DREAMS Summary Report

September 2019

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DREAMS
Drone European AIM Study

The DREAMS exploratory research project aims to contribute to the definition of the European UTM (U-space) Aeronautical Information Management operational concept by exploring the needs of the different stakeholders and the feasibility of new processes, services and solutions for drone aeronautical information management within the U-space concept.

The methodology of the project combines analysis of existing resources, research, user surveys, simulation and validation of the results obtained and thus constitutes a novel approach to compare the needs and expectations of future users of U-space with the proposed implementation, identifying gaps and providing actionable conclusions and recommendations directed to the stakeholders that are developing the future U-space.

This document is an extract of the deliverable D2.2 – DREAMS Final Project Results Report by the DREAMS Consortium as well as other documents generated within the project.

For more information about the project, and to obtain other public documents, please visit the project website.

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Glossary of terms

Term	Acronym	Definition
Aeronautical Information Management	AIM	The provision of aeronautical data from source data acquisition to its end users by ensuring the integrity of the data and information throughout all involved processes
Aeronautical Information Service	AIS	A service established in support of international aviation whose objective is to ensure the flow of information necessary for the safety, regularity and efficiency of international air navigation
Aeronautical Information Exchange Model	AIXM	An specification for the provision of aeronautical information in digital form supporting the collection, verification, dissemination and transformation of the information
Acceptable means of compliance	AMC	Non-binding standards adtopted by a regulatory body to illustrate means to establish compliance with the applicable regulation
Air Navigation Service Provider	ANSP	Any public or private entity providing air navigation services for general air traffic
Air traffic control	ATC	A service provided by ground–based air traffic controllers who direct aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non–controlled airspace
Air traffic management	ATM	The aggregation of the airborne and ground-based functions (air traffic services, airspace management and air traffic flow management) required to ensure the safe and efficient movement of aircraft during all phases of operations;
Beyond visual line–of–sight (operation)	BVLOS	An operation in which the remote pilot **does not** maintain direct unaided visual contact with the UAS at all times
Concept of Operations	CONOPS	A document describing the characteristics of a proposed system from the viewpoint of a user or stakeholder of the system
Concept of Operation for European UTM Systems	CORUS	An exploratory research project tasked with the definition of the Concept of Operations for U-space
Detect and Avoid	DAA	A system to detect incoming traffic, ensure separation and avoid a collision with said traffic
Geotagging		The process of adding geographical information metadata to various media, such as photographs or video
Geofence		A virtual geographic boundary, defined by GPS, RFID, Wi–Fi or other technology, that enables software to trigger a response when a device enters or leaves a particular area.
Joint Authorities for Rulemaking on Unmanned Systems	JARUS	A group of experts from National Aviation Authorities and regional aviation safety organizations joined to recommend a single set of technical, safety and operational requirements for the certification and safe integration of UAS into airspace

Term	Acronym	Definition
Notice to airmen	NOTAM	A notice containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations
Specific Operations Risk Assessment	SORA	An aviation risk assessment methodology developed by JARUS and adopted by EASA as the basis for the approvals of UAS operations in the Specific Category
System Wide Information Management	SWIM	Standards, infrastructure and governance enabling the management of ATM related information and its exchange between qualified parties via interoperable services
Technology readiness level	TRL	A method to estimate the maturity of technologies taking into account their conceptualisation, technology requirements and demonstrated capabilities. TRL levels range from TRL1 to TRL9
Visual line–of–sight (operation)	VLOS	An operation in which the remote pilot maintains direct unaided visual contact with the UAS at all times.
Very low level (operation)	VLL	An operation taking place below 500 feet (400 feet in some countries) above ground level (AGL)

Executive Summary

The DREAMS exploratory research project aims to contribute to the definition of the European Unmanned Aviation Traffic Management (U-space) Aeronautical Information Management operational concept by exploring the needs of the different stakeholders and the feasibility of new processes, services and solutions for drone aeronautical information management within the U-space concept.

DREAMS OBJECTIVES

The high-level objectives of the project are:

- To provide safe and high quality data and information to UAS operators, as well as sufficient information to other airspace users on planned and current drone activity in VLL airspace.
- To identify gaps in the current data provided by AIS/AIM and services in VLL airspace, taking into account the overall U-space concept.
- To study, including through simulations, which additional information is needed and how such information could be originated, managed and disseminated.
- To ensure the safety and integrity of AIS/AIM information through various service providers and the related safety, regulatory and cost implications.
- To analyse and validate the technologies needed for the implementation of a U-space system in support of UAS flights, including the implementation of geofencing and flight planning management functionalities.

CONCLUSIONS AND RECOMMENDATIONS

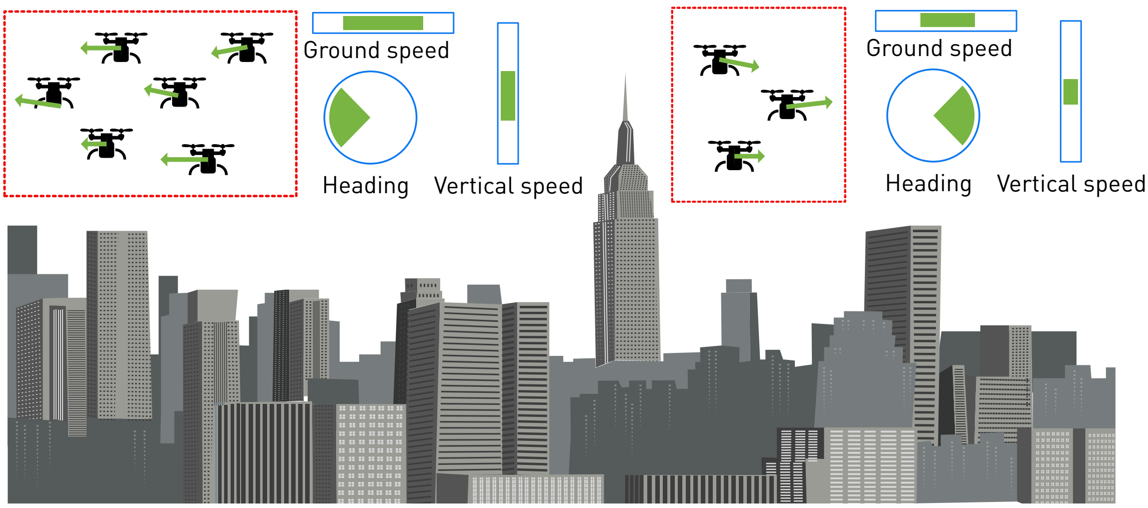
The main recommendations regarding the Aeronautical Information management tailored to U-space needs are:

- Identification of **new aeronautical features, new Airspace Types and extension of existing features**, in order to include the additional needs coming from U-space.
- The aeronautical data service should be able to **provide the same content in several formats**.
- The aeronautical data service provision has to be able to **interact with consumers using several protocols** in order to allow the data exchange with different clients capability.
- The aeronautical data exchange service has to **provide data querying capabilities**.
- It is highly recommended to use a **micro-service paradigm** that is fully compliant

with CORUS CONOPS architecture principles.

- In all open-data provision services, **the source of the data is critical for safety and security**, as in Aeronautical Data Quality concept in traditional AIM.
- The project has demonstrated the importance of a **flexible airspace use to enable safe high-density drone traffic** in an urban environment. This was demonstrate using the strategic geovectoring service.
- The **geovectoring service can be provided in U2 strategic conflict resolution and U3 dynamic capacity management**. The service imposes a degree of traffic alignment to the drone flight trajectories, which is used to reduce traffic complexity particularly, for high-density drone operations such a express package delivery and food delivery.
- The relevant aeronautical data protocols for geovectoring will urgently need to be addressed for information exchange in order for **geovectoring to be implemented as a mandatory service for drone flights**. This protocol would be similar to the geofencing/geocaging, albeit with additional information on speed, heading, and vertical speed restrictions.

What is geovectoring?



Geovectoring is the definition of a particular area of the airspace where certain restrictions of the vector speed (magnitude and direction) are defined.

Tipically it will be implemented by enforcing an allowable range for the following dimensions:

- Ground speed
- Vertical speed
- Course heading

Geovectoring improves the safety and the capacity of the airspace by **reducing the conflict resolution** that would be necessary in congested areas.

Geovectoring allows to establish a a large variety of airspace designs using a common protocol:

- Segregated airspaces
- Semi-circular rules
- Separate departure/arrival zones
- Layered airspaces
- Tube-like airspace (corridors)

DREAMS CONSORTIUM

IDS – Ingegneria Dei Sistemi S.p.A.

The Coordinator – is a company with more than 20 years of experience in the development of Aeronautical Information Management Systems and it is also a UAS manufacturer with a portfolio of drones ranging from less than 5 kg up to 25 kg.

Delft University of Technology – Faculty of Aerospace Engineering

Is the largest Aerospace Engineering faculty of Western Europe. It has performed pioneering work into autonomous airspace, detect & avoidance algorithms and micro-aerial vehicle (MAV) system design.

EuroUSC España, S.L.

Is a limited company established in Madrid, part of the European group EuroUSC, leading independent Accreditation Specialist for 'Operations, Airworthiness and Pilot Qualification' covering Unmanned Aircraft Systems (UAS) with a Maximum Take-Off Mass of less than 150kg.

EuroUSC Italia SRL

Is a consultant company with practical experience on drones, internationally achievements in safety assessment, human factors, safety regulation, flight test of new prototype aircraft or new airborne systems and flight inspection of navigation aids. The company is also involved in Air Traffic Management matters and Aerodrome rulemaking.

TopView SRL

UAS operator authorized since 2014 – is an innovative SME focused on study, research and development of autonomous remote piloted systems for aerial, maritime and terrestrial applications, together with innovative products as custom payloads and IoT (Internet of Things) sensors.

The DREAMS Consortium is comprised of five organisations with a proven track record in drone operations

U–space overview

U–space[1] is a set of new services and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. These services rely on a high level of digitisation and automation of functions, whether they are on board the drone itself, or are part of the ground–based environment. U–space provides what is needed to enable and support routine drone operations, as well as a clear and effective interface to manned aviation, ATM/ ANS for service providers and authorities.

U–space will be capable of ensuring smooth operation of drones in all operating environments, including urban areas, and in all types of airspace, in particular to VLL airspace. It will address the need to support the widest possible variety of missions, and may concern all drone users, as well as every category of UAS, as defined by EU Commission proposed Regulation on unmanned aircraft operations. According to the criticality of the provided services, performance requirements will be established for both structural elements and service delivery, covering safety, security, availability, continuity, resilience and so on.

U–space services will be delivered by service providers within the given U–space environment. They do not replicate the function of ATC, as known in ATM: instead, they will deliver key services to organise the safe and efficient operation of drones and ensure a proper interface with manned aviation, ATC and relevant authorities.

INITIAL SERVICES

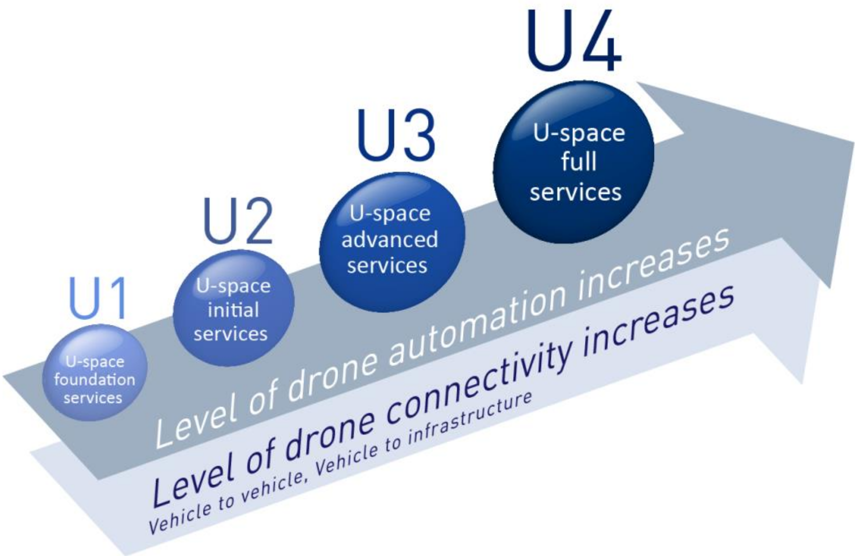
The first two U–space services, which rely on agreed EU standards, are the following:

1. Electronic registration (**e-registration**): Draft EU UAS Regulation envisage that electronic registration will be mandatory for drone operators, except operators of drones weighting below 250 grams, as well as some classes of drones used in the **open category**, and all drones used in the **specific category**.

2. Electronic identification (**e-identification**): It will allow authorities to identify a drone flying and link it to information stored in the registry; the identification supports safety and security requirements as well as law–enforcement procedures.

[1]The diagrams and the U–space Use Case example on this chapter have been extracted from the SESAR JU document U–space Blueprint.

U–SPACE ROLL OUT



- **U4**: U–space full services, particularly services offering integrated interfaces with manned aviation, support the full operational capability of U–space and will rely on very high level of automation, connectivity and digitalisation for both the drone and the U–space system.

By 2019, U–space is expected to be established with U1 services facilitating a great number of current drone operations while enabling new ones.

Also in 2019 pre–operational demonstrations of the initial U–space services (U2) will take place, as well as the first results from SESAR research and development projects, including the DREAMS project, paving the way for the roll–out of U–space (U2–U4).

The progressive deployment of U–space is linked to the increasing availability of blocks of services and enabling technologies. Over time, U–space services will evolve as the level of automation of the drone increases, and advanced forms of interaction with the environment are enabled (including manned and unmanned aircraft) mainly through digital information and data exchange over a **cloud–based platform**.

- **U1**: U–space foundation services provide e–registration, e–identification and basic geofencing services
- **U2**: U–space initial services support the management of drone operations and may include flight planning, flight approval, tracking, airspace dynamic information, and procedural interfaces with air traffic control.
- **U3**: U–space advanced services support more complex operations in dense areas and may include capacity management and assistance for conflict detection. Indeed, the availability of automated DAA functionalities, in addition to more reliable means of communication, will lead to a significant increase of operations in all environments and may require a more robust framework.

SUPPORT FOR MISSION PHASES

The diagram below and the example case of use on the following page show how U–space will provide support to all phases of a mission, when its complete deployment is finalised.

U–SPACE USE CASE EXAMPLE

A drone operator plans to fly a drone to carry a small package from a village to the city centre 30 kilometres away. She selects a suitable drone from her fleet and selects a drone supervisor who will not actually be piloting the drone, but will be supported by automated functions and tools allowing to monitor several drones flying at the same time.

1. Preparation of the drone mission

To prepare the flight, the drone operator uses information–sharing services, like meteorological conditions, combined with other U–space services, such as navigation and communication coverage services, flight planning assistance services and services providing the expected density of traffic in the mission area. Since the drone is registered, the system automatically links the elements described in the registry with elements of the flight request, in which full details of the airworthiness of the drone and its behaviour in emergency situations are described. For example, this information could include designated safe landing areas, or details of the equipage and capabilities of the drone. That way, if the drone fails at any point in its flight, it will behave in a predictable manner, minimising risk to people and property on the ground.

2. Submission of a flight request and reception of an acknowledgement

The planned route adheres to applicable regulation, airspace requirements (including airspace availability, temporary and permanent restricted areas) and requirements on specific drone equipment. If the flight requires an additional approval, then the request is submitted to the relevant entity and an answer is sent to the drone operator. The planned flight does in fact conflict with several other planned drone operations so, the operator is offered the possibility of a longer route or a delay to the drone's arrival by 5 minutes. She chooses the latter option and receives an acknowledgement, which includes the drone's 4D trajectory describing the entire flight. When the drone is airborne, it receives information and alerts and might alter its original route to avoid traffic, meteorological conditions or any changes to airspace accessibility. Throughout the flight, the drone broadcasts its unique identifier. The tracking service allows the drone flight path to be followed and supports other services like the situation awareness, which is provided, with some limitations, to a wide range of customers (e.g. drone operators, ATC, police).

3. Execution of the flight

The drone is equipped with a "detect and avoid" (DAA) system which allows it to avoid hazards. The DAA system navigates it around a flock of birds and an unreported obstacle (e.g. a crane). As it arrives in the city, it receives an alert on a modification of airspace availability on its route: a car accident has just taken place and the local police have set up a temporary highly restricted zone to automatically geofence the site. The geofenced zone is not actually empty as the police are using a drone to give them an aerial view of the accident, and this mission is approved. The incoming helicopter ambulance is a priority flight, and this information is shared to ensure drones crossing its path will route round it.

4. Mission completed

The drone arrives safely at its destination, delivering the parcel. It is now ready to be prepared for its next mission: a roof survey of a building 500 metres away.

U–SPACE SERVICES

The following table shows the services defined for the U–space implementation organised by the stage of development blocks (U1 to U4) for which they are planned. Services for the U4 block have not been defined yet.

U1	U2	U3	U4
E–registration	Tactical geofencing	Dynamic geofencing	*[Pending definition]*
E–identification	Tracking	Collaborative interface with ATC	
Pre–tactical geofencing	Flight planning management	Tactical deconfliction	
	Strategic deconfliction	Dynamic capacity management	
	Weather information		
	Drone aeronautical information management		
	Procedural interface with ATC		
	Emergency management		
	Monitoring		
	Traffic information		

Project methodology

The methodology used in the DREAMS project starts by identifying a number of real–world scenarios of use of the U–space services, as a means to explore their information requirements and perform a gap analysis between these requirements and the current state or the planned implementation of the different services that will constitute the future U–space, once the the first three stages are rolled–out (U1 to U3). Finally, a simulation of these scenarios is performed and validated.

Thus, DREAMS uses a bottom–up approach, trying to answer the three following questions:

- *What kind of operations will be carried out in the future?*
- *What flow of information will be required by the different users (and providers) of U–space services?*
- *How does the planned implementation of the U–space services complies with these requirements?*

These objectives are achieved through a series of intermediate steps which are shown on the diagram at the bottom of the page.

PHASE 1 – INFORMATION AND REQUIREMENT ANALYSIS

In the first phase a representative set of operational scenarios and related preliminary requirements of candidate U-space services involved have been identified, starting from the description of the state-of-the-art process that actual (and diligent) UAS operators implement for their aerial work operations, in accordance with applicable local regulations.

The scenarios defined are operational scenarios, whose main purpose is to provide a description of how a future system could work. Each scenario includes the description of the behaviour of actors, their interactions and the wider context of use. From a detailed scenario, the U-space stakeholders should be able to identify user requirements and potential business cases.

The information provided is based upon assumptions on actors and services interactions, therefore only high-level main streams of use cases can be provided at this stage.

1. Information and requirement analysis
2. Gap analysis and solution identification
3. Platform update
4. Validation

DREAMS project methodology

Scenario identification process

The methodology followed to identify the different scenarios is shown on the diagram above.

A preliminary safety assessment of the selected scenarios and verification of the regulatory compliance of the requirements related to U-space service providers have been carried out, taking into account current and expected future UAS regulations.

The SORA risk assessment methodology has been applied to the most relevant scenarios with the following high level objectives:

- Evaluating both Ground and Air Risk
- Identifying requirements in terms of required barriers (mitigations) and robustness
- Investigate qualitatively the impact of U-space services in the different steps of the process

SORA methodology basically treats U-space services as possible mitigations for ground and air risk, but specific possible failure condition affecting the U-space services are not considered. In addition, the current version of the SORA does not consider risks deriving from the presence of multiple drones operating in the same area.

These risks not covered by SORA have been addressed using a more traditional risk matrix based approach. The matrix model employed in the analysis is the one provided by EASA in the *Pre-Regulatory Impact Assessment*.The risk is defined as a combination of hazard probability of occurrence and severity of effects produced by the hazard. In the EASA model, the risk index is fully numeric, and the severity scale is non-linear so that high risk areas are better differentiated. In other words, the risk index provides a more immediate comprehension of the identified hazardous situations.

In the assessment of Regulatory Compliance, U-space services are *compared* to traditional ANS services as defined in EU Reg. 549/2004, keeping in mind that several differences may exist in terms of:

- Information content of the provided services; and
- Means (both procedural and technological) for service provision to airspace users.

Finally, possible options to ensure oversight of service providers in the U-space have been investigated.

PHASE 2 – GAP ANALYSIS AND POTENTIAL SOLUTION IDENTIFICATION

In the second phase of the project , a catalogue of candidate services for U-space purposes have been identified, starting from existing and defined service catalogue available to manned aviation in ATM domain. Several information services were derived from SWIM services, open-source aviation services and commercial off-the-shelf services. Similarly, a study was carried out to determine the existing U-space services present in the market, and a variety of services were deemed useful for U-space.

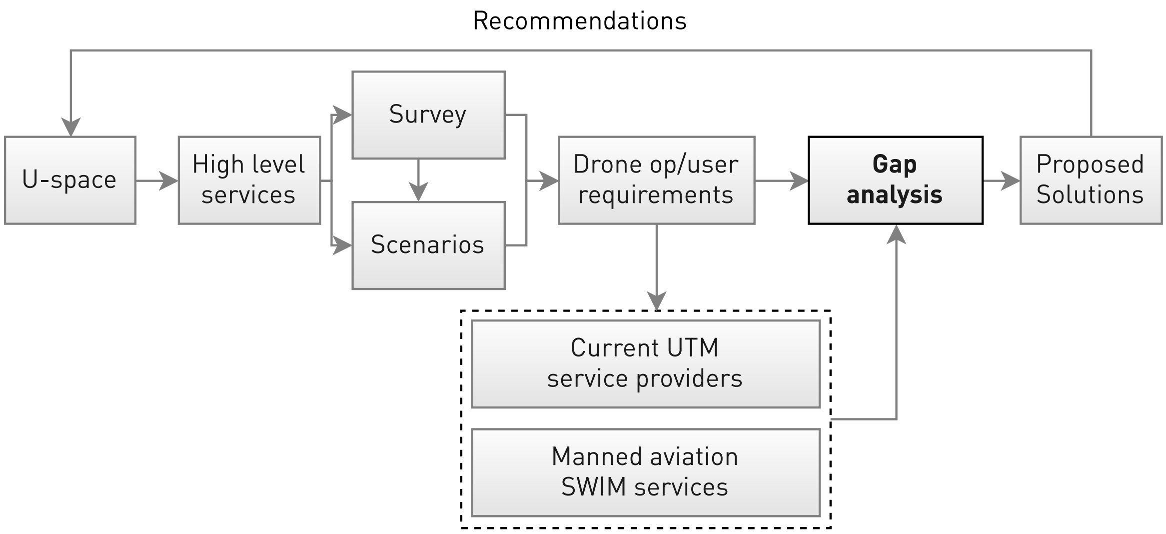
The gap analysis activity identified the information gap between existing manned aviation and existing and future unmanned aviation and outlined a comprehensive set of solutions in order to bridge the gap, meant as recommendations by the DREAMS consortium. The methodology followed to conduct the Gap analysis is shown on the diagram below.

In particular, the gap (difference between supply and demand of data services) analysis captured data services that enable safe drone operations at Very Low Level altitude airspace.

The solutions to some of the gaps were made more concrete in the Preliminary U-space AIM Concept of Operations document. In such document, a set of U-AIM data models were defined to deliver consistent, accurate and up-to-date U-space data set for U-space stakeholders.

The scope of the U-AIM data models has been arranged in three main information categories:

- **Airspace and flow management data** – airspace management, flight planning and flow management;
- **Aeronautical data** – static, dynamic and drone aeronautical data;
- **Environment and drone data** – weather and drone vehicle data.



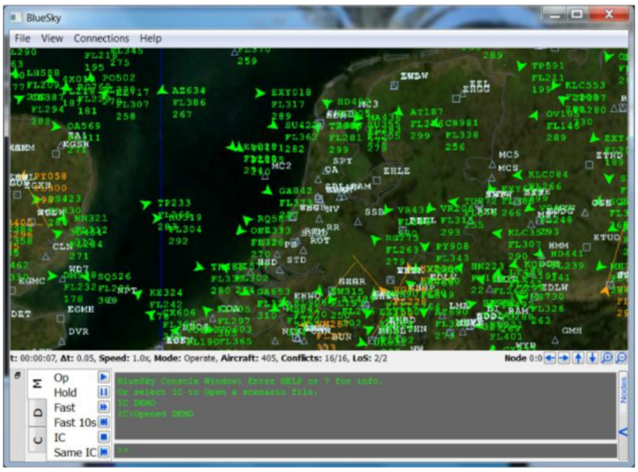
Gap analysis methodology

PHASE 3 – PLATFORM UPDATE

The third phase of DREAMS is oriented towards validating the platforms used and the newly proposed data services.

In the framework of DREAMS, the simulation platforms to used: DREAMS UTM platform by IDS and BlueSky Flight simulator by TU Delft were interconnected and several additional functionality was added to perform the simulation and validation activities.

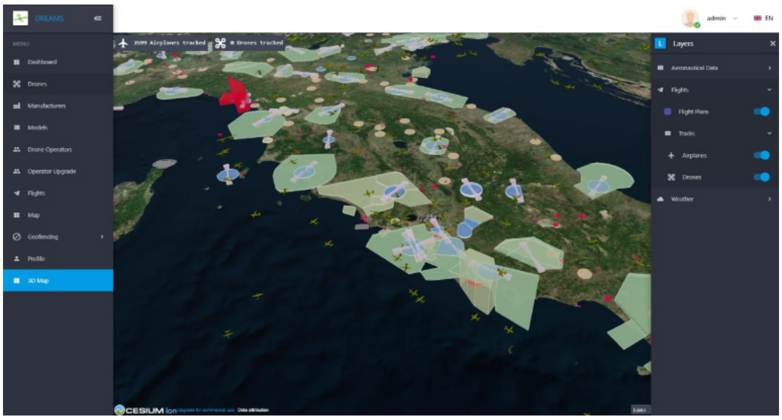
BlueSky simulation platform



BlueSky is an open-source Air Traffic simulator used to perform Air Traffic Management and Air Traffic Flows research studies. This simulation platform belongs to TU Delft and is freely available for use via the online repository, GitHub. The goal of BlueSky is to develop a fully portable, open-source ATM simulator. The simulator's target users are ATM researchers and therefore, it requires some background in aeronautics in order to operate it. The software is written in Python which is an open-source multi-platform language

DREAMS Unmanned Traffic Management Platform

DREAMS UTM platform is a U-space tool created by IDS with the aim to support unmanned operation in all its phases. The main capabilities of the tool are listed below:



- User management (including user registration and profile change workflow)
- Drone manufacturers catalogue management
- Drone models catalogue management
- Fleet management
- Visualisation of static aeronautical data (e.g. Airports, ATZ, Take-off and landing area, etc.)
- Dynamic aeronautical data management: definition and visualisation of geofencing and geovectoring areas
- Flight plan management and authorization process based on 4D interference check including static , dynamic and concurrent operations data
- Tracking: manned and unmanned tracks

PHASE 4 – VALIDATION

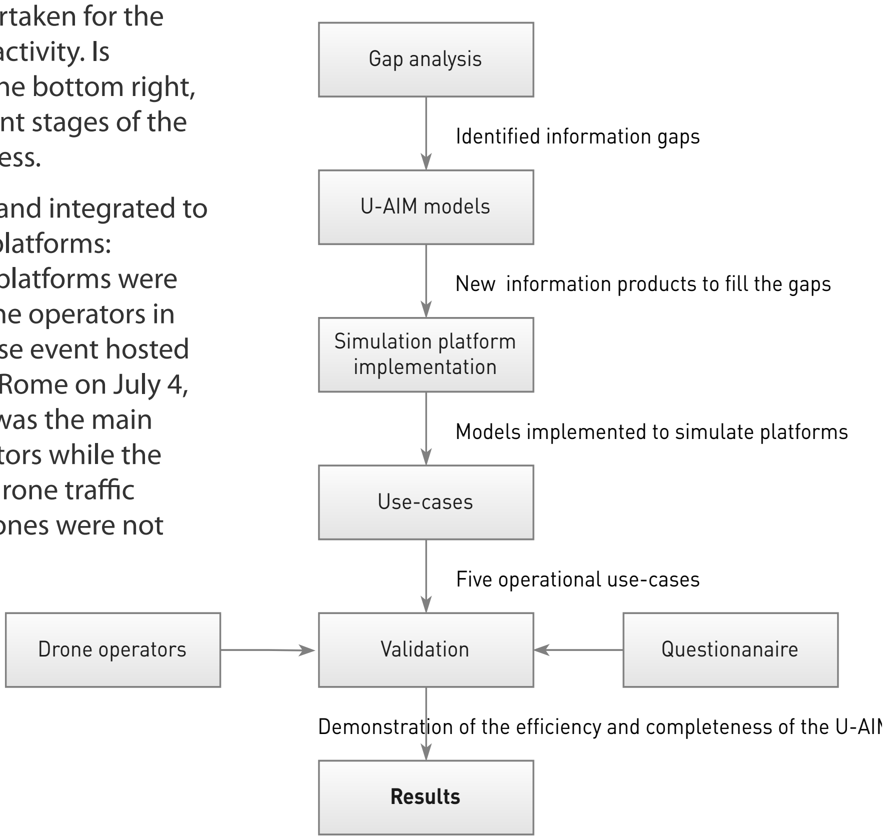
Before the execution of simulation exercises, some useful indications for the configuration of the scenarios have been achieved through a Parametric Model implemented with SimEvents software tool. The aim of such model is to identify and replicate possible critical patterns in the sequence diagrams developed within the DREAMS scenarios, especially in those cases where the impact of automatic (or semi-automatic) actions for the services (e.g. provided by a BOT) must be compared to those performed by introducing a human in the loop.

As stated before, in order to validate the proposed U-AIM data models, two challenging scenarios M4 "Cooperative Geo-tagging" and M9 "Capacity Management" were chosen. In total, five use cases were used to demonstrate the efficiency and comprehensiveness of the U-AIM data models. To do this, DREAMS project involved actual drone operators in the validation tests. These experienced operators helped to achieve the goal of this validation exercise.

The development cycle undertaken for the planned DREAMS validation activity. Is described in the diagram at the bottom right, which highlights the important stages of the validation development process.

The models were developed and integrated to the consortium's simulation platforms: BlueSky and DREAMS. These platforms were introduced to a group of drone operators in an exclusive validation exercise event hosted at the IDS validation room in Rome on July 4, 2019. The DREAMS platform was the main interface for the drone operators while the BlueSky platform acted as a drone traffic simulator since real-world drones were not used for the validation test.

Validation session



Validation methodology

Key project results

PHASE 1 – INFORMATION AND REQUIREMENTS

Scenario Identification

A total of 11 scenarios were identified covering all phases of flight and all three U-space roll-out stages. These scenarios are summarised on the tables shown on the next page.

For each scenario, the following information is provided:

- **Key parameters** of the scenario
- **Storyboard**: a textual description of the scenario providing the relevant context (e.g. urban environment, type of airspace, concurrent UAS involved, …) to be translated in the main information stream to be shared among actors and services in a textual sequence of events.
- **Sequence Diagrams**: The representation methodology used for the description of scenario is the Unified Model Language (UML), by means of Use-Cases and Sequence diagrams.

  Up to three sequence diagrams from the most relevant Use-Cases of the scenario proposed are described, highlighting the perspective from the specific U-space users involved in each scenario.

  Sequence diagrams describe the interactions between actors and services that are derived directly from the definition of the U-space services.
- **Phases of flight involved**: Scenarios can have their sequence of events concentrated in one phase of the flight (Planning, Pre-Flight, Execution, Post-Flight) or spread over more of them (see the *Dreams Scenarios* table on the next page)
- **UAS specification and capabilities**: Information about the technical capabilities and performance of the UAS participation in each scenario is provided so that the safety assessment to be performed uses that information.
- **A summary of the initial conclusions and recommendations** arising from the analysis of the scenario, as well as potential issues that will require further exploration is also derived from the scenario identification activity.

Scenario	U-space block			Flight phases
1 Electronic Registration	U1			1
2 Concurrent Operations	U1	U2		2 3
3 Territory Control	U1			3
4 Cooperative Geo-tagging	U1	U2		1 2 3
5 CTR Crossing		U2		1
6 Long Range Operations		U2		1 3
7 Deconfliction Management		U2		3
8 Emergency Management		U2	U3	3
9 Capacity Management		U2	U3	1 2 3
10 Intelligence Service		U2		4
11 Personal Mobility		U2	U3	1 2

1 Preparation 2 Pre-flight 3 Execution 4 Post-flight

DREAMS Scenarios

	Service	1	2	3	4	5	6	7	8	9	10	11
U1	e-registration	●										
	e-identification			●								
	Pre-tactical geofencing		●		●							
U2	Weather information		●				●					
	Drone aeronautical information management						●	●				
	Tactical geofencing				●			●				
	Tracking			●	●		●					
	Flight planning management		●	●	●	●	●	●	●	●	●	●
	Strategic deconfliction		●					●				
	Procedural interface with ATC					●						
	Emergency management								●			
	Monitoring			●			●					
	Traffic information						●					
U3	Dynamic geofencing									●		
	Collaborative interface with ATC											●
	Tactical deconfliction									●		
	Dynamic capacity management									●		

Coverage of the U-space services

Regulatory and safety assessment

To perform the regulatory and safety assessment, both the SORA methodology and EASA risk matrix approach have been applied to a subset of DREAMS scenarios. The most relevant **scenarios dealing with safety issues** are considered for the risk assessment analysis, as follows:

- Scenario 2: "Concurrent operations"
- Scenario 4: "Cooperative Geo-tagging"
- Scenario 5: "CTR crossing"
- Scenario 8: "Emergency Management"

These **scenarios cover a wide range of UAS operations** (VLOS/BVLOS conditions, controlled/uncontrolled airspace, urban/rural environment) and U-space services. In fact, both VLOS and BVLOS conditions are investigated in different operational environments (rural, urban and suburban). Therefore, the operational range of the scenarios included in the risk assessment is deemed reasonably exhaustive, allowing to **define the most demanding requirements** (both performance and safety requirements) for U-space services.

The impact of U-space services in the different steps of the SORA process is summarised in the table below.

As mentioned, SORA methodology has been complemented by a **risk matrix approach**. The output of such analysis is a set of **performance parameters** (i.e. transaction time, continuity, availability), applicable to each U-space service and resulting safety requirements (mitigations and software design assurance level). The set of performance parameters allows to adopt a PBCS (Performance Based Communication and Surveillance) approach including **specifications specific for the U-space context**. The potential need for the adoption of such approach is two-fold:

- the operational introduction of one or more new air traffic management operations (U-space) may prescribe a new RCP/RSP (Required Communication/ Surveillance Performance) specification; and

Domain	Impacted SORA requirement	U-space service
Ground	M1: Strategic Mitigation for Ground risk	• Pre Tactical/Tactical geofencing • Flight planning management • Emergency management
	M3: Emergency Response Plan	• Emergency management • Flight planning management
Air	Strategic Mitigation by Operational Restriction/ by Structures and Rules	• Procedural Interface with ATC • Flight planning management • Strategic deconfliction
	Tactical Mitigation for BVLOS	• Tracking • Tactical deconfliction
Air & ground	Adjacent airspace considerations	• Pre-tactical geofencing • Tactical geofencing • Flight planning management)
General	OSO#8/21: Procedures are defined to address technical issues/adverse operating conditions	• Emergency management • Flight planning management • Weather information
	OSO# 13: External services supporting UAS operations are adequate to the operation	• All services
	OSO#23: Environmental conditions for safe operations defined and measurable	• Weather information

Impact of U-space services in SORA

- the introduction of a new communication media technology may require an evaluation against the existing RCP/RSP specification (due to the use of cellular networks/wireless connections).

Appropriate validation tests will have to be conducted to evaluate whether the identified performance requirements (integrity, availability, continuity and transaction time) are consistent with U-space environment.

The results of the risk assessment, in terms of the **most demanding performance and safety requirements** are summarised in the table below.

The main outcome from SORA is the SAIL parameter. The selected scenarios obtain a in general SAIL equal to IV. This has repercussion on the barrier (i.e. mitigation) "External services supporting UAS operation" which refers to U-space services. Although SORA does not prescribe any specific performance requirement on U-space services, it **recommends their validation by a competent third party**, thus ensuring a high level of robustness.

Regarding the Regulatory compliance analysis, possible differences with traditional ANS providers have been detected and highlighted. Current definitions of ANSP (Reg. 549/2004) could be reviewed considering the new features introduced by U-space services. Consequently, in some cases new definitions should be introduced for some services.

In addition, the content and the format of each service could be modified keeping in mind that drones may require more *local* and/or different types of information. Operational area may be more limited than traditional aviation and data like Population Density is not provided in the current aeronautical information. This leads to

		Most demanding performance requirements		
U-space service	**Most demanding processes**	**Transaction time** (seconds)	**Continuity** (Max tolerable probability of interruption of service per flight/hour)	**Availability** (Max tolerable probability of non-availability of service per flight hour)
Flight planning management	Modify flight plan Check active flight plan Land immediately notification	10	10^{-5}	10^{-5}
Strategic deconfliction	Check and deconflict plan	120	10^{-2}	10^{-2}
Tracking	Obstacle detection	10	10^{-5}	10^{-5}
Pre-tactical geofencing	Check restricted areas	120	10^{-2}	10^{-2}
Procedural interface with ATC	Request to access airspace	60	10^{-3}	10^{-3}
Tactical geofencing	Update geofence Notify geofence change	10	10^{-5}	10^{-5}
Emergency management	Loss of control Loss of control broadcast Battery low Loss of landing pads	10	10^{-5}	10^{-5}
Weather information	Check MET and micro weather	10	10^{-5}	10^{-5}
Convey information related to the service	All processes	10	10^{-5}	10^{-5}

Most demanding performance requirements for U-space services the necessity to adapt classical aeronautical concepts such as *meteorological minima*, or *safe separation* to drones specific needs.

For regulation purposes, different options may be envisaged to define requirements of Service Providers in the U-space:

- **Option A**: making of regulations for quality of service but no formal requirement on service providers;
- **Option B**: inclusion of U-space service providers in EU Regulation 373/2017 [20];
- **Option C**: making of new specific regulation on U-space service providers.

However, option A does not seem a sufficiently safe solution due to high SAIL derived from SORA. In fact, SAIL IV requires external service providers to be validated by a competent third party.

Option B looks like the more affordable. Inclusion of U-space service providers in EU Regulation 373/2017 implies that such providers shall be subject to a certification process in which some tasks could be performed by independent **Qualified Entities** (being this option also supported by SORA).

On the other hand, option C is not in line with article 1(e) of regulation 1139/2018 "to promote cost-efficiency in the regulatory and certification processes and to avoid duplication at national and European level"; because traditional ANS providers would be subject to a double regime for oversight.

In any case **Qualified Entities could perform some certification tasks** even if new regulations are adopted for the U-space.

The definition of Qualified Entities, together with their roles, are provided in EU Regulation 1139/2018, Article 69.

Gaps with existing ANSP may be filled by introducing new Annex/Annexes in the current regulation or foreseeing a new custom U-space regulation.

Furthermore, Service Providers in the U-space could be certified by national (or EU) competent authorities and/or *approved* by qualified agencies, i.e. Qualified Entities.

Qualified entities may be also involved in auditing /training processes of U-space service providers.

Another element of discussion is to determine who will provide U-space services; we could have a specific U-space service provided by:

- Traditional ANSP only; or
- Traditional ANSP and other new providers; or
- New service providers only.

From the analysis of DREAMS scenarios, it is evident that **most U-space services are interconnected among each other**; in fact, services belonging to different families (e.g. Tactical geofencing and Flight planning management) are expected to share information. In any case all services have necessity to get access to aeronautical information or other data in order to ensure an efficient and safe support to UAS operations. As a result of the study, **some U-space services will require information in addition to classical aeronautical data**; the diffusion of all these data might then lead to the introduction of new providers.

Furthermore, all the **providers** involved in the U-space **should be able to inter-operate** in the same network. In a future perspective, this concept of interoperability should be extended with the aim to integrate U-space providers and classical providers for manned aviation.

Development and production of new and more performing technology is a key-point of U-space realisation. But **technology needs to be applied by specific Service Providers in a suitable regulation framework**. New services are coming for U-space and new Service Providers might be part of the U-space. Authorities could be supported in this process by new *actors* like the already mentioned Qualified Entities.

Finally, it is expected that EASA will publish a new regulation on U-space, possibly complemented by and amendment of the rules of the air (to include VLL rules), defining also the **responsibilities and requirements for the service providers**.

PHASE 2 – GAP ANALYSIS

Gap analysis

A thorough review of existing and defined data services from manned and current unmanned traffic management service providers was performed and then compared against the demands from drone operators/users identified from a targeted extensive online survey, a comprehensive reference scenario analysis, the high-level U-space services and lastly the consortium expertise.

To bridge the gaps in drone information services requirements for safe drone flight operations in VLL airspace, a set of proposed solutions have been outlined.

The key outcomes of the gap analysis activity are summarised below:

- Drone operator/user requirements were formulated with respect to a **systems engineering approach** which comprised of unique identifiers and with specific lexicon.
- The aeronautical information supply comprised of defined and implemented aviation data services provided by SWIM (for SESAR demonstrations only) and Open Source services and existing unmanned data services from U-space services providers.
- The drone information demand for safe flight operations in VLL operations was amalgamated from the drone operator/user requirements from an **extensive survey analysis**, a comprehensive **reference scenario analysis** and the **consortium's expertise** on the subject matter.
- The **information supply and demand were compared** in order to determine gaps in the data services.
- Attention was given to **urban environment operations** since it is deemed the most challenging to execute due to the large number of constraints such as dense obstacles both static and dynamic, uncertain urban atmospheric conditions and uneven terrain layouts.
- Ensuring **safe separation between unmanned and manned traffic** is critical with respect to safe integration. This gap is even more evident in an urban environment, especially at VLL in uncontrolled airspace. In this situation, it would be challenging to capture in real-time the position of manned traffic, especially helicopters which are not fitted with ADS-B transmitters. This problem can be solved by mandating all aircraft flying in VLL to be equipped with ADS-B transmitters.
- An important gap that needs to be addressed by U-space are the data and information services required to achieve **flexible management of high-density traffic**. A proposed solution to this is geovectoring. As geofencing and geocaging tells a drone "where to fly", geovectoring tells a drone "how to fly". This way, **geovectoring uses the principle of alignment to reduce conflict probability and traffic complexity**, thus enabling higher traffic densities in a flexible and robust manner. The data protocols for geovectoring would be similar to the geofencing/geocaging, albeit with additional information on speed, heading, and vertical speed restrictions.

U-AIM Concept of Operations

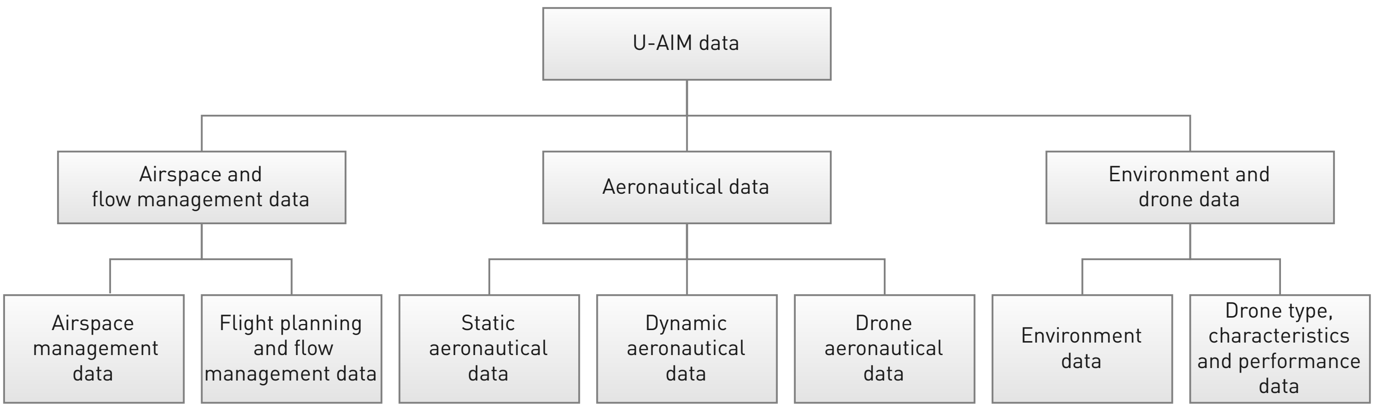
The solutions to some of the gaps were made more concrete the Preliminary U-space AIM Concept of Operations document. A set of U-AIM data models were defined to deliver consistent, accurate and up-to-date UTM data set for U-space stakeholders. The benefits of this includes:

Reduced Safety Risks: Potential hazards can arise from inconsistencies in U-space services information, difficulties in interpreting multiple data sources, out dated information and the lack of dynamic updates in digital data sources. Having consistent, complete, accurate and up-to-date information will reduce the likelihood of such hazards arising for U-space. The provision by the U-AIM of advanced pre-flight capabilities (based on the availability of digital static and dynamic data e.g. NOTAMs, integrated MET and geo-referenced maps) will also reduce the risk of drone pilots missing safety critical NOTAM information and therefore, this will enhance their awareness.

Increased Efficiency: Inclusion of required static and dynamic information in the digital data sets will enable automated systems to improve airspace access possibilities and drone flight efficiency. The intent of U-AIM is to offer functional and operational benefits, both tangible and intangible, to the U-space community:

- **digital format of aeronautical data** and information allows for rapid dissemination of digital data and information, to maintain the integrity of the data and to tailor the information according to the different U-space stakeholders, thus increasing operational value;
- the adoption of **open standards and SWIM data models** makes information more readily exchangeable with other information sources and other information domains, thereby increasing the operational value of the information.
- **geo-referenced maps and graphics** contribute to guaranteed coherence between information elements and between different information layers, thus increasing operational value and achieving greater transparency into data quality issues.
- **shared situational awareness** to ready access to aeronautical information by all (authorised) stakeholders.
- **better situational awareness** and hence decision making by drone pilots based on the availability during in-flight phase of more real-time and relevant aeronautical information.
- **different economic models** in the provision of U-space aeronautical information domain contribute to keep aeronautical information affordable to its end users.
- more **precise dynamic data** contribute to improve the accuracy of the performance calculations done by drone operators and their service providers;
- enable U-airspace management solutions to achieve the **most efficient use of airspace** by providing consistent up-to-date airspace situation;
- improve the ability of drone operators to take advantage of **airspace availability** based on accurate and updated airspace status information.
- enhanced **planning and pre-flight services** featuring static and dynamic digital data (e.g. NOTAM), weather data, and graphical displays.
- improved airspace planning activities for the U-space manager in order to **enhance available capacity and reduce the need for airspace restrictions**.
- Increase **consistency and quality** of the U-AIM data for all U-space actors resulting in data fit for daily drone operations;
- Enable a **reliable airspace demand and capacity calculation** thus allowing the effective detection and resolution of capacity imbalances.

The scope of the U-AIM data models has been arranged in three main information categories as shown on the diagram.



U-AIM categorisation of data

PHASE 3 – PLATFORM UPDATE

The DREAMS U-space platform was developed tacking into account the CORUS U-space architecture principles. In order to satisfy all these valuable principles, IDS decided to adopt the **micro-service paradigm** for the implementation of DREAMS system. The high level representation of such architecture is shown in the diagram below.

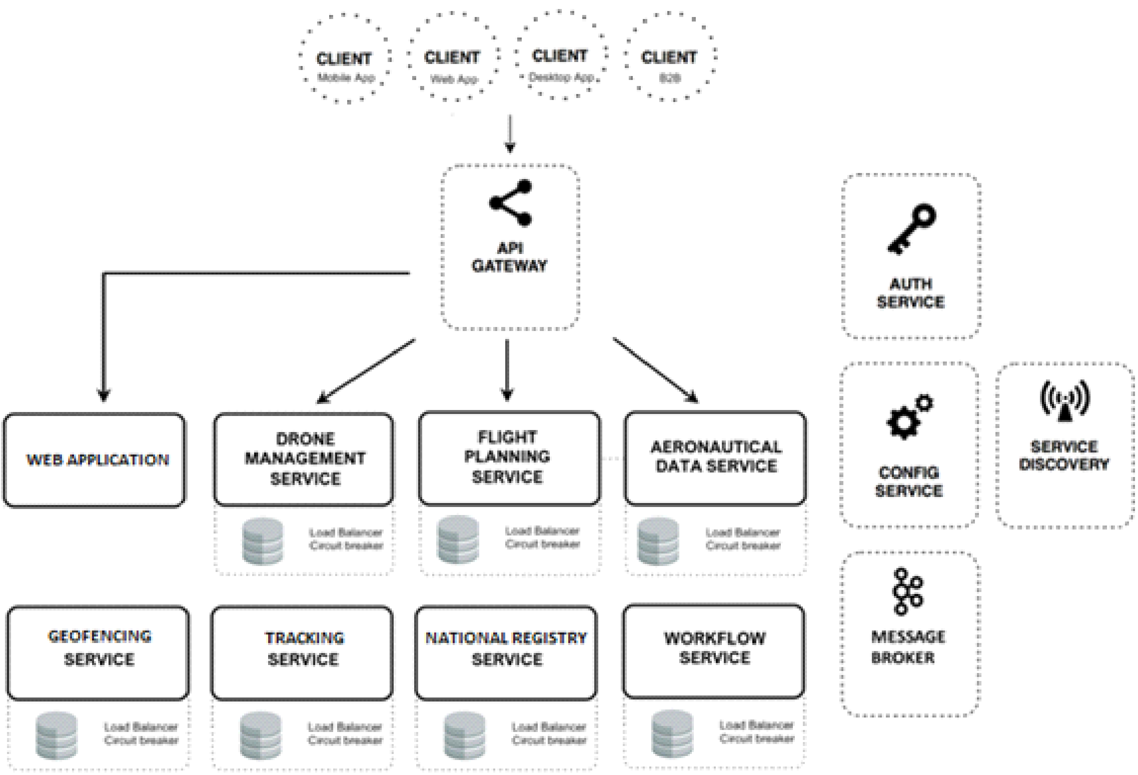
To execute the validation scenarios selected ("Geotagging" and "Capacity Management") the following features have been included:

- Urban obstacles,
- Path planning algorithms for flight planning in an urban environment,
- Geovectoring for conflict management,
- No-Fly-Zones or geofenced areas,
- An extended version for AIXM 5.1 in-line with U-space features,
- Flight plan interference and monitoring features.
- 4D interference check;
- Flight tracking;

These data models were developed and implemented in both simulation platforms, the DREAMS tool and the BlueSky ATM simulator. The platforms were also upgraded to exchange streams of data on asynchronous channels in a publish and subscribe pattern. This approach provides advantages in term of scalability and loose coupling between involved systems. For these purposes, an open-source stream processing software platform (named Apache Kafka) has been used.

DREAMS and BlueSky exchange four different type of messages:

- **Flight plans**, submitted by DREAMS users (recreational users, pilots, operators (drone delivery operators);
- **Tracks**, created by BlueSky traffic scenario generator based on flight plan information;
- Anticipated **congestion zones** from BlueSky;
- **Geovector zones**, created by DREAMS based on the anticipated congested zones.



DREAMS micro-service architecture

PHASE 3 – VALIDATION

Parametric model

The Parametric model proposed in DREAMS is implemented in the form of a **configurable State Machine** with SimEvents modelling environment and it is aimed to verify some draft U-space requirements.

The verification of the these requirements by means of the parametric model developed in this study, provides valuable information about the **threshold conditions and the limits of the system**, by which such requirements are still satisfied (e.g. number of clients requesting a service, service response time, probability of queues and mean waiting time after requesting a service,…). By tuning the parameters in the model with a given input, it is possible to **identify** such **thresholds** and freeze the respective output in order to provide indications about the configuration for the upcoming validation exercises on the simulation platforms (for example in terms of number of concurrent drones requests to access the airspace, or probability of queues in input in case of service congestion at a given time slot of the day).

The simulations performed with the parametric models developed generated interesting outcomes for further activities and for the upcoming validation exercises.

The parametric model itself is a powerful tool for the verification of behaviours of complex systems in presence of different kind of inputs (stimulus) generated, and the respective assumptions made on the transferring functions of the services involved in the model (average waiting time before response).

Transaction time has been identified as the **key parameter** to verify whether a specified service is capable to reply in the required time (nominal case) and what are the conditions and the limitations by which the requirement cannot be met (e.g. number of concurrent requests, dimension of queues, daily traffic profile, …). In other cases where no requirement is set, the simulation performed provided indications about the **expected average waiting time** for accessing the airspace or some indication about the possibility to insert new requirements.

Another important consideration is represented by the possibility to insert a **man in the loop** (Human vs BOT) for the deployment of some services. In this case the impact on the Transaction Time is obviously relevant, in comparison to a BOT (software) that requires few seconds to answer. However, it is important to highlight that although normal operations can be handled very well by BOTs (in our understanding of U3 services) considering their excellent response time, it is not obvious that such software may be capable to handle all kind of requests. In fact, a lower rate of success for authorisation requests is expected from BOTs, compared to those handled by a human operator, capable also to handle more complex requests, but in a longer time.

One recommendation for Validation purposes arisen from this model is related to the global transaction time. In fact when more U-space services are involved in a transaction, the **front-end service** (e.g. Flight planning management) is likely requested to **interact with other services** in order to obtain the most updated information. In this case the simulations suggest a better formulation for the transaction time requirements in order to specify whether services might need interactions with other services to respond. For example, the Tactical geofencing service that is required to respond in 10 seconds in order to update its database of fenced areas, may likely experience significant delays to update and publish the new dynamic fenced areas, discovered by the Drone DAA system and geographically *tagged* for other users' awareness.

Validation methodology

For the Validation tests, the consortium opted for a **pragmatic approach**. This was carried out by implementing the respective U-AIM models to the respective platforms: DREAMS and the BlueSky simulator. Once the U-AIM models were implemented and tested, a set of **five subset-scenarios** have been designed in order to test the efficiency and information comprehensiveness of the U-AIM models. The five scenarios encompass a **range of U-space services, use-cases** (including cooperative geo-tagging and capacity management) **and different flight phases**. These scenarios were then performed by drone operators using the DREAMS platform. The operator's subjective responses on the **efficiency and completeness** of the U-AIM models were captured using a tailored questionnaire which was presented to the operators after completing the scenarios.

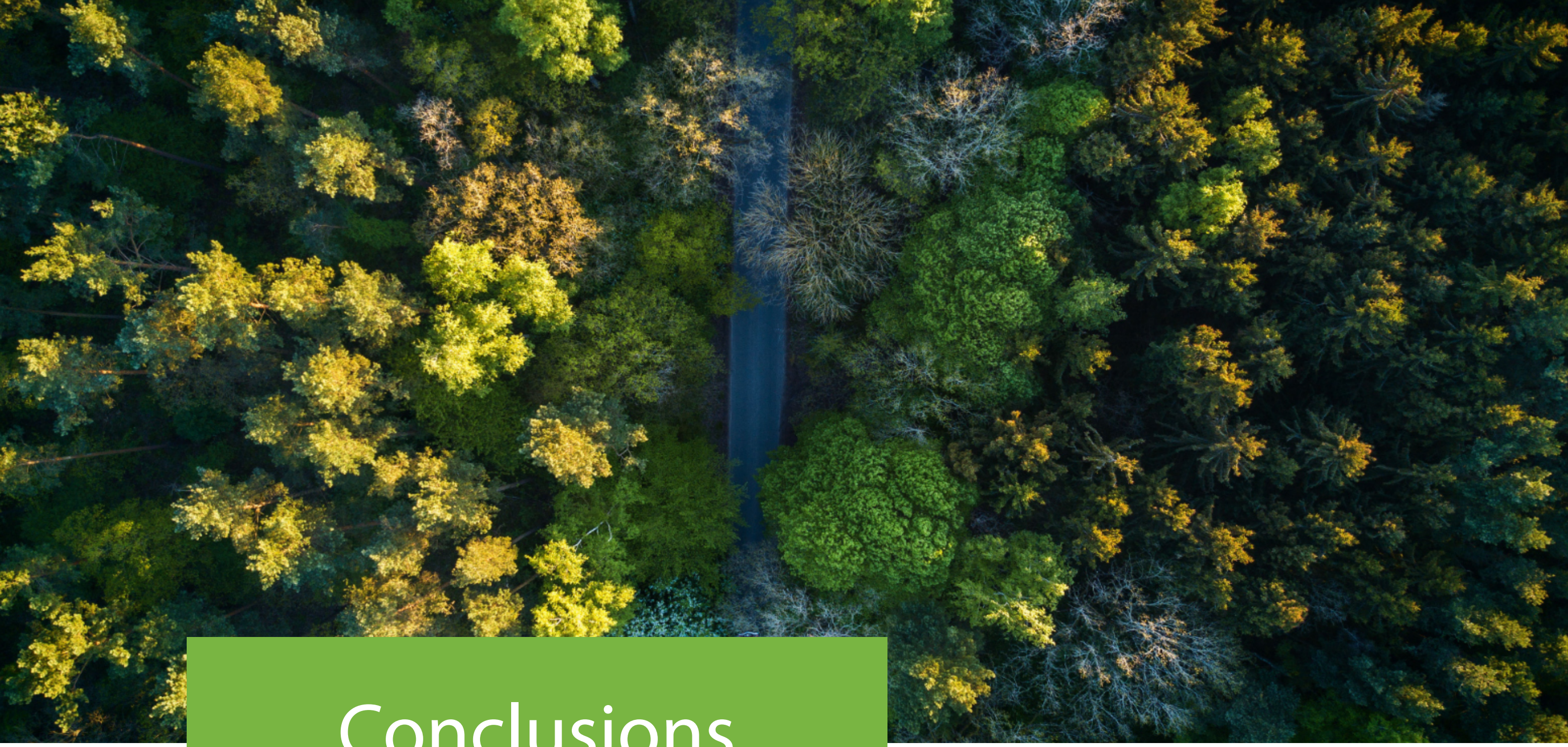
Validation exercise

A successful validation campaign involving five top-tier Italian drone operators was held. A questionnaire comprising 24 questions were used to capture the results of the validation. The results also serve as recommendations to the DREAMS project and also for future U-space projects.

The key outcomes of this activity which focused at demonstrating the efficiency and completeness of the U-AIM data models (only those within the scope of project DREAMS are included) designed to fill the information gap in order to realise safe drone operations in VLL airspace, are summarised below:

- U-AIM models, within the scope of project DREAMS, and its associated information exchanges were **validated by actual drone operators** from four reputable drone companies: TOPVIEW SRL, Ai View Group, Rescue Drone Network and Topcon Positioning Italy.
- **Five real-world scenarios** encompassing the elements of flight planning, tracking, cooperative geo-tagging, geovectoring and geofencing were simulated in the DREAMS and the BlueSky platform and performed by five drone operators during the validation simulation exercise.
- Results from the validation simulations were **captured using a comprehensive questionnair**e aimed at identifying the efficiency of the U-AIM models and the usability of the DREAMS platform.
- The results indicated that the **U-AIM models are efficient and useful for U-space stakeholders**.
- **New data elements** will need to be incorporated into relevant AIM models **to meet drone operator requirements** such as night-time flying. However, more research is needed in the area of night-time drone flights in order to understand the safety, as well as societal aspects.
- To increase safety for integrated operations, services similar to **Terrain Avoidance Warning Systems** in traditional aircraft should need to be adapted for U-space. Such a service is important for VLL urban operations which is congested with dense obstacles. Hence this service will provide a "safety net" for aerial vehicles. However, more research is needed to develop the necessary equipment and data models for this type of service.

Operators participating in the Validation session



Conclusions

CONCLUSIONS ON MATURITY OF THE SERVICES

The following tables summarise the current status of maturity reached during the project for the different services envisaged for U-space.

MATURITY OF PLANNED U1 SERVICES

Service	Definition	Coverage	Maturity assessment	Rationale
e-Registration	The service enables the registration of the operator, drone and pilot with the appropriate information according to Regulation. A level of security of the service will be defined.	Full	**TRL6**	The service has been implemented and validated during the DREAMS activities. External drone operators attested the implementation of the information service.
e-Identification	The service allows the identification of a drone operator from a drone in operation. The identification provides access to the information stored in the registry based on an identifier emitted electronically by the drone. The identification service includes the localisation of the drones (position and time stamp).	Full	**TRL6**	The service has been implemented and validated during the DREAMS activities. External drone operators attested the implementation of the information service.
Pre-tactical geofencing	The service provides the operator with geo-information about predefined restricted areas (prisons, etc.) and available aeronautical information (NOTAM, AIRAC cycle) used during the flight preparation. This service requires the identification of accredited sources and the availability of qualified geoinformation related to restricted areas. This service provides information that allows the drone operator to make use of the geofencing capability of the drone.	Push notification to operator/pilot terminal informing about new geofence	**TRL6**	The service has been implemented and validated during the DREAMS activities. External drone operators attested the implementation of the information service.

MATURITY OF PLANNED U2 SERVICES

Service	Definition	Coverage	Maturity assessment	Rationale
Tactical geofencing	Compared to U1 pre-tactical geofencing, tactical geofencing brings the possibility to update the operator with geofencing information even during the flight.	Push notification to operator/pilot terminal informing about new geofence	TRL4	The service has been partially implemented and validated during the DREAMS activities.
Emergency management	The service receives emergency alerts from operators and informs relevant actors of the ecosystem. These may include drone operators operating drones nearby, ANSPs, police, airport authorities. The service also provides the drone/operator with assistance information to manage the emergency situation (e.g. location of landing pads).			Not evaluated
Strategic conflict resolution	The service provides deconfliction assistance to a drone operator at strategic level. This service could be mandatory or optional according to the operating environment.	Full	TRL6	The service has been implemented and validated during DREAMS activities. External operators deemed positively the implementation.
Weather information	The service provides drone operators with forecast and actual weather information either before or during the flight; it can also collect and make available weather information from different stakeholders.	Simulated weather information in validation exercises	TRL4	A simulated hyperlocal weather information scenario was performed during the validation activities. The validation participants attested the hyperlocal information for ensuring safe operations.
Tracking	This refers to the service provider using cooperative and non-cooperative surveillance data to maintain track-identity of individual drones. The capability includes ground and air surveillance systems, as well as surveillance data processing systems.	Management and visualisation of tracking data	TRL6	The service has been implemented and validated during DREAMS activities. External operators deemed positively the implementation.
Flight planning management	This service covers the receipt of a flight notification or a flight plan and provides the appropriate answer according to the characteristics of the mission and applicable regulations This service will be available for any drone operator/user with different levels of requirements.	Full	TRL6	The service has been implemented and validated during DREAMS activities. External operators deemed positively the implementation.
Monitoring	Subject to appropriate data-quality requirements, this service retrieves data from the tracking service and fuses it with information related to non-cooperative obstacles and vehicles in order to create air situation for authorities, service providers, and operators. This service may include conformance monitoring.			Not evaluated
Traffic information	This service provides the drone operator with traffic information coming from any kind of monitoring services.	Implemented	TRL6	Tracks of manned aircraft traffic from ADS-B data were available
Drone AIM	This service provides the operator with relevant aeronautical information for drone operations. It will connect to the Aeronautical information service (AIS) to guarantee coherent information provision for manned and unmanned operators.	Full	TRL6	The service has been implemented and validated during DREAMS activities. External operators deemed positively the implementation.

MATURITY OF PLANNED U2 SERVICES (CONTINUED)

Service	Definition	Coverage	Maturity assessment	Rationale
Procedural interface with ATC	The service is a set of defined procedures for some mission types where there may be an impact on ATC. The procedures ensure clear and unambiguous drone operation, and provide an appropriate flow of information between the drone operators and ATC. Such procedures will allow drones to fly in controlled airspace and near airports with more flexibility and procedural approval/rejection based on agreed rules.			Not evaluated
Operations managment	Ability to plan and manage drone missions. This includes access to and use of all aeronautical, meteorological and other relevant information to plan, notify and operate a mission.	DREAMS implements the full life-cycle of the drone operation	TRL6	The service has been implemented and validated during DREAMS activities. External operators deemed positively the implementation.
Legal recording*			TRL2	Definition of what data should be recorded
Incident / accident reporting*				Not evaluated
Digital logbook*				Not evaluated
Terrain map*		Implemented	TRL4	Terrain map used
Building and obstacles map*		Implemented	TRL4	Some obstacles represented
Population density map*		Partial	TRL1	Taken into consideration the definition.
Flight plan preparation and optimisation*				Not evaluated

**These additional services have not been defined in the U-space blueprint*

MATURITY OF PLANNED U3 SERVICES

Service	Definition	Coverage	Maturity assessment	Rationale
Dynamic geofencing	Compared to tactical geofencing in U2, the dynamic geofencing targets the drone itself and then this service requires data-link connectivity to a geofencing system that allows the data to be updated during the flight.			Not evaluated
Tactical conflict resolution	This service provides information to the operators or the drones to ensure separation management when flying. The differences with the strategic deconfliction described in U2 are twofold: the drone may receive the information and this deconfliction is set for the in-flight phase. It will be necessary to appropriately define the boundaries with the use of Detect & Avoid capabilities.	Partially implemented	**TRL4**	The service has been partially implemented and validated during the DREAMS activities.
Collaborative interface with ATC	The service provides a mechanism to ensure proper effective coordination when drone operations using U-space services impact ATC. It encompasses shared situational awareness and procedures to enable a two-way dialogue supporting the safe and flexible operation of drones in airspace where ANS are provided.			Not evaluated
Dynamic Capacity Management	Upon the definition of drone density thresholds (that can be dynamically modified), the service monitors demand for airspace, and manages access to that airspace as new flight notifications are received. This service may be coupled with the flight planning management service. There should be appropriate set of rules and priorities for slot allocation when a portion of airspace is expected to reach its capacity limits. Apart from the demand and capacity balancing, the service could manage capacity due to non-nominal occurrences, such as weather hazards or emergency situations.	Integration of the two platforms	**TRL4**	The proposed amendment is that alignment is added as a possible capacity management strategy. Especially for higher traffic densities, alignment guidelines can be set for flight trajectories and actions within a given airspace. Dynamic capacity management through alignment of trajectories becomes relevant for high traffic densities, where multiple vehicles sharing one piece of airspace becomes unavoidable. Example missions are drone deliveries (food, express packages), and personal aerial transport. The service of geovectoring was implemented and studied in the DREAMS project.

TRL definition for H2020 Projects

CONCLUSIONS ON CONCEPT CLARIFICATION

DREAMS was structured, organised and developed in order to analyse all the aspects of Aeronautical Information Management for U-space (U-AIM). We mainly focused on the Aeronautical data analysis in terms of data format, exchange protocol and services; since one of the objective of our work was to validate the outcome on U-AIM executing different scenarios, we extended our analysis also on all the services and data formats needed for the validation providing recommendation for the implementations of such services.

The team started by defining realistic scenarios for which this type of information is needed. This exercise allowed us to understand the role of all the stakeholders involved aligning the terminology and the meaning, taking into account the definition of CORUS CONOPS.

After that, we focused on the services and the data needed for the execution of the scenarios in order to understand by the gap analysis the level of maturity; indeed some services identified are currently available (operational), other ones are experimental (e.g. defined in SESAR framework) and other ones have to be implemented from scratch for U-space purposes. During the execution of this task we started by the high level Blueprint services definition and refining and detailing every service involved in the scenario execution with a continuous cooperation with CORUS team members for sharing information and points of view on the meaning, usage, data exchange and stakeholders of the services.

The gap analysis allowed us to analyse the current services, applications and solutions in ATM/UTM domain coming from commercial and open source communities in order to identify which services are already available and applicable in U-space (reference services), which one are available, but they need to be modified or extended and which one are missing.

The aspects analysed during the gap analysis of the Aeronautical Information data needed for U-space operations allowed to reach some conclusions:

- to understand that **some tailoring or extension of the traditional Aeronautical information** is needed and can be performed with different formats and protocols.
- to understand that the current Aeronautical information data format (**AIXM**) **can be re-used or tailored** for U-space purposes.
- to define the **content** and the **format** of the **new information** needed for U-space purposes.

CONCLUSIONS ON TECHNICAL FEASIBILITY AND ARCHITECTURE

The DREAMS platform used for the validation exercises was developed taking into account the requirements of the project topic, the architecture principles defined by CORUS CONOPS and other additional not functional requirements listed below.

- New team members must quickly become **productive**
- The application must be **easy to understand and modify**
- To practice **continuous deployment** of the application
- To run multiple copies of the application on multiple machines in order to satisfy **scalability and availability** requirements
- To take advantage of **emerging technologies** (frameworks, programming languages, etc)

To implement an architecture fully compliant with those principles, DREAMS decided to use the **micro-service paradigm** which allows to define an architecture that structures the application as a set of loosely coupled, collaborating services. Each service implements a set of narrowly, related functions.

Services communicate using either synchronous or asynchronous protocols. Services can be **developed and deployed independently of one another**. Each service has possibly its own database in order to be **decoupled** from other services. **Data consistency** between services is maintained using an event-driven architecture.

The **main benefits** of the micro-services pattern confirmed by the project are:

- Each micro-service is **relatively small**
- Each service can be **deployed independently** of other services - easier to deploy new versions of services frequently
- Easier to **scale development**. It enables you to organise the development effort around multiple teams.
- Improved **fault isolation**.
- Each service can be developed and deployed **independently**
- **Eliminates** any **long-term commitment to a technology stack**. When developing a new service you can pick a new technology stack.

Regarding the **drawbacks** of this pattern, we identified the following ones:

- Developers must deal with the **additional complexity** of creating a distributed system.
- Developers must implement the **inter-service communication** mechanism.
- Multiple services using distributed transactions constitutes a more **complex system**
- Multiple services requires careful **coordination** between the teams
- **Deployment complexity.**
- **Increased memory consumption**. The micro-service architecture replaces N monolithic application instances with (NxM) services instances. If each service runs in its own virtual machine , which is usually necessary to isolate the instances, then there is the overhead of M times as many virtual machine runtimes.

Such architecture paradigm allowed the DREAMS development team to **develop quickly and incrementally** of the functionalities and services needed for the integration with TU Delft platform and for the scenario validation.

Moreover this solution is easily upgradable for further developments for experimental or operational purposes.

CONCLUSIONS ON PERFORMANCE ASSESSMENT

The simulations performed with the parametric model developed, highlighted the relevance of the **global transaction time** requirement and of the related impact on the U-space services involved in the transaction.

During the analysis, the emphasis has been put on the **automation of drone operations** (e.g. authorisation requests in strategic or tactical phases) provided by BOT (i.e. Software based on Artificial Intelligence algorithms that learns autonomously from the users behaviours, starting from a given set of rules), versus traditional approach that involves a man in the loop to address each specific case.

Although BOTs / software obviously can provide **better performance** in terms of response time than a human in nominal cases, the latter can properly m**anage non-nominal situations and complex cases**. From the user/drone operator point of view, both ways are important.

In fact, one of the most perceived concerns of drone operators is about the **time needed to obtain authorisations** to fly at strategic phase (e.g. in controlled airspace or for BVLOS operations). Speeding up this process, with respect to Safety, will mean not only unlocking an hidden market with enormous business opportunities, but also offering to the final clients of drone services, trust and credibility. Actually, the gap identified from a legal/contractual prospective between drone operator and final client, is about the **uncertainty of the mission execution** (e.g. customer satisfaction), until the final authorisation(s) from the Authority (or Authorities) is given. This process can take a long time (not compliant with the market demand) or sometimes it does not have a response at all, forcing the operator to abort the mission (losing business and credibility to the final client) or pushing him to fly illegally to upkeep the business and credibility towards the final client.

The analysis performed with the parametric model developed, showed that the actual procedures (with a bottleneck at authorisation stage) can be s**ignificantly improved with the help of BOTs** only for nominal cases (e.g. authorisation requests in standard scenarios).

The U-space, with respect to the Flight management service, is requested to address the drone operators' need at strategic or pre-tacti**cal stage for flight authorisations. The achievement of the authorisation for a flight operations within one hour** from the digital request is a reasonable goal and a tangible need strongly requested by drone operators.

The simulations justifying these conclusions, were the Parametric Model has been put in place, regarded two of the scenarios defined in DREAMS, namely "Cooperative geotagging" and "Capacity management". In both scenarios, emerges a front-end service: **the user only interacts** (submit/send answer and receive answer) **with one service**, which queries other U-space services when needed, receiving answers necessary to generate the final response to the user. Clearly, the total transaction time depends on the aggregate response time of the several services involved, either front-end or back-end services. The evaluation of the transaction time, in different conditions has determined the conclusion of our study.

Concerning the service performance in terms of response time and total transaction time, each service should have **a response time compliant with the total transaction time defined** in the requirements identified with the other services involved,and adequate to the number of requests expected (e.g. daily UAS traffic profile expected).

It can be observed that the same response time value of a U-space service could be optimal for the total transaction time needed in a scenario, but not in other scenarios.

Some U-space services, cross-cutting with respect to the majority of the possible scenarios, could be more **efficiently provided by a single service provider**, maintaining at the same time interoperability with external services. As an example, the flight planning interface could be unique for all users to ensure that the same data are consistent and provided in the same way, in order to improve the usability and the user experience.

On the other hand, **niche services could not need a unique provider** or interface, given their peculiarity with a more limited impact in the U-space framework.

Another group of considerations to keep in mind is related to the attribution and the division of the responsibilities for drone operations and services, among the actor involved (e.g. the Drone Manufacturer, Drone Operator, Drone Pilot, U-space service provider,…).

Let's assume that a drone pilot requests authorisation to take off for a BVLOS flight in a certain area and receives clearance from the automated service (BOT), without any observation nor limitation to the request. Once started the mission, the drone encounters an issue related to the lack of updated information (e.g. Tracking Service failure, Ground obstacle undetected, …), thus experiencing an accident with another drone or a building. In cases like this it should be well denoted the boundaries of responsibilities and liability among the actors involved in the chain.

Liability for incidents involving Drones, is a **new developing area of law and policy** that will determine who is liable when a drone causes physical damage to persons or property in a similar way like for self-driving cars.

Finally, we believe that the **introduction of BOTs in the authorisation chain is the only possible way to increase the number of drone operations,** though their involvement shall be limited to low risk operations or standard scenarios. In more complex operations (i.e. in the proximity of airports or over cities) BOTs can be still used only as support to human decision makers with the big advantage to reduce the processing time for authorisation. Nevertheless, particular attention shall be given to the liability/ responsibility issues especially for BVLOS operations. U3 and U4 services should also address these challenges when more automation and connectivity will be reached.

Performance assessment on Validation activities

An extensive performance assessment was performed on U-space information services in U1, U2 and U3 deployment sstages. This performance assessment, or **validation** test, has been **done pragmatically**. With the participation of a group of well-experienced drone operators from four reputable companies: TopView SRL, Ai View group, Rescue Drone Network and Topcon Positioning Italy; the drone operators helped explore and evaluate the efficiency and completeness of the U-space information services developed by the DREAMS project.

To achieve realistic and measurable validation results, five real-world scenarios were developed:

- planning a flight in Rome city airspace;
- planning a flight in an airspace populated by no-fly zones;
- dynamic geofencing of an obstacle along a drone flight-path;
- planning a flight in an airspace with traffic alignment rules (geovectored airspace); and
- assessing drone performance limits for approving a drone flight in an extreme cross-wind zone.

The results of the above validation activity were captured using a **comprehensive** 24-question **questionnaire**. The questionnaire underlines the outcome of the validation study by evaluating the efficiency and completeness of the newly developed information services. Similarly, the questionnaire was used to obtain a clear indication of any gaps in the aeronautical information.

The following conclusions of the performance assessment/validation tests can be drawn:

- The respondents (drone operators) indicate a high focus on **drone construction surveying**.
- The drone operators show strong interest to **operate in both rural and urban areas under BVLOS conditions** while occupying the entire VLL airspace.

- All drone operators indicate **positive interest to operate at night-time** because of new business opportunities. This calls for new requirements to be considered by CORUS especially, the amendment of anti-collision LED lights to drones operating at night. Relevant AIM data will need to be developed for night-time operations.
- **Manufacturers will need to provide the relevant equipment** (anti-collision LED lights) **to enable night-time operations**. However, more research is needed in the area of night-time drone flights in order to understand the safety, as well as societal aspects.
- Drone operators also confirmed a **5 day per week operations frequency** and they also preferred **semi-autonomous control**.
- The drone operators recommended the **transaction time to be lowered to 5 or 6 seconds** from the original value of 10 seconds.
- The **flight planning trajectory** drawing capability needs to be improved to **include the selection of polygons** etc.
- The flight planning data model needs to **include** geolocation points such as **home and landing points**.
- The respondents attested the **ease of using the DREAMS platform**.
- The respondents affirmed the **importance of the cooperative geotagging service by the geofencing data model** to increasing the safety of drone operations.
- The participants requested for an **aural alert to be integrated with cooperative geotagging** for better situational awareness.
- The ability to **submit NOTAMs** was also indicated by the respondents.
- The **flight plan description** of R&D flights can be left **undisclosed** in the tracking data model f**or privacy concerns**.
- For obtaining data on obstacles, it is prudent that each State's **Cadastre** should be mandated to **supply obstacle data** to the state's U-space Service Provider **with accuracy of 1m.**
- The operators requested for services that would provide an **additional layer of safety with obstacles**. Such services are seen in current aviation, e.g., Terrain Avoidance Warning Systems. Therefore, U-space stakeholders might benefit from similar services and it could increase the safety of the VLL airspace. However, necessary equipment will need to be installed on drones.
- Such service is **particularly important for VLL urban operations** which take place in a congested area with many obstacles. Hence this service will provide a "safety net" for aerial vehicles. However, more research is needed to develop the necessary equipment and data models for this type of service.
- **Geovectoring** data model s**hould take into account the mission of the drone** flight to avoid heavy or unacceptable change of trajectories.
- The **benefits of alignment** provided by geovectoring algorithm will become more pronounced when drones operate at **high traffic densities**, and fu**lly autonomous**.
- Flexible use of airspace through the alignment principles of g**eovectoring can benefit** such high-demand drone applications because of its ability to **flexibly manage capacity**.
- **Strong winds have been categorised as no-fly zones** in the geofencing data model in order to maintain a certain level of safety for drone flights.
- The DREAMS platform results indicate the **high usability of the platform**. No negative human performance of the information services were observed.
- The drone operators requested for **post-flight recordings**, which is already covered in U2 (data recording services).

CONCLUSIONS ON SAFETY ASPECTS

Ensuring safety of all airspace users (manned and unmanned) in the U-space ecosystem **is a primary goal**. The operational and technical aspects associated to drone operations bring new safety issues: flying at low altitudes, possibly inside urban environment (i.e. in proximity of obstacles and people) which implies that new risks shall be mitigated. Ground risk (i.e. the risk for third parties on the ground) as well Air Risk (i.e. the risk of collision with third parties in the air) have to be addressed. In addition, the number of drones operating in the same volume or airspace is expected to increase, especially at Very Low Level (VLL). Therefore, risks deriving from the possibility to have multiple drone interactions in the same airspace volume shall be considered as well.

JARUS has developed the methodology for Specific Operations Risk Assessment (SORA) to address risks associated to drone operations in the Specific Category (in which most of BVLOS flights are included). This methodology is being progressively refined and is already being widely used by operators and accepted by Civil Aviation Authorities as it will be recommended by EASA as AMC to carry out the risk assessment in compliance with Art. 11 of EU Regulation 947/2019.

Within the DREAMS project, SORA has been applied to address risks associated to typical U-space scenarios; a range as wide as possible of environmental and flight conditions has been considered in order to carry out a comprehensive risk assessment. The **computed level of risk is generally high**, especially for BVLOS flights in urban environments or inside controlled airspace, thus requiring a **high level of robustness** for the mitigations to be implemented. High robustness means the necessity to validate the operator's technical and organisational aspects by competent third parties (e.g. qualified entities according to EU Reg 1138/2018) and to ensure that service providers in the U-space meet specific quality and safety requirements. Several standardisation activities are ongoing to define AMC to SORA and requirements for U-space service providers.

Another issue which emerged from the analysis is that **manned aircraft may still be present at VLL** (i.e. Helicopters in Emergency Medical Services). The current vision of the U-space is mainly focused on ensuring deconfliction and raising situational awareness only among unmanned users. However, the analysis carried out by DREAMS shows that **cooperation with manned aviation at VLL is crucial to ensure safety**: a possible solution could be to prescribe all users (i.e. manned and unmanned) at VLL to carry and use some functionality (e-Identification) to comply with specific rules, such as the new rules of the air at VLL as envisaged by EUROCONTROL and procedures relying on a mandatory set of U-space services.

Consequently, services such as e-Identification, tracking, monitoring and traffic information should provide **real time information also on and to manned traffic**, in order to raise situational awareness of pilots (whether remote or on-board), controllers and/or U-space supervisors.

Although the current version of SORA does not allow to take advantage of the presence of U-space services to mitigate risks, this aspect has been anyway investigated in DREAMS, based on the more general methodology of ICAO Doc 9859. In other words, one of the safety outcomes of DREAMS is the mapping between each service with the possible related impact on the Ground/Air risk. It is expected that JARUS will in the future publish a new annex of the methodology to include the availability of U-space services.

In DREAMS it has been recognised that **SORA has presently some limitations** which do not allow to address all the possible risks associated to operations in the U-space. These gaps basically include:

- Risks deriving from the **presence of multiple drones** in the same airspace volume;
- Risks deriving from **failure conditions of U-space services**.

Therefore, a traditional risk matrix-based approach has been used to fill these gaps and derive minimum safety and performance requirements for the U-space, in terms of transaction time, continuity, availability and integrity.

In conclusion, the full integration of unmanned traffic in the consolidated manned aviation domain, starting from VLL airspace, will be possible only after the full deployment of U-space services and the establishment of a clear regulatory framework, including new rules of the air for VLL flights, requirements for U-space service providers and related oversight. These rules might be supported by voluntary industry standards

Recommendations

RECOMMENDATIONS FOR U-SPACE IMPLEMENTATION

- **New aeronautical features**, **airspace types** and **extension of existing features** have been identified to include the additional needs coming from U-space
- No specific data format for data exchange has been identified, but it is recommended that services are able to **provide the same content in several formats** suitable for different client capabilities, ensuring data quality and performance.
- The aeronautical data service provision has to be able to **interact with consumers through several protocols** to allow the data exchange with different client capabilities.
- The aeronautical data exchange service has to provide **data querying capability**.
- Since the information to be provided by U-space is similar to the traditional AIM it is recommended to **follow the AIXM exchange model specification**.
- It is highly recommended to build U-space on the **micro service architecture** which is fully compliant with the CORUS CONOPS.
- In all open-data provision services, the source of the data is critical for safety and security. Therefore, it is recommended that **U-space data provision suppliers should provide the data source**. In addition, U-space should validate such open-data provisions.
- **Transaction time** of U-space information services **should be less than 10 seconds**, especially, in a congested airspace.
- Important **geolocation navigation aids** such as home/take-off/landing points **should be displayed on the U-space flight planning tool**. This will further enhance situational awareness for U-space stakeholders.
- **Obstacle information** such as building height, type and coordinates **should be communicated by local authorities to U-space service suppliers**. A database with the latter obstacle data should be maintained and regularly updated.
- **U-space should cooperate with existing geoinformation mapping services** such as Map Box®, Google Maps®, Open Street Maps®, HERE®, etc., to coordinate efforts of building and maintaining the database of obstacle information.
- Hyper-local weather information is still lacking. This is mainly due to cumbersome process of acquiring/extracting data on a hyper-local scale **U-space should promote and incentive crowd-sourcing of hyper-local weather information**.

- **Temporary No-fly zones should be created for hazardous weather conditions** such as extreme winds, updrafts etc. and, approval to fly in such areas should be based on drone performance characteristics.
- U-space should investigate the **provision of Terrain Avoidance Warning Systems** for drone pilots and operators. Manufacturers should be mandated to supply provisions for aural alerts, in specific challenging environments. This would create better situational awareness and thus, increase safety.
- **Deconfliction and dynamic capacity management services should take into account different mission types**. For many missions, grounding of a flight and delaying a flight can impact the business model of a drone operator. Limiting the flight path can reduce the efficiency of flight. Conducting a flight with specific flight rules in-lieu of the above-mentioned alternative, reduces the number of conflicts and the conflict probability which enhances the safety of VLL urban drone operations.
- The benefits of alignment or geovectoring services will become more pronounced when drones operate at high traffic densities and fully autonomous which will be inevitable if operations like package and food delivery by drones become a reality. This is because of latter's ability to flexibly manage capacity. **U-space should therefore, investigate use of geovectoring**.
- **Requirements by drone pilots and operators are continually evolving**. Some envisioned applications could generate high-densities of drone traffic and generate large revenues for U-space service providers.
- **Drone operators wish to operate at night-time** in order to capture more business opportunities. To address these demands, U-space should mandate manufacturers to include anti-collision LED lights. Drone pilots state that anti-collision LED lights give visibility even at a distance of almost 5 km, creating situational awareness for night-time operations.
- **For night-time operations**, the following **additional information should be included in the flight planning process** in order to ease the approval process by the local authorities: description of the drone flight in detail, name of pilot, name of persons responsible, night-time flying experience (in hours), identification of risks in area of flight operation, appropriate mitigation methods, coordinates of flight path, method for maintaining visual contact, inclusion of anti-collision LED lights. It is recommended to include the above information management aspect in U2- Flight planning management and also to the relevant U-AIM data models. This will increase the safety of night-time drone operations and also increase business opportunities for drone operators. In addition, U-space should conduct studies to investigate the public's perception of night-time drone operations.

RECOMMENDATIONS ON REGULATION AND STANDARDISATION INITIATIVES

- To support a safe and harmonised deployment of the U-space, a solid **performance-based and risk-based regulatory framework** shall be defined.

  The performance-based and risk-based approach has already been taken by the European Commission in Implementing Regulation 2019/947 on UAS operations and therefore it would be logical to apply it also to U-space services.

- The **legally binding regulations** (so called "*hard rules*") **should define privileges, responsibilities and high-level requirements for all the stakeholders operating or providing services in the U-space**, including UAS operators, airport operators, service providers and authorities.

- Performance-based and risk-based approach means that **rules should be as much as possible independent from technological solutions** and, consequently, should be complemented by consensus-based voluntary industry standards (so called "soft rules").

- **Developing adequate standards for U-space is an urgent need** as several companies are already developing U-space solutions. Standards covering U-space functional structure and interface with ATM are needed as well.

- Besides technological aspects, **ensuring the oversight of service providers is a key point to ensure safety**.

- Some key differences exist between the traditional service provision for manned aviation (Reg. 373/2017 in the EU) and the service provision in the U-space: different operational and technical aspects related to drone operations require different types of information, means of communication, data resolution and performance requirements. Therefore, **custom U-space standards are required to define minimum safety, quality, security and privacy requirements** which could be used as AMC to support oversight processes by Authorities or by operators.

- Working group 4 of **ISO TC 20/SC16** is currently working on this topic and **is expected to publish a dedicated standard** within 3 years. As an element of support to this approach, ICAO already recognises ISO certification as AMC for the certification of MET and AIS service providers.

- In addition, a **safe integration between manned and unmanned traffic** will be possible only after the development of **new flight rules at VLL** as well as a **common altitude reference system** to ensure vertical separation.

RECOMMENDATIONS ON FUTURE RESEARCH INITIATIVES

Taking into account the findings and outcome of the DREAMS project the following R&D topics have been identified:

- Investigating the **use of geovectoring in complex environments**: The VLL airspace is a complex environment which includes obstacles as well as unpredictable urban wind-effects. Future R&D studies should investigate the use of geovectoring in (simulated) obstacle rich environment which emulate typical urban cities. Fast-time simulations should also be conducted accordingly.
- **Analyse the effect of geovectoring for the three-layers of conflict management**: conflict prevention, conflict resolution & detection and conflict avoidance are the three-layers of conflict management. Current research focuses on the first-layer (conflict prevention). Future studies could study how the alignment constraints of geovectoring can be incorporated into CD&R and conflict avoidance schemes.
- **Dynamic geovectoring**: the current geovectoring method is static in time. To maximise the efficiency with the available airspace, it may be beneficial to have adaptable alignment constraints for: heading angle, airspeed and/or vertical speed to particular airspace in order to better match the traffic demand. This adaptable airspace capacity management method may prevent under-utilisation of the airspace and thus maximise the airspace capacity. Future research will also need to study the information management aspects concerning dynamic geovectoring.
- **Night-time operations**: Specific studies to investigate include: the public's perception of night-time drone operations and studying the safety aspects of night-time flights
- **Terrain Avoidance Warning Systems** (TWAS) for drones: Drone operators propose a service similar to TWAS could enhance the safety of drone flights operating in VLL. The VLL is full of obstacles. A service that provides alerts of terrain and obstacle warning could be beneficial for U-space stakeholders. Future research should investigate the development and provision of TWAS for drones.

Notes

Notes

To get more information about the project DREAMS, please contact us at:

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