space services can operate in the flight execution phase**

SERVICES
U2 U3
TECHNOLOGIES
ENVIRONMENT

SAFEDRONE: Unmanned and manned integration in very low-level airspace

SAFEDRONE

Partners
CATEC
CRIDA
ENAIRE
INDRA (Coordinator)
IAI
Unifly
University of Seville

Assessment of 4G communication and GNSS for height estimation and communication services

Advanced autonomy functionalities are necessary to support safe integration of drones

Addressing the safe integration of general aviation aircraft and drones in very low-level airspace

Maintaining the safety of air operations when drones and conventional aircraft share low-level airspace, close to an airport for example, will require a high degree of digitalisation and automation. The SAFEDRONE project sought to define and detail pre-flight services including electronic registration, electronic identification, planning and flight approval; as well as in-flight services such as geofencing, flight tracking, dynamic airspace information and automatic technologies to detect and avoid obstacles in order to demonstrate how to integrate manned aviation and drones into non-segregated airspace. The objective was to accumulate evidence and experience about the required services and procedures necessary to operate drones in a safe, efficient and secure way within U-space.

SAFEDRONE partners carried out demonstrations involving eight different aircraft types ranging from drones to fixed-wing and rotatory wing light aircraft, flying simultaneously in the same airspace. The flights were carried out in rural and semi-urban areas in southern Spain, recreating situations such as the delivery of medical supplies, aerial mapping and land surveying, and operating BVLOS. The project performed flight operations with initial and advanced U-space services, in addition to technologies required for full U-space services including autonomous detect and avoid capabilities and multi-drone operations by a single operator.

The project also considered increased levels of autonomy necessary to operate in non-segregated airspace to carry out dynamic in-flight activities such as on-board re-planning trajectories within the U-space approved flight plan, and autonomous generation of coordinated trajectories within an approved U-space area of operation. It assessed the viability of using 4G networks for communication during BVLOS flights and GNSS technologies enabled by Galileo to estimate the drone's height.

Finally, the research included a pre-risk assessment scenario of the concept of operation based on the technical, safety and operational requirements as detailed in the SORA drone guidance material.

Lessons learned and results from the technologies tested have been passed to EASA and standardisation bodies EUROCAE and GUTMA to help develop the standards that will enable safe integration of different drone categories under U-space.

SERVICES

U2 U3

TECHNOLOGIES

ENVIRONMENT

Automation brings efficiency to drone operations

To safely integrate drones into the airspace, the U-space SAFIR consortium conducted a series of demonstrations to show how technology can support the safe deployment of a multitude of drones in a challenging airspace environment. Three U-space service providers and one air navigation service provider integrated their services to control the airspace collaboratively. The test scenarios included parcel delivery flights, aerial survey, medical inter-hospital flights and emergency prioritisation supported by leading operators in these domains.

The use cases were first successfully tested at DronePort in Sint-Truiden, Belgium, a secure test environment for manned and unmanned aircraft, before transferring to Antwerp City (urban area), Antwerp Airport terminal area and the Port of Antwerp to test the viability of the use cases in a realistic environment. In addition, SAFIR tackled the issue of unregistered drones and their impact on legal drone operations and manned aviation. A specialised radar developed by the CLASS project (See page 20) was deployed to detect rogue drones in critical areas and provide a live feed for the U-space service providers. SAFIR's federated model enabled information sharing between multiple interoperable services, categorised according to their function.

SAFIR proved the ability of drones to safeguard critical areas, such as an international port or an urban environment.

It was demonstrated how the Port of Antwerp could request a drone to inspect a certain area should there be reason for concern, as well as create no-drone zones to manage safety in the port. The project also showed how multiple U-space service providers can operate in the same geographical area at the same time thanks to UTM systems can be interoperable.

SAFIR demonstrated full availability of the following services: e-identification; pre-tactical, tactical and dynamic geofencing; strategic and tactical deconfliction; tracking and monitoring. The project successfully tested initial, advanced and full U-space services and made recommendations for further research. For example, it concluded that tracking data sourced from different places needs to be fused; full integration is needed between UTM and drone operators on the ground; and interaction with air traffic control is important, preferably in an automated way. Flight authorisation is complex and SAFIR expects European regulation to help clarify drone categories. It also found satellite mobile connectivity performed well, but 4G degrades at higher altitudes and would benefit from a dedicated 4G drone overlay network, particularly relevant to beyond visual line of sight operations.

SAFIR findings will contribute to the EU regulatory process and deployment of interoperable, harmonised and standardised drone services across Europe.

SAFIR: Safe and Flexible Integration of Initial U-space Services in a Real Environment

SAFIR

Partners

Amazon EU S.a.r.l.
Aveillant
C-ASTRAL
DronePort
ELIA SYSTEM OPERATOR
Explicit APS
Havenbedrijf Antwerpen NV van publiek recht (APA)
Helicus BVBA
High Eye B.V.
Proximus
S.A.B.C.A
skeyes
TEKEVER II AUTONOMOUS SYSTEMS
Unifly (Coordinator)

Interoperability between different systems is necessary for complex operations

SAFIR proved the ability of drones to safeguard critical areas, such as an international port or an urban environment.

SERVICES U2

TECHNOLOGIES

ENVIRONMENT

USIS: Easy and Safe access to the airspace

U-SPACE INITIAL SERVICES

Partners
Altametris
DFS
DSNA
ENAC
HungaroControl
Thales (Coordinator)
Unifly

Ensuring U-space services are safe and secure

U-space relies on a higher level of automation than ATM. Many services are currently being developed and need to be validated and regulated to ensure safe and secure operations. USIS research sought to validate the services that will be provided by U-space service providers to drone operators and third parties, including the authorities in charge of the airspace, to demonstrate their readiness at a European level.

The USIS project considered initial U-space services of e-registration and e-identification, as well as more advanced flight planning, authorisation and tracking services necessary for beyond visual line of sight and operations over people. It also looked at scheduling and dynamic airspace management.

USIS partners carried out live demonstrations using a secure and resilient cloud-based platform at locations in France and Hungary. A dedicated application allowed drone operators to submit flight requests which were then analysed and approved or declined by the appropriate authority. An embedded hardware connected to the mobile phone network was used to securely identify and track the equipped drones.

In France, the trial focused on current use cases. For example, drone operators in Lille region participated while conducting regular operations such as aerial videos in rural and sub-urban environments. A few dedicated flights were also organized around Lille airport. In Hungary, the trial focuses on future use cases. Dedicated flights were carried out in a rural environment, exploring search and rescue, parcel delivery, agricultural surveying and surveillance scenarios.

The research validated the use by a platform of a national registry (using the example of the French AlphaTango service); and confirmed the technical feasibility of secured identification and tracking of drones through an embedded hardware connected to mobile phone networks. This was used to monitor the compliance between the position of the drones and the approved operations.

The project showed that initial U-space services can support multiple numbers of drone operations without creating additional workload for an operator or impacting the safety of the airspace. It highlighted the need for flexibility when carrying out flight planning and approval management processes to cope with different national and local regulations. Further examples by active drone operators will contribute to future research and development.

All stakeholders need to be involved in the development of U-space services

Deploying U-space services will enable us to learn from the operational environment

SERVICES

U2 U3

TECHNOLOGIES

ENVIRONMENT

Defining rules for manned and unmanned systems to share the same airspace

Drones will need to adhere to rules of the air to operate safely alongside manned aviation. This is especially important in urban environments. Demonstrations carried out by members of the VUTURA consortium looked at the new digital smart cities, and how unmanned vehicles can become a part of this interconnected world.

VUTURA focused on four major goals. These are: validating the use of shared airspace between existing, manned airspace users and drones; validating more than one U-space service provider providing U-space services in a specific airspace and the procedures needed to support drone flights; ensuring alignment of regulation and standardisation between SESAR developments and U-space service providers; and increasing the pace by which European cities and companies exploit emerging technologies related to drones. The goal was to improve the quality of life in cities, create concrete socio-economic outcomes and help European companies to take a leading position in the new smart city market.

The consortium conducted beyond visual line of sight demonstration flights involving multiple U-space service providers in rural, urban and smart city environments. Each scenario featured two service providers coordinating their services where interoperability was a major focus. Manned aviation, different levels of automation, commercial and leisure drones, off-the-shelf drones as well as custom made ones all featured in the scenarios. Information was shared allowing all stakeholders to access the data via a web interface. In the tests, drones gave way to high priority drones autonomously, for example medical deliveries, and the U-space service providers facilitated the drone traffic de-confliction using interoperable systems.

The work done by VUTURA demonstrated that commercial drone traffic can safely co-exist with traditional air traffic in different kinds of environments and the technology to safely manage drone traffic is feasible, scalable and interoperable. It also flagged up areas in need of further research. This includes closer alignment of flight planning activity by USSPs and a set of procedures for cross-border flight planning; a common interface for exchanging information and acceptable transmission delay; and reliable detect and avoid capability. Among key findings, VUTURA concluded that airspace users need to be registered in order to share airspace, be identifiable and meet geofencing requirements before the industry can move closer to supporting urban air mobility.

VUTURA: Validation of U-space by Tests in Urban and Rural Areas

Partners

AirHub B.V.
AirMap
Gemeente Enschede
Luchtverkeersleiding Nederland (LVNL)
NLR- Royal Netherlands Aerospace Centre(Coordinator)
Robor Electronics B.V.
TU Delft,
UAVInternational B.V.
Unifly
Unisphere

- **VUTURA is helping to establish rules for all shapes and sizes to operate in any airspace**
- **To fly in complex airspace, drones need U-space services as registration, identification and geofencing. Detect and avoid services can be established where U-space provides traffic information allowing thus on-board systems in drones to be capable of avoiding other traffic.**

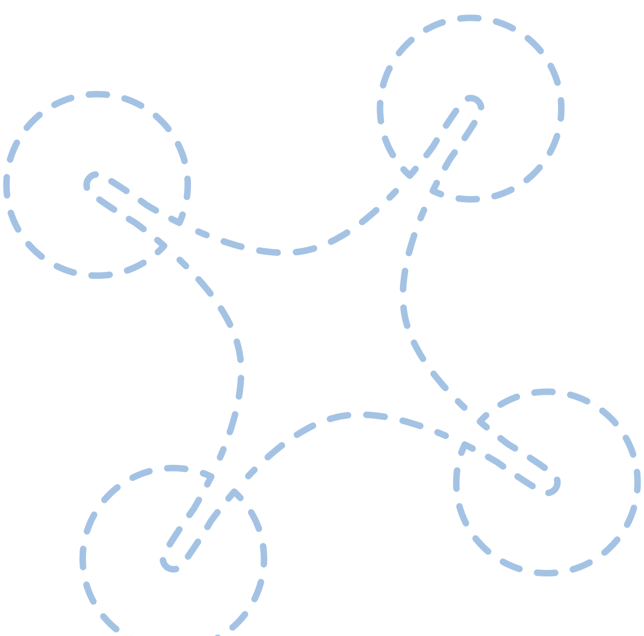
Conclusions

This brochure has described the activities undertaken by the SESAR JU and its partners to begin the creation of U-space. U-space will open up new business opportunities and has the potential to raise the quality of life of European citizens. The SESAR research and innovation programme has brought together many key players across Europe and has provided a sound basis that allows regulators, ANSPs, standardisation bodies, industry and researchers to continue to build this new environment, and the results presented in this document show real progress from almost nothing to initial deployment of certain features in only two years.

The results summarised in this brochure will be fully detailed in a comprehensive report due for publication in the second half of 2020.

The findings from these 19 projects take Europe several steps closer to implementing a safe, initial drone operating environment, and provide the necessary building blocks for more advanced U-space services leading to full integration with manned aviation. Stakeholders in some of the projects, such as DIODE, DOMUS, GOF-USPACE and SAFIR, are already working with the authorities in their respective countries to exploit solutions to deploy U-space. In addition, initial deployments that reflect the findings from U-space projects are planned or are in execution in a number of States across Europe.

Nevertheless, there is much that still needs to be done. The findings make clear that, whilst a lot has been achieved in the past two years, more work is needed on developing and validating drone capabilities and U-space services to ensure safe and secure drone operations. For the U3 concept to be realised, complex issues which these SESAR JU projects have started to address need to be resolved, including detect and avoid, C2 link, geo-awareness, contingency procedures, dynamic interface with ATM, etc. These issues must continue to be addressed in cooperation with international partners, including ICAO, and the traditional manned aviation community, whose operations are impacted by the rapid appearance of drones.



In addition, the scope of the U-space projects needs to be widened to include, *inter alia*, the following areas:

- Urban air mobility operations;
- Extension of U-space services beyond the VLL limit;
- Altitude references;
- U-space Interoperability with ATM, including the development of a collaborative decision making process between the urban operations, ATM and city authorities;
- Higher levels of automation, including machine-learning and AI; and
- Fundamental aviation tenets, such as airspace classification and the Rules of the Air.

Up to now, the SESAR JU has been the focal point of U-space research. Exciting and important work is being done by many stakeholders, and it is essential that this continues. The European Network of U-space Demonstrators, co-chaired by the European Commission, EUROCONTROL, EASA and SESAR JU, has created a powerful and well-attended forum to support the cross-pollination of ideas between all stakeholders involved in the development of U-space. However, full value from past work and the Network discussions can only be realised against the background of a research and development plan coordinated at a European level, and integrated into the global developments taking place elsewhere.

U-space has been born and is developing fast. The SESAR JU will continue to participate in and support further developments as part of a focussed and motivated pan-European team that will create a safe and productive operating environment for manned and unmanned aircraft alike.

ANNEX 1

List of U-space services

Registration	Functions to access the Registry or Registries. CRUD: Create, Read, Update, Delete. All operations have permission requirements, security features and so on.	U1
Registration assistance	A registration assistance service is a front end to the registry service. An example might supply standard values to ease the registration process at the point of sale in a drone shop.	U1
e-identification	Two services. One is The service is the fetching of registry and flight plan data related to the current operation of the drone corresponding to the broadcast remote identification. The second extends that to perform the network remote id function	U1
Tracking (position report submission)	Tracking is the statistical process of merging 4D position reports into a mathematical model of the motion of an aircraft.	U2
Surveillance data exchange	transfer of surveillance data to and from other trusted systems; e.g. ATC, neighbouring U-space implementations	U2
Geo-awareness	Provision of restriction data pre flight	U1
Drone aeronautical information management	The service that provides airspace restriction information used in the planning of flights.	U1
Geo-fence provision (includes dynamic geo-fencing)	The services used to collect, integrate, maintain and publish drone aeronautical information. Drone aeronautical information contains some parts of existing AIM but is extended with drone (VLL) specific restriction information.	U2
Operation plan preparation / optimisation	This is a service or a tool used by the drone operator to prepare operation plans (= flight plans) and submit them to the Flight Planning Management service.	U2
Operation plan processing	This function is used to file operation plans, to store them in a national / regional pool and make them available for appropriate uses before and during flight. The function is the enabler for a number of other services.	U2
Risk analysis assistance	A service to aid the development of a SORA or other risk assessment starting with a (hypothetical) operation plan and considering drone aeronautical data and similar.	U2
Dynamic capacity management	This function is used to manage demand.	U3
Strategic conflict resolution	Conflict resolution before flight - called within the Flight Planning Management system/service	U2

Tactical conflict resolution	Conflict resolution in flight	U3
Emergency management	A service delivered in flight allowing information to be sent or received relating to emergencies.	U2
Incident/accident reporting	A service generally used post flight to capture information related to an incident or accident.	U2
Citizen reporting service	A service to allow member of the public to report suspected incidents relating to drones	U2
Monitoring	An inflight service based on tracking. Alerts when the flight does not conform to the plan	U2
Traffic information	An inflight service based on tracking. Two versions. One alerts when another flight is nearby. The second provides an overall visualisation of the traffic.	U2
Navigation infrastructure monitoring		U2
Communication infrastructure monitoring		U2
Legal recording	Recording of data to support accident/incident investigation, performance improvement and training	U2
Digital logbook	A tool for pilots and drone operators to extract historic information from previous flight data such as hours flown.	U2
Weather information	Forecasts	U2
Geospatial information service	A map giving the height of the land and any buildings at any point	U3
Population density map	A map expressing levels of ground risk associated with presence of people	U3
Electromagnetic interference information	A map showing the probability of electromagnetic interference	U3
Navigation coverage information	A map showing the probability of loss of satellite navigation	U3
Communication coverage information	A map showing the probability of loss of mobile internet	U3
Procedural interface with ATC	A service for coordinating interactions with ATC used pre-flight - probably called via the flight planning management service	U2
Collaborative interface with ATC	A service for coordinating interactions with ATC used in flight	U3

ANNEX 2

List of acronyms

ADS-B	Automatic dependent surveillance – broadcast
ANSP	Air navigation service providers
ATM	Air traffic management
BVLOS	Beyond visual line of sight
C2	Command and control
CIA	Confidentiality, integrity and availability
CNS	Communications, navigation and surveillance
CONOPS	Concept of operations
EGNOS	European Geostationary Navigation Overlay Service
FIMS	Flight information management system
FLARM	Secondary surveillance radar and flight management
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
LTE	Long term evolution
MEDUSA	Method to assess the safety of service provision
R&D	Research and Development
RPAS	Remotely piloted aircraft system
SARPS	Standards and recommended practices (ICAO)
SME	Small and medium enterprises
SORA	Specific operations risk assessment
SWIM	System-wide information management
UAM	User access management
UAV	Unmanned aircraft vehicle
UCN	U-space community network
USSP	U-space service provider
UTM	Unmanned traffic management
V2I	Vehicle to Infrastructure
V2V	Vehicle to vehicle

ANNEX 3

List of partners

A
Aalborg Universitet
Aeromapper
Air Marine
Airbus Defence and Space SAS
AirHub B.V.
AirMap
AiviewGroup
Altametris
Altitude Angel Limited
Amazon EU S.a.r.l.
ANS Finland
Aslogic
Atechsys
ATESIO GMBH
Avartek R. Lindberg Ky Kb
AVEILLANT LIMITED
AVULAR BV

B
Boeing Research & Technology Europe S.L.U.
Bvdrone Oy

C
CAFA Tech OÜ
C-ASTRAL, Proizvodnja zračnih in vesoljskih plovil d.o.o
CATEC
CHPR Center for Human Performance Research BV
Correos
Cranfield University
Centro de Referencia de Investigación, Desarrollo e Innovación ATM, A.I.E. (CRIDA)

D
DELAIR
Delft Dynamics B.V.
Deutsche Zentrum für Luft- und Raumfahrt e.V.
DFS Deutsche Flugsicherung GmbH
DronePort
Drones Paris Region
Dronsystems Limited
Direction des Services de la navigation aérienne (DSNA)

E
Earth Networks
Ecole Nationale de l'Aviation Civil (ENAC)
Elia System Operator
ENAIRE
ENAV
Estonian Air Navigation Services (EANS)
Estonian Police and Border Guard Board (PPA)
EUROCONTROL
EUROUSC
Everis Aerospacial y Defensa S.L.U.
e-wGEOS
Explicit

F
FADA-CATEC
Finnish Communications Regulatory Authority
Fleetonomy.ai Oy
Frequentis
FuVeX Civil SL

G
Gemeente Enschede
GMV Aerospace & Defense S.A.U

H
Havenbedrijf Antwerpen NV van publiek recht (APA)
Helicus BVBA
Hellenic Civil Aviation Authority
Hellenic Post S.A.
Helsinki Police Department
HEMAV
Hepta Group Airborne OÜ
High Eye B.V.
HungaroControl

I
IDS Ingegnieria Dei Sistemi
Indra Sistemas
INECO
Integra Aerial Services
Ingeniería de Sistemas para la Defensa de España S.A. S.M.E. M.P. (ISDEFE)
Israel Aerospace Industries Ltd. IAI

J
Jeppesen GmbH

K
Katholieke Universiteit Leuven

L
Leonardo S.p.A.
Luchtverkeersleiding Nederland (LVNL)

N
NATS
Naviair
Nextant Applications & Innovative Solution (NAIS)
NLR - NLR- Royal Netherlands Aerospace Centre
Nokia Solutions And Networks Danmark A/S
Norges teknisk-naturvitenskaplige universitet (NTNU)

O
Orange

P
Parrot Drones
Pildo Consulting
Post Italiane
Proximus

R
Robor Electronics B.V.
Robots Expert Finland Oy
Romanian Post

S
SABCA
Saab AB
SCR
Sensofusion Oy
skeyes
SPH Engineering
STICOL Robotics Systems

T
Technische Universität Braunschweig
TechnoSky
TEKEVER II Autonomous Systems
Telespazio
Thales Alenia Space France SAS
The Central Aerohydrodynamic Institute TsAGI
The Finnish Air Rescue Society
Threod Systems
TopView SRL
TU Delft

U
UAVInternational B.V.
Unifly
Unisphere
Universita' degli Studi di Napoli Parthenope
Universitat Politècnica de Catalunya
University of Patras
University of Seville

V
VideoDrone Finland oy
Vodafone España
Volocopter

founding members

EUROPEAN UNION

EUROCONTROL

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