SUPPORTING SAFE AND SECURE DRONE OPERATIONS IN EUROPE

Consolidated report on SESAR U-space research and innovation results

SESAR JOINT UNDERTAKING

U-space

SUPPORTING SAFE AND SECURE DRONE OPERATIONS IN EUROPE

A report of the consolidated SESAR U-space research and innovation results

SESAR 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

U-space: Ushering in a new era of flight

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

Executive summary

Towards drone traffic management in Europe

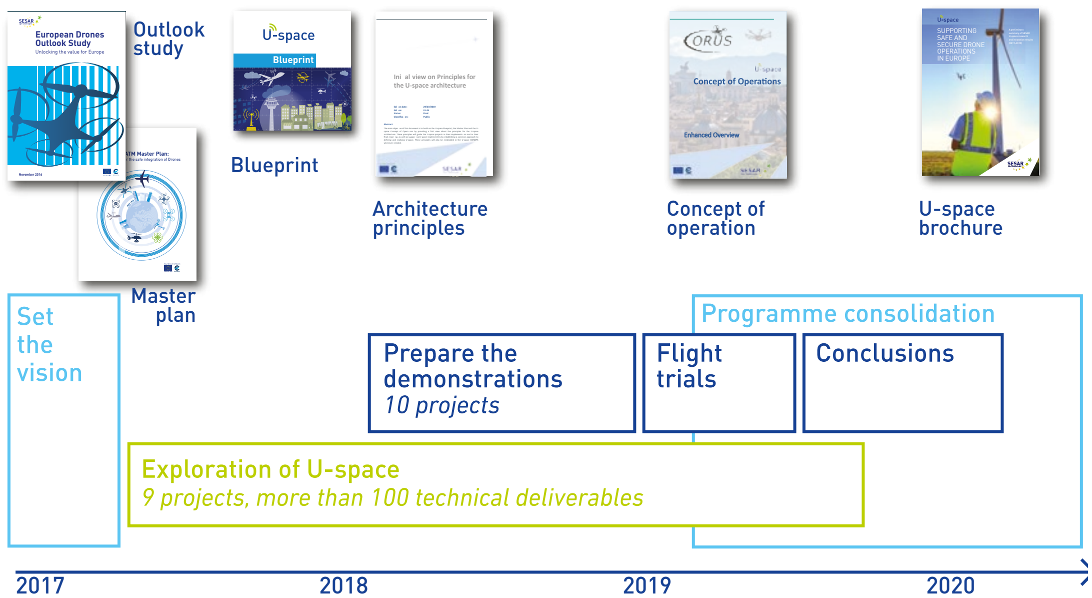
Background

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 above 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 of the growing drone ecosystem, in 2016 the European Commission launched U-space - an initiative aimed at ensuring the safe and secure management and integration of drones into the airspace. This 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 Joint Undertaking (JU) to coordinate all research and development activities related to U-space and drone integration.

In 2017, the SESAR JU published the U-space Blueprint, setting out the vision and steps for the progressive deployment of U-space services from foundation services to fully-integrated operations (U1 -U4). This was followed by the 2020 edition of the European ATM Master Plan, which incorporated a drone roadmap.

Figure 1: SESAR development of U-space



A comprehensive research and demonstration portfolio

In 2017 and 2018, the SESAR JU launched 19 exploratory research projects and demonstration projects aimed at researching the range of services and technological capabilities needed to make U-space a reality. The projects brought together some 25 European airports, 25 air navigation service providers, 11 universities, more than 65 start-ups and businesses, as well as 800 experts, working in close cooperation with standardisation and regulatory bodies, including EUROCAE and EASA. This document presents the consolidated findings of those projects.

Main findings

The central outcome of the research is the U-space Concept of Operations (CONOPS), providing an initial U-space architecture and description of airspace types and U-space services to enable safe and efficient very low-level drone (VLL) operations.

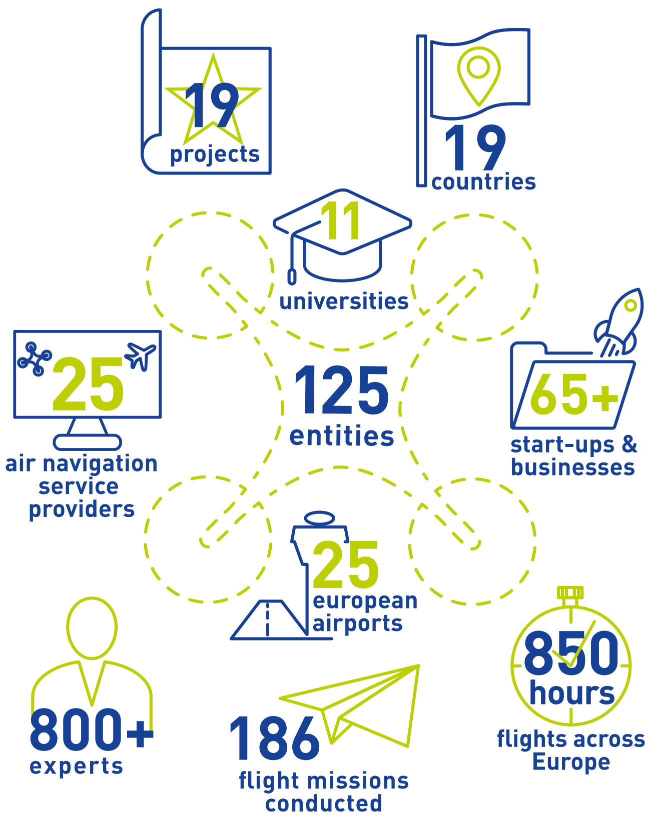
In parallel, the projects researched, developed and demonstrated U-space services from U1-U3 in a variety of geographical environments and airspace classes, while taking into account several types of flight mode and operational environment. The projects also looked at the density of drone traffic, as well as the complexity of the traffic and service provision, including multiple simultaneous service providers.

An analysis of the activities shows that collectively the projects addressed all U1 services and almost all U2 services. Meanwhile only limited coverage was achieved for U3. U4 was not covered by the research activities.

In terms of the level of readiness, the projects demonstrated U1 and U2 services were ready for use in environments with low levels of complexity (rural areas, segregated airspace) and a low density of traffic.

In these environments, the projects were able to show the feasibility of multiple service provision, strategic deconfliction,

U-space research and innovation in numbers



as well as the possibility of increasing situational awareness through information sharing. They also demonstrated the importance of reliable tracking and monitoring and addressed the interface with manned aviation.

Many technologies were successfully tested and demonstrated, but there is a strong need for performance requirements and system standardisation.

At the same time, the analysis underlined the need to further develop and validate U-space to cater for high complexity/ high density operating environments (urban operations, mixed traffic). This will require further research and innovation, in particular in relation to conflict management, emergency management and monitoring services – It is these services that will make U-space scalable and robust to support dense and complex operations in U2 and to ensure a transition to U3 and U4.

An overview of the key findings area available in chapter 2.

Standardisation and regulation

The consolidated findings from SESAR JU research activities supports the definition of required standards, protocols and regulation, providing:

- A **U-space Concept of Operations**, which can be used as the common reference for future validation, regulation or/and standardisation activities;
- An **initial set of performance data** for each service and technological capability, as well as the identification of operational or technical interoperability, acceptability (privacy/ noise), and security; and
- **Recommendations** on areas where standards and protocols are needed, such as on data exchange, multiple U-space service provision, as well as regulatory guidance material related to common terminology and a clear definition of roles and responsibilities.

An overview of the how the research outcomes can support standardisation and regulation is available in chapter 5.

Future research and development needs

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. Nevertheless, the findings make clear that more work is needed on developing and validating drone capabilities in several key areas:

- **Urban air mobility** (UAM), in particular UAM-related scenarios, services, procedures, infrastructures and tools to enable expected operations at low and very low level in inter-urban, suburban and urban areas;
- **Air traffic management (ATM)/U-space convergence**, including the development of a common altitude reference system (CARS), transition to autonomous vehicles, and a collaborative decision making process between the urban operations, ATM and city authorities; and
- **Advanced U-space services and technologies** (U3 and U4), including the development of miniaturisation, automated detect and avoid functionalities, and reliable means of communication.

In addition, more data will need to be collected to elaborate the necessary minimum operational performance standards (MOPS) for U-space services, equipment/systems and capabilities and the enabling infrastructure to be set to support U-space operations. Based on this data, industry, regulatory, research and standardisation bodies need to work together to complete the full implementation of U-space.

More details of the future research needs are provided in chapter 3.


Rail

1. Introduction

1.1 Background on U-space

Drones represent a rapidly growing sector of aviation in Europe and worldwide – potentially offering a myriad of services to businesses 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 that as many as 400 000 drones will be providing services in the airspace by 2050, and that the total market value will be 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 this initiative, 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 Joint Undertaking (JU) to coordinate all research and development (R & D) 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.***

1.2 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 and geoawareness, 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 (ATM) modernisation in Europe.

1.3 Research and innovation portfolio

In 2017, the SESAR JU launched a set of exploratory research projects [5] addressing everything from the concept of operations (CONOPS) for drone operations, critical communications, surveillance and tracking and information management, to aircraft systems, ground-based technologies, cyber-resilience and geofencing. 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 [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.

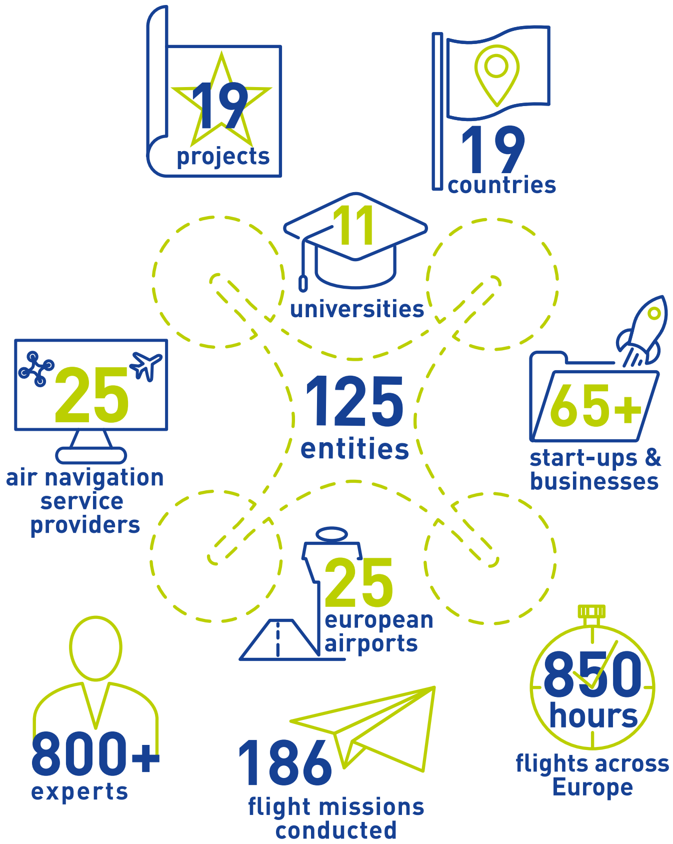
These range from parcel deliveries between two dense urban locations, medical emergencies and police interventions, as well as air taxi trials in an airport controlled airspace. The leisure user was also catered for, with projects demonstrating how private drone operators can also benefit from U-space services. The operations also aimed to demonstrate the different levels of automation that are possible, as well as the seamless exchange of information between multiple service providers in the same geographical area at the same time.

1.4 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 European Union Aviation Safety Agency (EASA), tasked by the Commission with drafting rules to govern

U-space research and innovation in numbers



the safe integration of drones into manned airspace, to help identify the operational requirements needed for this regulatory framework.

In addition, the SESAR JU also ensured close cooperation with the European aviation industry standards developing body, the European Organisation for Civil Aviation Equipment (EUROCAE), and supported wider standardisation work by the International Civil Aviation Organization (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 telecoms 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 the 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 grew to over 500 members over the course of the project and resulted in the release of a detailed and widely accepted initial CONOPS 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.

1.5 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. These projects followed a short but complex timeline, with almost all the activities performed in parallel to the production of a series of key documents, notably an architecture and concept of operations, as shown in Figure 1.

This report maps the state of play on development of the technological capabilities and services required for making U-space a reality, starting with foundation services (U1) before progressing to initial services (U2) and advanced services (U3). U4 was not covered by the research activities.

Figure 2 provides a view of the technological capabilities which were addressed by the research projects.

Figure 2 provides a list of U-space services, categorised according to U1 (foundation services), U2 (initial services) and U3 (advanced services) as defined in the U-space Blueprint [2].

Specifically, the brochure provides the following:

- Key milestones and findings from the projects, including the coverage and level of maturity of each U-space service (Chapter 2);
- A summary of future R & D needs (Chapter 3);
- An overview of the recommendations for standardisation and regulation activities (Chapters 4 and 5);
- A catalogue of U-space services ([1]), with a definition for each service (taken from the CONOPS ([2])), notable requirements and related project findings (Annex 1);
- A summary of the outcomes of each exploratory research and demonstration project (Annex 2).

1 The analysis was performed by the SESAR JU and Eurocontrol, based on an in-depth review of all project documentation.
2 The definitions of the U-space services are taken from the latest available edition of the CONOPS [7] (Section 5.1).

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-resillience
- Sense & avoid and separation provision

- Rural environment
- Sub-urban environment
- Urban environment

Figure 2: List of U-space services (CONOPS third edition)

- **Identification and tracking**
  - Registration
  - Registration assistance
  - e-identification
  - Tracking (Position report submission)
  - Surveillance data exchange
- **Airspace management/ geo-fencing**
  - Geo-awareness
  - Drone aeronautical information management
  - Geo-fence provision (includes dynamic geo-fencing)
- **Mission management**
  - Operation plan preparation/ optimisation
  - Operation plan processing
  - Risk analysis assistance
  - Dynamic capacity management
- **Conflict management**
  - Strategic conflict resolution
  - Tactical conflict resolution
- **Emergency management**
  - Emergency management
  - Incident/ accident reporting
  - Citizen reporting service
- **Monitoring**
  - Monitoring
  - Traffic information
  - Navigation infrastructure monitoring
  - Communication infrastructure monitoring
  - Legal recording
  - Digital logbook
- **Environment**
  - Weather information
  - Geospatial information service
  - Population density map
  - Electromagnetic interference information
  - Navigation coverage information
  - Communication coverage information
- **Interface with ATC**
  - Procedural interface with ATC
  - Collaborative interface with ATC

U1
U2
U3

2. Findings

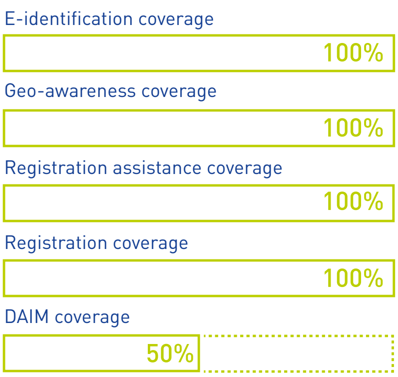
2.1 Is U-space fully covered?

The U-space services were researched, developed and demonstrated in a variety of environments (urban, rural, suburban), airspace (controlled, uncontrolled), taking into account numerous types of flights (manual, partly automated, fully automated, mixed), operations (visual line of sight (VLOS), BVLOS, very low level (VLL), above VLL), the density of drones, not to mention the complexity of the traffic (e.g. simultaneous flights) and the complexity of the service provision (e.g. multiple service providers). This led to a high number of possible service combinations, the analysis of which provides a picture of the coverage of the services researched by the projects.

2.1.1 Foundation services (U1)

An analysis of the individual reports shows that U1 services were fully addressed by the projects. For example, the registration assistance service was demonstrated by the 'D-flight internet of drones environment' (DIODE) project, with use cases involving one single U-space service provider (USSP) which corresponds to a low-complexity environment (see Figure 3).

Figure 3: U1 coverage



2.1.2 Initial services (U2)

Due to activities taking place in parallel, the demonstration projects based their work on the CONOPS (first edition – June 2018), while the current analysis considers the latest CONOPS (third edition – September 2019) as the reference. It is therefore not surprising to see that U2 services introduced in this latest edition (e.g. citizen reporting) are only partially covered by the projects. This is also the case for other services first introduced in the third edition, such as the population density map or electromagnetic interference information services. The overall U2 coverage is shown in Figure 4.

However, some projects address services that were not featured in the first CONOPS, such as geospatial information service. The Finnish-Estonian 'Gulf of Finland' very large U-space demonstration (GOF U-space) project and the 'European UTM testbed for U-space' (EuroDRONE) project demonstrated this service by addressing some cases involving only one unique USSP. The scenarios were based on partially automated flights in controlled airspace and fully automated flights in uncontrolled VLL airspace.

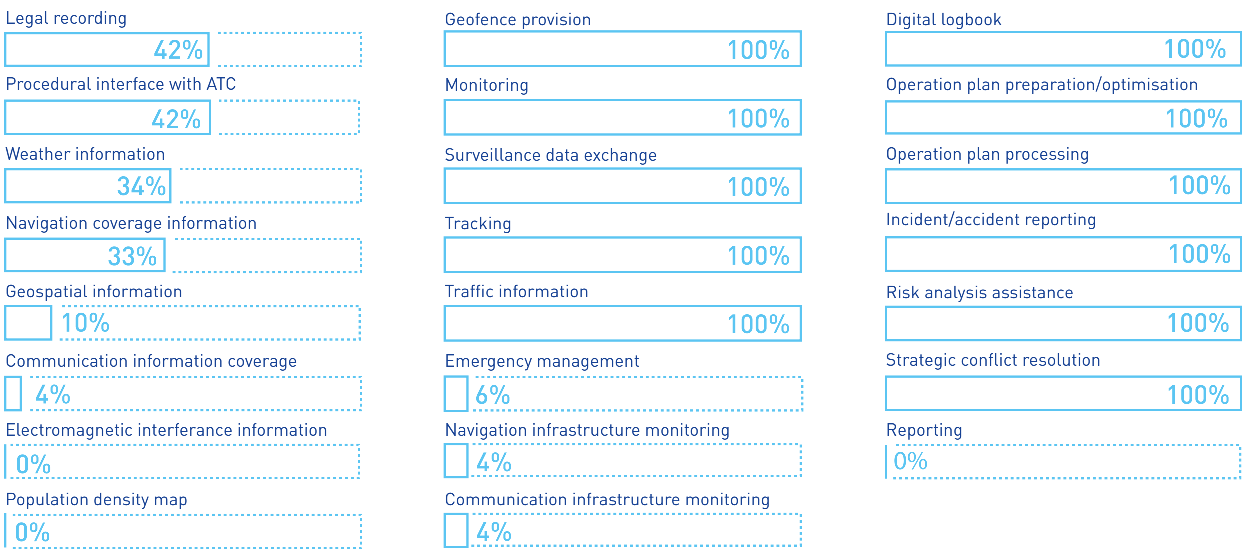
U2 is the main block of services for U-space when considering the services initially defined at the start of the research activities by the SESAR JU. As shown in Figure 2, almost all these services are fully covered.

Some services were partially covered as is the case for emergency management, which the DIODE, 'Demonstration of multiple U-space suppliers' (DOMUS) and EuroDRONE projects looked at. Their investigations were limited to uncontrolled airspace, in VLL, and with only one USSP at a time.

Research was also done on the communication and infrastructure service by EuroDRONE. Their investigations covered scenarios involving fully automated flights in uncontrolled airspace and one USSP.

Meanwhile, DOMUS and EuroDRONE addressed the navigation infrastructure

Figure 4: U2 coverage

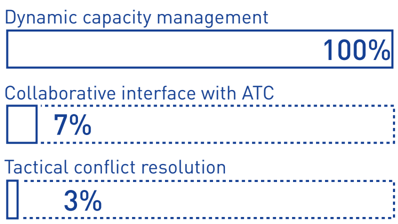


service with scenarios covering only uncontrolled airspace, which means that controlled airspace requires complementary activities.

2.1.3 Advanced services (U3)

The coverage of U3 services is mixed, as indicated in Figure 5. While the dynamic capacity management service was covered by various demonstration projects, only a limited number of configurations were carried out addressing the tactical conflict resolution service – notably by the 'Validation of U-space by tests in urban and rural areas'(VUTURA) project and the 'Safe and flexible integration of initial U-space services in a real environment'(SAFIR) project, which delivered a first set of valuable conclusions on tactical conflict resolution. Similarly only a limited number of activities were carried out on the collaborative interface with air traffic control (ATC). Several projects like VUTURA and SAFEDRONE developed solutions for this service, with demonstrations involving one single USSP and unmanned vehicles only.

Figure 5: U3 coverage



2.2 How mature is U-space?

In order to assess the maturity of U-space technologies, the SESAR JU research programme worked from 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 these assumptions and report on the extent to which they were true.

While 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 underperformance 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 allows for a rigorous analysis of both where we stand and how to focus further work to enable U-space to reach a higher level of maturity. For example, many business models need 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.

In conclusion, the projects demonstrated that U1 and U2 services are ready for environments with a low level of complexity (rural areas, segregated airspace) and a low density of traffic. At the same time, conclusions show the need to further develop and validate U-space to fit with the high complexity / density (urban operations, mixed traffic) of the future operating environments.

As further explained in chapter 3, all the U2, U3 and U4 services are subject to future research and innovation activities. Some of them are more critical: conflict management, emergency management and monitoring services are those that will make U-space scalable and robust to support dense and complex operations in U2 and will ensure a transition to U3 and U4.

2.3 Key milestones

The following are some of the key highlights and findings drawn from the projects to illustrate service coverage and maturity:

2.3.1 Delivering a concept of operations for U-space

The CORUS project received broad consensus for the U-space CONOPS. It provides an initial U-space architecture and detailed definition of the airspace types to be used for VLL 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.

2.3.2 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 ecosystem without having to adopt the structure of more traditional ATM. This will support the operation of multiple simultaneous service providers operating both in 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 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 unmanned aircraft systems traffic management (UTM) systems and supported a variety of drone types. It 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 ATC and performance requirements for satellite mobile connectivity. The project showed how technology can support multiple service providers, a core requirement for complex future applications.

2.3.3 Supporting strategic deconfliction

Among key capabilities, foundational U-space services (U1) such as e-registration, e-identification and geofencing were successfully demonstrated by the 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 USSP can provide a safe operational environment by exchanging information with drones and ATM. 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 DOMUS project. DOMUS used a federated architecture to show how several USSPs can support drone operations using key functionalities including dynamic geofencing and tactical deconfliction 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 ATC. 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.

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

2.3.4 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 GOF U-space 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 and rescue in maritime and city environments. The architecture relies on standard protocols to exchange data and serves as a flight information management system, which disseminates information about manned and unmanned vehicles to a wide range of stakeholders including local and national authorities, air navigation service providers (ANSPs) and USSPs. By using an open platform and system-wide information management, the solution collectively and cooperatively manages 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.

2.3.5 Focusing on tracking and monitoring

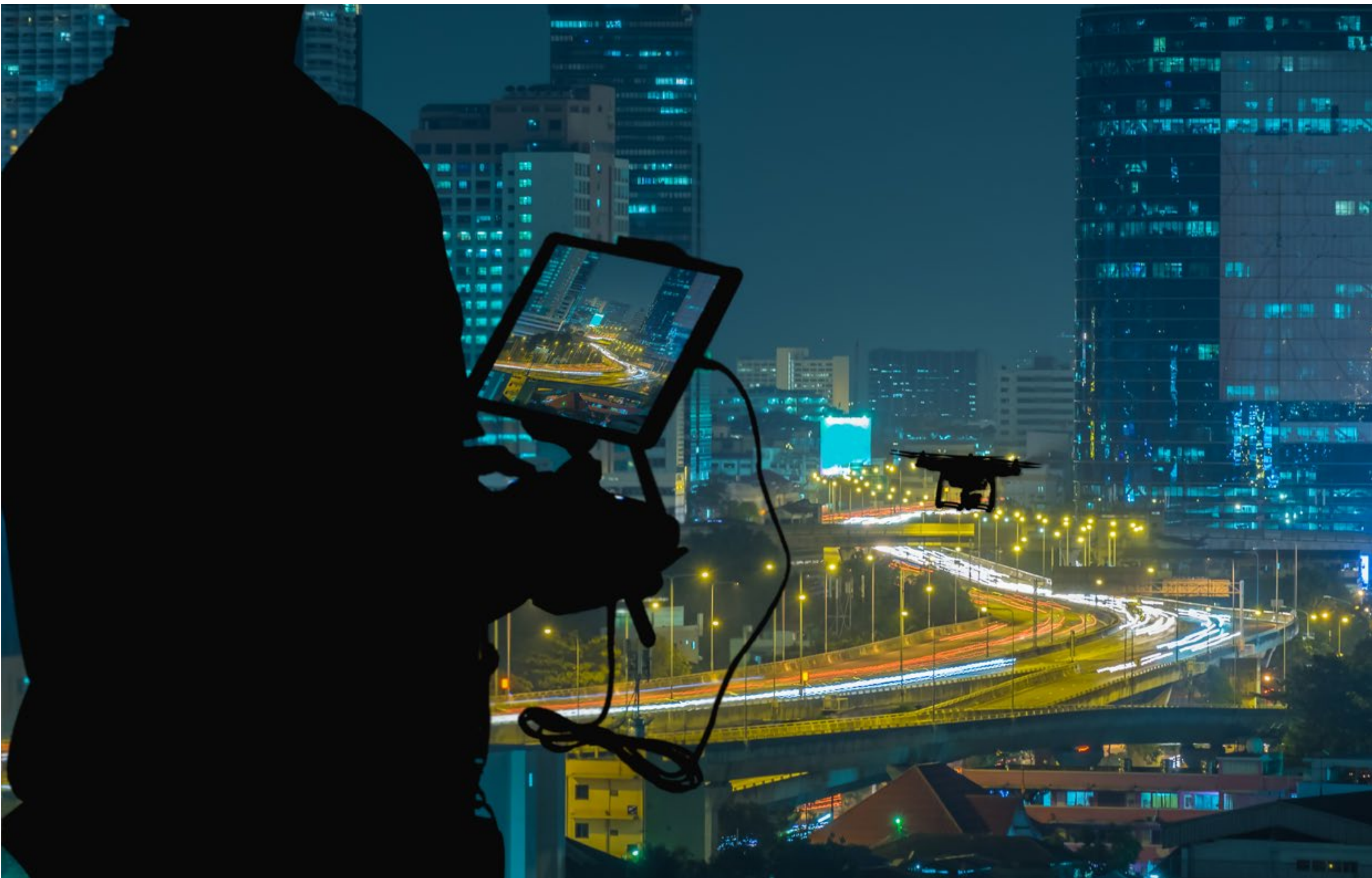
GOF U-space was one of several projects that also showed the importance of reliable tracking data for all airspace users. Flight tests assessed the performance of multiple collision avoidance and tracking systems (e.g. automatic dependent surveillance – broadcast (ADS-B), FLARM) and, while these technologies 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 the 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 U-space initial services (USIS). During long-distance flights in France and Hungary, 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 the 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 the Technological European research for RPAS in ATM (TERRA) project assessed whether machine learning can help monitor VLL 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.

2.3.6 Addressing the interface with manned aviation

Interaction with manned aviation proved to be one of the most challenging 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 airspace, 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 2 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 replanning 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 global navigation satellite system (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 U-space project, 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 the standardisation bodies, EUROCAE and GUTMA, to help develop standards that will enable the safe integration of drones in the airspace.

2.4 Harnessing results from non U-space SESAR research projects

Thanks to its broader mandate, the SESAR JU has a comprehensive and integrated view of ATM 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, general aviation improved navigation and surveillance 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 costs or requiring additional certification. The results showed that 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 heterogeneous aviation through cellular signals project examined affordable cooperative surveillance that is available using a low-power 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 that general aviation could interact successfully with unmanned vehicles using 4G/5G data links and justifies further R & D.

3. Future research and development needs

The 19 projects have significantly contributed to the development of U-space, but they also highlight the need for further R & D in order to deploy the advanced U-space services and capabilities needed to enable UAS and urban air mobility (UAM) operations to be safe, equitable and also ubiquitous and financially viable. These research and innovation needs are as follows:

URBAN AIR MOBILITY
UAM-related scenarios, services, procedures, infrastructures and tools that are needed to enable expected UAM operations at low and VLL in interurban, suburban and urban areas. This area of work should aim to investigate the ecosystem required for managing UAM operations in which more strategic management services are provided along with more tactical management services, such as en-route tactical separation management and departure and arrival management at vertiports.

3.1 Urban air mobility

UAM refers to an ecosystem that enables on-demand, highly automated, passenger or cargo-carrying air transport services with particular reference to the urban, suburban and interurban environments, where aviation is often highly regulated today (3). The UAM industry vision involves new vehicle designs (e.g. low emission / low noise electric vertical take-off and landing (eVTOL)), new system technologies, the development of new airspace management constructs, new operational procedures and shared services to enable an innovative type of transport network.

A growing number of manufacturers are working on UAM solutions and eVTOL technologies to enable runway-independent operations, with very high degrees of automation, up to and including fully self-piloted aircraft. Most operators envisage a significant number of simultaneous operations around metropolitan areas at altitudes of up to 5 000 feet and speeds of up to 150 knots. These aircraft will typically carry cargo or 1–4 passengers on short trips (e.g. less than 100 km) (4).

UAM is one of the most demanding use cases for U-space services: it requires exploring dependencies between services and approaching U-space as a system of services from the operational and performance perspective. Future R & D has to explore these dependencies between services to make U-space robust and scalable and to maintain the safety level.

Looking at UAM, a review of the European Drones Outlook Study should be made to update the predicted drone traffic and expected business activity regarding UAM. A study of the social acceptance of the expected traffic would be beneficial to support the future development and implementation of UAM. The take-off and landing solution for UAM (often called a vertiport) will have to be defined and developed to address all weather conditions for which operations will be authorised, as well as all contingencies.

In addition to flying taxis, UAM covers all types of urban air operations that will require the extension of U-space services beyond the VLL limit. Drone operators and UAM operations will require access to higher altitudes and areas close to commercial manned aviation (e.g. airports) when at the same time flying manned aircraft in or adjacent to VLL could make use of U-space services. A safe and equitable integration of these operations with manned aviation will require additional U3–U4 services.

The development of interoperability and a collaborative decision-making process between the urban operations, ATM and city authorities is key for future urban

3 () Booz Allen Hamilton, *Urban Air Mobility (UAM) Market Study*, 2018.
4 () The MITRE Corporation, *Urban Air Mobility Airspace Integration Concepts*, 2019.

operations. It will therefore be necessary to consider the roles and responsibilities of the national and local stakeholders (including USPs, UAS/UAM operators and ATM units involved). It will also be imperative to study the workflows they collectively engage in: defining solutions for ensuring the effective interoperability of USSPs and a proper interface with ATM, focusing on urban/suburban/airport scenarios, classes of airspace and addressing governance and regulatory challenges, security and non-aviation aspects for easing social acceptance.

Further guidance is required on how urban ground and air risks should be addressed or airspace designed over these densely populated environments. It is still unclear how these proposed data and information services, managed by ATM and USSPs, can be integrated and implemented in the busy urban U-space to adequately manage the relevant risks; properly design the relevant airspace; efficiently and safely manage high volumes of UAS/UAM traffic.

Some initial information services for these three aspects have already been defined, but it is less clear how these inputs will be integrated and structured into a practical urban/suburban U-space system to manage potentially hundreds, if not thousands, of UAS/UAM movements per hour over and around.

The primary safety hazards posed by UAS/UAM traffic operating in an urban/suburban/interurban environment are collisions between a drone and another airspace users, as well as the impact on infrastructure, objects and people on the ground, causing damages, injuries or possibly fatalities. The risks associated with these safety hazards must be addressed through the appropriate certification of drones for operation over an urban environment, coupled with comprehensive airspace architecture and dependable traffic management. Conventional drone risk analysis modelling methodologies, such as specific operational risk assessments (SORA), are useful for assessing risk for a single or low number of drones operating in relatively uncomplicated real-world environments (e.g., sparsely populated, rural areas). However, this methodology may not be best suited in scenarios where high volumes of drone traffic are projected to operate in the near future over densely populated environments[5].

5 Airbus UTM Blueprint. 2018. Available online: https://storage.googleapis.com/blueprint/Airbus_UTM_Blueprint.pdf.

Key needs in developing urban U-space systems are:

- identifying and categorising the unique characteristics of VLL and low-level urban environments;
- drafting more pragmatic approaches to identify and properly address relevant risks;
- developing guidance regarding the design and development of integrated urban airspace architecture;
- completing the definition of the UAM operations framework to build a consistent approach on how urban U-space systems should be operated.

ATM / U-SPACE CONVERGENCE

In aviation terms, U-space services include unprecedented levels of automation, and the best in class will likely make their way into traditional aviation. Drones / U-space users and traditional ATM users will coexist in some portions of airspace, such as airports. This area of work aims to enable safe, fully integrated ATM / U-space traffic management operations. This integration aims to unlock capacity and increase the safety and efficiency of all operations. This will include leveraging knowledge gained through prior exploratory research activities to develop concepts, technologies and procedures for traditional aviation and new entrants like UAS and UAM. New innovations and solutions in ATM / U-space convergence / interoperability research may also be transferred or adopted to improve air traffic operations for already existing airspace users.

3.2 ATM / U-space convergence

The introduction of new types of aerial vehicles within the airspace requires ensuring a fully collaborative approach between all actors with the objective of ensuring an efficient interface between U-space and ATM, as well as avoiding airspace fragmentation. An efficient U-space–ATM interface is required to enable an adequate, robust and timely exchange of U-space information services between various U-space stakeholders such as drone and UAM operators, USP, ATM service providers, data service providers, aeronautical data providers and authorities. The relevant solutions are expected to have a positive impact on access and equity, enabling seamless ATM / U-space high-density automated and fully digitalised operations managed in close cooperation with UAS/UAM fleet operators.

A fully integrated ATM / U-space CONOPS definition is required to cover seamless operations inside and outside controlled airspace, further defining the interface between ATM and U-space, as well as examining the corresponding information exchange concept and requirements. Information exchange will be critical to enable a safe convergence of U-space and ATM. The possibility of a fully integrated airspace without segregation between U-space and ATM users is the ultimate goal.

A fully integrated ATM / U-space ecosystem without segregation between U-space and ATM operations also requires the setting up of common fundamental enablers. Some of these enablers include the definition of a common altitude reference system (CARS), separation minima, safe operating distances from buildings and fundamental aviation tenets, such as airspace classification.

The need to revise the rules of the air becomes necessary to consider the specificities of VLOS and BVLOS operations, of unmanned traffic in general, as well as of mixed traffic (unmanned and manned). Such work will go through a mapping from VLOS and BVLOS to flight rules. If that mapping produces new flight rules, then the airspace classes need to be updated. X, Y and Z volumes need to be mapped to airspace classes, or guidance developed on what mappings are reasonable.

Further work will be required on enablers for automation and autonomy for U-space and UAS/UAM. In this framework, a critical aspect of the integration will be the role of humans, particularly regarding the high level of automation that will be delivered by U-space services and the known automation disparity between ATM and U-space. UAM integration in the ATM / U-space ecosystems is also a specific research topic, as well as the challenge of how to support the transition from piloted vehicles to UAM/autonomous operations. Of course, the evolution of the ATM / U-space convergence will need to be synchronised and coordinated with the development of UAM services and the certification of UAM vehicles. Special consideration should be given to the operational limitations of these new vehicles and how U-space and ATM can contribute to their operational safety by protecting their operations in contingency and non-nominal situations.

3.3 Advanced U-space services

The SESAR JU projects defined and demonstrated U1 and U2 services, as well as some early U3 services. It is now time to start work on the definition, design and development of the most advanced U-space services (U3/U4), which will also enable UAM missions in high-density and high-complexity areas. The required technologies to enable performance-based communications, navigation and surveillance (CNS) services in U-space need to be identified and assessed in operational environments. These advanced steps in the deployment of U-space require advanced strategic/tactical conflict resolution, advanced DAA systems and a suitable communication infrastructure. This also goes together with the multiple USSPs principle: multiple USSPs working at the same time in the same geographical area.

Advanced U-space services: U3 and U4 services will enable missions in high-density and high-complexity areas. Drones flying longer/higher/faster than before will have to be safely integrated into the airspace. New technologies, higher levels of automation, miniaturisation, including machine learning and artificial intelligence, automated detect and avoid (DAA) functionalities and reliable means of communication will enable a significant increase of operations in all environments and will reinforce interfaces with ATM/ATC and manned aviation

3.3.1 Strategic/tactical conflict resolution

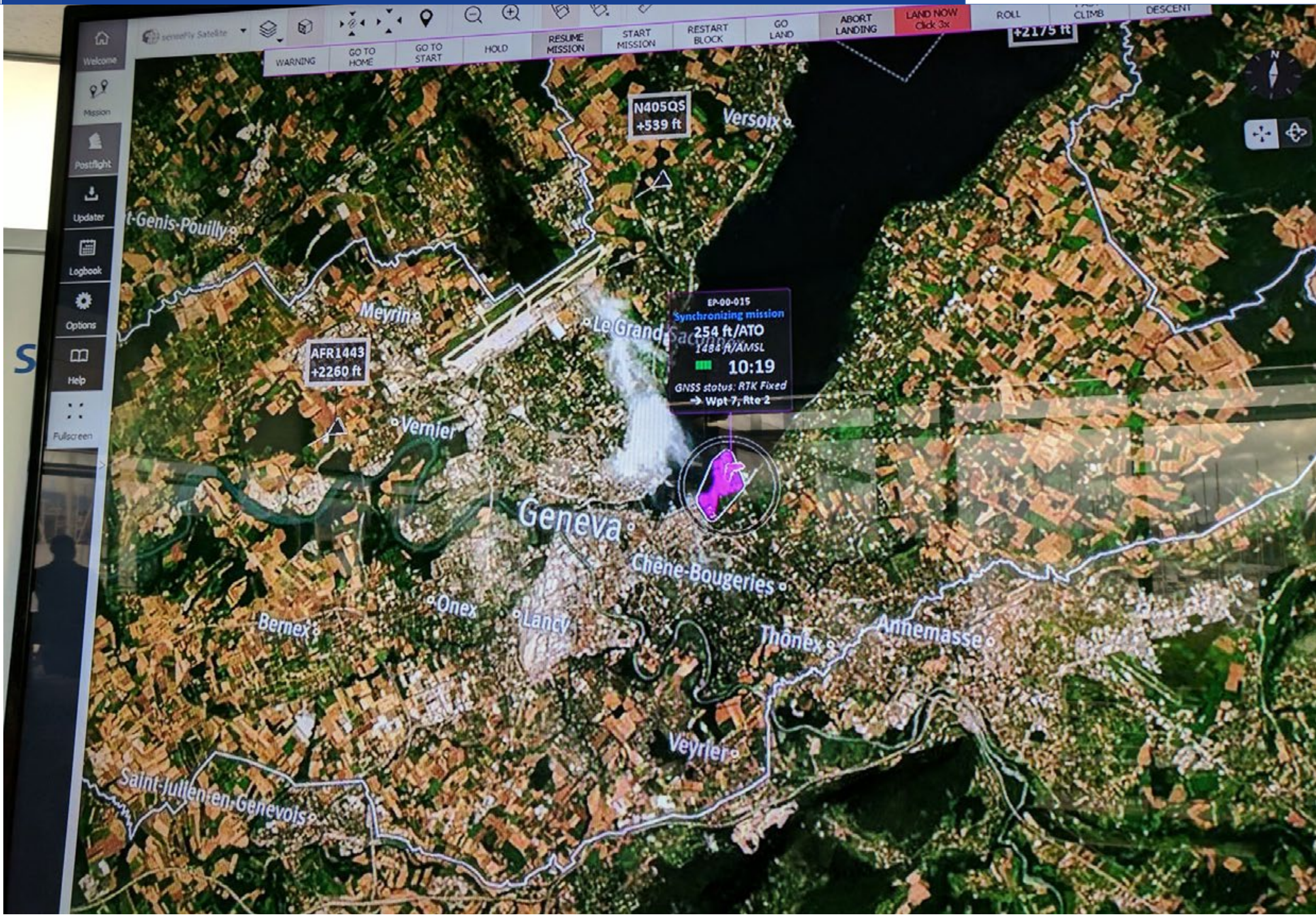
U-space services and capabilities will support a range of UAS/UAM operations ranging from rural sparsely populated areas with marginal manned aviation operations to urban operations with considerable manned aviation operations, terrain and surface obstacles to be considered. The corresponding requirements for separation provision / conflict resolution – in terms of data exchange / tracking / monitoring services, on-board aircraft capabilities / avionics and operators responsibilities – will be adequate to the relevant risks for people and properties.

UAS and UAM operators operating in areas with high-density or heterogeneous/ mixed types of traffic may be required to be equipped with DAA technologies to meet these requirements. Low-level manned aircraft operations in both uncontrolled and controlled airspace should have access to, and are encouraged to utilise, U-space mission management services to deconflict their operations from potentially conflicting unmanned operations in the same portion of airspace. Low-level manned aviation pilots will then share some responsibility with UAS/UAM operators for maintaining separation from each other (even if they will not share responsibility for separation from VLOS UAS operators).

U-space, within its defined airspace, should be ultimately responsible for maintaining an adequate separation among UAS/UAM, manned aircraft, airspace, weather events, terrain and other relevant hazards, and for avoiding unsafe conditions throughout the relevant operations. Separation/ conflict management service provision will be achieved via shared intent, shared awareness, strategic deconfliction of airspace volumes, tracking and monitoring, some digital technologies supporting tactical deconfliction and the establishment of ad hoc operational rules and procedures. U-space services will support operations planning, intent sharing, strategic and tactical conflict resolution/management, conformance monitoring, operations authorisation, airspace management functions and management of off-nominal situations.

Until Europe has validated more advanced services and relevant technologies, U-space services supporting strategic and tactical conflict management cannot be fully deployed; yet these services are key for the adequate functioning of initial U-space implementations.

With its first portfolio of research projects, the SESAR JU has demonstrated several initial solutions for strategic conflict resolution (e.g. on delay in SAFIR and EuroDRONE; rerouting without considering terrain or other issues in DOMUS), however these were limited in their ability to



deconflict given the level of uncertainty: during the flight trials, no vertical separation was used.

Advanced conflict detection is essential for multiple drones to operate simultaneously. U-space systems must be implemented in a common way to be able to efficiently exchange data, and all systems have to be able to use the exchanged data. Low quality / delay of input data from the other services degrade the strategic conflict resolution. These conclusions are about strategic conflict resolutions but many parallels can be drawn with the tactical conflict resolution service.

Several areas will require further investigation in order to develop robust, advanced and scalable U-space services supporting strategic and tactical conflict management. These include:

- conflict management principles and related algorithms;
- the impact of the fairness principle on the decision-making process;
- how conflict detection should be optimised;
- how CARS and vertical separation should be implemented;
- how conflicts should be resolved in a federated system;
- how conflicts should be resolved with manned aviation in VLL and low-level environments;
- strategic deconfliction introducing more variables: weather, GNSS availability;
- interactions between the tactical conflict resolution service and on-board DAA systems;
- use of machine learning in tactical conflict detection.

Finally, monitoring is a key enabler for strategic and tactical deconfliction (like response and recover elements). Any research related to conflict management must therefore consider dependencies with monitoring services.

3.3.2 Detect and avoid solutions (cooperative and non-cooperative)

U-space will impose requirements on UAS/UAM/manned aviation operations and performance commensurate with the required level of services, operational environment and airspace class conditions. Airspace management will refer to a layered approach to safety, security and equity of airspace access that also includes the capability of ensuring aircraft and obstacle avoidance through the use of appropriate ground-based or on-board equipment, including DAA / collision avoidance logic. Based on that, it is expected that in U-space airspace, UAS and UAM operators flying in areas with high-density or heterogeneous/ mixed types of traffic may be required to be equipped with DAA technologies to meet these requirements. It means that in terms of R & D needs, Europe should address the following needs:

- development of on-board DAA capability:
- full demonstration of DAA (detecting equipment for cooperative intruders) in dense airspace;
- exploration of technical feasibility for detecting non-cooperative intruders and integration with the current collision avoidance algorithms.
- cost-effective, lightweight electronic conspicuity and collaborative DAA developed by the PercEvite project needs to be further developed and matured for large-scale deployment in environments with and without U-space tactical conflict resolution.
- cost-effective, non-collaborative DAA developed by the PercEvite project needs to be brought to maturity.
- operational procedures are needed for pilots reacting to electronic conspicuity and DAA.

3.3.3 Mobile telecommunication infrastructure and its suitability for U-space

Mobile telecommunication networks could be the best solution to provide scalable connectivity solutions for U-space services and BVLOS operations in the future. Mobile telecommunication infrastructures/ solutions for the U-space services should enable increased flexibility in the design and implementation of new types of services making reference to the U-space services requirements. The mobile telecommunication infrastructure should be capable of meeting appropriate U-space services performance requirements for coverage, quality of service, safety, security and reliability (resilience, failure modes, redundancy), while minimising environmental impacts and respecting the privacy and safety of citizens.

Current mobile telecommunication networks can already provide sufficient connectivity and enable U-space services in some environments and use cases. In the future, developed mobile telecommunication solutions for U-space services could enable scalable, flexible and adaptable services, also for demanding environments and use cases.

However, there are some challenges to meet to enable cooperation in the telecoms and aviation sectors. The telecoms industry providing the mobile telecommunication services is market driven. In addition, current commercial mobile networks are typically built and optimised for users on the ground. Large numbers of users in the air will cause interference to the mobile networks and users on the ground, if not implemented in a controlled manner. Coverage and service requirements are also not currently optimised for users in the air. Close cooperation between the two sectors is needed, firstly to understand the performance requirements that U-space services put on the mobile telecommunication services, and secondly to develop a compromise on how the requirements can be met by the mobile telecommunication networks and services. The technical requirements of U-space services should be realistic and possible to meet in practice. This will also require developing new common business models for the cooperation between U-space and mobile telecommunication service providers.

U-space must be able to adapt to new communication technologies and automation, both ground-based and airborne, and increasingly allow for more advanced forms of interaction with the overall U-space ecosystem, predominantly through interoperable communication systems capable of digital information and data exchange such as the 5G mobile telecommunication infrastructure. Ultimately, the next generation of mobile telecommunication infrastructure must be persuaded to encompass the range of UAS/UAM demand, business models, applications and technologies, and to support safe and efficient U-space operations that also include manned aviation and existing ATM systems to ensure a fair and equitable access to the airspace.

Although mobile telecommunication networks can provide connectivity for many challenging environments and operations in the future, there will always be environments where mobile networks are not the optimal connectivity solution, such as high altitudes or remote locations.

3.3.4 Multiple U-space service providers

When U-space services, such as mission management or conflict management, are centralised this can work relatively well (as there is one decision made by the ecosystem). The complexity comes when multiple USSPs have to exchange information and to make collective/ coordinated decisions that are consistent. Research needs to be carried out on specific use cases and safety-critical services that are impacted by this federated approach e.g. tactical resolution services.

Solutions need to be developed that define the exchange of data between multiple USSPs and enable this vision of a federated U-space with multiple USSPs: Failure management, discovery mechanisms, tracking (multiple sources) in a federated system and a common information service as the definition of standards for inter-USSP communication without centralised services are needed.

Fair access needs to be guaranteed to the airspace. Equity and fairness principles are essential and, at the same time, they affect the service provision. This is related to the needs of data integrity and consistency within a fully federated U-space service architecture. Both may influence the VLL rules of the air.

Further R&D will be critical for the development of the multiple USSPs concept, addressing how conflicts will be resolved in a federated system; how authorisations will be provided in a multilayer environment; the reliability of communications in a in a federated system; roles and responsibilities for for the provision of services when several USSPs share the same portion of airspace; and the requirements for a technical implementation of a fully federated U-space service architecture for unsegregated airspace.

3.3.5 Geofencing

Geofencing services are key components for U-space, which is why many SESAR projects have investigated them. In particular, the Geofencing for safe autonomous flight in Europe (GEOSAFE) project was fully dedicated to geofencing.

Several needs are identified. To ensure that:

- geoawareness has 'a single point of truth';
- geoawareness is efficiently distributed in a scalable way;
- the reactions of drones to a geofence are known or even standardised.

When analysing the results from the flight trials, the following areas for further work were identified by specific projects:

- The need to integrate the geoawareness information into the drone's ground control station (GCS) was commented on by several projects (SAFIR, SAFEDRONE, GOF U-Space and GEOSAFE).
- Human factors associated with the safety critical function geoawareness need be reinforced.
- GOF U-Space commented on an issue that the human machine interface would have to deal with, either in a GCS or in a planning tool. When a geofenced area is larger than the whole area being shown on the map (due to zooming in), then there is a risk that the person looking at the map might not understand that the entire map is covered by a geographic zone.
- SAFEDRONE commented on the need to use acoustic alerts for geoawareness.

3.4 Mapping of U-space service research

As a result of their research activities, the projects identified areas where further R & D is needed, impacting almost all the services, particularly for complex and dense environments.

R & D needs	Relevant U-space services
▸ Safety/risk assessment, including risks related to multiple drones interaction in the same area of operations) ▸ CARS, in particular addressing the vertical separation within VLL and with regard to manned aviation too *(Source: DIODE)*	▸ Airspace Management/geofencing ▸ Separation/conflict management ▸ Emergency management ▸ Monitoring ▸ Interface with ATC
▸ Definition of separation minima UAS/UAS and unmanned versus manned ▸ Tactical conflict resolution service integration WRT DAA airborne capabilities ▸ Interaction of dynamic geofencing with tactical geofencing/conflict resolution service ▸ Analysis of U-space centralised architecture versus federated architecture performance *(Sources: DOMUS)*	▸ Separation/conflict management ▸ Interface with ATC ▸ Airspace Management/geofencing ▸ Monitoring ▸ Emergency management
▸ Automation of ATM to U-space interfaces, including linking with tracking and monitoring activities Integration of unmanned eVTOL WRT other AUs ▸ Onboard DAA with non-cooperative intruders Minimum separation distance among UAVs, taking into account their performance, systems on board, and mandatory flying dynamics ▸ CARS *(Source: EuroDRONE)*	▸ Interface with ATC ▸ Airspace Management/geofencing ▸ Separation/conflict management ▸ Emergency management
▸ Integration of U-space into eVTOL avionics eVTOL integration with regard to general and manned aviation ▸ High levels of automation and increased reliance on V2I, V2V and ATC/UTM communication links and cybersecurity *(Source GOF U-space)*	▸ Interface with ATC ▸ Airspace Management/geofencing ▸ Separation/conflict management ▸ Emergency management
▸ Conflict resolution capabilities and how to exchange flight plan data between the drone operation plan processing and operation plan preparation assistance services during the conflict management phase ▸ Definition of standards for inter-USSP communication without centralised services ▸ Impact of federated architecture on U-space services provision (e.g. for separation/conflict management). ▸ Data integrity and consistency within a fully federated U-space service architecture ▸ Weather information service in an urban scenario ▸ Monitoring and traffic information contingency scenarios ▸ Tactical deconfliction and dynamic capacity management services	▸ Airspace Management/geofencing ▸ Separation/conflict management ▸ Emergency management ▸ Monitoring

R & D needs	Relevant U-space services
▸ Conflict resolution capabilities and how to exchange flight plan data between the drone operation plan processing and operation plan preparation assistance services during the conflict management phase ▸ Definition of standards for inter-USSP communication without centralised services ▸ Impact of federated architecture on U-space services provision (e.g. for separation/conflict management). ▸ Data integrity and consistency within a fully federated U-space service architecture ▸ Weather information service in an urban scenario ▸ Monitoring and traffic information contingency scenarios ▸ Tactical deconfliction and dynamic capacity management services *(Source IMPETUS)*	▸ Airspace Management/geofencing ▸ Separation/conflict management ▸ Emergency management ▸ Monitoring
▸ UTM/GCS full integration (Source SAFEDRONE/GOF-USPACE) ▸ ATC/U-space interfaces ▸ Separation minima ▸ Common altitude reference system Telecommunications networks for U-space ▸ U-space services in urban or semi-urban environments ▸ Multi-USPs sharing the same portion of airspace responsibility for the provision of services (Source SAFEDRONE)	▸ Interface with ATC ▸ Airspace Management/geofencing ▸ Separation/conflict management ▸ Emergency management ▸ Environment
▸ Strategic and tactical deconfliction in a federated ecosystem ▸ Tactical deconfliction with regard to manned aviation ▸ Tracking (multiple sources) in a federated system ▸ Priority/emergency services ▸ Analysis of mobile telecommunication network for U-space (coverage, data integrity, authorisation, location based services…) ▸ Full testing, in all operational circumstances, of individual U-space services. ▸ Further in-depth testing and standardisation of U-space services in ground control station applications, (Source SAFIR)	▸ Emergency management ▸ Environment ▸ Separation/conflict Management
▸ Relevant CNS technologies for U-space services supported by them ▸ Conflict detection and tactical deconfliction (DAA) (Source TERRA)	▸ Separation/conflict management ▸ Relevant CNS services to support the required U-space services deployment
▸ Deconfliction strategy rules (Source USIS)	▸ Separation/conflict management
▸ Streamlining information exchange between USPs ▸ R&D and governances needs to be established at EU level in or to deliver/validate U-space. (Source VUTURA)	▸ Airspace Management/Geofencing ▸ Interface with ATC and other USPs
▸ Non-cooperative DAA solutions ▸ U-space reference communications backbone ▸ Further definition of the full set of U-space services and capabilities with an ad-hoc inventory (Source AirPASS)	▸ Separation/conflict management ▸ Relevant communication backbone services and performances to support U-space Services deployment
▸ Specific U-space reference communication backbone services (Source DROC2COM)	▸ Relevant communication backbone services and performances to support U-space Services deployment

4. Performance requirements

In researching and demonstrating the U-space services, the SESAR JU projects identified an initial set of requirements in support of standardisation and regulation activities. These requirements are categorised according to minimum performance, level of safety, operational or technical interoperability, acceptability (privacy/noise) or security.

The development of these requirements is progressive and uses an iterative process. Each iteration leads to a baseline that provides a set of requirements mainly developed by the exploratory projects, and finally demonstrated by the projects performing flight trials. At the time of writing this document, the applicable baseline is baseline #3.

Figure 6 presents the number of requirements developed by each exploratory research project. Requirements produced by the CORUS projectare not included. Inputs from the PercEvite project were not available in Baseline #3 (this is expected in the next baseline).

Figure 6: Number of requirements per exploratory research project

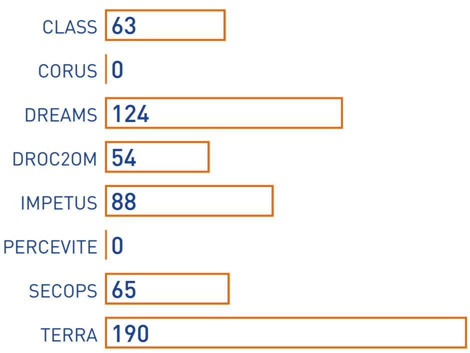
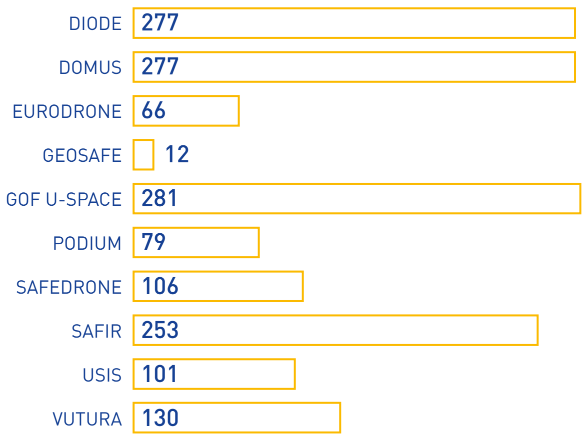


Figure 7 shows how the requirements have been covered in the demonstration activities. A requirement may be covered by more than one demonstration project. The number of requirements tackled by a project depends on its scope: a project like GEOSAFE focused on geofencing, while projects like SAFIR, DOMUS or DIODE were more generic as they were focused on the service provision in general.

Figure 7: Number of requirements per demonstration project



A quality analysis was conducted to categorise the requirements and to assess their relevance (i.e. well defined and/ or corresponding to services cited in the CONOPS – third edition) and value as input to standardisation/regulation work.
A scoring of their value was established - requirements with a score lower than six mainly correspond to the those that cannot be linked to the CONOPS.

Figure 8 indicates that a large part of the existing requirements are highly valuable, with almost 75 % of the requirements meeting the minimum level of quality (i.e. above 6).

Figure 8: Quality analysis of identified requirements

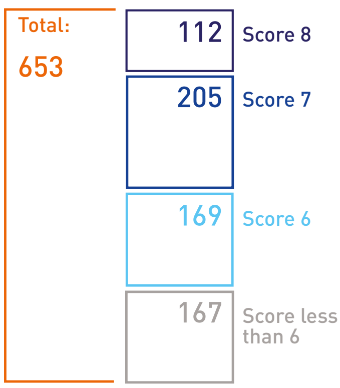
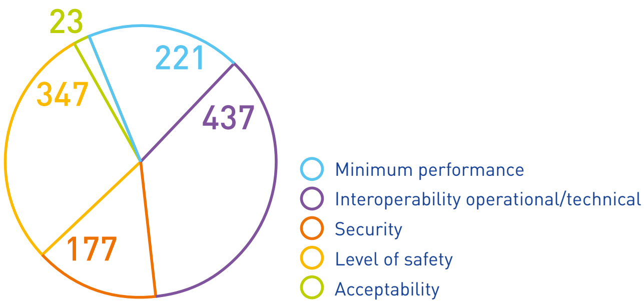


Figure 9 shows the distribution of all the requirements among the categories. A requirement may be allocated to more than one category. Consequently, the total number of allocated requirements (1 205) is higher than the total number of Baseline #3 requirements (653).

This view identifies the categories that could be strengthened in the future. In particular, 'acceptability' needs to be further addressed in terms of requirements.

Figure 9: Categories of requirements



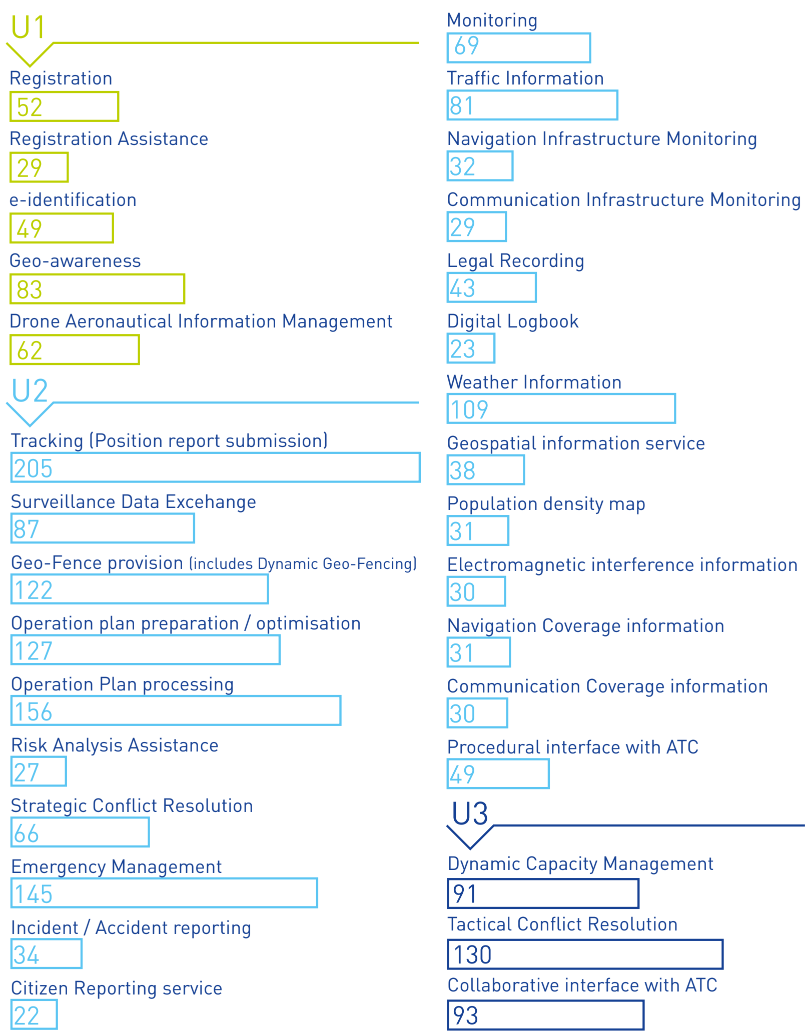
Finally, Figure 10 shows the allocation per service. A requirement may be allocated to one or more services. Consequently, the total number of allocated requirements (2 175) is higher than the total number of requirements (653).

The number of requirements allocated to U1, U2 and U3 services is respectively 275, 1 586 and 314 (13 %, 73 % and 14 %), which reflects the intensive focus on U2 services.

The projects have extensively addressed some services (tracking, plan processing, plan preparation/optimisation, etc.) with some omissions (e.g. citizen reporting). To understand such variances, it should be noted that the projects started in 2017 and based their scoping on the services in the U-space Blueprint. Throughout the CONOPS development (2017 to end of 2019), new services were progressively introduced, and as a result the most recently added were addressed to a lower extent.

Refer to the baseline of SESAR requirements for U-space and related guidance document for more details.

Figure 10: Number of requirements per service/capability



5. Standardisation and regulation

In addition to providing a breakdown of the development work still required, the SESAR results feed directly into the regulation and standardisation process underway in Europe, as well as in other world regions. Research findings and demonstrationss 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 requires comprehensive understanding of the performance of drones in operational scenarios.

U-space implementation is dependent on the available technologies and the use of harmonised standards, as well as the maturity of the U-space services. These services are scaled to integrate drones' operations in the airspace and to enable them to operate together with manned aircraft, in a safe, efficient and sustainable manner. The findings from the SESAR JU projects pave the way for this implementation and for the required standards, protocols and regulations. An initial conclusion is to use and maintain the U-space CONOPs developed by CORUS as the common reference for future validation, regulation and/or standardisation activities.

Another key conclusion of the projects is the need to support the standardisation process by collecting data. This need for data is essential to elaborate the necessary minimum operational performance standards (MOPS) for U-space services' equipment/systems and capabilities as well as for drones. This is also needed for the enabling infrastructure to be set to support U-space operations. Those performances have to be commensurate to the traffic and traffic complexity to ensure the safety of operations.

This could be done through the development of a number of R & D projects that focus on large-scale demonstrations of cooperative and non-cooperative traffic, and of manned and unmanned traffic. These demonstrations should be large-scale scenarios with tens, hundreds or even thousands of participating drones and USSPs, and the implementation of flight corridor testing and hardware and software robustness testing. Regarding security, penetration testing of U-space services must be organised by an independent party: an ethical hacking approach for testing the implemented security measures of a U-space service would be beneficial. In addition to the MOPS, these R & D activities will be the basis for the development of acceptability criteria and best practices needed to support all the open-source or proprietary developments done in parallel.

From the experience gained from the demonstration projects, it can be concluded that until advanced services are developed, U-space services supporting strategic conflict management are key for the functioning of initial U-space airspace implementations. The operation risk assessment to consider air collisions also needs to be updated to ensure safe implementation.

Guidance material needs to be developed to support the application of the regulation, including a common terminology and a clear definition of roles and responsibilities. This addition to the existing regulation will support the safe management of the traffic.

As U-space is about the safe integration of drones in the airspace, project conclusions and recommendations on standardisation and regulation naturally fall in the safety area. A common and unique set of exchanging information needs to be shared between all involved stakeholders, whether they are manned or unmanned; clarifying the information and data required to access an airspace managed by U-space. One piece of information that must be shared, in a cooperative way between the airspace users, is the traffic information.

This information sharing goes with data exchange. In this respect, standards are required related to protocol, data models, interfaces and services behaviour, time synchronisation method, encoding mechanisms and failure modes. Standards must also be developed related to the notion of a single source of truth. Specific privacy standards are also needed, particularly with drones under BVLOS operations. Current privacy and data protection laws and rule-making, including e-identification and tracking, are to be further developed.

Finally, having multiple service providers acting in the same geographical area at the same time requires coordination procedures between them (USSPs and air traffic service providers). Such procedures will enable interoperable, safe and secure operations across Europe. A special emphasis on the coordination between air traffic services and USSPs will contribute to a safe management of the traffic in all airspace classes. Other concerns specific to the multiple USSPs have been identified by the projects, one example being the need to develop standards for a 'U-space service providers discovery' mechanism.

6. Conclusions

This report describes 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 improve 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. The results presented in this report show real progress from almost nothing to the initial deployment of certain features in only a short space of time.

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 U-space 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 it clear that, while a lot has been achieved in the past 2 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 DAA, command and control (C2) link, geoawareness, contingency procedures and dynamic interface with ATM.

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:

- UAM 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 artificial intelligence;
- 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's discussions can only be realised against the background of a R & D 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 19 projects are now closed but the SESAR JU continues its work in the development of U-space with new projects, such as ICARUS[6], BUBBLES[7] or DACUS[8], which explore U3/U4 and topics such as common altitude reference, dynamic capacity management and separation management.

Further demonstration activities dedicated to U-space and UAM are planned by the SESAR Joint Undertaking in the coming months in preparation for the future Digital European Sky – These activities will take up the R & D needs outlined in this U-space brochure. The SESAR JU will continue to participate in and support further developments as part of a focused and motivated pan-European team dedicated to delivering a smart and sustainable operating environment for manned and unmanned aircraft alike.

6 Website: www.sesarju.eu/projects/icarus
7 Website: www.sesarju.eu/projects/bubbles
8 Website: www.sesarju.eu/projects/dacus

ANNEX 1

U-space services catalogue

1. Identification and tracking

1.1. Registration and registration assistance services

The registration service allows drone operators to access the registry, to register or update their entries, as is required by law. The registration service also allows law enforcement agencies or other authorised users to retrieve operator details.

The registration assistance service is a user-friendly assistance for some specific registrations that occur routinely, for example allowing a shop owner to register a new drone operator when a drone is sold, or a training school to register pilots for training.

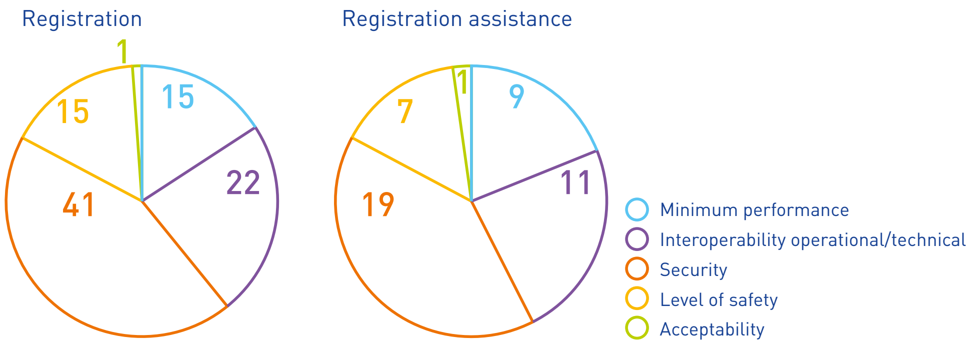
Following are the requirements for the implementation of these services that were identified by the Information management portal to enable the integration of unmanned systems (IMPETUS) and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 1: Registration service requirements (non-exhaustive)

Title	Description
e-registration	The operator shall complete the e-registration process before starting operations.
Registration process	The system shall facilitate the storage of registration information about drone/pilot/operator in a national/local database. The registration information contains at least an electronic identifier to link the e-registration and the e-iIdentification.
e -registration validation	The relevant national authority should confirm what the drone/operator/pilot is allowed to fly when submitting the registration acknowledgement.
Authorisation acknowledgement	The system should confirm what the drone/operator/pilot has been allowed to fly by the authority, when submitting the registration acknowledgement.
e- registration validation	The authority shall provide an e-registration certificate.
User profiling	The system shall allow user profiling: restricted content and functionalities will be accessible depending on the profile of the authenticated user. Access to each content and function type must be configurable by the supervisor.
Registering information for law enforcement agencies	Law enforcement units shall be able to access drone/operator/pilot registration information when required.
Provision of pilot location and operator contact details to law enforcement units	The system shall provide pilot location and operator contact details for drones in flight to law enforcement agencies when required.
Drone capabilities e-registration	To develop complex operations (e.g. Urban, BVLOS, etc.), the operator shall register drones capabilities and sensors.

Figure 11 shows the distribution of all the requirements (81) identified by the SESAR research projects relating to these services - Considerable focus was placed on the security requirements.

Figure 11: Distribution of requirements for registration



1.2. Remote identification and e-identification service

Broadcast remote identification is a drone capability that allows operators or authorities nearby to receive some information about the drone and its operator. The network remote identification service allows a drone to be identified by comparing the position reported by the observer with the known position as tracked by U-space.

The e-identification service is used primarily, but not only, by law enforcement agencies. It takes the remote identification information and uses it to retrieve operator details from the registry and operation details from a set of current and known operations. A simpler version of the service, which protects the privacy of the drone operator, is expected for public use.

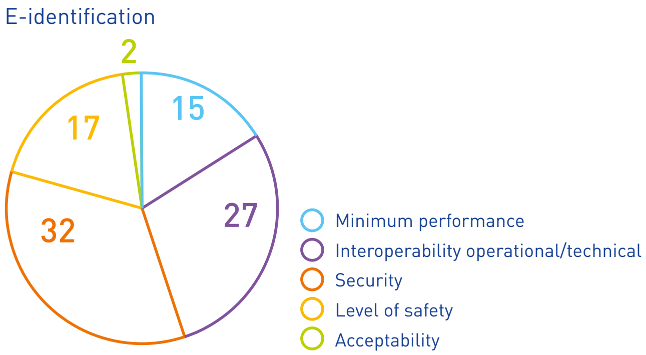
Following are the requirements for the implementation of these services that were identified by the Advanced integrated RPAS avionics safety suite (AIRPASS), Drone European AIM study (DREAMS), IMPETUS and TERRA projects– Refer to the latest available baseline for more requirements and details.

Table 2: Identification service requirements (non-exhaustive)

Title	Description
Electronic identification of drones for territory control	In the interest of public security and safety, law enforcement agencies shall be able to identify with a dedicated portable equipment any flying drones.
Provision of e-identification information to law enforcement agencies	Law enforcement agencies shall be able to access to e-identification information about drones in flight when required.
Pilot location and operator contact details to law enforcement agencies	Law enforcement agencies shall be able to access to pilot location and operator contact details for drones in flight when required.
Provision of drone' location information to law enforcement	In urban areas or near to critical infrastructure, law enforcement agencies shall be able to have continuous up-to-date information about drones' location, linked to e-identification and e-registration data.
E-identification	The system should process the electronic identifier code received together with the tracking message (position and time stamp) and link them to the e-registration assigned to a drone, allowing unique identification of drones in flight.
Registering information data provision	The system will provide e-registration information relative to a certain drone in flight detected by the system to authorised users (e.g. all useful information to law enforcement agencies)
Continuous operator contact data	Drone pilot location or operator contact details shall be registered and available by the system during the whole flight.
Profiling of data visualisation-operator contact	The system shall provide drone or pilot location and operator contact data relative to a certain drone in flight presented in the map, when requested by a supervisor or other authorised user (e.g. Law enforcement unit).
Communication for e-identification	The on-board system shall provide a physical data link and a protocol to identify the UAS and UAS operator in U-space services from power-up or first movement until landing.
Navigation for e-identification	The on-board system shall provide position information (including accuracy and integrity) of UAS for initialisation of U-space services.
Flight control functions for e-identification	The on-board flight control system shall trigger the transmission of e-identification messages upon power-up or first movement.
Database for e-identification	For identification, a unique identifier shall be stored on board the UAS in a database. Optionally this identifier contains UAS information like UAS class, equipment list, technical data (including minimum and maximum airspeed, manoeuvrability for deconfliction information), purpose, manufacturer and operator.
Drone identification and tracking information broadcast	The drones shall broadcast tracking messages (i.e. positioning) to allow the system calculating the position of every drone linked to its e-identification.
E-identification should be linked with e-registration	E-identification data should not rely on a flight plan for identification data. E-identification should rely on e-registry data.

When looking at the distribution of all the requirements (49 in total), security, interoperability and the level of safety are the main areas where work has been performed.

Figure 12: Distribution of requirements for e-identification



1.3. Tracking, position report submission and surveillance data

For some drone operations, the identity and position of the drone must be reported to U-space at regular intervals to allow tracking, a network remote identification and other services. The position report submission sub-service allows the drone operator to send position reports to U-space, and associates them with a particular drone operation. The sub-service may be provided with reports by different means, for example from a remote-piloting-station or from a tracking service offered by a telecoms provider. The sub-service includes start-of-flight and end-of-flight messages. The sub-service gives feedback that the reports are being received correctly.

The tracking service generates a track for the operation and is an enabler for services that are based on the current position and motion of the drone, such as conformance monitoring, traffic information, tactical conflict resolution and network remote identification. Tracking depends on position reports sent by the position report submission sub-service, but combines other sources such as drone detection systems, if any are available. The tracking service will provide both tracks and an indication of the uncertainties associated with these tracks. The extent of these uncertainties will determine what can be done with the track information, or the margin which must be applied when the track is used. The technical requirements associated with some airspace volumes will often be in terms of tracking performance.

The surveillance data service supports exchanges between the tracking services and other sources or consumers of tracks, such as air traffic control or drone detection systems.

Below are the requirements for the implementation of these services that were identified by the Clear air situation for UAS (CLASS), DREAMS, GOF U-space, IMPETUS and TERRA projects - Refer to the latest available baseline for more requirements and details.

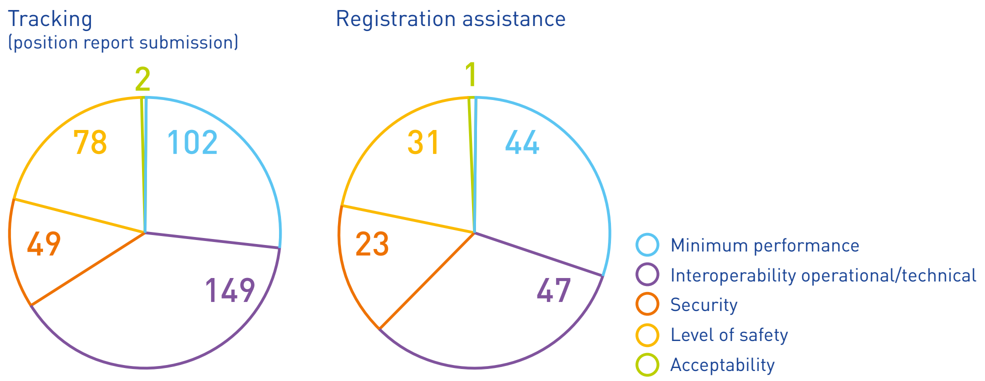
Table 3: Tracking service requirements (non-exhaustive)

Title	Description
Communication for tracking	The on-board system shall provide a data link and a protocol to track the UAS by U-space services from start-up to landing, and providing the data on the position, time stamps (and their accuracy), altitude and velocities, and any expected changes in velocity and direction. A label with the drone's identity shall be included.
Communication for tracking	The on-board communication system for tracking purposes shall be reliable, stable and secure.
Navigation for tracking	The on-board system shall provide position information (equivalent to latitude, longitude, height ([1])), should provide velocity and direction information and could provide upcoming changes (due to flight planning) in velocity and direction.
Track ID	The tracking service shall provide each track by a unique ID number. In case the target is unknown, the ID number may be arbitrary. In case the track drones carries a cooperative tracker, the tracks shall carry the drone-ID.
Indication of track source	The UTM system shall indicate the different track sources via a label on the vehicle to ensure correct monitoring of different tracks
Interface with trackers	The UTM system shall interface with the drone to obtain: ▸ Non-cooperative tracks ▸ Cooperative tracks ▸ Fused tracks
Helicopters/VFR traffic position	The system should be able to receive tracking messages sent by helicopters/VFR traffic flying in areas where drones traffic is allowed.
Helicopter/manned aviation position	The system should be able to calculate the position of helicopters/VFR Traffic flying in areas where drone traffic is allowed, using the tracking information sent by them or an ATM system.
Drone identification broadcast and independent tracking processing	Above critical areas (airports, national security facilities, mass events, etc.), law enforcement shall be able to obtain drones' positions calculated independently from the tracking information provided by the drones.
Direct interface with non-cooperative tracker	The UTM system shall interface directly with the non-cooperative tracker.
Non-cooperative tracking data minimum content	The non-cooperative tracking device shall transmit for each tracked target classified as a drone the track ID, target category, 3D position and timestamp.
Continuity requirement for tracking	The tracking service shall deliver information with a continuity (Max tolerable probability of interruption of service per flight/hour) equal to 1E-05.
Drone identification broadcast and independent tracking processing	Above critical areas (airports, national security facilities, mass events, etc.), law enforcement shall be able to obtain drones' positions calculated independently from the tracking information provided by the drones.
Non-cooperative classification latency	The non-cooperative tracker shall classify the target in less than 8 seconds from track initiation.
Data fusion tracker detection performance	The data fusion tracker should achieve a probability of update >90 % for the specified drone types over the required coverage area
Data fusion latency	The data fusion tracker will declare the target classification in <6 seconds from track initiation
Technology agnostic	Tracking is technology agnostic (successfully demonstrated based on [existing technology:] Scanning surveillance radar (SSR), ADS-B, FLARM, mobile network trackers and telemetry (ground control station – GCS – integration) [and open to any new technology])
Altitude reference	Recommend standardising the treatment of altitude references, such as above take-off location (ATO, also known as QFE), above elevation data (AED), above mean sea level (AMSL), QNH or QNE (FL).

1 How altitude is measured and expressed in U-space is the subject to ongoing research. The term height is used in the general sense here.

Figure 13 shows the distribution of all the top requirements (292) developed by the projects related to these services. The work focused mainly on interoperability and minimum performance.

Figure 13: Distribution of requirements for position report submission and surveillance data exchange



1.4. From our flight trials

The following are extracts from the final reports of the DOMUS, GOF U-space, EuroDRONE and SAFIR projects.

Table 4: Extracts from project final reports relating to identification and tracking

Project	Report extract
DOMUS	The project explains the different elements of the tracking service, distinguishing the supply of position reports ('telemetry') and the process of making a track by statistical methods.
DOMUS	The project gives some achieved performance figures. For example, tracks were updated twice every second.
DOMUS	The project describes the secondary tracking functions such as detecting loss of inputs.
DOMUS	The project gives some figures for achieved uncertainty of tracks. Mean position error is stated as 5 to 6 metres horizontally or vertically.
GOF USPACE	The project recommends that vehicle registration identifier information is standardised based on e-registration information and is made mandatory.
GOF USPACE	The project highlights the need to resolve the issues of altitude. At the minimum it should be possible for position reports to unambiguously identify what altitude measurement frame is meant. Furthermore, GOF identified the benefits of 'reliable tracking capabilities and services, including single source of truth for any flying object, manned or unmanned.'
EURODRONE	The project identified the requirements of RADAR sensors for drone tracking, in particular for UAV flight corridors have to be further developed.
EURODRONE	The project demonstrated real-time tracking via LTE/4G transponder/mission director system (DronAssistant). Demonstrations of high volume operations with combination of RADAR sensors in flight corridors are needed.
SAFIR	The cooperative tracking existed of an add-on Unifly BLIP tracker that downlinked the position information over the Proximus Mobile Telecommunication Network. Proximus had adapted their network slightly to improve coverage at higher altitudes. Due to some technical issues, the Unifly BLIP could not connect to this modified layer, and therefore the coverage was limited to about 120m AGL. Other cooperative solutions exist (Mode-S, ADS-B…) but were not demonstrated within SAFIR due to the lack of coverage at low altitude (no Mode-S coverage below 50m AGL in Antwerp) or the absence of ground infrastructure (no ADS-B ([1]) ground network in Antwerp).
SAFIR	The non-cooperative tracking consisted of a counter-UAS radar of Aveillant to provide a drone independent tracking service to protect critical infrastructure in a defined area. SAFIR demonstrated that this can be an additional data source for the tracking service but proper data fusion between these different data sources needs to be performed.

1 ICAO has recently informed states that ADS-B should not be used on drones.

2. Airspace management and geofencing

2.1. Geoawareness, geofencing provision and drone aeronautical information management services

The geoawareness service provides geofence data for use by the drone operator, pilot and the drone itself. The geofence data is delivered in a standard format that can be interpreted by operation plan preparation optimisation tools and services. The geofencing provision service extends this and provides capable drones and remote pilot stations directly with geofences, even during flight. The drone aeronautical information management service allows authorised organisations to create, update or remove geofences and other geographic data at any time.

Below are the requirements for the implementation of these services that were identified by the DREAMS, IMPETUS and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 5: Geoawareness requirements (non-exhaustive)

Title	Description
Temporary segregation of area	The tactical geofencing service shall enable authorised users to segregate areas dynamically and temporarily.
Dynamic geofencing	The dynamic geofencing system shall provide drone operators and users with coordinates of dynamic geofence polygons with a minimum accuracy level of 1 metre.
Safety requirements for U-space service providers deriving from specific operational risk assessment (SORA)	In accordance with SORA Annex E, the provision of external services (as the U-space services) shall comply with safety requirements. The higher the SAIL, the most demanding are these requirements. For operations dealing with SAIL IV, service providers shall be subject to oversight mechanisms (a competent third party shall be involved).
Transaction time requirement for pre-tactical geofencing	The pre-tactical geofencing service shall deliver information with a maximum transaction time of 120 seconds.
Continuity requirement for pre-tactical geofencing	The pre-tactical geofencing service shall deliver information with a continuity (max tolerable probability of interruption of service per flight/hour) equal to 1E-02.
Availability requirement for pre-tactical geofencing	The pre-tactical geofencing service shall deliver information with an availability (max tolerable probability of non-availability of service per flight/hour) equal to 1E-02.
Integrity requirement for pre-tactical geofencing	The pre-tactical geofencing service shall deliver information using a software with a minimum design assurance level (DAL) equal to C.
Transaction time requirement for tactical geofencing	The tactical gefoencing service shall deliver information with a maximum transaction time of 10 seconds.
Continuity requirement for Tactical Geofencing	The tactical gefoencing service shall deliver information with a continuity (max tolerable probability of interruption of service per flight/hour) equal to 1E-05.
Availability requirement for tactical geofencing	The tactical gefoencing service shall deliver information with an availability (max tolerable probability of non-availability of service per flight/hour) equal to 1E-05.
Integrity requirement for tactical geofencing	The tactical gefoencing service shall deliver information using a software with a minimum DAL equal to B.
Human-machine interface	Geofencing information should be received and displayed through by the ground control station so as enhance human performance and to allow for automation.

2.2. From our flight trials

Geoawareness and drone aeronautical information management formed part of the research activities of the DIODE, DOMUS, EuroDRONE, GEOSAFE, GOF U-Space, Proving operations of drones with initial UTM (PODIUM), SAFEDRONE, SAFIR, USIS and VUTURA projects. In the case of GEOSAFE, the project consortium surveyed the state of the art of geofencing in planning tools and UAS. Between the projects, all the related U-space services were tested.

The following are extracts from the final reports providing conclusions on safety and performance.

Table 6: Extracts from project final reports relating to airspace management and geofencing

Project	Report extract
DIODE	The pre-tactical geofencing service was considered strictly linked with flight planning management services. This, together with provision of needed information to identify area where drone operations are allowed, was considered as main enabler to avoid risky interaction among drones operating in the same area.
DIODE	Most of the involved actors considered the information provided during the mission planning and for the pre-tactical geo-fencing especially complete and useful to initially mitigate risks during the flight.
DIODE	In addition, from debriefing it has been highlighted that ATSU (AFIU) improved their situational awareness thanks to geo-fence provision service.
DIODE	Tactical geofencing allows notification for immediate operational intervention (e.g. urgent closure of airspace volume) that received positive feedback from competent authorities about the potential of the tool.
DOMUS	Reflecting their prototype HMI, DOMUS reports that the Authority was able to create the emergency zone without any difficulty at the same time that the Ecosystem Manager does not have problems for transmitting this to the different USPs.
EURODRONE	The pre-tactical geofencing service is considered to be mature. The tactical (i.e. rapid updates) service is considered slightly less mature.
EURODRONE	EURODRONE considered the drone's reaction to a geofence should be the same as to a physical obstacle.
GEOSAFE	The existing AIM is considered very mature but not a complete source of drone AIM.
GOF	The report mentions the creation of drone aeronautical data using a graphical HMI and this information being rapidly distributed and displayed in the planning and traffic information displays of drone operators. For those with integrated GCS, the geofences emerged in their mission plan, making it easy and intuitive to react to. The only caveat is that very large geofences, that cover the whole screen, may be overlooked unless coupled with a very clear warning and clear supporting information.
GOF	GOF reported success with Geoawareness services, including speedy provision of updates.
GOF	Aeronautical Information, such as geofence data and geo-awareness should be made available in U-space in all locations [inside a FIR]. As AIM information becomes available and always up to date, U-space effectiveness increases vastly.
SAFEDRONE	SAFEDRONE confirmed the monitoring function giving alerts, when the drone crossed a geofence.
SAFIR	SAFIR successfully demonstrated dynamic geoawareness (i.e. the reception of updated geo-awareness during flight).
SAFIR	Interconnection of multiple USSP was confirmed: the Amazon drone platform was able to receive the geofencing area and reroute (to counter it) by submitting a new flight plan considering also the geo-awareness and the current drone operation of other operators.

SAFIR	For the authorities, the geofencing service is a simple and very important feature that supports other services as the collaborative interface with ATC. The latter requires moreover to be more developed for an efficient interaction between ATC and drone operators.
USIS	USIS looked at mulitple USSPs and concluded: This preliminary conclusion promotes the critical needs for setting up as soon as possible a Drone AIM service. In order to bring a single source of truth.
USIS	USIS commented on the difficulty (today) of getting the relevant drone aeronautical information: Regulation is clear enough, but the data to support the assessment of the operation are not all easily available and sometimes even not existing.
VUTURA	VUTURA's report mentioned that tactical geo-fences have been used in all flight demonstrations. In all cases, the tactical geo-fences were used to create a safe flight area for high priority drones. In one test these no-fly-zones were exchanged between USSP

3. Mission management

3.1. Operation plan processing, operational plan preparation and optimisation and risk analysis assistance services

An operation plan gives a detailed description of a flight by a drone, stating who will fly what, where and when. This is mandatory in some airspace volumes – the flight can only occur if the plan is approved. The operational plan preparation and optimisation service helps the drone operator to prepare an operation plan and submit it to U-space. The service should present the operator with relevant information for their business needs, such as maps or trajectories optimised for their own fleet. The operation plan processing service receives the plan and then replies with approval or an explanation of why approval has not been given. The operation plan processing service is the gateway to a number of other services that are based on the operation plan, such as the strategic conflict resolution service. The operation plan processing service also allows the operator to change or cancel the operation plan. A risk analysis assistance service can be used to check an operation plan against environmental data (population density, communication coverage, etc.) to support SORA or 'per flight insurance' services.

Below are the requirements for the implementation of these services that were identified by the DREAMS, IMPETUS, TERRA and GOF U-space projects. Refer to the latest available baseline for more requirements and details.

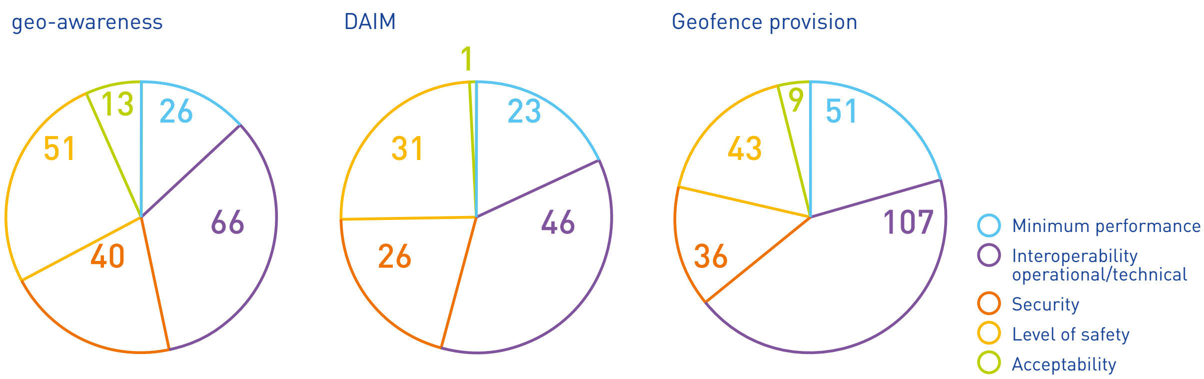
Table 7: Mission management requirements (non-exhaustive)

Title	Description
Main capabilities of flight planning management service during flight plan submission	The flight planning management service shall act as the U-space 'front end' for drones and drones users. During the flight plan submission the most relevant information shared with the U-space front end (flight planning management service) will include: drone Identification and capabilities, drone user identification; drone position and height, and time of operations; and drone capabilities and settings.
Mission request contact information	The mission request shall include operator and pilot contact data, which must be available during the flight.
Mission request volume of operation	The mission request shall include a definition of the desired trajectory or the volume for the operation.
Mission request approval	The operator shall be able to submit a request to fly in a certain piece of airspace (mission request).
Mission request approval	The operator shall receive a mission plan approval before the flight is started.
Mission validation or automatic alternative mission proposal	If the requested trajectory is not feasible, the operator shall be advised by the system about all the constraints (including, at least, other drone trajectories, drone/pilot capabilities, risk to third parties, geofenced areas, restrictions, controlled airspace and forbidden areas) and, if possible be provided with a feasible alternative trajectory.
Flight plan update	The MPM service shall report every update of the individual flight plan status from the FPM service to the drone operator.
Flight plan conflict notification	The FPM service shall notify the MPM service when a conflict emerges with the initially approved flight plan and provide with an explanation about the issue
Flight plan transmission	The MPM service shall transmit the flight plan to the FPM service in a common format.
Flight plan re-submission	The FPM service shall allow the MPM service to modify the flight plan and re-submit it.

Approved mission plan modification	The operator shall receive alerts about modifications and updates of the approved mission plans when they have to be adapted due to new restrictions (geofenced areas, etc.) or optimisation of trajectories to increase capacity.
Approved mission plan modification airspace (Classes A-D)	The operator shall receive alerts about modifications to the airspace class (A-D) approved flight plans, requested by the ANSP, when required for the operation.
Mission plan status accessibility	The operator shall have access to the system before starting the flight to confirm that the accepted route is still valid or if there has been any modification.
Impact of flight planning management, Pre-tactical geofencing, tactical geofencing and emergency management services on SORA based-risk assessment	Flight planning management, pre-tactical geofencing, tactical geofencing and emergency management services shall be used as M3 mitigation to the ground risk in SORA.
Trajectory alerts processing for pre-tactical deconfliction	The operator shall receive alerts to modify drone trajectories in order to avoid potential conflicts with other drone operators or manned aviation.
Data quality	Operation plan data should be identical in U-space and in drone ground control station, and be available in four dimensions.
Efficient use of airspace	It shall be possible to divide a flight plan into segments with ability do defined minimum and maximum altitude separately for each segment.

Figure 14 shows the distribution of all the requirements (310) developed for these services. Among the categories, technical and operational interoperability followed by safety are the main areas where work has been performed.

Figure 14: Distribution of requirements relating to operation plan services



3.2. Dynamic capacity management service

Strategic and tactical conflict resolution services reduce the probability of collision to a residual level, albeit not to zero. As the number of operations planned in a volume of airspace rises, so do the cumulative residual risks of conflict. When the residual risk reaches the maximum acceptable level, then capacity is reached. The dynamic capacity management service calculates this residual risk and detects when capacity is reached. It then either takes measures to provide more capacity or to limit the traffic. The dynamic capacity management service is one of the services that approves an operation plan submitted to the operation plan processing service.

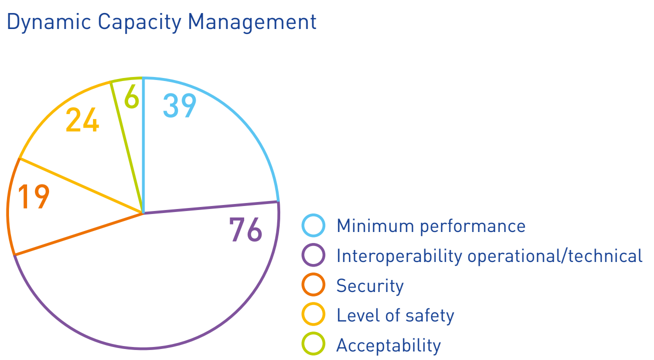
Below are the requirements for the implementation of these services that were identified by the Drone critical communications (DROC2OM), DREAMS, IMPETUS and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 8: Dynamic capacity management requirements (non-exhaustive)

Title	Description
Flight plan approval process	The FPM service shall only approve the flight plan after validation through the deconfliction and the airspace capacity management functions.
Area density	During the validation phase, the system should take into account the availability of the area, considering all the missions within the same space/time horizon
Datalink interoperability	The C2 link system underlying network shall support interoperability with multiple ground operators and multiple communication service providers simultaneously.
Approved mission plan modification	The operator shall receive alerts about modifications and updates of the approved mission plans when they have to be adapted due to new restrictions (geo-fenced areas, etc.) or optimisation of trajectories to increase capacity.

Figure 15 shows the distribution of all requirements (91) developed for this service: technical and operational interoperability followed by the minimum level of performance are the main areas where work was performed.

Figure 15: Distribution of dynamic capacity management requirements



3.3. From our flight trials

The following are extracts from the final reports of the DOMUS, DIODE and GOF U-SPACE projects.

Table 9: Extracts from project final reports relating to mission management

Project	Report extract
DIODE	The importance of planning the operations, performing a risk assessment and a specific field analysis has been confirmed.
DIODE	The pre-tactical geofencing service was considered strictly linked with flight planning management services.
DIODE	DIODE proposes a link between the operation plan preparation system and the weather service.
DIODE	As possible elements of improvement, the flight planning management service could be linked to the weather Information.
DIODE	A satellite view layer is required in addition to the street view' in the operation plan preparation tool. The HMI for mission planning must contain appropriate cues.
DIODE	DIODE recommends presentation of the weather forecast in the operation plan creation tool, to allow the optimal time to be chosen for a flight. DIODE also recommends to standardise the information of latitude and longitude required during the mission planning – a call for a standard format and process for operation plan processing.
DOMUS	DOMUS points out the dependency of the emergency management service on the operation plan data.
DOMUS	DOMUS explains the need for an 'end of flight' message to drive the operation plan processing service.
DOMUS	The different actors considered that the processes for mission preparation were complex but acceptable. In particular operators highlighted that the processes for the creation and acceptance of the flight plans should be simplified and faster.
DOMUS	DOMUS explains the function of pre-tactical geofencing as part of operation plan preparation and processing.
DOMUS	DOMUS explains that operation plans should be updated in response to changes in geofences.
DOMUS	DOMUS explains the central place of operation plan processing in strategic conflict detection.
DOMUS	Domus describe interconnection of U-space service providers in process of strategic conflict detection and provide an achieved reaction time of under 2 seconds.
DOMUS	Automation of syntax and completeness checking, for example during the flight plan filling, is necessary to ensure scalability.
GOF U-SPACE	GOF USPACE detected problems in submitting the same operation plan to the USSP and the drone itself. Work is needed on the integration of the drone planning software and/or ground control station with U-space.
GOF U-SPACE	GOF USPACE highlights the need for both a standard identifier for an operation ('call sign'), a standard operation plan format and interconnected tools to prepare missions for both U-space and the UAS. They describe problems of matching identifiers due to mistakes in typing.
GOF U-SPACE	GOF USPACE reports on their implementation of operation plan preparation and optimisation. The project highlights the need for an integrated tool to develop the plan sent to U-space and the plan uploaded into the drone.

4. Conflict management

4.1. Strategic and tactical conflict resolution services

There are two services for conflict management in U-space: strategic conflict resolution, which occurs before take-off and resolves conflicts in the planned operations; and tactical conflict resolution, which resolves conflicts that are detected during the flight.

The strategic conflict resolution service is initiated by the operation plan processing service. It can be initiated when a new operation plan has been submitted or when an already submitted operation plan has changed. Strategic conflict resolution occurs before take-off. In detection, the service compares the probabilities of where each aircraft ([1]) will be at each moment in time. A conflict can be resolved by asking the operator of one flight to change the plan and propose conflict-free alternative trajectories.

Tactical conflict resolution resolves conflicts detected during flight and can only be offered if the positions and movements of all aircraft are known by the tracking service. The tactical conflict resolution service is activated following the strategic conflict resolution, which solves low-probability conflicts before flight, for example changes in the aircraft trajectory due to wind. The performance of the tactical conflict detection service depends on the accuracy of the data provided by the tracking service.

Below are the requirements for the implementation of these services that were identified by the DREAMS, IMPETUS, CLASS and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 10: Strategic and tactical conflict resolution requirements (non-exhaustive)

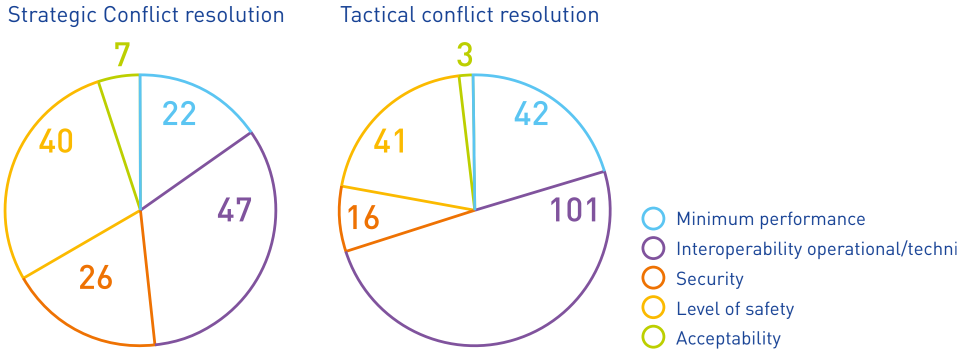
Title	Description
Strategic deconfliction capabilities	The strategic deconfliction service shall capable of detectiing conflicts between flight plans and of proposing reasonable modifications to the flight plan to the flight planning management service (alternative flight plan, different time slot,...).
Flight plans information kept in strategic deconfliction service	The strategic deconfliction service shall have access to a cloud data base (or other distributed structures) where all the known flight plans are stored.
Impact of Flight planning management, Pre-Tactical Geofencing, Tactical geofencing and Emergency Management services on SORA based-risk assessment.	Flight planning management, pre-tactical geofencing, tactical geofencing and emergency management services shall be used as M3 mitigation to the ground risk in SORA.
Safety requirements for U-Space service providers deriving from SORA assessment.	In accordance with SORA Annex E, provision of external services (as the UTM services) shall comply with safety requirements. The higher the SAIL, the most demanding are these requirements. For operations dealing with SAIL IV, service providers shall be subject to oversight mechanisms (a competent third party shall be involved).
Integrity requirement for strategic deconfliction	The strategic deconfliction service shall deliver information using a software with a minimum design assurance level (DAL) equal to B.
Vertical separation in VLL airspace	The U-space shall ensure a common reference frame for vertical separation of drones in VLL airspace.
Alternative flight plan	The flight planning management service shall propose alternative routes to users in case of conflicting plans due to changes in the environmental conditions.

1 Could be any flying objects: drones or manned aviation.

Mission plan status accessibility	The operator shall have access to the system before starting the flight to confirm that the accepted route is still valid or if there has been any modification.
Trajectory alerts processing for pre-tactical de-confliction	The operator shall receive alerts to modify drone trajectories in order to avoid potential conflicts with other drone operators or manned aviation.
Mission Request privacy of information provided	The system shall not show information about other drone operators.
Area density	During the validation phase, the system should take into account the availability of the area, considering all the missions within the same space/time horizon.
Raise conflict alert	The conflict detection service shall raise conflict alerts to drone operator 1 and 2 based on the deconfliction functionality.
Mission plan status accessibility	The operator shall have access to the system before starting the flight to confirm that the accepted route is still valid or if there has been any modification.

Figure 16 shows the distribution of all the requirements (196) developed for these services. Technical and operational interoperability followed by safety and minimum level of performance are the main area of where work was performed.

Figure 16: Distribution of requirements for conflict resolution services



4.2. From our flight trials

The following are extracts from the final reports of the SAFIR and EuroDRONE projects.

Table 11: Extracts from project final reports relating to emergency management

Report	Content
SAFIR	Strategic deconfliction is implemented in both drone traffic manager system systems. The way it is implemented in both systems differ in such a way that in one DTM the deconfliction area was blocked during the complete duration of the operation. Another implementation limitation was that the airspace was always calculated taking into account from ground level and not from an adaptable minimum altitude.
SAFIR	Operator must be able to tactically deconflict based on time (according to the estimated end time of the on-going drone operation) and based on altitude, as several volumes can be available for the same area and depending on the type of drone operation.
SAFIR	The tactical deconfliction worked well when the Amazon drone platform received a geofencing area (during the flight) due to a high priority flight and deconflicts by landing.
SAFIR	The strategic conflict management was only based on time. As the flight plans duration is shared, the system was able to propose a new time slot to the operator with the conflicting flight plan. Regarding the proposition of new routes when a conflict is identified, it depends on the type of the operation. It not possible to propose a new route or a new flight plan to an operator that needs to perform a mapping drone operation of specific area. The best option will be to give to the operator the choice on the way to deconflict. According to the type of his drone operation, the operator can then select the most suitable solution proposed by the system.
SAFIR	Lowest operational altitude, lowest safe altitude and return to home time are valuable parametres for ATC in case of tactical de-confliction needs.
SAFIR	In order to provide deconfliction, authorisation or traffic info services the U-space service provider would need to have access to flight plans and real-time position and identification data of manned aircraft operators. How would such be made possible in uncontrolled airspace?
SAFIR	The system is usable for both strategic and tactical de-confliction, however its capability was limited by the way conflicts operator conformance volumes were sent from the Unifly system. Unifly conformance volumes block the entire mission volume for the entire duration of the mission from ground level to the upper altitude of the mission, meaning flights could not be deconflicted by altitude or the actual time.
SAFIR	For manned aviation, the submission of a flight plan will be required for flights that will fly within U-space airspace. Also accurate and precise flight intentions (route, buffer, etc) are recommended to take manned aviation (IFR and VFR) into account for accurate monitoring and deconfliction services.
EURODRONE	In current version of EuroDRONE system, waypoints are not modified when a flight plan is submitted, but DroNav, interacting with AsLogic's PARTAKE solution([1]), can anticipate or postpone the take-off time respect to the one submitted by the operator in order to make a flight plan approved that otherwise is rejected due to conflicts with other flights.

EURODRONE	The strategic deconflicting tool (PARTAKE) maps UAV missions, and analyses and detects potential conflicts (loss of separation minima) with other UAVs, aircraft RBTs or non-flying area. If a conflict is detected, a mitigation module studies and suggests a departure shift, within a pre-defined interval of time (launch window), assuring the approval of a conflict free mission. The mission is denied when a deadlock is detected (no departure time shift can solve the conflict with other missions already approved). Note that the strategic conflict resolution service interacts with the mission planning service in two well defined time instants.
EURODRONE	The algorithm utilises differential geometry concept (DGC), which provides an analytical guarantee of minimum separation with low computational cost. Also, this concept improves efficiency, reducing deviations from the original flight plan. The safety and efficiency of the developed CA algorithm have been validated both analytically and numerically.
EURODRONE	Use of detect and avoid solution, as the ability for drones to detect cooperative conflicting traffic, or other hazards, and take the appropriate action to comply with the applicable rules of flight. (DronAssistant Category B)
EURODRONE	Need for UTM/U-space standards (sense and avoid, confirmation of right of way separation distances, deconfliction rules) and specific standards for hardware critical to UTM (sense and avoid sensors, UAV tracking, e-registration)
EURODRONE	The strategic de-conflicting tool was offered as an API integrated in the mission planner solutions, receiving all the missions planned and mitigating any conflict shifting the departure time inside the launch window assigned by the airspace manager (6 min, with a take-off tolerance of 2 min). Synthetic traffic was injected in the database simulating different operators using a given airspace at the same time.
EURODRONE	Tactical deconfliction was partially demonstrated in EuroDRONE using cooperative UAVs equipped with DronAssistant (DA). Need to mature services and extend to high volume UAV traffic and combine with dynamic capacity management.
EURODRONE	During the demonstration activities performed in the framework of EuroDRONE project a min. horizontal separation value of 150m was settled in the strategic deconflicting services.
EURODRONE	The DAA algorithm implemented in DronAssistant enables the drone to guarantee the minimum separation of 30 m with cooperative intruders and fixed-obstacles/no-fly-zones.

1 https://www.sesarju.eu/projects/partake

4.3. Emergency management service

The emergency management service of U-space has two aspects:

- giving assistance to a drone pilot experiencing an emergency with their drone;
- communicating emergency information to the drone pilot, for example that there is danger nearby or some function of U-space is impaired.

The communications channel of the emergency management service is an essential safety feature as it is the only way to deliver emergency messages to the drone operator.

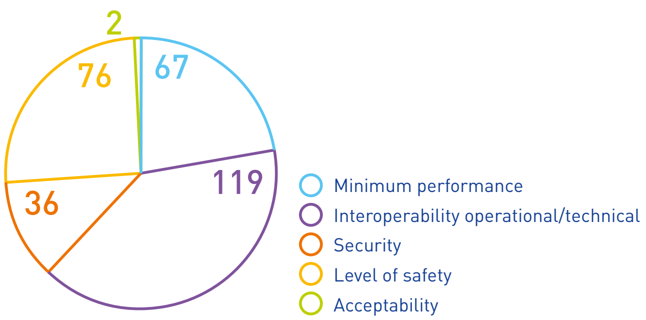
Below are a small number of the many requirements common to these services and developed by the DREAMS, IMPETUS, DROC2OM and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 12: Emergency management requirements (non-exhaustive)

Title	Description
Emergency communication submission	The operator shall be able to communicate emergencies to the system in real time.
Operator/Pilot /Drone communication performance	Drone pilot/operator shall be continuously connected to the system to know if their drone has to land in case of emergency flight, using an APP or by cellular.
Temporary segregation of area	The tactical geofencing service shall enable authorised users to segregate areas dynamically and temporarily.
Alerts to drone operators	Drone pilots/operators shall receive alerts to land or modify their trajectory in case a manned aircraft is operating near them.
Bounding volume for emergency procedures	The traffic information service shall extend the information area for a certain operation in cases where emergency procedures have been activated in the surroung airspace.
Approved mission plan modification	The operator shall receive alerts about modifications and updates of the approved mission plans when they have to be adapted due to new restrictions (geo-fenced areas, etc.) or optimisation of trajectories to increase capacity.
Weather updated information	Sudden local weather changes should be notified to operators to mitigate potential risks.
Detection of loss of information periods	The role in charge shall be able to detect periods in which the information is not available and raise and alert that will scale to the Orchestrator, which will be in charge of activating the emergency procedure.
Flight control functions for emergency management	The on-board flight control system shall be able to perform risk mitigating activities like flight termination or mission abortion on request of U-space services immediately. Ground control station and U-space services should be informed accordingly.

Figure 17 shows the distribution of all the requirements (145) developed for these services. Technical and operational interoperability followed by safety and the minimum level of performance are the main areas where work was performed.

Figure 17: Distribution of requirements for the emergency management service



4.4. Accident and incident reporting and citizen reporting services

Accidents and incidents for drones are reported in the same way as for manned aviation. The U-space accident and incident reporting service supports the standard aviation process for accident/incident reporting, tailored for the drone user. Not all incidents will be investigated but the collection of statistics is in the general interest. Similar to the accident and incident reporting service, U-space should allow citizens to report what they have observed when they believe incidents or accidents involving drones have occurred via a citizen reporting service.

Below are some requirements common to these services and developed by the DREAMS, IMPETUS and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 13: Reporting requirements (non-exhaustive)

Title	Description
Provision of drone location information	The system shall provide registered tracks to law enforcement or aviation authorities, when required.
Provision of registeration information	Law enforcement agencies shall be able to access drone/operator/pilot registration information when required.
Provision of mission plan information	Law enforcement agencies shall be able to access mission plans when required.
Tracking logging	The tracking service shall log all the data for at least one month.
User profiling	The system shall allow user profiling: restricted content and functionality will be accessible depending on the profile of the authenticated user. The accessibility of each content and function must be configurable by the supervisor.
Connectivity	The selected communication infrastructure shall provide connectivity between the central system and all nodes.

Figure 18 shows the distribution of all the requirements (56) developed for these services. Security and technical and operational interoperability are the main areas of work.

Figure 18: Distribution of requirements for reporting services

4.5. From our flight trials

There was limited coverage of the Emergency management services by the projects, as these were not captured in the CONOPS at the time of projects' scoping. Nevertheless, some references to emergency services can be found in the reports of the SAFIR and EuroDRONE projects, extracts of which are provided in the table.

Table 14: Extracts from project final reports relating emergency management

Project	Report extract
SAFIR	Within SAFIR, emergency recovery capabilities are used to perform the risk assessment. Some of the drone platform demonstrated their emergency recovery capabilities to the Belgian civil aviation authorities (BCAA) in advance at DronePort of the SAFIR demonstration in Antwerp.
SAFIR	The behaviour in case of emergency (low/critical battery, C2-link loss, GNSS link loss, return to home path (direct or via defined rally points), altitude, are valuable to know in advance or to update the operation in case an emergency situation occurs.
EURODRONE	A minimum set of codified procedures and standards (SARPs) and how services can be available to government authorities need to be defined.
DIODE	During the flight planning phase, the emergency management service could help to indicate emergency landing spots (e.g. for long range BVLOS flights) to be included in the flight plan – further usability refinements are also proposed.

5. Monitoring

5.1. Monitoring and traffic information services

The monitoring service warns the remote pilot and/or drone operator if the drone is not following its operation plan. The warnings are based on information coming from the tracking service and the operation plan processing service. As operation plans will be deconflicted before flight, monitoring that the operation plans are followed is a safety critical service. In the same way, monitoring feeds the tactical deconfliction with critical information. Also based on the tracking service, the traffic information service provides the drone pilot and/or operator with information and warnings about other flights – manned or unmanned – that are expected to come near their aircraft. The traffic information service will also present the 'air situation' graphically.

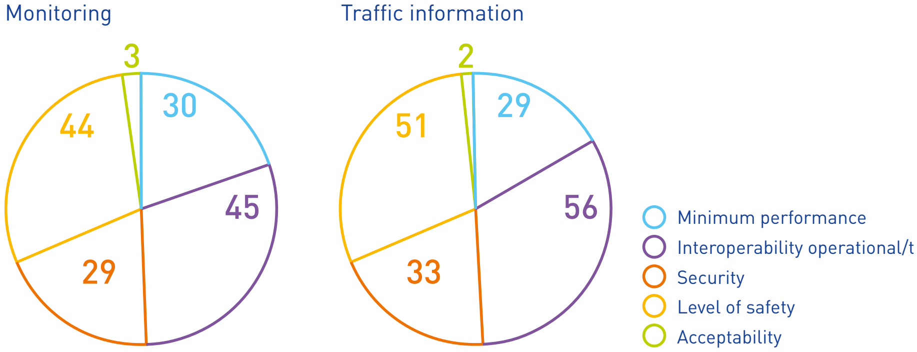
The following are some requirements common to these services that were developed by the AIRPASS, DREAMS, IMPETUS, CLASS and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 15: Monitoring requirements (non-exhaustive)

Title	Description
Trajectory alerts reception	In case the flight is going to be conducted in a volume that cannot be geocaged for the user, the operator shall be alerted if a minimum separation distance with other drones cannot be maintained, to guarantee that the risk of collision is negligible over populated areas and low enough in sparsely populated areas.
Pilot accessibility to nearby unmanned traffic information	Operators shall be able to receive the location of nearby drones and other aircraft, although not their private data (Traffic Information), to improve situational awareness.
Geographical extension of the information	The traffic information service shall provide all the relevant information about traffic within a geographic bounding volume dimensioned large enough to ensure the safety of all the operations contained within.
Bounding volume for emergency procedures	The traffic information service shall extend the information area for a certain operation in case of emergency procedures has been activated in the surroundings of its bounding volume.
Mission Request privacy of information provided	The system shall not show information about other drone operators.
Traffic information to operators	In urban or high drone density areas, the system should provide traffic information to operators to allow adequate situational awareness.
VFR information	The system should provide information of geo-caged areas to VFR aviation.
Monitoring	The system shall allow monitoring of the functional status of each capability.
Display of the flight track of drones	The UTM system shall display the tracks of the drones to: - other drone operators - The authority responsible for the area
Front end track filtering	The UTM system shall filter the tracks to show: - Non cooperative tracks - Cooperative tracks - Fused tracks - A combination of the upper
Maximum allowed latency in UTM system of 1 second	The UTM system shall show all the data (positions, tracks, zones, alerts,...) with a maximum latency of 1 second.

Figure 19 shows the distribution of all the requirements (56) developed for these services. Technical and operational interoperability and level of safety are the main areas of work.

Figure 19: Distribution of requirements for monitoring and traffic information



5.2. Legal recording and digital logbook services

The legal recording service supports accident and incident investigation. The service should record all inputs to U-space and allow the full state of the system at any moment for post-analytical purposes. In view of the commercial sensitivities of drone operators, access to the recordings will be restricted. The digital logbook service extracts some information from the legal recordings. Drone operators and pilots will be able to see summaries and statistics for flights they have been involved in.

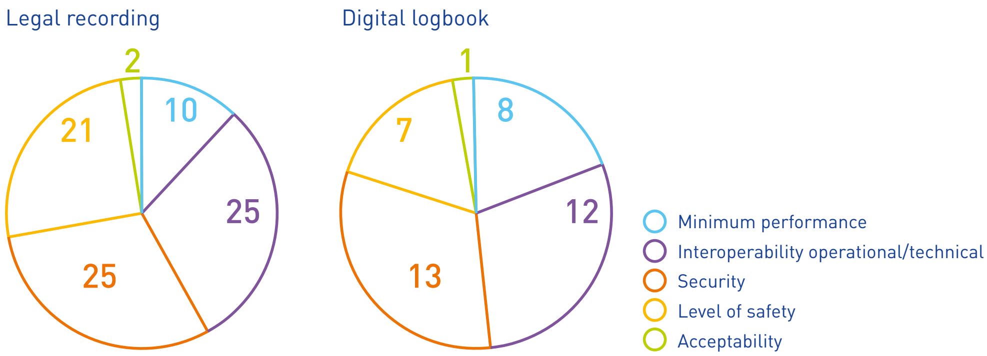
The following are some requirements common to these services and developed by the DREAMS, IMPETUS, CLASS and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 16: Recording services requirements (non-exhaustive)

Title	Description
Data recording and auditing	The service shall record all activity. All activity must be recorded for post analytical review, this includes all inputs, analysis, and rerouting decisions and commands.
Provision of location information to authorities	The system shall provide registered tracks to Law Enforcement or aviation authorities, when required.
Provision of mission plan information to law enforcement agencies	Law enforcement agencies shall be able to access mission plans when required.
User profiling	The system shall allow user profiling: restricted content and functionality will be accessible depending on the profile of the authenticated user. The accessibility of each content and function must be configurable by the supervisor.
Mission plan information to Law Enforcement agencies	The system shall provide access to Mission Plans to Law Enforcement agencies when required.
Provision of drone log access to authorities	The system shall provide access to drone logs and registered tracks to law enforcement and aviation authorities.
Tracking logging	The tracking service shall log all the data for at least one month.

Figure 20 shows the distribution of all the requirements (66) developed for these services. Security and technical and operational interoperability are the main areas of work.

Figure 20: Distribution of requirements for the recording services



5.3. Navigation and communication infrastructure monitoring services

The navigation infrastructure monitoring service provides status information about navigation infrastructure such as GNSS. The pilot and/or operator uses this service before and during operations. The service should give warnings of loss of navigation accuracy. The communication infrastructure monitoring service provides status information about communication infrastructure such as the mobile telephony networks. The pilot and/or operator uses this service before and during operations. The service should give warnings of current or predicted degradation of communications, e.g. scheduled maintenance.

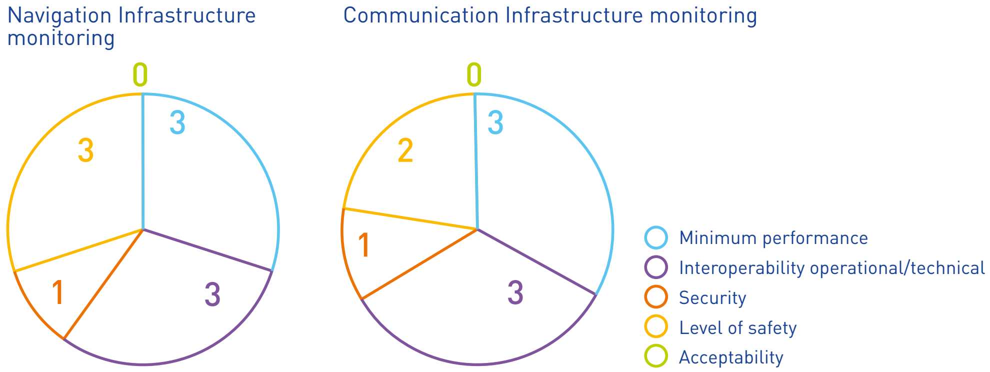
The following are some requirements common to these services and developed by the DREAMS, IMPETUS and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 17: Infrastructure monitoring requirements (non-exhaustive)

Title	Description
Integrity alerts	The operator should receive alerts if the navigation system is not able to provide an accurate position.
Monitoring	The system shall allow monitoring of the functional status of each capability.
Connectivity	The selected communication infrastructure shall provide connectivity between the central system and all nodes.
Safety requirements for U-Space service providers deriving from SORA assessment.	In accordance with SORA Annex E, provision of external services (as the UTM services) shall comply with safety requirements. The higher the SAIL, the most demanding are these requirements. For operations dealing with SAIL IV, service providers shall be subject to oversight mechanisms (a competent third party shall be involved).

Figure 21 shows the distribution of the top requirements (61) developed for these services. Security and technical and operational interoperability are the main areas of work.

Figure 21: Distribution of requirements for infrastructure monitoring services



6. Environment

6.1. Weather information service

The weather information service provides current and forecast weather information relevant for drone operation. The service should include hyperlocal weather information when available and required.

The following are some requirements common to these services and developed by the DROC2OM, DREAMS, IMPETUS and TERRA projects. Refer to the latest available baseline for more requirements and details.

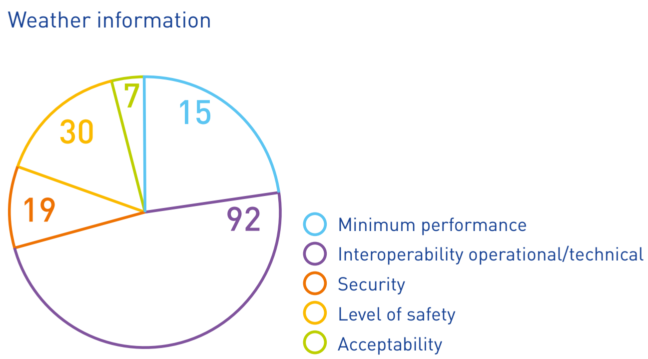
Table 18: Weather information service requirements (non-exhaustive)

Title	Description
Weather information accessibility	The operator shall have access to weather information when preparing the mission plan to confirm that meteorological conditions are acceptable for the flight.
Hyperlocal weather information	The weather management system shall provide drone operators and users with minute-by-minute hyperlocal weather data.
Local-scale weather information aspects to be provided	The local-scale weather information service shall provide a configurable combination of the following weather information: ▸ Weather information provider ID [unique identifier] ▸ Look-ahead type [nowcast/forecast] ▸ Data generation time [Julian date & time of data generation] ▸ Applicability timeframe [period of time of data applicability since data generation] ▸ Temperature [K] ▸ Pressure [Pa] ▸ Icing [% probability] ▸ Visibility [m] ▸ Precipitation [{ % probability, type}; type: (freezing) rain/sleet/snow] ▸ Convective precipitation [% probability] ▸ Lightning [% probability] ▸ Average wind (u,v,w) [m/s] ▸ Turbulence [Turbulent Kinetic Energy (TKE) m^2/s^2] ▸ Gusts [frequency spectrum of specific kinetic energy J/kg] ▸ Thermals [% probability] ▸ Forecast/nowcast uncertainties [STD associated with data items 5) to or such data items are N-tuples, N being the number of members of an ensemble meteorological forecast/nowcast] ▸ Reminders, warning and alerts [new dataset available, expiration of applicability timeframe, data items 5) to 15) exceeding predefined thresholds or nowcasted data items 5) to 15) deviating from the forecasted versions of the same data items beyond the estimated uncertainty]
Geospatial domain	The weather information provided by the service shall correspond to the geographical domain specified by the petitioner. To specify such domain, the service shall provide the following geospatial primitives: 1) Geolocation [geodetic longitude, latitude and altitude in a geodetic reference system, e.g. WGS-84]; 2) Geocube [interval of geodetic longitudes, latitudes and altitudes in a geodetic reference system]; and 3) Geoprism [base geopolygon plus interval of altitudes in a geodetic reference system]which the petitioner can instantiate to make the petitions of weather information.

Impact of Weather information service on SORA based-risk assessment.	Weather information service shall be taken into account in the threat barrier named 'Environmental conditions for safe operations defined, measurable and adhered to ' (SORA Annex E).
Weather updated information	Sudden local weather changes should be notified to operators to mitigate potential risks.
Transaction time requirement for weather information	The Weather information service shall deliver information with a maximum transaction time of 10 seconds.
Mission planning management – data visualisation	The MPM service shall visualize the types of information to the operator that are relevant for mission planning.
Supported weather conditions	The system should inform if the weather conditions could not be supported by the drone, considering its features.

Figure 22 shows the distribution of the requirements developed for this service. Technical and operational interoperability and level of safety are the main areas of work.

Figure 22: Distribution of requirements for weather information



6.2. Geospatial information, population density map, electromagnetic interference information, navigation coverage information and communication coverage information services

A number of services provide the current and forecast data needed in planning and operating in VLL, as well as supporting SORA. Each meets agreed standards for quality including timeliness and accuracy. The geospatial information service assembles and provides operation-in-VLL relevant map data describing terrain, buildings and obstacles. The population density map service collects and forecasts population density, which is used to assess ground risk. The information should be based on proxies for instantaneous population density, such as mobile telephone density. The electromagnetic interference information service delivers reports and forecasts of electromagnetic interference that are relevant for drone operation; typically, such interference hampers communications, navigation or the operation of sensors or the drone itself. The navigation coverage information service provides maps showing measured and forecast information about the navigation coverage indicating where performance is reduced. These maps may be specialised depending on the navigation infrastructure available (e.g. ground or satellite based). The communication coverage information service provides maps indicating reported and expected communication coverage by service or provider, as far as it is known. This service is used to plan operations.

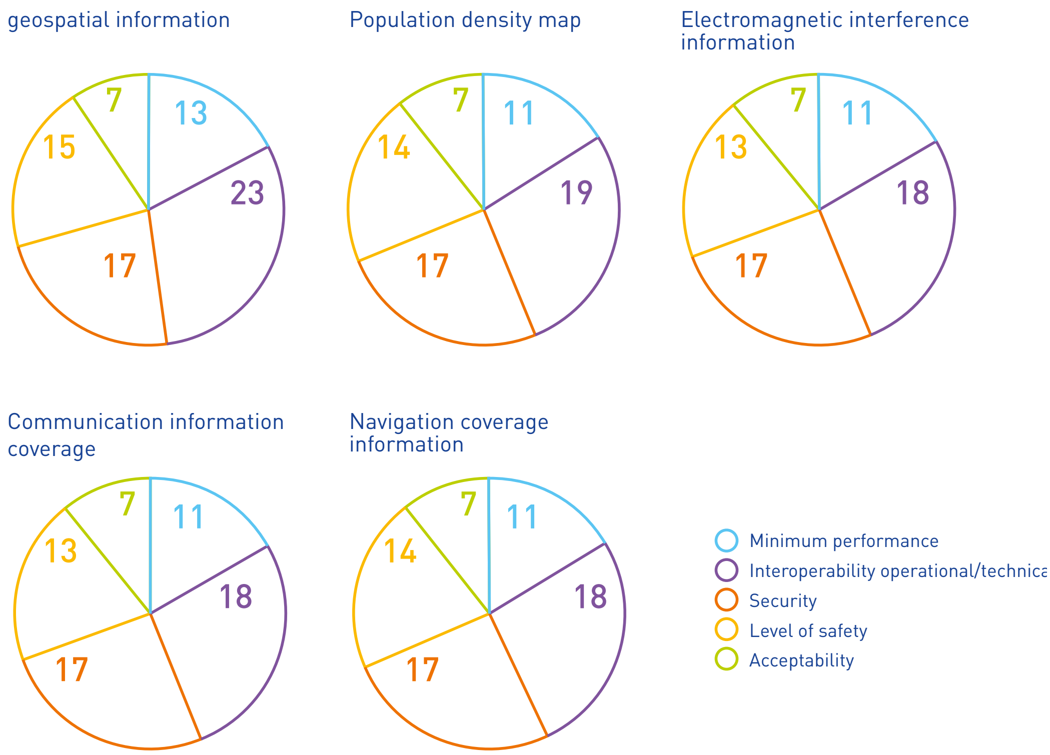
The following are some requirements common to these services and developed by the DREAMS, IMPETUS and TERRA projects. Refer to the latest available baseline for more requirements and details.

Table 19: Map-based services (non-exhaustive)

Title	Description
Geospatial information	The service shall programmatically access geospatial information to enable drones to carry out safe operations. The data set should include both airborne and ground hazards. Therefore the service requires access to geospatial data, which needs to include some or all of the following; ground hazards, obstacles, terrain, city maps, etc., in addition to airspace restrictions such as airspace classifications.
Terrain model service	The U-space shall provide geographic information services to users with digital cartographic information and digital elevation model. The proposed accuracy of the model is 1 metre (horizontal and vertical). The proposed resolution of map is 0,5 metre.
Obstacle information	The flight planning management system shall provide obstacle data with a minimum resolution of 1m (both horizontal and vertical).
Vertical separation in VLL airspace	The U-space shall ensure a common reference frame for vertical separation of drones in VLL airspace.
Mission planning Management – data visualisation	The MPM service shall visualise the types of information to the operator that are relevant for mission planning
Flight plan approval	A flight conformance module built in the FPM service shall be the instance responsible for approving or rejecting the individual flight plans based on defined rules and prioritization criteria.

Figure 23 shows the distribution of all the requirements developed for these services. Technical and operational interoperability and level of safety are the main areas of work.

Figure 23: Distribution of requirements for the map-based services



6.3. From our flight trials

The following are extracts from the final reports of the SAFIR, EuroDRONE, VUTURA and SAFEDRONE projects:

Table 20: Extracts from project reports

Report	Content
SAFIR	Separation minima must also be defined and will help the operators in planning their drone operation with a safe buffer to avoid collisions. These separation minima are also needed for the monitoring service that offers manned-unmanned and unmanned-unmanned collision alerts. The separation between unmanned and manned aircraft must be defined.
EURODRONE	The project demonstrated real-time monitoring. Need to link up with other resources (ATC, multiple ground sensors, blue light monitoring services) and automate. A standard for UAV flight corridors is needed.
EURODRONE	Tracking and monitoring tasks should be potentially combined.
VUTURA	The project demonstrated monitoring in all flight demonstrations with a focus on situational awareness for the pilot and operator, hence the human machine interface for the drone users. To ensure both the AirMap and Unifly displays provide a similar picture, drone traffic information was shared between both USPs.

VUTURA	No alerts as indicated in the definition of the monitoring service, like flight plan conformance or obstacle alerts were demonstrated in VUTURA. Since the demonstrations included flights over buildings and near construction sites, the monitoring function must be designed to provide obstacle alerts.
VUTURA	Flight crews report that their awareness on flight approvals and the appearance of no-fly zones should be optimised. They additionally demand a higher refresh rate for monitoring, since it seems difficult to track a drone in a relatively small area.
SAFEDRONE	The UTM system should be directly integrated into the ground control station that manages the drones so that all of the necessary information can be available on a single screen. To have multiple screens showing different information increases the workload of the operators and can lead to missing important/safety information. This integration must be studied and worked jointly with the leading autopilot/GCS industry/developers as soon as possible to create common standards.
SAFEDRONE	U-space warnings are a critical factor for operators. In that way, it is advisable to create a list with all the warnings that are necessary for a safe operation, to create a guide of standard colours that indicates their importance, etc.
SAFEDRONE	Drones shall be depicted on the moving map with forward heading indication, as well as attitude information.
SAFEDRONE	Sound (acoustic) alerts alongside visual warnings are crucial for notifications. In many situations, the operator is paying attention to the aircraft so an audible alarm is necessary to allow the operator to react in time to any situation. In this respect, it should be noted that more tests are required for measuring the pilot reaction time. In the trials, pilots were aware of the procedures that they had to perform, so they were listening/observing and waiting for the warning messages. In real-life situations, pilot reaction times become a critical factor, especially for manoeuvres in which manual pilot control is expected as a contingency measure.

7. Interface with air traffic control

7.1. Procedural and collaborative interfaces with air traffic control

The procedural interface with ATC is a service to coordinate an entry/exit of a flight into controlled airspace. The interface works before the flight. The operation plan processing service will invoke the service and through it:

- ATC can accept or refuse the flight;
- ATC can describe the requirements and process to be followed before and during the flight.

The collaborative interface with ATC is a service providing communication between ATC and the remote pilot or the drone itself in case of automatic flight. The service is used when the drone is in a controlled area and allows flights to receive instructions and clearances in a standard and efficient manner.

An example involving both would be a drone flight that starts and ends in uncontrolled airspace but during the flight crosses an airport (controlled airspace). The operation plan would trigger the procedural interface with ATC, who would either respond with a standard set of instructions or combine that with a process to give approval for the flight. The standard instructions might be to fly to some particular point and then hover or circle and contact the tower by telephone. If a collaborative interface with ATC were available, the instructions given with the plan approval would involve using the collaborative interface to coordinate with the tower. The collaborative interface would enable the tower to communicate with the drone pilot in real time.

Below are the requirements for the implementation of these services that were identified by the AIRPASS, DROC2OM, DREAMS, IMPETUS and TERRA projects. Refer to the latest available baseline for more requirements and details.

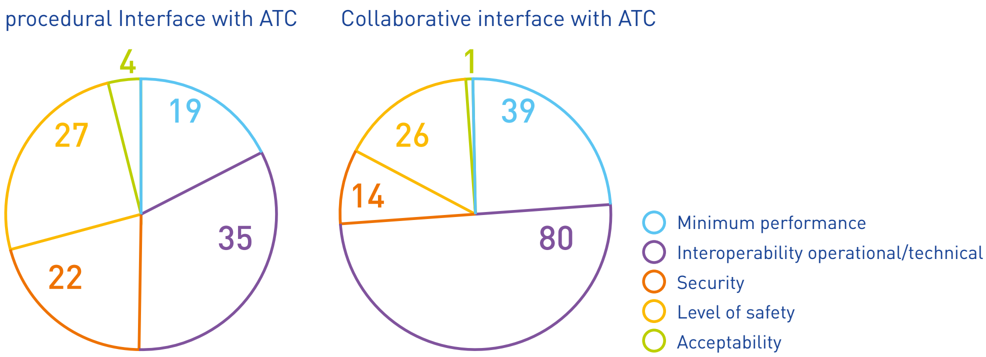
Table 21: Service requirements for the interaction with ATC (non-exhaustive)

Title	Description
Flight plan approval	A flight conformance module built in the FPM service shall be the instance responsible for approving or rejecting the individual flight plans based on defined rules and prioritization criteria.
Communication	The system shall allow the communication between ATCO/manned aviation pilots and operator/pilot through: ▸ R/T or ▸ D/L or ▸ general voice communication means
Datalink ATC voice performance	The C2 Link system may offer, for the relay of ATC voice services, at least the following performance: ▸ Voice latency: 400 ms (maximum) ▸ Availability: 99.998 % (minimum)
Provision of drone information to ATM system in controlled airspace	ATM systems shall receive drone positions, identification and foreseen trajectories in the proximity of airports or controlled airspace.
Alarm to supervisor	The system shall provide alarms to ATM systems in case of drone deviations near controlled airspace.
Vertical separation in VLL airspace	U-space shall ensure a common reference frame for vertical separation of drones in VLL airspace.

Sensors for Collaborative ATC Interfacing	A sensor or a set of sensors shall be available to measure the altitude.
Redundancy of communication channel for U-space information exchange	Since U-space information exchange is expected to rely on cellular networks (e.g. LTE), a redundant communication channel (e.g. satellite-based) represents a safety mitigation in areas where coverage of such networks is not ensured.
Connectivity	The selected communication infrastructure shall provide connectivity between the central system and all nodes.

Figure 24 shows the distribution of all the requirements developed for these services, showing a large proportion of technical and operational interoperability and minimum performance requirements

Figure 24: Distribution of requirements



7.2. From our flight trials

The following are extracts from the final reports of the SAFIR, VUTURA and PODIUM projects which relate to the interface with ATC:

Table 22: Extracts from project reports

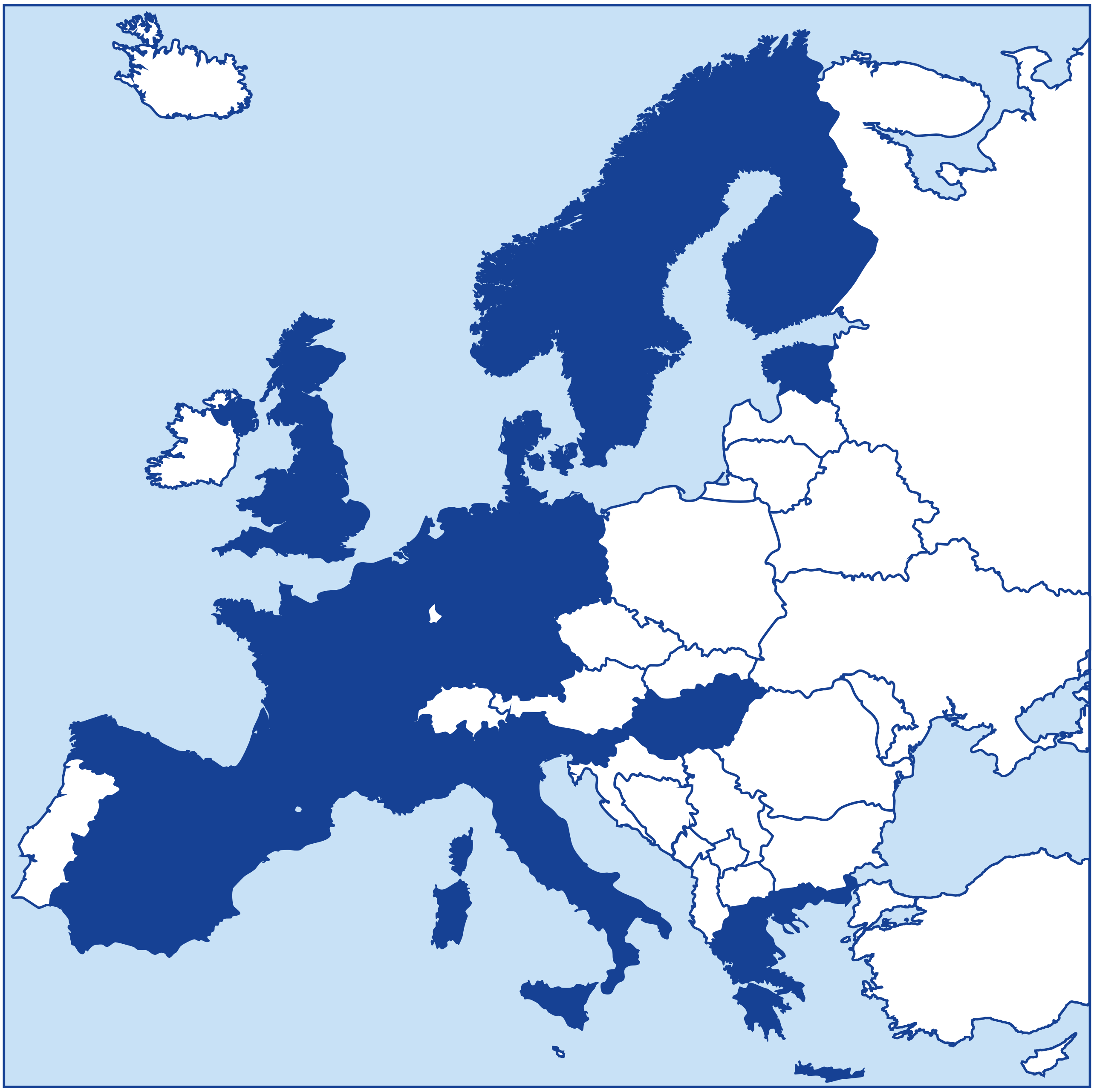
Project	Report extract
SAFIR	A technical interface with ATC through which authorisation can automatically be granted or denied is required to reduce manual workload on both ATC and the DTM/ operator representatives. DTM flight plans should then be displayed within the ATC tower to enable ATC to safely deconflict manned and unmanned aviation.
SAFIR	A few elements were considered regarding the collaborative interface with ATC as the flight status exchange between ATC and the operators. The geofencing feature was used to reroute an operator to a restricted and safe part of their operation area (during the Antwerp demonstration, a helicopter doing pipeline inspection was flying close the C-astral flight operation area and obliged a reroute of the C-astral flight to a safe part).
SAFIR	For the authorities, the geofencing service is a simple and very important feature that supports other services as the collaborative interface with ATC. The latter requires to be further developed for an efficient interaction between ATC and drone operators.
SAFIR	We concluded that voice link between ATC and the drone operators is not the best way to have a safe and secure exchange. The upgrade will be digital interaction between both parties via messages and notification with a potential integration of the GCS.
SAFIR	The human performance of ATCOs related to the effective handling of drone operations inside controlled airspace is key to further support the development the drone sector. Certainly in the case of the SAFIR, scenarios that consisted of complex drone operations (BVLOS, high altitude) were affecting conventional traffic. This demonstrates the urgent need for implementing a collaborative interface with ATC.
SAFIR	A technical interface with ATC through which authorisation can automatically granted or denied is required to reduce manual workload on both ATC and the DTM/Operator representatives. DTM flight plans should then be displayed within the ATC tower to enable ATC to safely deconflict manned and unmanned aviation.
VUTURA	Establish the minimum performance for the interface with ATC such that ATC needs only one interface to connect to all USP systems.
PODIUM	Phraseology and coordination procedures shall be defined between all actors involved (pilots, supervisors and ATCOs), in order to ensure the smooth operability. The ATC collaborative interface tested in Rodez was found to be globally operable and acceptable by the air traffic controller supervising the drone operation.
PODIUM	It is recommended to define operational procedures for drone flights entering a controlled airspace environment (CTR, airport) and for responding to abnormal situations (e.g. areas for stacking or emergency landings in the event of traffic conflicts, equipment failure).

ANNEX 2

Project results

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.

Geographic coverage of the SESAR U-space research projects



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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.

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Safe drone operations require reliable tracking and monitoring

CLASS: Clear Air Situation for uaS

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.

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.

Partners

Airbus D&S (Coordinator)

Aveillant

Ecole Nationale de l'Aviation Civile (ENAC)

Norwegian University of Science and Technology (NTNU)

Unifly

- **Data from dozens of field flights have improved drone detection and tracking**
- **Sensitive categories of airspace need higher performance tracking services**

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CORUS:
Concept of Operation for EuRopean UTM Systems

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.

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Safe and secure drone operations in each and every environment

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.

DIODE: D-flight Internet Of Drones 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

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DREAMS:
Drone European Aeronautical information Management Study

Partners
EuroUSC
IDS AirNav (Coordinator)
Topview
TU Delft

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.

DREAMS delivered a stronger understanding of data items and services that are important for U-space users

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 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

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.

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Reliable communications are central to safe drone operations

DroC2om: Drone Critical Communications

Partners

Aalborg University (Coordinator)

ATESIO GmbH

Nokia Bell Labs

Thales Alenia Space

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.

- **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**

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DOMUS: Demonstration Of Multiple U-space Suppliers

Putting multi-service provision to the test

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

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.

Drones can respond to emergency situations, including recreational flights without flight plans

Drones can conduct strategic and tactical conflict resolution in real-time

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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.

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.

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.

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)

- **First end to end U-space demonstration in South East Europe/ Mediterranean Region**
- **EuroDRONE is helping to define a practical, highly automated cloud-based UTM system architecture**

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GEOSAFE:
Geofencing for safe and autonomous flight in Europe

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

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.

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

SERVICES U2 U3

TECHNOLOGIES

ENVIRONMENT

New technologies to support U-space information needs

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.

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

Partners

Altitude Angel
Boeing R&T-E
C-ASTRAL
CRIDA (Coordinator)
INECO
Jeppesen
University of Darmstadt- TUDA

- **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**

SERVICES
U2 U3

TECHNOLOGIES

ENVIRONMENT

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.

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.

Common standards are required for communication between information systems

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

SERVICES

U2 U3 U4

TECHNOLOGIES

ENVIRONMENT

Developing an autonomous sense and avoid package for small drones

PercEvite: Percevoir et Eviter – Detect and Avoid

Partners

KU Leuven
Parrot
TU Delft (Coordinator)

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.

- **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**

SERVICES U1 U2 U3

TECHNOLOGIES

ENVIRONMENT

PODIUM:
Proving Operations of Drones with initial UTM

Putting U-space services to the test in operational scenarios

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

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.

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

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.

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**

SERVICES

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TECHNOLOGIES

ENVIRONMENT

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

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.

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.

SERVICES

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

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: an integrated SECurity concept for drone OPerationS

Partners

Delft Dynamics

NLR- Royal Netherlands Aerospace Centre (Coordinator)

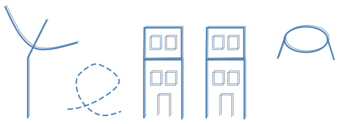
Sensofusion

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**

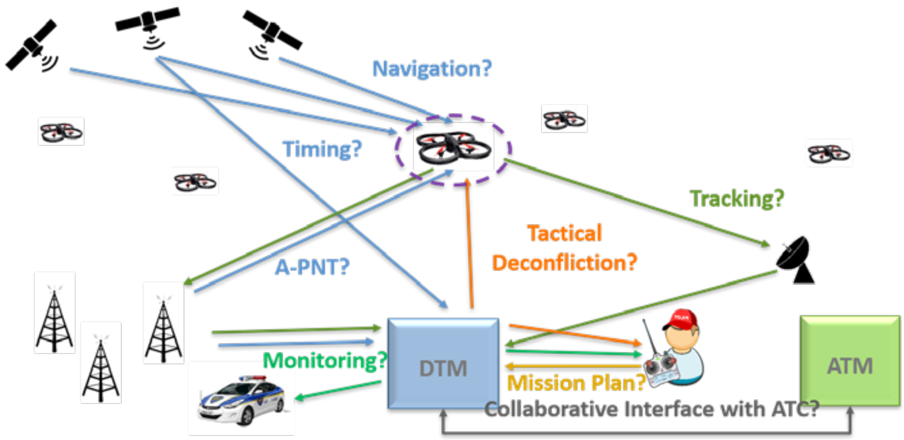
SERVICES U2 U3 | TECHNOLOGIES | ENVIRONMENT

TERRA: Technological European Research for RPAS in ATM



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

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.

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 | TECHNOLOGIES | ENVIRONMENT

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.

USIS: Easy and Safe access to the airspace

USIS
U-SPACE INITIAL SERVICES

Partners

Altametris
DFS
DSNA
ENAC
HungaroControl
Thales (Coordinator)
Unifly

- **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

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

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

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.

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.

ANNEX 3

List of acronyms

ADS-B	Automatic dependent surveillance – broadcast
AED	Above elevation data
AFIU	Aviation flight information unit
AIM	Aeronautical information management
AIRPASS	Advanced integrated RPAS avionics safety suite
AMSL	Above mean sea level
ANSP	Air navigation service providers
API	(Meaning missing) PM: Application programming interface
ATC	Air traffic control
ATCO	Air traffic controller
ATO	Above take-off location
ATM	Air traffic management
ATSU	Air traffic service unit
BCAA	Belgian Civil aviation authority
BVLOS	Beyond visual line of sight
C2	Command and control
CARS	Common altitude reference system
CIA	Confidentiality, integrity and availability
CLASS	Clear air situation for UAS
CNS	Communications, navigation and surveillance
CONOPS	Concept of operations
CORUS	Concept of operation for EuRopean UTM systems
DA	Drone assistant
DAA	Detect and avoid
DAL	Design assurance level
DGC	Differential geometry concept
DIODE	D-flight internet of drones environment
DOMUS	Demonstration of multiple U-space suppliers
DREAMS	Drone European AIM study
DROC2OM	Drone critical communication
DTM	Drone traffic management
EGNOS	European Geostationary Navigation Overlay Service
EuroDrone	European UTM tested for U-Space
eVTOL	Electric vertical take-off and landing
FIMS	Flight information management system
FIR	Flight information region
FLARM	Secondary surveillance radar and flight management
FPM	Flight progress monitoring
GCS	Ground control station
GEOSAFE	Geofencing for safe autonomous flight in Europe
GNSS	Global Navigation Satellite System GPS Global Positioning System

GOF	Gulf of Finland
HMI	Human machine interface
IFR	Instrumental flight rules
IMPETUS	Information Management portal to enable the integration of unmanned systems
LTE	Long term evolution
MEDUSA	Method to assess the safety of service provision R&D Research and Development
MOPS	Minimum operational performance standard
MPM	Main planning meeting
QNE	Altitude over sea level calculated with standard atmosphere
QNH	Altitude over sea level
RBT	Reference business trajectory
RPAS	Remotely piloted aircraft system
SAFEDRONE	Project to acquire practical experience in VLL operations, where both manned and unmanned aircraft will share the airspace.
SAFIR	Safe and flexible integration of initial U-space services in a real environment
SAIL	Specific assurance and integrity level
SARPS	Standards and recommended practices (ICAO) SME Small and medium enterprises
SORA	Specific operations risk assessment SWIM System-wide information management
SSR	Scanning surveillance radar
UAM	User access management
UAS	Unmanned aerial systems
UAV	Unmanned aircraft vehicle
UCN	U-space community network
USP	U-space service provider
USSP	U-space service provider
UTM	Unmanned traffic management
V2I	Vehicle to Infrastructure
V2V	Vehicle to vehicle
VFR	Visual flight rules
VLL	Very low level
VLOS	Visual line of sight
VUTURA	Validation of U-space by tests in urban and rural areas

ANNEX 4

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 Darmstadt-TUDA
University of Patras
University of Seville

V
VideoDrone Finland oy
Vodafone España
Volocopter

ANNEX 5

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