Drone Information Users' Requirements

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IMPETUS

INFORMATION MANAGEMENT PORTAL TO ENABLE THE INTEGRATION OF UNMANNED SYSTEMS

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Abstract

D2.1 performs a domain analysis dealing with the information management of the future U-Space system. The analysis is focused on capturing users' needs and the characterization of data requirements through specific use cases. This task was performed by following a bottom-up approach, including an extensive literature review and a stakeholders' survey designed by the IMPETUS Consortium.

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Executive Summary

D2.1 performs a domain analysis dealing with the information management of the future U-Space system. D2.1 aims at capturing users' needs and the characterization of data requirements.

The domain analysis was conducted through a stakeholders' survey, the evaluation of outlook studies, a description of existing UTM concepts and current information services for manned as well as unmanned aviation. Furthermore, two different system architectures were outlined before detailing six use cases, which cover the most relevant operation types in rural and urban environment: inspection, surveying and light load movement, with a focus on information exchange. The entire set of information was finally used to execute a gap analysis and an intense study of requirements for different operation types, flight phases and information categories.

The exploratory research identified a holistic set of information that should be considered for the future U-space drones' traffic management system. The inputs from diverse stakeholders showed that the focus of the dedicated users is on primary elements to enable a safe and efficient conduct of operations, e.g. data concerning airspace usage, obstacles, terrain, drone tracking, regulations and weather. The study also confirmed that, in typical domains of manned aviation such as meteorology, aeronautical facts or geospatial data, information is available throughout established methods, but often lacking to meet the special requirements arising from the significant differences in drone operations, for instance high resolution and dynamic update rates. At the same time, current service providers designated for unmanned traffic, are suffering from the absent of harmonized standards, rules and approval mechanisms in Europe.

Based on these acknowledged information packages and requirements, the next deliverable, D2.2, will identify and describe the main services that are tailored to fit the needs of all future U-Space users. D2.2 will follow a top-down approach that may imply the identification of inconsistencies and gaps with the bottom-up approach performed in D2.1. IMPETUS consortium foresees a second iteration of D2.1 to introduce further refinements to the categorized information, especially in regard to characterization, possible sources of information and secondary information required to support the future U-Space system. This second iteration will allow ensuring full consistency between D2.1 and D2.2.

Founding Members

1 Introduction

1.1 Purpose of the document

D2.1 performs a domain analysis dealing with the information management of the future U-Space system. The analysis is focused on capturing users' needs and the characterization of data requirements through specific use cases. This task was performed by following a bottom-up approach, including an extensive literature review and a stakeholders' survey designed by the IMPETUS Consortium.

1.2 Intended readership

This document is intended to be used by IMPETUS members and SJU (included the Commission Services). The document will be exchanged with those exploratory research projects with high dependencies with IMPETUS such as the project in charge of the definition of the U-Space concept of operations, CORUS and the other project in same research topic, DREAMS.

1.3 Acronyms and Terminology

It is necessary to highlight that UTM acronym is used in this document both for the general notion of a drone traffic management system and for the specific system which will be designed in the USA.

Table 1: Acronyms

Abbreviation	Description
AD	Aerodrome
AGL	Above ground level
AIBT	Actual In-Block Time
AOBT	Actual Off-Block Time
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
AIXM	Aeronautical Information Exchange Model
AU	Airspace User
ANSP	Air Navigation Service Provider
API	Application Programming Interface
BD	Big Data

Abbreviation	Description
BI	Business Intelligence
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CAGR	Compound Annual Growth Rate
CAP	Common Agriculture Policy
CNPCL	Control and Non-Payload Communication
DAA	Detect and avoid
DEM	Digital Elevation Model
DIA	Drones in Activity
DSM	Digital Surface Model
DTM	Digital Terrain Model
EASA	European Aviation Safety Agency
EIBT	Estimated In-Block Time
EGNOS	European Geostationary Navigation Overlay Service
ENR	En-route
EOBT	Estimated Off-Block Time
EUSCG	European UAS Standards Coordination Group
FAA	Federal Aviation Administration
GBAS	Ground-Based Augmentation System
GEN	General Aeronautical Information
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organization
ICD	Interface Control Documents
IFR	Instrument flight rules
ILS	Instrument Landing System

Abbreviation	Description
INS	Inertial Navigation System
LTE	Long term evolution
LUC	Light UA operator certificate
MC	Multicopter
NAA	National Aviation Authority
NASA	National Aeronautics and Space Administration
NDB	Non-Directional Beacon
NM	Network Manager
OGC	Open Geospatial Consortium
PA	Precision Agriculture
PIC	Pilot in Command
PSS	Public Safety and Security
RDP	European UAS Standardisation Rolling Development Plan
RPAS	Remotely-piloted aircraft systems
RTT	Research Transition Team
SAA	Special Activity Airspace
SARPs	Standards and Recommended Practices
SOP	Signal of Opportunity
SORA	Specific Operations Risk Assessment
SWIM	System Wide Information Management
TSA	Temporary Segregated Area
UAS	Unmanned aerial system
UA	Unmanned aircraft
UTM	Unmanned traffic management (general term)
UTM	Unmanned Aircraft System Traffic Management (USA)

Abbreviation	Description
USS	UAS Service Supplier
VLL	Very Low Level
VLOS	Visual Line of Sight
VOR/DME	Very high frequency Omnidirectional Range and Distance Measuring Equipment
WXXM	Weather Information Exchange Model

1.4 Scope and Approach

IMPETUS (**I**nformation **M**anagement **P**ortal to **E**nable the in**T**egration of **U**nmanned **S**ystems) is addressing the scientific analysis of information management requirements for a safe and efficient integration of unmanned aerial systems (UAS) in very low level airspace. As a result, technologically and commercially feasible service solutions are elaborated and deployed in an experimental testing environment in the scope of the project.

The expected growth of future UAS movements in rural as well as urban areas indicates the need for traffic management solutions, ensuring a normal course of trouble free operations of manned as well as unmanned aviation [22]. IMPETUS contributes by investigating potential services that serve the airspace user's needs in all phases of the operation life cycle, from strategic planning over pre-flight, in-flight and post-flight data provision. Since information management is an infrastructural prerequisite of future unmanned traffic systems, the results support the European goal to gain in prosperity by means of the job and business opportunities of an emerging drone service market [39].

Ensuring a scalable, flexible and cost efficient system, IMPETUS proposes the application of the Function as a Service paradigm, the notion of microservices for the design of the architecture and the use of Smart solutions based on emerging IT technologies (Big Data (BD) and Business Intelligence (BI) among others). Concurrently, data quality and integrity is taken into account to guarantee a safe conduct of all operations. To fulfil these purposes, the project started to characterize data processes and services of vital importance for drone operations. Following the requirements derived from these preliminary studies, a Smart U-space Design is drafted in alignment with the U-Space concept, which describes a framework for a progressive implementation of services to "enable complex drone operations with a high degree of automation to take place in all types of operational environments, including urban areas" [11]. Specific services[1] will be prototyped and laboratory scale tested in a server-less cloud-based environment in the later course of the project [15].

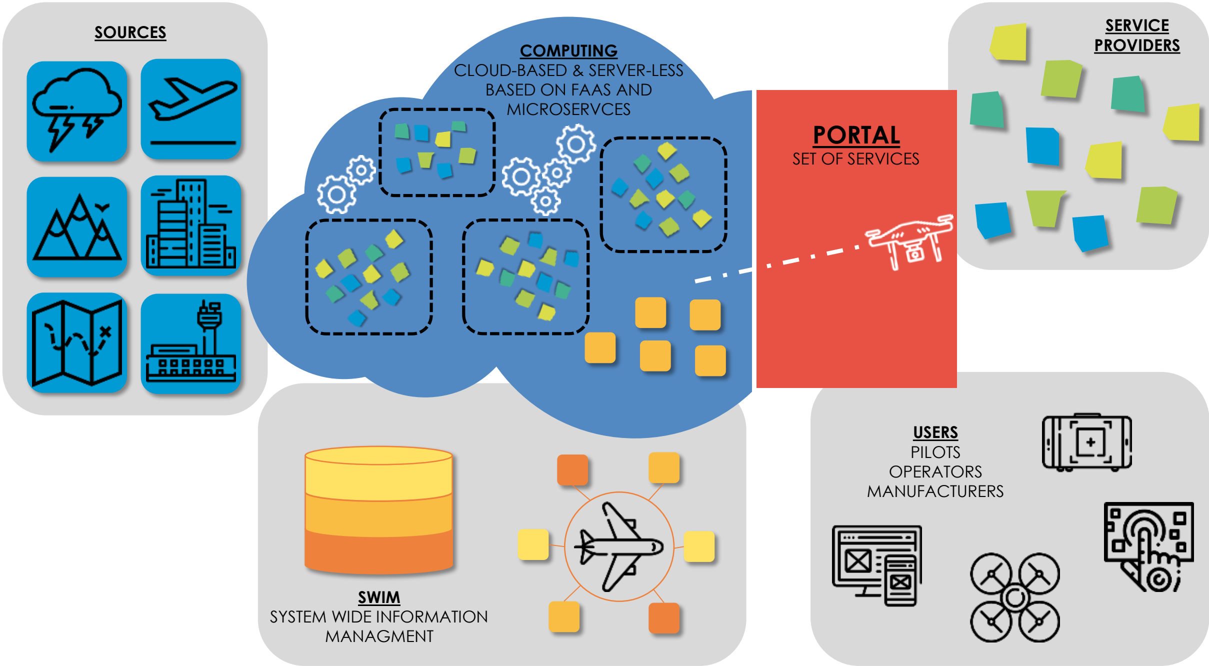


Figure 1: IMPETUS high-level system outline [43]

The present report introduces general information about future drone operations and their associated stakeholders to identify a set of data which will be needed to fulfil the purpose of a drone information management as part of the U-Space concept. Therefore, a method was applied that consists of 4 major blocks as shown in the next figure.

[1] We should distinguish between the notion of drone services within U-Space Blueprint - which are mainly oriented to the operations - and the notion of IMPETUS microservices which is more related to the architecture of the future U-Space system. In this document, microservices are making reference to the architecture and services to those identified by U-Space plus others that could emerge as a consequence of the analysis.

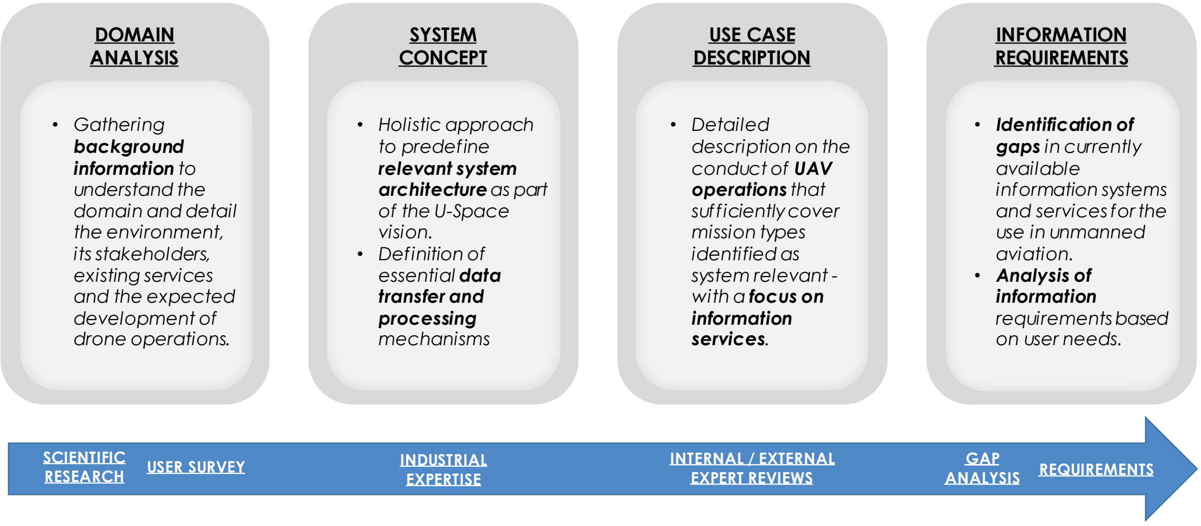


Figure 2: Overview of content in D2.1

As illustrated in Figure 2, the work reported in D2.1 starts with the analysis of the drone information domain. This step is necessary to guarantee a sufficient understanding of the context and necessities that the IMPETUS solution addresses. Therefore, comprehensive background information was collected in order to detail the development of the drone operation environment of the next 15 to 30 years. Furthermore the positions of the stakeholders were analysed as well as typical drone operation sectors. To ensure the development of a system that takes into account the actual needs of the users, the identified stakeholders were invited to participate in a survey and share their expertise. The results are then processed to facilitate a reasonable categorization of information types. Additionally, information services were described, that are currently used in manned and / or unmanned aviation.

Based on the previous research, the gathered knowledge is used to predefine a system outline that details the most relevant elements and processes inside the future U-Space concept. This step is necessary since IMPETUS addresses a system which is not yet in place, but developed concurrently. Consequently, a vision was developed by our industrial partners to clarify invariant system functions and a statement of responsibilities and dedicated authority. The same chapter introduces essential data transfer and processing mechanisms, which are needed for the management of data through the whole process.

In a third step, use cases are drafted that aim to further detail information usage processes during drone operations in a U-Space environment. Thus, generalized operating schemes were identified that are most relevant for U-space: surveying, inspecting and light-load movement. In addition, they shall cover different time horizons as well as operation areas (urban vs. rural). These use cases will also be used for communication as they can be internally or externally reviewed by experts.

As final step, a gap analysis is performed by comparing existing solutions for information management, predominantly in manned aviation, with the information types identified for the drone operations in the lower airspace. In addition, the gathered information is used to determine the difference in information needs depending on the type of operation and flight phase of the drone.

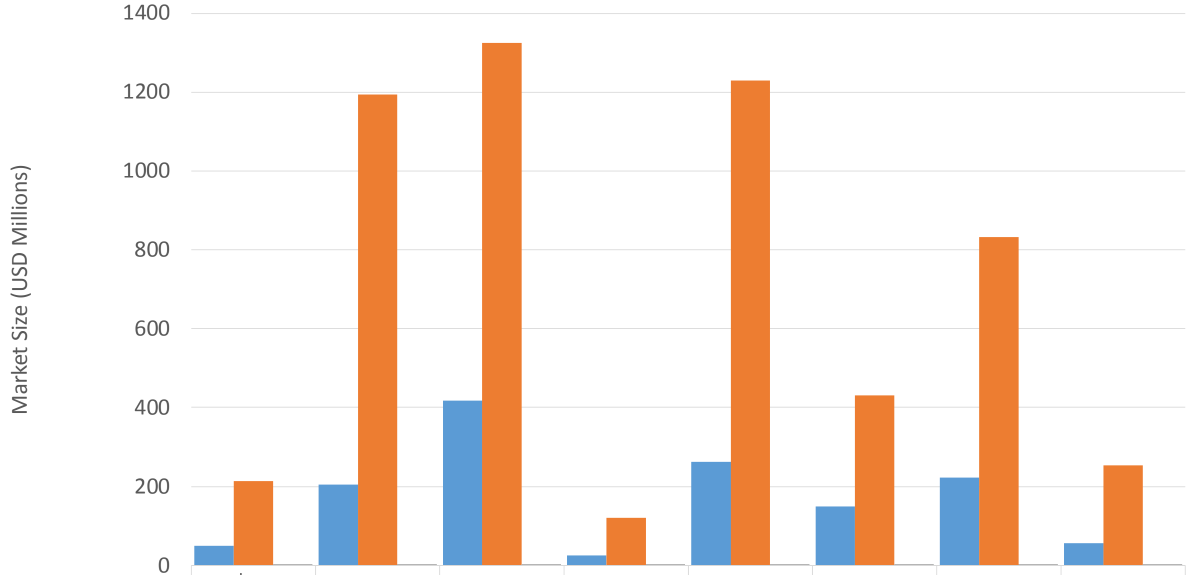
2 Drone Operations – Domain Analysis

2.1 Environment Outlook

The SESAR European Drones Outlook Study [22] foresees a tenfold increase in the current drone fleet size in Europe by 2020, consisting of around 100k drones. By 2050, the number of drones in operation in Europe is expected to be around 415k. The areas of applications for drone operations and services are plentiful and are only expected to increase as the market matures. These operations will be very dynamic in nature, ranging from human-operated within visual line of sight (VLOS) local flights, to human overseen semi-autonomous flights over a confined area to completely autonomous long-range flights beyond visual line of sight (BVLOS) of the operator. The impact of this development will be quite substantial. From an economic standpoint the entire value chain surrounding drone operations is expected to exceed EUR 10 billion annually by the year 2035 and the creation of 100.000 new jobs, with commercial and government drone operations being the largest contributors in the long run [22]. This value chain will encompass product related sectors (design & commercialisation and assembly & manufacturing), services (value added services and piloting & operations) as well as maintenance & insurance of drones and equipment. The service sector will have the largest overall impact: value added services will encompass the largest chunk of the economic impact, whilst piloting & operations alone will account for half of the jobs created [22].

Unlocking all this potential will depend largely on the progression of development of a few key factors: Technology, Air Traffic Management (ATM), regulations and societal acceptance [22]. Commercial viability and acceptability of several applications will depend on more robust technology to be developed. Current operations of drones are highly restricted (such as limiting flights to VLOS) in nearly all European countries, which govern their own sets of rules and regulations for drones. Therefore regulations will need to be adapted to the expected operations and a new framework will need to be developed to harmonise drone regulation across Europe, to enable economically crucial operations such as BVLOS flights. Traffic management solutions are a key factor in enabling safe operations of such large numbers of drones. Key points in traffic management are the safe integration of drones into European airspace and the mitigation of cybersecurity threats. Developments in these areas will also require the formulation of industry-wide standards. Finally, societal worries concerning privacy and accidents will need to be addressed, as these create additional barriers that will need to be overcome [22].

In general, current European efforts have been focused on the development of autonomous flying capabilities and its associated technologies, providing platforms for drone flight management and information analysis such as data processing and 'Big Data' analytics. This amounts to multi-billion euro investments in defence, research & development and private stakeholders [22]. On a global perspective, the largest chunks of investment into the drone sector come from the United States (mainly on production of defence systems) and China (mainly on production of leisure units). The US is allocating EUR 1.4 billion a year on research & development in defence solutions, and EUR 20 million annually on air traffic management (which compares to the EUR 10 million annual investments in the Horizon 2020 programme). The accessibility of new venture funding and technologies originating from Silicon Valley have made the US a global leader in drone services and integrated platforms [22]. China has a strong position on leisure and commercial drone hardware across many different areas, including navigation, propulsion, batteries, cameras and sensors. Chinese player and global market share leader DJI is amounting investments exceeding EUR 100 million. The graph in Figure 3 indicates that the window of opportunity for Europe is now – since the compound annual growth rates for the drone market are expected to be globally rising at least until 2020 –. In this short period, all major operation types will grow about 20 – 40% (CAGR - Compound Annual Growth Rate) and raise a business value of more than 5.5 billion US dollars.



	Law Enforcement/ Public Safety	Precision Agriculture	Media & Entertainment	Retail	Inspection/ Monitoring	Surveying/ Mapping	Hobbyist/DIY	Education
2015	49,3	204,9	416,8	24	262,6	149,9	221,9	55
2020	212,9	1193,5	1323,8	119,7	1228,9	430,8	831,3	254,2
CAGR % (2015-2020)	33,99%	42,25%	26,00%	37,89%	36,16%	23,50%	30,23%	35,81%

Figure 3: Global UAS market size by application, 2015-2020 [44]

According to the European Drones Outlook Study [22], the most appropriate way for Europe to remain competitive and take the chance is to leverage assets in designing automatic flying capabilities, safety features and integrated platforms, and be highly efficient with its investment.

2.2 Description of Operations

The following section profiles the different business areas, in which the SESAR European Drone Outlook Study identified the largest potential for the application of UASs and a disruptive transformation of traditional operations. Apart from the expected economic impact for a time horizon up to the 2050s, the selective criteria included environmental benefits, increased global competiveness of the European market and expanding job opportunities [22]. This lead to the following selection: agriculture, energy, public safety & security, e-commerce & delivery and mobility & transport. Furthermore, we are briefly introducing additional industry sectors, which are also associated with benefits of a successful integration of drones into airspace, such as mining & construction, telecommunications, insurance and scientific research provided by universities. The last subchapter summarizes the described operations in an overview and proposes an applicable simplification for the further use in the scope of this deliverable.

2.2.1 Agriculture

Today's agriculture industry faces trends that are expected to challenge the business sector in the near future. On the one hand, the global population is steadily growing and expected to reach 10 billion by the year 2050. This leverages the demand for food in general, but also the accession of wealth is especially boosting the consumption of meat, fruits and vegetables, relative to that of cereals – which possess a higher rate of kcal/m². On the other hand, the enhancement of productivity is limited due to a shortage of natural resources, environmental damage and climate change. Together these trends are resulting in a high pressure on the industry sector, including threats to food security and sustainable growth [27].

In Europe, the Common Agriculture Policy (CAP), which is supporting the agriculture sector with subsidies and development programmes, has identified **precision agriculture** (PA) as a key strategy to meet these challenges. This approach shall optimise the usage of resources by providing insight through geospatial information systems. Obtaining the necessary information via high-resolution satellite imagery is neither cost efficient nor always locally available, which are two of the reasons why PA practise is "lagging behind the technological developments" [28]. Instead of satellites and traditional aerial photography, drones are capable of providing access to remote sensing and mapping services with a low initial investment, high spatial/temporal resolutions, and high flexibility in image acquisition programming [29]. In the end, these services can help farmers to make better decisions in an appropriate time scale and develop their business towards a Smart Farming concept [30].

Other primary applications of drones in agriculture are the **precise spraying of chemical agents**, seeding of plants and herding. On the contrary to the long range surveying missions which are mostly executed by fixed winged drones, these operations require light load vehicles that come with a higher agility and vertical take-off and landing (VTOL) capabilities. Some examples are Yamaha's Fazer and RMax remote helicopters, which are used in Japan since the early 90s to execute PA operations, such as the pest control of 35% of all rice fields, and are recently prepared to enter the USA market [31].

According to these assessments, the SJU expects the European agriculture sector to have a demand for up to 150.000 BVLOS drones in activity (125k in surveying and 25k in light load movement) until 2050. Since the comparably low risk of flying in unpopulated, rural environments and the limited social concern, they estimate that the development of this market starts in the next years, being responsible for up to 4.5 billion EUR of business impact (products, services, support etc.) until 2035 and another 4.2 billion EUR until 2050 [22].

2.2.2 Energy

The critical infrastructure of energy facilities is subject to frequent routine and non-routine inspections and maintenance operations. Commonly, these operations are executed by professional climbers, which use ropes or scaffold hangings to get access to the surveyed structures. Besides the risks for personnel and environment, the need to shut down facilities during the inspections is impacting the profitability. Furthermore, the upkeep of electricity grids and pipelines inflicts high costs when done manually by feed or with helicopter flights [21].

Drone operated monitoring is expected to improve quality and economic efficiency by two different types of missions. First, the opportunity to use drones for **localized inspections** – an application that is already used in the oil and gas industry to maintain offshore facilities and refineries –. Further development in remote flying and digital image processing, such as crack detection systems to analyse concrete structures [32], are expanding the capabilities of these drone operations. In addition, the legal basis to facilitate more autonomous flights, which enable frequent and less complex servicing, are expected to increase the demand for such applications up to 10.000 active drones in Europe by the year 2035 [22]. The second type of operations is concerning the **long distance surveying of more linear assets**. This application is presuming the feasibility of operating fixed-wind drones beyond visual line of sight in altitudes of at least 150 m above ground. Thus, the European energy sector has a demand for an amount of 1,000 additional drones, to survey the approximately 8 million kilometres of above ground assets [22].

The application of such services is principally not limited to energy facilities. But in this special sector, the high criticality and the economic benefits are facilitating the fast adoption, and are estimated to impact the European market with 1.6 billion EUR by the year 2050. This value could even be higher, if more futuristic applications are realized, such as tethered drones that convert wind energy to electricity and deliver it to a ground station [22].

2.2.3 Public Safety and Security

The need for cost efficient, flexible aerial imaging and coordination in combination with a public interest of supporting services, such as police, firefighting and border control, indicates that the sector of safety and security (PSS) is going to be an early adopter of drone operations. Therefore it can be expected that soon, the drone will be a standard emergency management tool to receive real-time information as today are e.g. helicopters. The challenges faced here are not necessarily based on technical concerns, since affordable and accessible systems enable the collection of data readily. Instead, current projects focus on how to make best use of the data and support the decision making process [33]. In addition, other projects help to set up standard operating procedures for flying drones in emergency situations, training outlines and instructions for pilots as well as for operators [34].

The SJU expects three main types of operations for PSS: In a first wave, it is expected that **localized operations** will take place, executed by first responders and on-site forces that are equipped with multicopters inside their vehicle. These are equipped with the necessary sensor arrays to achieve the intent of the particular units. For instance, thermal imaging for firefighters or search and rescue missions can be mentioned. In a second wave and by a European harmonisation of BVLOS flight rules, these specialised UASs would be situated at **local drone depots**, ready to be activated and directed to the field of operation. Apart from that, the third type of operations covers large areas and distances by providing fixed-wing drones for purposes of **border or maritime surveillance** [22].

The demand for drones in activity will peak in the next 10 years with approximately a 100,000 units. After that the total numbers will decrease to 60,000 in 2035 and 50.000 units in the year 2050. The reason therefore are the above described more efficient usage of capabilities by advances in autonomy technology and the resulting opportunity to centralize drone depots, so only rural or special task forces will be equipped with in-vehicle drones. The economic impact thereby is estimated to be about 1.4 billion EUR until 2035 and 1.2 billion EUR by 2050 [22].

2.2.4 Delivery and e-Commerce

The logistics industry is challenged by similar trends as the future agriculture sector: first, a steady growth of the global population, which is leading to a higher urbanization and demand of parcel deliveries. Second, the need to respect the business affected environment by reducing pollution and congestion caused by traffic. At the same time, a probable climate change can alter the conventional distribution ways, for instance: infrastructural restrictions by the thawing of ice crossings [35] and permafrost [36][38] in polar and far north regions.

It is unclear in the accounted studies if drones are capable of resolving these issues and consequently, current efforts have to be rated as visionary [37]. One of the benefits of drones in **urban areas** is, under the assumption that the sky is unlimited, that they are avoiding any traffic jams. At the same time, they are (individually) faster and more flexible than the conventional methods. Anyway, the operating costs have to be calculated against each other. The SJU exemplified that, with the expected developments, the break-even point can only be reached in the premium segment of same-day deliveries and with small packages about 5 lb, since the drone operating costs are most likely at 50,000 – 90,000 EUR per year. Furthermore, these operations will only be profitable under the constraints that the consumer is willing to pay approximately 10 EUR per shipping for this value added service and that drone technology is robust enough to allow for 5k – 9k short distance deliveries (approx. 30 min. flights) per year and unit. In addition, it is a prerequisite that one human operator will be allowed to control multiple drones at the same time and beyond the visual line of sight. Otherwise, the annual operating costs would be even higher.

Other scenarios assume that instead of the urban environment, drones will provide delivery for **rural areas**, traditionally difficult to access and less frequented. In this case, depot-to-depot transportation is cost-efficient, too. For instance, on remote islands this method could replace a transport chain that consists of cars, trucks, boats and postal workers [37]. This approach can also be combined with other aeronautical transport technologies, as for example in Amazon's U.S. patent 9,305,280, which proposes an unmanned airship that serves both, as hub for small delivery drones and heavy load carrying vehicle for long distances.

Based on the assumption that BVLOS regulations are established harmonically throughout Europe in the next 5 years, the sector wide number of drones in activity would rise quickly up to 70,000 until 2035 (business impact: 2 billion EUR) and an additional 30,000 until 2050 (2.9 billion EUR).

2.2.5 Mobility and Transport

Commercial and business aviation are sectors with a high competiveness and non-negotiable safety expectancies. Consequently, industry shows interest in ways to decrease operating costs and rotorcrafts maintaining a safe and effective conduct of the flight at the same time. Related to this, manufacturers (e.g., Boeing) are currently researching the opportunities to lower costs by reducing the headcount of the cockpit crew to a single pilot. Furthermore, this can be seen as transition phase for introducing a full autonomy later on.

According to the SJU, the adoption of unmanned or more precise, **unstaffed passenger aircrafts**, depends not only on technological feasibility. Despite the fact that autopilot capabilities are in an advanced state already, regulations and public acceptance need to be benevolent. They expect such a development to be highly linked to success and reception of other technological uses of autonomous systems, as for instance self-driving cars [22].

Based on these assumptions, it is anticipated that the propagation will start with gradual progression starting in the mid of the 2040s. A transition phase, starting with safety redundancy to optionally piloted to fully unstaffed solutions is expected. Finally, this could lead to approximately 12.000 autonomous air- and rotorcrafts until 2050, representing 28% of the then expected fleet size. Early adopters will be located in the cargo sector, followed by business travel and lastly scheduled airlines. In the long-term, this results in a total business impact of 3.7 billion EUR [22].

The studies that this summary has focused on **were not considering individual or multi-person air taxing in urban environments** to be substantial in the next 30 years. Hence, it has not been identified as crucial development that has to be taken into account in this domain analysis. Examples for research describing this type of autonomous air vehicles are Project Vahana (A³, Airbus Group), capable of transporting passengers approximately 80 km, or the comparable concept Volocopter, which successfully performed a test flight in Dubai in 2017.

2.2.6 Other Operation Sectors

Various other business areas benefit by the previously mentioned operations types that are best described as inspection and surveying missions, facilitating aerial photography, image processing and remote sensing. They also have the potential to utilize a high amount of active drones, but contribute with a lower economic impact of circa 1 – 2 billion EUR in total. Such operations will be situated at construction & mining sites with a demand of approximately 42,000 active drones, media & entertainment with 30,000 drones and 15,000 drones operated by purposes of the real estate sector. Another 15,000 are distributed among university research, telecommunication and in the insurance branch.

2.2.7 Summary of the Expected Development for Drone Operations in Europe

As shown in the former description of potential business sectors for drone operations, the future of the European airspace has to take into account multi-diverse industries. The following Figure 4 summarizes the sectors characterized by the work of the SJU and adds the likely flying modes, operation and vehicle types.

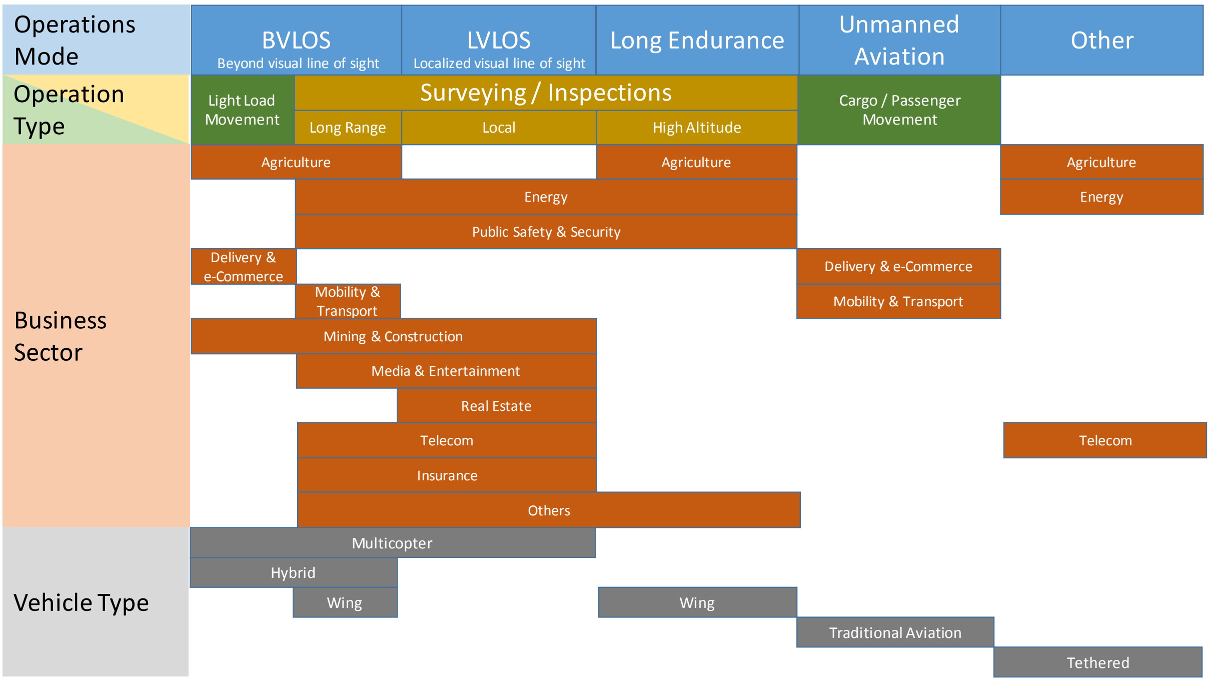


Figure 4: Overview of future drone operations by business sector

Since the **IMPETUS project necessitates a classification model** to systemize information packages and arrange research efforts, a simplification of this figure is reasonable to facilitate an efficient working concept which can be enriched in the later stages.

According to the information gathered by the descriptions, the most significant differences in drone operations are the operation modes (such as BVLOS), the operation type, which determines the flight behaviour (e.g. *surveying* could indicate a higher altitude flight with extended range and multiple horizontal legs), and the area of operation (urban vs. rural). Taking into account the scope of the IMPETUS project (immediate time horizon starting with 2020, low level airspace only and scalable to sufficiently cover great numbers of drones in activity), the modes *Long Endurance*, *Unmanned Aviation* and *Others*, can be neglected for now, since they do not show high numbers, are set far in the future or otherwise irrelevant for the low level airspace. Furthermore the *Operation modes* can now be reduced to three essential types depending on the main purpose:

- **Surveying**: Observation of broad areas, e.g. for mapping purposes;
- **Inspections**: Local examinations of horizontal or vertical structures, e.g. for crack detection;
- **Light Load Movement**: Point to point carrying of loads, e.g. transportation or spraying.

The numbers taken from the Drone Outlook Study of the SJU [22] indicate that the most likely scenarios for 2035 lead to a distribution of such operations with about 45% in the surveying segment (185,000 **d**rones **i**n **a**ctivity), 30% in localized inspections (110,000 dia) and 25% in light load movement (95,000 dia). Based on the expectations that rural and industrial applications are adopted and enabled earlier than operations in rather urban environments, the total numbers will be constituted over time. These simplified proportions are represented in the simplified categorization in Figure 5. It also shows the most probable type of UAVs that will be used in such operations.

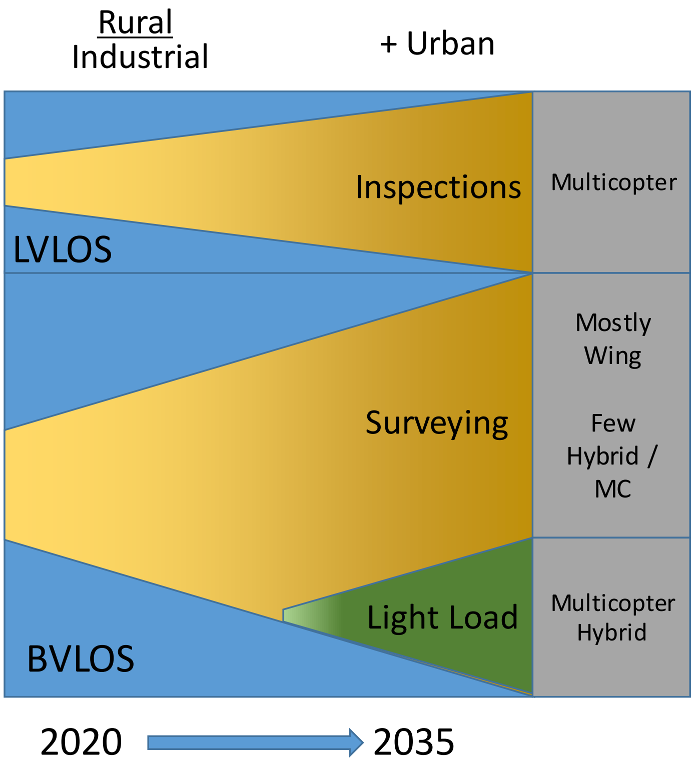


Figure 5: Simplified categorization of operation types

This classification does not impose to cover all possible intricacies or be unchallengeable; it merely depicts the current state of knowledge about the essential, future operation types which will be covered by IMPETUS.

2.3 Description of Stakeholders

This section outlines the various users and other stakeholders that are affected by a future U-space system. Figure 6 provides an overview of all of the stakeholders outlined in this section and their relation to the U-space environment.

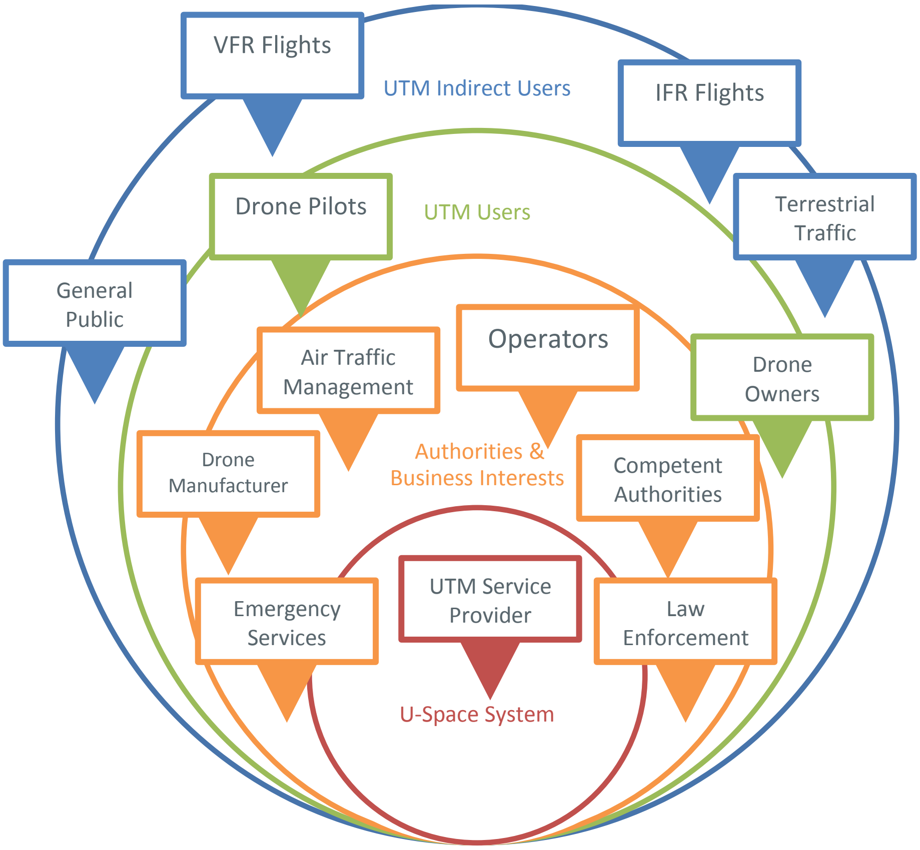


Figure 6: Overview of identified U-space stakeholders and their relation to the U-space environment

Based on this depiction, we can identify 4 main categories of stakeholders: Authorities, protagonists with business interest, actual users of a U-space environment and indirect users. The next subchapters will detail these different groups.

2.3.1 Drone Pilots

Drone Pilots are users of the U-space environment for both leisure and commercial purposes. They are the ones responsible for the safe execution of a drone flight. Drone Pilots can be categorized by the type of operation they perform, as well as the license they require to operate a specific drone. National regulations for licensing, authorisations and identification may vary. Their interaction with the U-space environment will be the use of U-space related services (for all phases of flight: strategic, pre-flight, in-flight and post-flight) [1].

2.3.2 Drone Owners

A **Drone Owner** is a person/entity that is in legal possession of a drone, and depending on national regulations, might be required to register himself/itself and the drone. Interactions with U-space fall under the use of strategic services, specifically concerning registration [1].

2.3.3 Drone Manufacturer

Drone Manufacturers are stakeholders in the U-space environment, given that they will be required to construct drones based on the specifications set out by the U-space system as well as by the **National Competent Authorities**. Furthermore, the technology that they can implement onto a drone platform will shape the operating context of the U-space environment. Interactions with the U-space system therefore include the adherence to U-space specifications as well as the provision of data (drone characteristics, performance values, contingency features, etc.) to the U-space system [1].

2.3.4 Air Traffic Management

Air Traffic Management (ATM) is a stakeholder and user of the U-space system, as it relies on U-space to provide accurate drone-traffic information for separation purposes, the safe and predictable implementation of contingency measures, functioning detect and avoid systems and adherence to aeronautical standards. Interactions of ATM with the U-space environment will be the reception of drone-related traffic information.

2.3.5 U-Space Service Providers

U-Space Service Providers have the prime stake in the U-space system, as this entity encompasses any provider of U-Space services, such as data provision and traffic control. Core interactions with the U-space environment encompass the exchange of information between members of the U-space system as well as between U-space and ATM systems [1].

2.3.6 Public Entities

The **National Competent Authorities** have a substantial stake in the U-space environment, given that they authorise and oversee all operations to be held within national airspace. Primary interests include the regulation of drone traffic and the way that traffic is integrated into the airspace system. Foreseeable interactions with U-space include the certification of development and the operation of the U-space system as well as its components, maintaining and updating restrictions/permissions to operation and the analysis of data [1].

Law Enforcement is considered a stakeholder and user of the U-space system. The stakeholder function comes from the necessity to restrict or prioritise access to certain chunks of airspace for security reasons. Law Enforcement will also use U-Space services for their own operations of drones, i.e. for traffic surveillance and prosecution as well as observation purposes. Foreseeable interactions with U-space systems include the implementation of geofencing on specific parts of airspace, as well as the reception of drone traffic and registration information [1].

Emergency Services have a similar use case to those of Law Enforcement, especially concerning the restriction of access to specific chunks of airspace for emergency procedures as well as the use of their own drones to assist in emergency service provisions. Hence they are both stakeholders and users of U-Space services. The implementation of areas for geofencing will be a key interaction between Emergency Service providers and the U-space environment [1].

2.3.7 Operators

Operators are entities accountable for commercial operations of drones, which are authorised by the **National Competent Authorities**. Operators manage a fleet of one or several drones and will employ **Drone Pilots** as well as other personnel to execute the authorised operations. Operators' interactions within the U-space environment will be as a stakeholder (given that the type of operations performed will influence the development of U-Space services) and as a user (related to the use of fleet-oriented services) [1].

2.3.8 Manned Aviation

Manned aviation can generally be divided into two parts: **IFR Flights** and **VFR Flights**

IFR Flights will rely on Air Traffic Control (ATC) for separation from drone traffic. Therefore, direct interaction with the U-space environment is not foreseen [1]. **VFR Flights** will be a lot more likely to encounter drone traffic, given that the operating altitudes are usually lower than those of IFR Flights, and the operating environment includes flights in uncontrolled airspace. In that aspect, pilots of VFR Flights have high interests in drones being detectable and rely on drones implementing collision avoidance systems. Their interactions with the U-space environment include the provision of position and flight plan information to the system as well as the reception of drone traffic information [1].

2.3.9 Society

Terrestrial Traffic (which includes ground, rail or sea traffic), similar to the requirements of **VFR Flights**, will expect drones to be detectable and to implement collision avoidance technology, given the low operating altitudes possible for drones. It is not foreseen that Terrestrial Traffic will use U-Space services, unless they have specific use cases for doing so [1].

The **General Public** will function as a stakeholder in the U-space environment. Public acceptance of drones and related operations is a key factor in shaping the limitations and restrictions of the U-space system and the commercial application of drones in general. On the other hand, the General Public will also make up a large portion of the user base of drone-related services, which will shape how U-space operates. The General Public expects drones to be detectable, follow national regulations concerning safety and privacy as well as utilizing active collision avoidance systems to air traffic and structures. Direct interactions of the General Public in U-space systems are not foreseen.

Recent surveys for Germany identified that the public attitude towards UAV operations is correlating with the associated public benefits. Thus, the highest acceptance exists for drones in disaster control (89%), inspection of technical infrastructure (80%) and agriculture (63%). Although strong privacy concerns exist (84%), the operation for public safety and security is also rated positive with 59%. On the contrary, the operations with less profit for the society have a low acceptance, e.g. leisure flying (28%) [42].

2.4 U-Space Domain Context

With the purpose to fully understand and represent the domain we are analysing inside this deliverable, the following part will explain how different regulations and concepts UTM influence the current situation as well as the expected development of the U-space vision of the SJU.

2.4.1 European Regulations

The first chapter outlines the current state of drone-related regulations and imminent EU-wide regulatory implementations with the aim of a system wide harmonisation.

2.4.1.1 Current (National) EU Regulations

As there is no regulation from the European Aviation Safety Agency (EASA) in place yet, national competent authorities are providing their own regulations on drone operations. As indicated in the examples listed in Table 2, this causes discrepancies between the regulations of different EU member states. Consequently, there are no harmonized and platform independent methods for active UTM available.

Table 2: Showcase of current national regulations in various European countries

Country	Drone/Operational Classification	Drone/Operational Classification Description	Traffic Management
Austria [2]	"Klasse 1"	• Drone operations in VLOS • Maximum operating altitude 150m AGL • Competent authority authorisation is required for drones heavier than 250g and operations higher than 30m AGL • Operational restrictions based on mass and operational area • Flight via "first person view" goggles only allowed with additional bystanders	None "Drone Space" app available for the provision of aeronautical information services (AIS)
	"Klasse 2"	• Drone operations BVLOS • Certified as civil aircraft • Adherence to aeronautical standards • Require drone pilot license to operate	
Germany [3]	Mass > 250g	• Name and address of operator must be placed on the drone • Maximum operating altitude 100m AGL (if drone is a multicopter) • Drone operations in VLOS • 100m horizontal distance of crowds and specified locations • Flight via "first person view" goggles upwards of 30m AGL only allowed with additional bystanders	None

Country	Drone/Operational Classification	Drone/Operational Classification Description	Traffic Management
	Mass > 2kg	• All of the above • Pilot license or competent authority approval is required	
	Mass > 5kg & mass < 25kg	• All of the above • Competent authority operational authorisation is required	
Spain [4]	VLOS Operations	• Mass between 2kg and 10kg • Maximum operating altitude 120m AGL • 50m horizontal distance from people and properties • Competent authority approval of operation • Name and address of operator must be placed on the drone • Drone pilots must hold a remote pilot license	None "ENAIRE drones" app available for the provision of aeronautical information services (AIS) and initial functionalities for the flight plan design
	BVLOS Operations	• All of the above • Live video feed to pilot • Competent authority approved equipment for detect and avoid **OR** establishment of temporarily segregated area (TSA)	
	Operations requiring prior authorisation	• Mass > 25kg **OR** • Nocturnal operations **OR** • Operations within urban areas or near groups of people **OR** • Operations within controlled airspace	
United Kingdom [5]	Mass < 20kg	• Operations in VLOS • Maximum operating altitude 120m AGL • 50m horizontal distance from people and properties • 150m horizontal distance from crowds and built up areas • Operational restrictions in specified areas • Flights with camera-fitted drone and within horizontal restrictions require competent authority approval and demonstration of piloting competence	None "Drone Safe" app and website available for the provision of aeronautical information services (AIS)
	Mass > 20kg	• Certified as civil aircraft • Adherence to aeronautical standards • Require specific approval to operate	

2.4.1.2 Imminent EASA Regulations

The European Aviation Safety Agency (EASA) has established three categories for the classification of drones, which are subjected to different safety requirements based on the risk their operation poses. These three categories are [6][7]:

- **Open**: Drone operations of identified low risk, which do not require prior authorisation from the competent authority;
- **Specific**: Medium risk category of drones which do require prior authorisation to operation from the competent authority. The authorisation includes an operational risk assessment to identify necessary mitigation measures;
- **Certified**: This category involves high risks and requires the certification of the unmanned aerial system (UAS) to be operated, a licensed remote pilot as well as an operator approved by the competent authority.

EASA published a prototype regulation for the “open” and “specific” drone categories in August of 2016, and is pending to be implemented this year [6]. The prototype regulation [7] states that, for the “open” category, risk mitigation will be performed through the application of safety measures, such as limitations on operation, geofencing, and requirements specific to a drone’s subcategory (C0 to C4). Noteworthy, extracts of the operational requirements based on the subcategory system include that the maximum operational altitude of the most complex system (C4) is 150m, that drones of class C2 and upwards require active geofencing systems as well as active transmission of their position and status and that, if the airspace of operation requires such provisions, the UA has to receive information about flight plans, temporary restricted areas and position information of other UAs and manned aircraft.

The “specific” category will be subjected to operation-specific risk assessment measures as well as operational authorisations issued by the competent authority or by the holder of a Light Unmanned aircraft operator Certificate (LUC) with privileges to authorise operations. The prototype regulation further calls on the competent authorities to define special zones where unmanned aircraft (UA) operations are not permitted or require authorisation, where UA shall comply with defined technical or performance specifications and zones which require adherence to environmental standards. The prototype regulation also foresees a transitional timeframe of three years after application of the regulation, during which associations and clubs may continue to operate UAs under operational authorisations from the competent authority, before regulations take effect.

2.4.1.3 Safety and regulatory needs

Development of the regulatory framework for the integration of drones into the aviation system is being performed by the EASA. The agency´s aim is to set a level of safety, environmental protection, security and privacy concerning the operation of drones that is acceptable to society [8]. The implementation differs from that of manned aviation, through the emphasis on a progressive and risk-based approach, with special focus on the aircraft, mission and operating environment [8]. This is where “objective-based” design requirements come into play, which links the operational environment and procedures of the drone to industry standards. As an example of this approach, [8] details: “the operation close to crowds could be acceptable when the drone has some additional functionality (e.g. automatic loss of link procedures), and the competencies of the remote pilot and the operational procedures are adequate.” The implementation of regulations is closely linked to the level of integration of RPAS into the existing airspace system and the development of drone operation related services (U-space) in very low level (VLL) airspace – See section 2.4.2.2 and section 2.4.2.2.2 for further details. The regulatory approach is depicted in Figure 7.

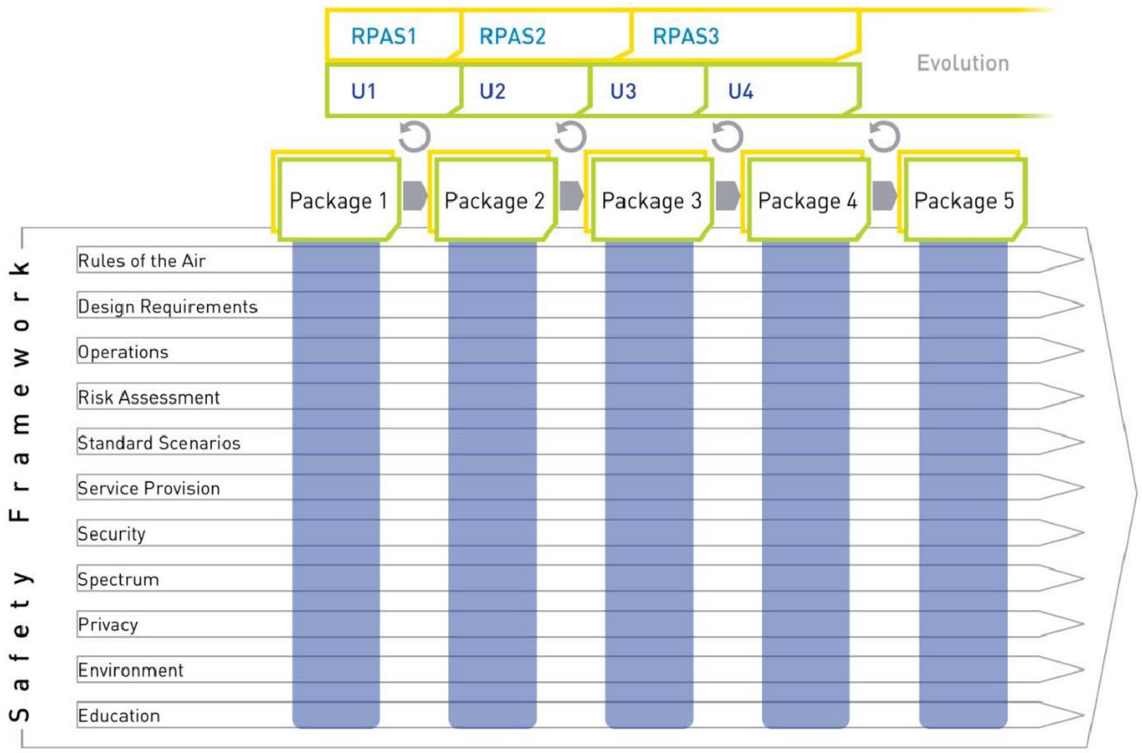


Figure 7: Depiction of the regulatory approach to the implementation of regulations concerning the operation of drones. The illustration is cited from [8].

2.4.1.4 Standardization

Given the wide variety of aircrafts within the drone family – including large and complex aircraft as well as small consumer-electronics aircraft – standardization efforts shall be designed in such a way that it fits the type of drone, the type of operation as well as its operational environment [8]. The European UAS Standards Coordination Group (EUSCG) has been established for the development of drone-related standards. Its main deliverable is the European UAS Standardisation Rolling Development Plan (RDP), which reflects the current status quo of the development of standards [9]. As described in [8], the "main task of the EUSCG is to develop, monitor and maintain an overarching European UAS standardisation rolling development plan, based on inputs from the EUSCG members, while addressing the needs identified in the European ATM Master Plan." Furthermore, [8] lists the major standardization activities which are required for the safe integration of drones, linked to the respective fields of operation and separated by EASA drone categorization. Figure 8 cites the illustration provided by [8] concerning these activities.

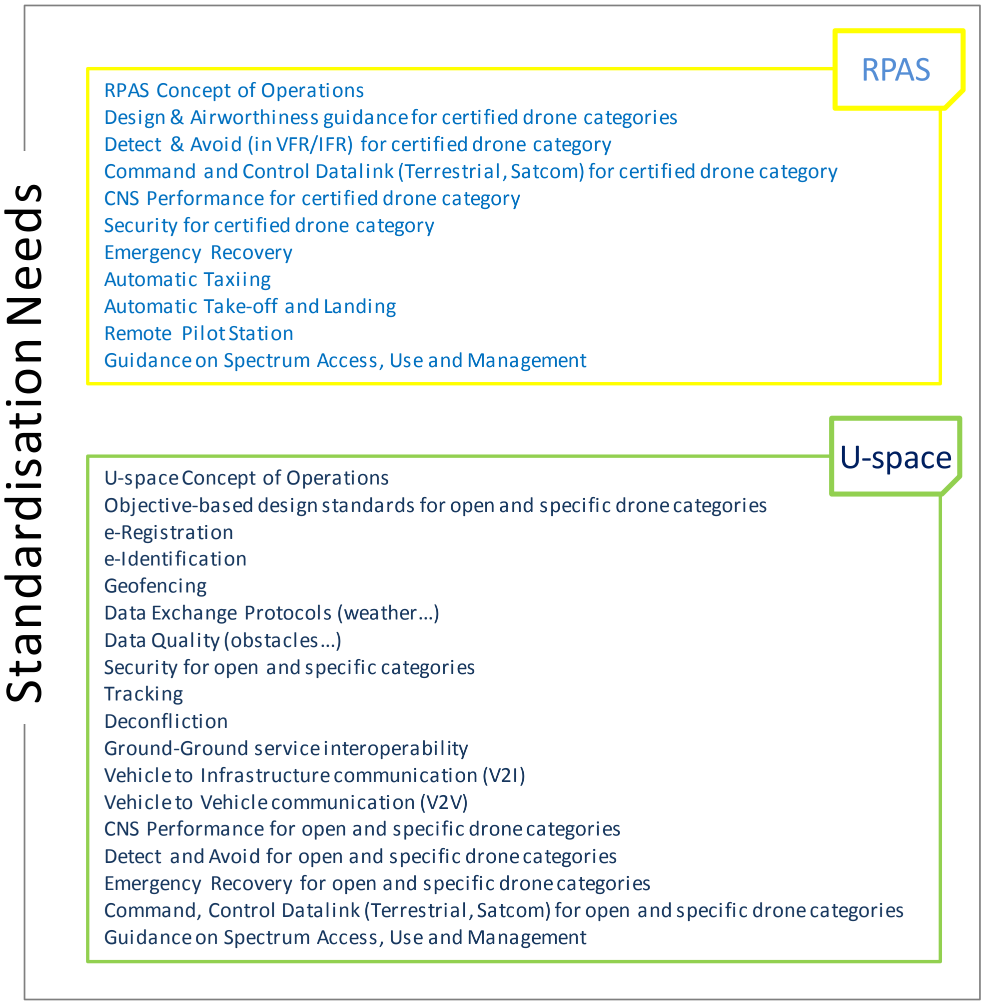


Figure 8: Depiction of crucial standardisation requirements for the implementation of drones into the current airspace system[2]. The illustration is cited from [8].

2.4.2 Drones' Traffic Management Concepts

This chapter outlines concepts currently in development for the provision of drones' traffic management services.

2.4.2.1 Currently available drones' traffic management services

There are currently several mobile apps on the market to fill the need of drones' traffic management service provision. Companies such as Altitude Angel, Airmap and Unifly provide third party applications to assist drone operators in providing information on no-fly zones, NOTAMS, airborne traffic and regulations as well as the submission of flight plans to the competent authority. As an

[2] Drones of the "certified" category fall under "RPAS"-regulations (see section 2.4.2.2.2 for further details), and drones of the "open" and "specific" category fall under "U-space" regulations (see section 2.4.2.2 for details).

example, Altitude Angel is cooperating and coordinating with NATS to provide drone operators with easily accessible information on airspace regulations [10]. For further details, please concern chapter 2.7.

2.4.2.2 European drones' traffic management concept

The following chapters list the emerging concept within the European Union concerning the provision of drones' traffic management in European airspace.

2.4.2.2.1 U-space

Following the Warsaw Declaration on drones in 2016, the European Commission officially recognised the potential of drone related services and emphasized the need to take urgent action on the integration of drones in European airspace. The framework established for this integration is the, so-called, U-space, which consists of "a set of new services and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones [11]." A strong emphasis was placed on the fact that U-space should be highly flexible and adaptable, to address the needs of the missions and to serve all kinds of drone users and categories. U-space shall allow the smooth operation and integration of drones in all types of airspace [11]. Therefore basing the concept on existing ATM frameworks, such as defining a segregated volume of airspace for the sole use of drones, is out of the question [11].

The development of U-space is based on a set of key principles, which are detailed in the U-space Blueprint [11] and can be summarized as follows:

- Safety of all airspace users;
- Scalable and flexible to changes in demand, volume, technology, business models and application;
- Enable high-density operations of multiple automated drones;
- Competitive and cost-effective service provision at all times;
- Use existing aeronautical service infrastructures;
- Adopt technologies from other sectors;
- Use risk-based and performance-driven approach.

The services being developed for U-space do not aim to replicate the function of ATC, but to "organise the safe and efficient operation of drones and ensure a proper interface with manned aviation [11]." The implementation of these services will happen in phases, labelled "U1" to "U4" (see Figure 9). The foundation services (U1) of e-registration, e-identification and geofencing are currently rolled out and the development of initial services (U2) – tracking, flight planning, weather, aeronautical information, emergency management, etc. - is concerned in present projects [8]. U3 will focus on enhanced applications and missions in high density areas, as well as make use of new technologies and higher automation to increase operations in all environments. With these improvements, U3 services should allow the initiation of new types of operations, such as air urban mobility [8]. With the completion of U4 services, the U-space environment will offer full integration with manned aviation and rely heavily on automation, connectivity and digitalisation [11].

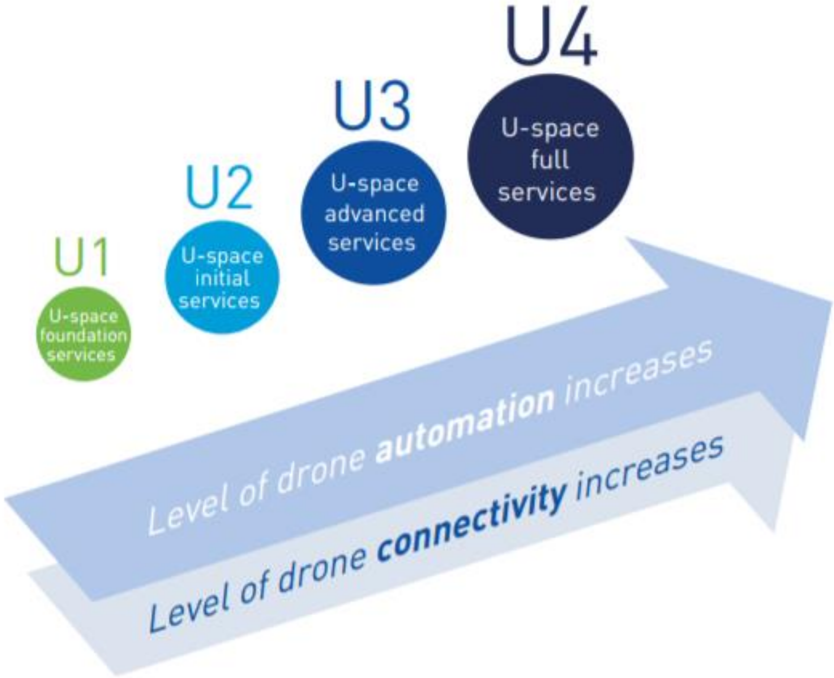


Figure 9: Depiction of the development of U-space services, based on the level of automation and drone connectivity. The illustration has been cited from [11].

2.4.2.2.2 IFR RPAS integration with manned aviation

U-space services are initially intended for traffic of highly automated fleets of small drones in very low level (VLL) airspace. The operation of larger drones, specifically RPAS – for state, military, cargo and other civil operations – will be built into the existing ATM system and subjected to ICAO SARPs to be harmonised globally [8]. Progress on the accommodation of large drones as well as the development of U-space services will run in parallel, as depicted in Figure 10.

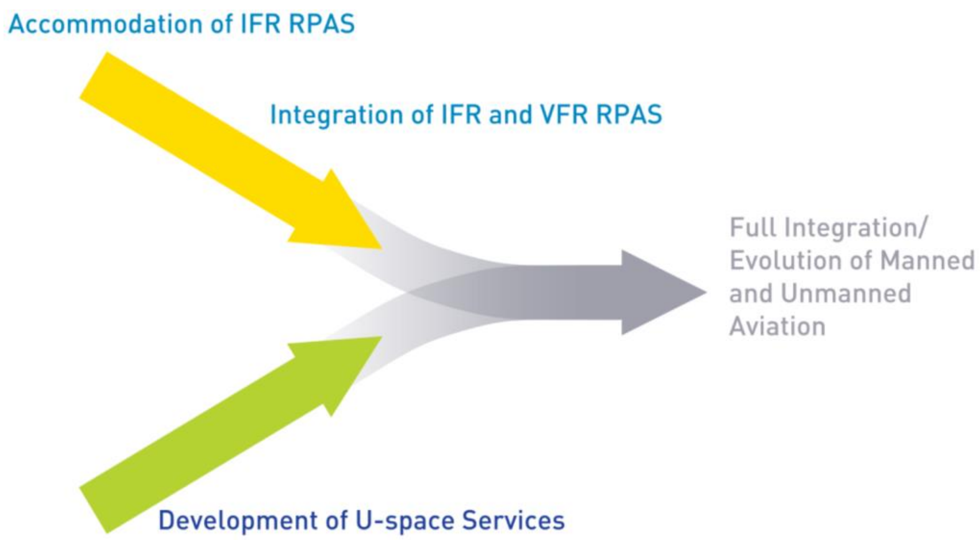


Figure 10: Depiction of the parallel development of IFR RPAS and U-space Services. The illustration is cited from [8].

Focusing on the accommodation of RPAS alongside manned aviation, adherence to ICAO´s key principles is crucial. These principles include compliance with operational procedures that exist for manned aviation, upholding of the current level of aviation safety and conform to manned aviation standards [8]. Similar to the development of U-space, the integration of IFR RPAS will occur in phases, based on the capabilities of their on-board equipment. Crucial technologies will be Detect And Avoid systems (DAA), systems to deal with contingency situations, communications and security systems. Initially, IFR RPAS will operate in airspace classes A-C, but will be systematically introduced into more "liberal" airspaces (such as ones with VFR traffic) as these systems progress. Figure 11 depicts the expected timeframe of the co-development of RPAS and U-space services, as of 2018.

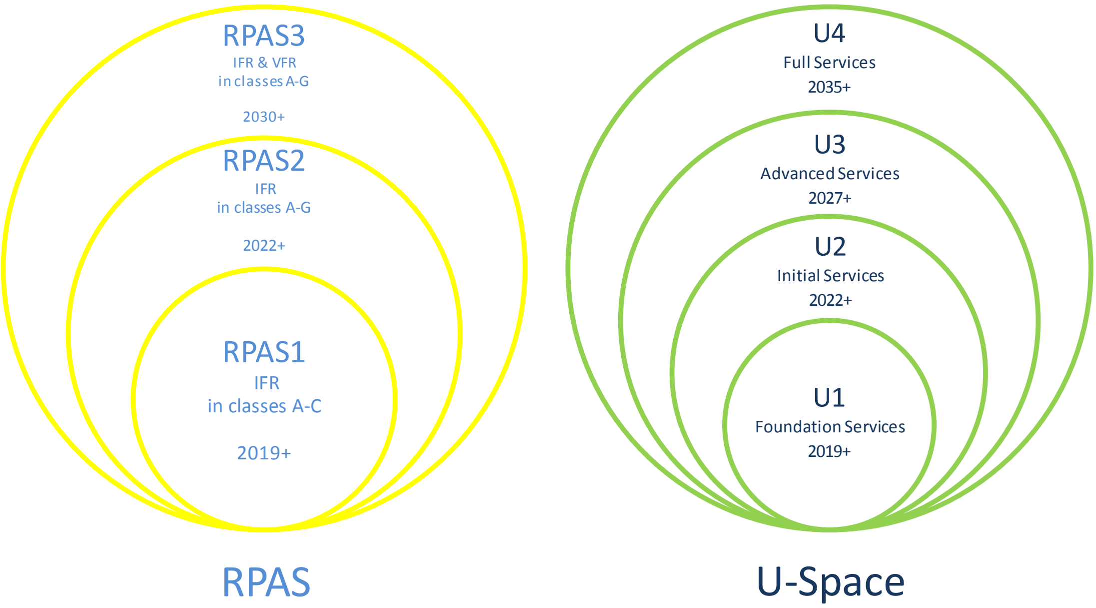


Figure 11: Expected time horizon for the co-development of IFR RPAS capabilities and U-space. The illustration is cited from [8].

2.4.2.3 Concept of UTM in the United States

The National Aeronautics and Space Administration (NASA) is cooperating with the Federal Aviation Administration (FAA) to develop a UTM solution for the United States, called Unmanned Aircraft System Traffic Management (UTM – same acronym as the general term). (Note that in the United States' UTM environment, the term "UAS" is used rather than the term "drone", but they describe the same concept). As in the European design (U-space), the solution focuses on enabling multiple BVLOS operations at low altitudes (below 400ft (121.92m) above ground level (AGL)) [12]. Together with industry stakeholders, NASA and the FAA established the "Research Transition Team" (RTT), to develop the UTM use cases, system architecture, navigation, communications and sense and avoid technologies [12]. The scope of the UTM development envisions three operating environments: first, operations in uncontrolled airspace (class G); second, UAS operations inside controlled airspace but segregated from controlled traffic; and third, UAS operations alongside controlled air traffic. Initial research is performed only within the scope of uncontrolled airspace [13]. The UTM approach is that of an incremental risk-based model, where operations of UAS are limited based on the risk impact of the operating environment and the level of technology available, initially limited to VLOS operations, segregated from other airspace users (AUs) in sparsely populated areas and extending to BVLOS operations once the necessary on-board technologies have become available [13]. As in U-space, UTM does not envision the provision of a segregated airspace for UAS operations [13]. An important pillar of UTM operations is the continuous sharing of information between UTM, UAS services and UAS operations, which will be subjected to verification and validation efforts [13]. A further, fundamental goal of UTM development is to raise public acceptance of UAS operations, by addressing key issues such as validation of operation, privacy, security and the environment [13].

The proposed architecture of UTM relies on three main components, which are organised as depicted in Figure 12 [13]:

- UAS Operators;
- UAS Service Suppliers (USS);
- Regulator/Air Navigation Service Provider (ANSP).

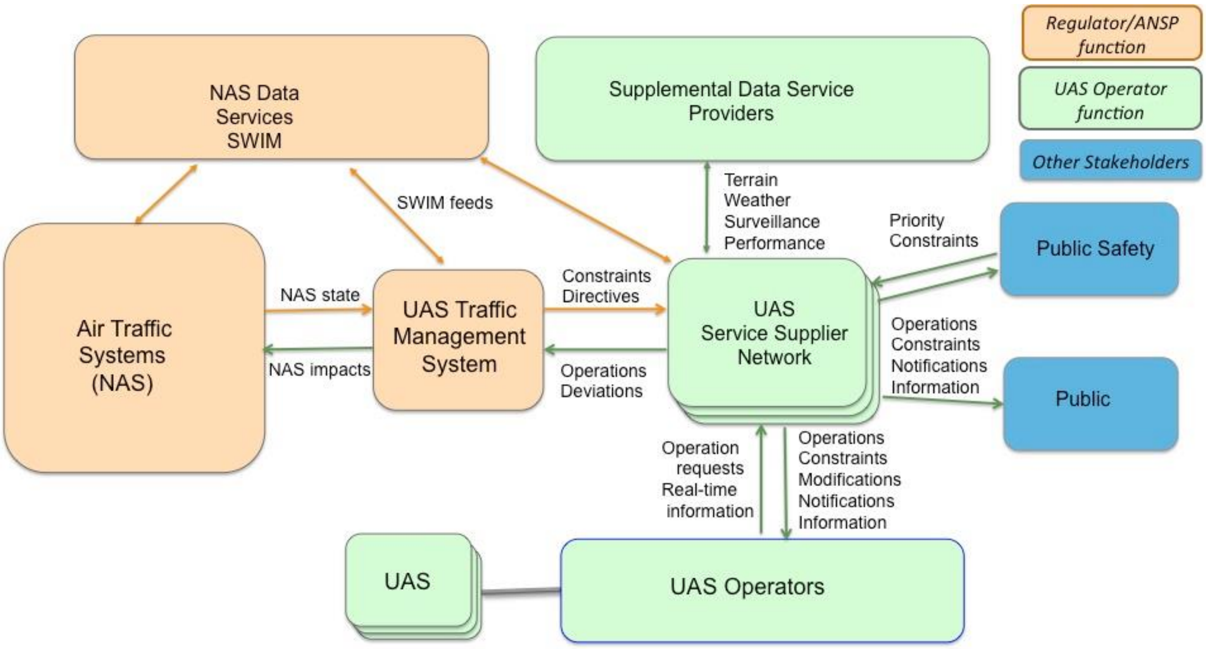


Figure 12: Depiction of the high level organisation of the NASA/FAA proposal for a UTM system. Illustrations has been cited from [13].

The system described in Figure 12 (cited from [13]) calls on the regulator/ANSP (which both falls on the FAA in the US) to operate the UTM system, its interface with ATM and to provide directives and constraints to the UAS operations via the USS. USS are cloud-based services intended to be provided by UAS operators, commercial or US government entities. The provision of these services is not intended to fall under the responsibility of the regulator/ANSP, but of that of the UAS Operator. An overview of regulator/ANSP and UAS Operator/USS responsibilities is listed in Table 3.

Table 3: Overview of UTM system stakeholder responsibilities. Cited from [13]

Regulator/ANSP Responsibility	UAS Operator /USS Responsibility
• Set performance based regulatory environment • Define and update airspace constraints • Foster collaboration among UAS by setting up architecture for data and information exchange • Define data and information exchange specifications for collaboration among multiple stakeholders/operators • Real-time airspace control if demand/capacity imbalance is expected • Provide notifications to UAS operators and Public • Set static and dynamic geo-fence areas • Provide flexibility as much as possible and structures (routes, corridors, altitude for direction, crossing restriction) only if necessary • Manage access to controlled airspace and entry/exiting operations	• Register UAS • Training and qualification of operators • Avoid other aircraft, terrain, and obstacles • Don't harm people and animals • Respect airspace constraints • Avoid dangerous and incompatible weather situations • Follow performance based regulation • Broadcast identity – no anonymous flying • Broadcast intent • Provide access to operations plans • Detect, sense and avoid manned aircraft predicated on right of way rules • Status and intent exchange according to ANSP standards • Participate in collaborative decision making • Contingency planning and response (large-scale outages – cell, GPS, security, an unanticipated severe weather)

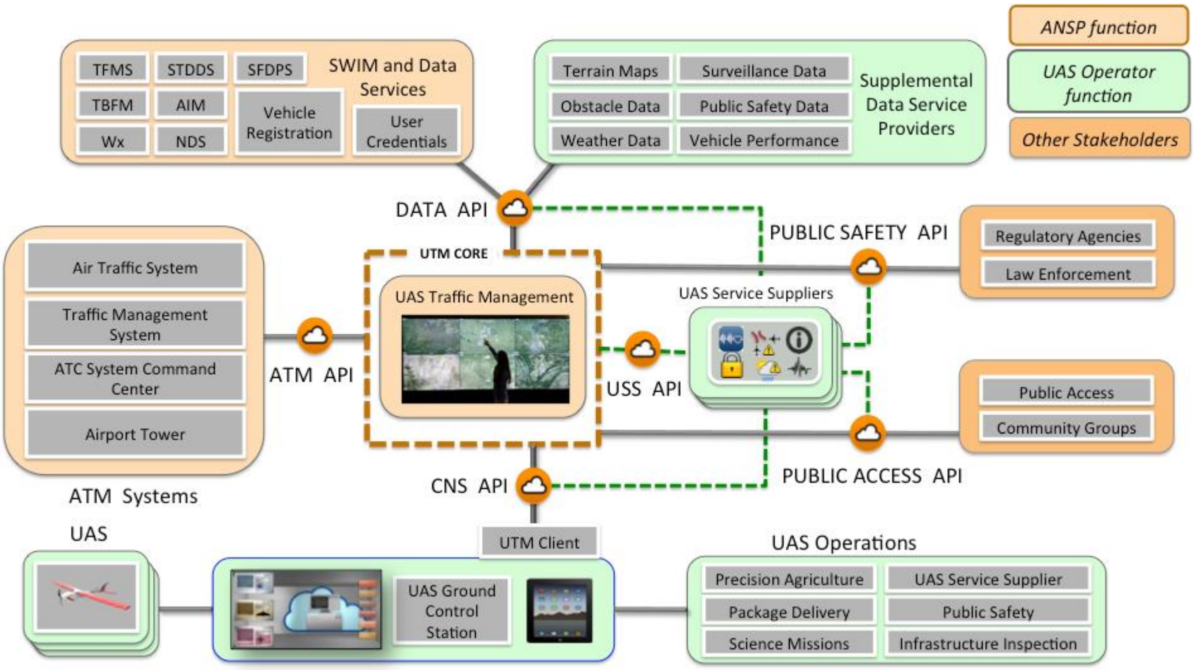


Figure 13: Depiction of the NASA/FAA envisioned UTM architecture. The illustration is cited from [13].

The UTM system will be designed to have access to all operations and is informed about deviations with impact on the airspace. Interactions between the ANSP and USS will be based on common Application Programming Interface (API) and Interface Control Documents (ICD) and follow an authentication scheme to ensure consistency and cyber security. De-confliction and collision avoidance will also fall on the USS, and in certain cases be reduced to the responsibility of the UAS operators affected. Real-time collision avoidance is expected to be handled directly by the UAS in conflict. The concept specifically states that no third-party entities may manage the airspace. Finally, performance and reporting requirements will depend on the operating environment (operations in remote areas will have less stringent requirements than those in urban areas). The intended UTM system architecture is summarized in Figure 13.

2.4.3 Technological Developments and Assumptions

For the concept outlined in this deliverable to work, the operating environment assumes a harmonised European implementation of U-Space U1, U2 and U3 services and drone capabilities, which are summarized in Table 4.

Table 4: Overview of U-Space service and drone capability assumptions for the content of this deliverable [8]

U1	**U-space services**	**Associated drone capabilities**
	• **e-Registration** • **e-Identification** • **Pre-tactical geofencing**	• e-Identification • Geofencing • Security • Communication, Navigation and Surveillance • Command and control
U2	**U-space services**	**Associated drone capabilities**
	• **Tactical geofencing** • **Tracking** • **Flight planning management** • **Weather information**	• e-Identification • Geofencing • Security • Telemetry • Tracking • Vehicle to Infrastructure communication (V2I) • Communication, Navigation and Surveillance • Detect and Avoid • Emergency recovery • Command and control • Operations management
U3	**U-space services**	**Associated drone capabilities**
	• **Dynamic geofencing** • **Collaborative interface with ATC** • **Tactical deconfliction** • **Dynamic capacity management**	• e-Identification • Geofencing • Security • Telemetry • Tracking

	• Vehicle to Vehicle communication (V2V) • Vehicle to Infrastructure communication (V2I) • Communication, Navigation and Surveillance • Detect and Avoid • Emergency recovery • Command and control • Operations management

The services provided above are ones that are currently being implemented (Phase U1 of U-Space), currently in development (Phase U2 of U-Space) [1] or being researched by U-Space related projects (CORUS [14], IMPETUS [15], DREAMS [16], TERRA [17], CLASS [18], DroC2om [19], SECOPS [20] and PercEvite [21]).

2.5 Drone Information Analysis

For the purpose of establishing a common understanding for information requirements, the following chapter is characterizing information needs as stated by the actual users and categorizing the general drone information for potential U-space environments as described in the previous chapters.

2.5.1 Questionnaire on the Need of Special Types of Information

First, we introduce the questionnaire conducted by the IMPETUS project from 12/17 until 01/18. Therefore, about 200 stakeholders of a future U-space system were directly invited via email to participate in an online survey. Due to the early stage of the project, the survey intended to gather a first collection of information relevant to drone users and experts of the entire aviation sector. In order to suit the special knowledge of both parties, the participants had the choice to answer the set of questions either as actual operator, **describing missions** they already carry out or plan to do so, or as expert, **stating objectives** they have in relation to necessary information distribution.

2.5.1.1 Population of the survey

As shown in Table 5, we retrieved answers from 32 participants. They cover the three main groups of stakeholders: authorities (NAA/CAA, law enforcement, and public entities), contacts with business interest (service providers, manufacturers) and the main users of a future system, the drone operators. Indirect users such as general aviation pilots have not yet been taken into account. The table also shows that we received a balanced result for mission descriptions as well as for objective summaries.

Table 5: Distribution of participants among stakeholder type and provided mission / objective summaries

Stakeholder Type	Participants	Missions	Objectives
ATM	3	1	2
Operator	7	7	0
Manufacturer	6	5	1
NAA / CAA	6	0	6
Law Enforcement	3	0	3
Public Entities	4	0	4
UTM Service Provider	3	2	1
	32	**15**	**17**

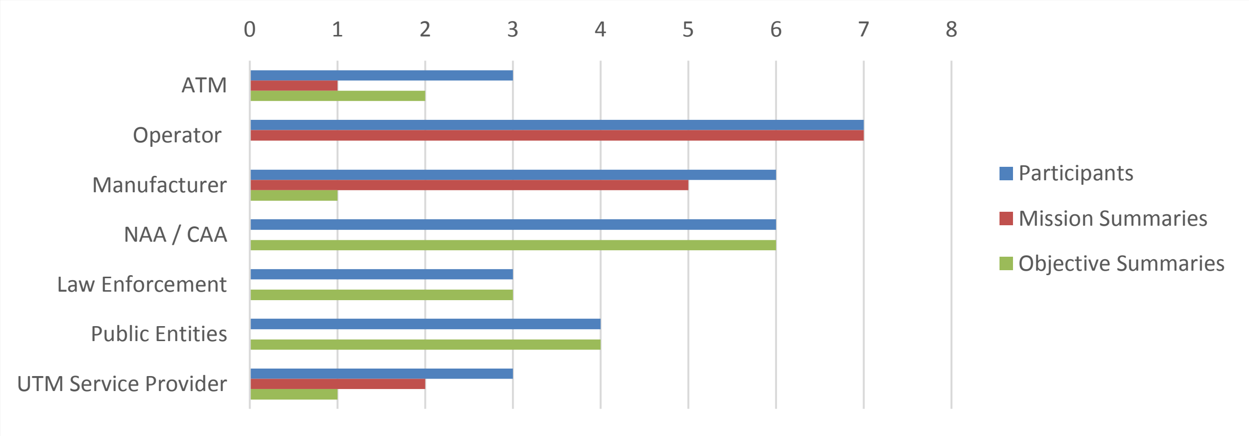


Figure 14: Graphical distribution of participants according to Table 5

An investigation of the operating sectors among the main users confirms that our survey covers several of the most important sectors selected in the Drone Outlook Study (2016) of the SJU (see Table 6). The unrepresented sectors in the essential businesses category are characterized by the fact that they do not practically exist in Europe yet: e-commerce and delivery as well as mobility and transport. To that effect, it is more difficult to establish a contact to possible survey participants.

Table 6: Business sectors covered by the participants of the survey

Sectors	Count	Note
Agriculture	2	Essential business categories for drone operations in Europe, according to the SJU
Energy	1	
Public Safety and Security	2	
E-commerce and Delivery	0	
Mobility and Transport	0	
Mining and Construction	2	Other relevant categories according to SJU
Media and Entertainment	2	
Real Estate	0	
University Research	4	
Telecommunication	0	
Insurance	0	
Photogrammetry (General)	2	Generalized answers with respect to operation types
Inspections (General)	2	
Surveying (General)	2	
Mapping (General)	1	
	20	(Not answered by all participants, e.g. NAA/CAA)

Furthermore, the population consists mostly of European contacts (compare Figure 15). This is related to the desire to show a representative result for a system designed not only but especially for the European market, and the fact that only such contacts were invited that are known to the partners inside the project. This also explains why some countries indicate a higher distribution. Additionally, some countries, e.g. Ireland, already have less restrictions and more advanced regulations for commercial drone operations.

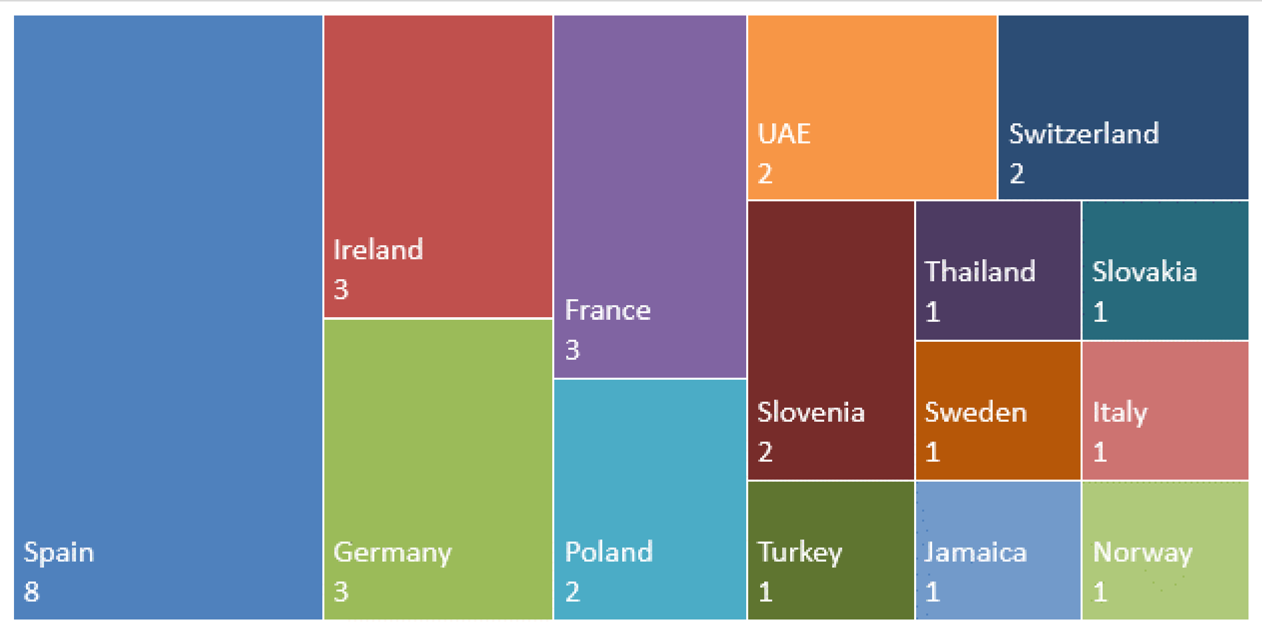


Figure 15: Distribution of participants among countries

2.5.1.2 Results of the survey

Due to the range of the survey and the intent in this chapter to produce a meaningful overview of user required pieces of information, the following table only shows an excerpt of the results. Therefore we focus on the generally provided information needs of all participants, collected in mission summaries as well as in objective statements. The entire results can be accessed in Appendix A.1 and include more detailed information, e.g. on the exact mission types, flight phases or desired transmission frequency (such as continuously, push or periodically).

Table 7: Excerpt of the IMPETUS survey on information needs

Information Category	Details	Stakeholder Type	Subcategory	Mission Type
Aeronautical Information Publications	Procedures, References, Competencies (GEN, ENR, AD)	UTM Service Provider	Commercial	General
Airspace Design	Static/Long-term Sector Information	ATM		General
Airspace Design	Static/Long-term Sector Information	Manufacturer	Wing, MC	Inspection
Airspace Use	Dynamic Sector	Manufacturer	Wing, MC	Inspection

Information Category	Details	Stakeholder Type	Subcategory	Mission Type
	Information			
Airspace Use	Dynamic Sector Information	NAA/CAA		General
Airspace Use	Dynamic Sector Information	UTM Service Provider	Commercial	General
ANSP Data	Relevant data input from ATMs, CNS, AIS/AIM etc.	NAA/CAA		General
NOTAM		UTM Service Provider	Commercial	General
Obstacles	Permanent and temporary structures	ATM		General
Obstacles	Permanent and temporary structures	Manufacturer	Wing, MC	Surveying / Inspection
Obstacles	Permanent and temporary structures	Operator	Energy	Surveying
Obstacles	Permanent and temporary structures	UTM Service Provider	Research	General
Terrain	Permanent Topography (DEM, DTM, DSM)	Manufacturer	Wing, MC	Surveying / Inspection
Terrain	Permanent Topography (DEM, DTM, DSM)	Manufacturer	Wing	General
Terrain	Permanent Topography (DEM, DTM, DSM)	Operator	Mining / Construction	Surveying
Terrain	Permanent Topography (DEM, DTM, DSM)	Operator	Agriculture / Research	Inspection
Terrain	Permanent Topography (DEM, DTM, DSM)	UTM Service Provider	Commercial	General
Terrain	Permanent Topography (DEM, DTM, DSM)	UTM Service Provider	Research	General
Performance Capabilities	Exact flight range	Operator	Research	Surveying / Inspection
Routing	Planned routes and altitudes	ATM		General
Visual Detection	Visually detected Information on aviation hazards / obstacles	Public Entity	Public Safety and Security	General
Critical Infrastructure	Location, structure, restrictions	Manufacturer	Automated Control	Inspection
Flight Permission	Authorization	Manufacturer	Wing	Surveying
Notifications	E.g. Ground-based human activities	UTM Service Provider	Research	General
Notifications /	Visually detected	Public Entity	Public Safety	General

Information Category	Details	Stakeholder Type	Subcategory	Mission Type
Alerts	Information on aviation hazards / obstacles		and Security	
Regulations	National rules, regulations and laws	ATM	Research	General
Regulations	National rules, regulations and laws	ATM	ATC	General
Regulations	National rules, regulations and laws	Manufacturer	Wing, MC	Surveying / Inspection
Regulations	National rules, regulations and laws	NAA/CAA		General
Regulations	National rules, regulations and laws	NAA/CAA		General
Regulations	National rules, regulations and laws	NAA/CAA		General
Regulations	National rules, regulations and laws	Public Entity	Civil Protection / Disaster Relief	General
Regulations	National rules, regulations and laws	UTM Service Provider	Commercial	General
Restrictions	Permanent / temporary flight restrictions	Manufacturer	Wing, MC	Surveying / Inspection
Risk approval	Risk Assessment, Risk Database, Authorization	Manufacturer	Wing	Surveying
Air Traffic Data	Manned / Unmanned Traffic	Manufacturer	Wing, MC	Surveying / Inspection
Air Traffic Data	Manned / Unmanned Traffic	UTM Service Provider	Research	General
Drone Tracking	Drone Position	ATM		General
Drone Tracking	Drone Position	NAA/CAA		General
Drone Tracking	Drone Altitude, Position, Time	NAA/CAA		General
Drone Tracking	Drone ID	NAA/CAA		General
Information Protection	e.g. Data Link Security, Data Link Integrity	Operator	Photography	Surveying / Inspection
Drone Registration / Identification		UTM Service Provider	Communication Services	General
Flight permissions	E.g. Capabilities-based certifications	Manufacturer	Wing	Surveying
Performance Reference	Performance reference e.g. under rain, cold, payload etc.	Operator	Media / Engineering	Inspection
Performance Reference	Exact flight range	Operator	Research	Surveying / Inspection

Information Category	Details	Stakeholder Type	Subcategory	Mission Type
Pilot Registration / Identification		UTM Service Provider	Communication Services	General
Weather	General	UTM Service Provider	Research	General
Weather	Forecast	Manufacturer	Wing, MC	Surveying / Inspection
Weather	Maps	Operator	Mining / Construction	Surveying
Weather	Radar	Manufacturer	Wing, MC	Surveying / Inspection
Weather	Wind Speed	Operator	Research	Surveying / Inspection

2.5.1.3 Conclusion

The survey successfully provided a first, general overview of the full range of required information from the perspective of all major stakeholders. Significantly often mentioned information types are in the segment of airspace usage, obstacles, terrain, regulations, drone tracking and weather.

Unfortunately, the numbers of participants as well as the individually provided answers were not sufficient to diversify the needs among different operating sectors. In consequence, the IMPETUS partners decided to use the provided mission descriptions and company internal expertise to propose representative use cases in chapter 3 of this deliverable. They are used to refine the results of the questionnaire and identify requirements according to the user specific needs and the different phases of drone operations. The results presented in the previous subchapter are instead used to establish a categorization of information types which will act as a general agreement on the full scope needed in the unmanned aviation context. To prove the indicated correlations among e.g. certain types of operators, mission types or flight phase concerning particular information packages could be evaluated in further surveys. Therefore, the already gathered information in this questionnaire should be used to design individual surveys that will be reduced to the essential points of interest and fit to the expertise of a selected group.

2.5.2 Drone Information Categorization

The content provided in this section describes an opportunity to structure the data which details all information necessary for drone operations in U-space - backed by the results of the questionnaire (section 2.5.1.2), literature research and information on the existing structure of the System Wide Information Management (SWIM) service network [23]. From the current state of the project, this classification shall avoid to introduce the interrelations between the different classes. As matter of course, they depend on each other, as for example there cannot be surveillance without navigational data for referencing.

2.5.2.1 Aeronautical/Geospatial

Aeronautical and Geospatial information is required to assure that drone operators have the necessary information about the airspace which their drone operation is conducted in order to operate it safely. The minimum requirement for this data consists of the following points:

Aeronautical:

1. Permanent airspace sectorisation
    a. Type of sector
    b. Coordinates of sector
    c. Restrictions imposed by sector
2. Non-permanent airspace sectorisation
    a. Notice to Airmen (NOTAM) data
    b. Temporary airspace restrictions
    c. Activation/deactivation of sectors
    d. Special Activity Airspace (SAA)
    e. Coordinates of NOTAM/restriction/SAA
    f. Duration
3. Airport reference and configuration
    a. Airport status
    b. Restrictions imposed by airports
    c. Active arrival/departure routes
4. Additional aeronautical data
    a. Airspace messages
    b. Aeronautical operations

Geospatial

5. Permanent geographical data
    a. Reference datum
    b. Terrain data
    c. Static obstacles
        i. Position
        ii. Height
        iii. Material (frangibility)
    d. City configuration
        i. Buildings
        ii. Support Technologies
    e. Accuracy of the sources
6. Non-permanent geographical data
    a. Reference datum
    b. Dynamic obstacles
        i. Position
        ii. Height
        iii. Material (frangibility)
    c. Temporary obstacles
    d. Duration
    e. City emergencies
7. Data verification and validation

The first piece of information required is that of *permanent airspace sectorisation data*, which covers all static airspace data, as published in the Aeronautical Information Publication (AIP). *Non-permanent airspace sectorisation data* covers airspace data which is prone to change. This not only implies geographical changes in sectorisation due to dynamic restrictions but also temporary changes in permanent sectors (including changes in restriction as well as activation/deactivation of sectors). Similar to airspace sectorisation data, *airport reference and configuration data* will be required, which deals mostly with the current state of activity of an airport and the restrictions which this operation imposes on drone traffic. *Additional aeronautical data* covers non-binding additional information which may be beneficial but not essential for operation, such as supplemental information, alerts or advisories. Access to accurate *permanent geographical data* must be guaranteed, in order for drones to operate safely in VLL airspace. This data must include information about terrain and static obstacles (natural and man-made). *Non-permanent geographical data* should have the same information as permanent geographical data, but include a time frame of validity. The time frame should encompass very short and very long timespans (a few seconds for moving (dynamic) obstacles up until several months for temporary obstacles). Finally, notifications about the validity and accuracy of the data provided should be covered by *data verification* information.

Results of the questionnaire 2.5.1.2 reinforced the need for more precise and higher resolution terrain and obstacle data, as the former was mentioned 6 times and the latter 4 times. This includes that new 3D/4D geospatial primitives might be required and criteria for vertical/lateral clearance with regards to terrain and obstacles be defined.

2.5.2.2 Flight

Flight data is used to describe, manage, and control the safe movement of airborne vehicles, including flight itinerary, identification, planning, events and status, and manned (ATM) and unmanned Air Traffic Management (UTM) control events. The information required for this purpose is:

1. Flight plan
    a. Set of IDs
        i. Flight plan / flight
        ii. Operator
        iii. Pilot
        iv. UAS
        v. GCS
    b. Start / end time
    c. Area / destination
    d. 4D trajectories
    e. Mode of control
    f. Associated risk
    g. Associated priority
    h. Geo-fencing boundaries
2. Flight monitoring
    a. Associated UAS
    b. Associated tracking information
    c. Associated flight plan
    d. Status of on-board systems

        e. Status of payload
3. Command and control (C2)
    a. Data
    b. Status
4. Payload control and management
    a. Reported payload
    b. Maximum payload
    c. Calculated payload
    d. Released payload
5. Flight management
    a. Itineraries / legs
    b. Schedules
    c. Flight Performance
    d. UTM measures
6. Contingency Management
7. Deconfliction
    a. Tactical
    b. Strategical

The filed *flight plan* describes all of the information approved for a specific drone operation. In combination with the actual *flight monitoring* it enables a validation and control of the actual adherence to this plan. Also covered in is the necessary *command and control* link, which is used by the pilot, the ground control system or some authority to operate the UAS. Furthermore this section includes several safety critical elements of UAS operations, such as the *payload control*, *contingency management* and strategical or tactical *deconfliction* measures.

The category *flight management* summarizes information that concerns indirect actions and measures as well as flight data related to a set of operations or flight itineraries. This includes monitoring of flight performance, implementation of DTM related measures (restrictions, commands, changes to the flight plan) as well as changes to flight schedule.

The results of the questionnaire 2.5.1.2 showed that there was a need for information specific to "UAV Performance", which is also included here. Specifically, the respondents asked for precise knowledge of the drone's flight range as well as performance specifications in cold temperatures, high altitude and rain at varying payload mass.

2.5.2.3 Communication

Communication is one of the safety critical factors to enable drone operations and therefore has to be seen as single category. A typical differentiating mechanism for remotely operated vehicles is between payload and non-payload communications [41]. Furthermore, information about the primary infrastructure to facilitate these communication needs to be included.

1. Payload communication
    a. Sensing / Operational Data
        i. Mapping
        ii. Hyperspectral Images
        iii. Sensor data
        iv. Etc.
    b. Transmitter/Source

   c. Channel
   d. Receiver
   e. Transducer
   f. Downlink
   g. Uplink
   h. Encryption
   i. Owner
2. Control and Non-Payload Communication (CNPCL)
   a. Control and Non-Payload data
      i. Metadata
      ii. Telecommands
      iii. Audio
      iv. Telemetry
      v. Video
      vi. Systems (e.g surveillance, navaids, sense and avoid, separation assurance)
      vii. Service provider data
      viii. ATM/DTM
   b. Transmitter/Source
   c. Channel
   d. Receiver
   e. Transducer
   f. Downlink
   g. Uplink
   h. Encryption
   i. Owner
3. Infrastructure
   a. Air-based
   b. Ground-based
   c. Satellite-based
   d. Hardware parameters
      i. Probability of Uncorrected Errors.
      ii. Signal Power Consumption
      iii. Encoding/ Decoding Delay
      iv. Encoder/ Decoder Hardware Complexity
      v. Number of Hardware Components
   e. Software Parameters
      i. 1. Overhead (Error Control Bits)
      ii. 2. Encoding/Decoding delay
      iii. 3. Bit Error Ratio (BER)
      iv. 4. Energy/bit(Eb) and EbN0
   f. Network Status
   g. Coverage

Information about drone communication, as control and non-payload transmission are likely to be relevant not only from *Air to Air* or *Ground to Air*, but also *Ground to Ground* for communication purposes in between administrative authorities, traffic management (also UTM to ATM and vice versa) and different services vendors, as well as for the actual service provision.

2.5.2.4 Navigation

Navigation data is used as reference to locate the position and describe the course of drones in flight. The requirements for this data can be split into two main groups, common aeronautical navigation data used in manned aviation today as well as drone-specific navigation data. The overall *navigation* requirements can be summarized as follows:

1. Navigation data
    a. Ground-based navigational aids (VOR/DME, NDB, GBAS, ILS)
    b. Space-based navigational aids (GNSS, EGNOS)
    c. On-board navigational equipment (INS, ADRS)
2. Signal Of Opportunity (SOO) data
    a. Cell tower triangulation
    b. Long term evolution (LTE) signal data
    c. AM/FM radio
    d. Digital television
    e. Iridium
    f. Wi-Fi
    g. Beacons
3. Vision-based navigation
    a. Visual odometry
    b. Image registration
4. Accuracy levels
    a. Availability of data sources (map of services provided in each area)
    b. Overall position accuracy

Given the large variety in possible drone sizes, many of the legacy *conventional aeronautical navigation data* sources might not be applicable for certain drones given the weight of the equipment required to be carried. However, since certain missions may require the inclusion of legacy systems (such as an ILS receiver for ILS-calibration missions or drones operating under IFR), they are included in this list. Furthermore, *conventional aeronautical navigation* methods are not precise enough (legacy equipment) or reliable enough (GNSS) to meet the needs of VLL drone traffic. *Signal of opportunity (SOO) data* or aerial/satellite imagery will likely be required to improve the navigation accuracy of drone operations. The current most promising method is the combination of SOO (especially LTE) with INS and GNSS to produce very accurate location identifications [24][25]. New and emerging technologies should also be considered, such as *Vision-based navigation*, which allows the drone to determine its position, velocity and orientation through analysis of the visual references around it. *Accuracy levels* of positioning data will also need to be determined.

An important side-note to be considered is that none of the respondents of the questionnaire 2.5.1.2 indicated the need for navigation information.

2.5.2.5 Operational

Operational data is used to describe information about the status of missions, equipment, systems, facilities, and maintenance schedules and requests, which is necessary to keep up the operative purpose of drone undertakings. Key data points include:

1. Mission intent
    a. Mission ID
    b. Operator ID
    c. Mission intent / classification
    d. Area of mission
    e. Type of mission
    f. Duration
    g. Priority
    h. Risk assessment
2. Mission monitoring
    a. Assigned flight plan
    b. Status
    c. Delays
    d. Progress
    e. Records
3. UAS facilities and infrastructure
    a. Take-off / Landing
    b. Reloading facilities
    c. Tether-docking stations
    d. UAS Navaids
    e. (Micro-)Weather stations
    f. Service stations
4. Equipment
    a. On-board
        i. Communications systems (4G/5G network)
        ii. Navigation systems
        iii. Surveillance systems (e.g. ADS-B)
        iv. Detect and Avoid Systems
        v. Sense and Avoid Systems
    b. Ground
5. Communication devices
    a. Ground Control Stations
    b. Infrastructure
6. Maintenance
    a. Status
    b. Schedule
    c. Requests
    d. Manuals
7. U-Space System
    a. Quality of coverage
    b. Accuracy of traffic information
    c. Status of U-Space services
    d. Status of U-Space system
    e. Status of U-Space coverage

A drone *mission intent* is understood as some pre-tactical flight planning, documenting the actual purpose of the flight that will be conducted, which includes for example the likely areas of operation,

operation types and risk assessment. This could lead to a better prediction trajectories types (for example, a surveying mission is likely to have relative high altitude paths in circular directions) or capacity demands. The *mission monitoring* however documents the actual operation status and performance. Apart from that, the section covers mostly status information about different types of infrastructure, such as the *equipment*, *communication devices* and the actual *U-Space system*. *Maintenance* is not limited to the relevant facilities, but also about schedules, requests and dedicated manuals.

However, none of the respondents of the questionnaire in 2.5.1.2 indicated the need for such operational data.

2.5.2.6 Surveillance

Information classified to the section *surveillance* is supposed to ensure the situational awareness of all vehicle movements inside an defined airspace. The essential data, necessary to provide this knowledge to UAV stakeholders should consist of:

1. Individual Tracking
   a. Associated airborne vehicle
   b. Planned
   c. Predicted
   d. Tracked
   e. Recorded
2. UAS Traffic Tracking
   a. Capacity Demand
   b. Forecast
   c. Count
   d. Records
3. Surveillance infrastructure
   a. Technology
   b. Sites
   c. Status

The first and the second bullet cover all aspects of tracking data, for *individual* vehicles as well as for the entire *traffic* situation. It is important to include real-time information about the position, altitude and identification of the vehicle as well as the predicted and actually planned flight movements. This data can improve information related to the deconfliction in the Flight category. The third bullet keeps track of all infrastructures directly related to surveillance, such as radar, beacon interrogators or ADS-B receivers.

2.5.2.7 Weather

Information represented in the category *weather* describes current and predicted atmospheric conditions, including ground and aerial measurements, forecasts and observations of weather phenomena. Since UAVs are not operating in the usual flight levels and zones, it becomes apparent that they need extended information compared to what is available for manned aviation. Consequently, more detailed, short-term information set in altitudes between 10 and 400 feet has to be in place and structured in a time-dependent 3D topology.

1. Measurements
    a. Source
    b. Location
    c. Time
    d. Air pressure
    e. Air temperature
    f. Dewpoint
    g. Horizontal visibility
    h. Vertical visibility
    i. Wind direction
    j. Wind gust
    k. Wind speed
    l. Wind turbulence
    m. Surface temperature
    n. Surface condition
    o. Precipitation
2. Observations
    a. Source
    b. Location
    c. Time
    d. Intensity
    e. Proximity
    f. Descriptor
    g. Phenomena (Precipitation, obscuration, other)
    h. Movement
3. Forecasts
    a. Source
    b. Location
    c. Time
    d. Valid time
    e. Type of Forecast
    f. Probability
    g. Confidence
4. Impact warnings
    a. UAV class
    b. Flight permission
    c. Alerts
    d. Closures

The first sub-category *measurement* describes the typical data values of public reports such as METAR or GAFOR, which are collected for manned aviation already by sensors on the ground and in the air. Same applies to the category *observation*, but more precisely concerning weather phenomena that have a diffuse and less data oriented description. *Forecasts* deal with all aspects of the previously stated meteorological factors, but extended with the necessary information to detail a predicted scenario such as a valid time, probability or a confidence interval. Lastly, the fourth sub category is used to classify local weather situations into an equivalent that determines if *impact warnings* to special type of drones are necessary and if they are still permitted to perform flights in a safe and efficient manner.

2.5.2.8 UAS

This category represents the entire static information about technical and administrative properties of the unmanned vehicles and their operators / pilots.

1. Vehicle properties
    a. Vehicle ID
    b. Full set of technical properties
        i. Mass / size / material
        ii. Propulsion
        iii. Emergency equipment (Airbags, parachutes, return-to-home, rotor-protection...)
        iv. Etc.
    c. Owner
    d. Classification and capability-based certifications
    e. Performance records
    f. Emission (e.g., noise level)
2. Associated GCS
    a. Equipment
    b. Software
    c. Certifications
    d. Capacity (maximum number of drones controlled simultaneously)
3. Operator database
    a. Operator ID
    b. Registry
    c. Fleet
    d. Records
    e. Certifications
    f. Insurance
4. Pilot database
    a. Pilot ID
    b. Registry
    c. Licenses
        i. Drone configuration
        ii. Operations
        iii. Flight Logs
    d. Insurance

The exact technical details covered in the *vehicle properties* are not specified yet, but shall comprise information such as the general drone type, dimension, propulsion, batteries, maximum take-off weight, equipment, sensor properties, safety/contingency systems and provision of e-identification. Theses information is supplemented with administrative attributes: owner and classification (open/specific/certified). Performance is differentiated in a reference type, which could be extracted from manufacturer information, and a record type that keeps track of the historical and current performance of the individual vehicle. Information must also be available about the *associated GCS* of the drone. Furthermore, the category UAS needs to store the information claimed in e-registration services in an *operator* and *pilot database*. Besides traditional contact information, necessary certifications and licences are categorized in this section.

2.5.2.9 Administrative Authority

Administrative Authority covers all information necessary to provide an awareness of the constraints in the air and on the ground being related with the conduct of UAS operations in the U-Space, provided through an official authority.

1. Regulations
    a. Definitions and general requirements
    b. Procedural rules
    c. Certification procedures
    d. Airworthiness
    e. Noise standards
    f. Maintenance
    g. Registration and identification markings
2. Law enforcement
    a. Investigative procedures
    b. Administrative actions
    c. Legal enforcement actions
3. Restricted access
    a. Privacy rights / private property
    b. Critical infrastructures
    c. Noise restrictions
    d. Speed restrictions
    e. Altitude restrictions
    f. Safety systems restrictions

4. Authorization
    a. Operation approval
5. Notifications
    a. Ground-based activities
    b. Operations of public safety and security
    c. Other hazards interfering with unmanned aerial systems
6. Alerts
    a. Violations
    b. Individual notifications
    c. Technical warnings
    d. Contingency situations
    e. Incident/Accident reporting
7. Third-party risk database.

The first category summarizes the information covered in national and international *regulations* that apply to the operation of UAS. The second category, *law enforcement* concerns the investigation and administration necessary to control and carry out the rules written down in the regulations and public legislation. Next is information about *restricted access* depending on the compliance to privacy rights, special noise, speed or other restrictions.

Notifications shall comprise information about area-specific hazards that are interfering with the operation of UASs, which are not covered by typical NOTAMs or their subcategories (SNOWTAMS, ASHTAMS, BIRDTAMS etc.). Most likely, this is information directly linked to the special set of rules that are set in current or future regulations, as for example the restrictions of flying over crowds of people. Consequently, these notifications could inform about soccer games, music festivals or other public events. Apart from that, other constraints could result from electromagnetic fields (signal disturbance), gas venting or ground-based activities (e.g. firework, sky lanterns).

Alerts refer to urgent and more individual notifications, such as an imminent or current violation that has been detected or technical warnings and contingency situations. The *third-party risk database* is a concept that may be included in U-Space, which overlays a geographical map with information about the classification of how much risk to third-parties an operation of a drone would pose in that area.

2.5.3 Summary of Information Categories

The following table shows a summary of all information categories listed in previous sections.

Table 8: Summary of information categories

Level 0	Level 1	Level 2 (Examples)
Aeronautical *Describe, manage and control aeronautical facts*	Permanent airspace sectorisation	Types, coordinates, restrictions etc.
	Non-permanent airspace sectorisation	NOTAMs, special activity airspaces, temporary restrictions etc.
	Airport reference and configuration	Status, restrictions, active arrival/departure routes
	Additional aeronautical data	Airspace messages, aeronautical operations
Geospatial *Manage general geospatial information*	Permanent geographical data	Terrain data, static obstacles, city configurations, data accuracy
	Non-permanent geographical data	Reference datum, dynamic obstacles, temporary (static) obstacles etc.
	Data verification and validation	
Flight *Describe, manage and control safe movement of airborne vehicles.*	Flight plan	Start/end time, area, destination, 4D trajectories, control modes, risk, priority etc.
	Flight monitoring	UAS, tracking information, flight plan, system status etc.
	Command and Control (C2)	Remote-control data, status

Level 0	Level 1	Level 2 (Examples)
	Payload control and management	Reported payload, maximum payload, calculated payload, released payload
	Flight management	Itineraries, legs, schedules, flight performance, U-Space measures
	Contingency management	Loss of link, loss of engine, loss of control, loss of surveillance etc.
	Deconfliction	Tactical, strategical
Communication	Payload Communication	Data (hyperspectral, mapping, sensing etc), uplink rates, downlink rates, encryption, channels, etc.
Describe, manage and control communication provision	Control and Non-Payload Communication	(Meta-)Data (Telecommands, system data, service provider data, ATM/DTM communication etc.), uplink rates, downlink rates, encryption, channels
	Infrastructure	Ground-based, air-based, satellite-based, network status, hardware / software parameters quality of service
Navigation	Navigation data	Ground-based navaids, space-based navaids, on-board navigational equipment
Reference to locate positions and trajectories of vehicles	Signal of opportunity (SOO) data	Cell tower triangulation, LTE signal data, Iridium etc.
	Vision-based navigation	Visual odometry, image registration
	Accuracy levels	Availability of data sources, position accuracy
Operational	Mission intent	Area of misson, type of mission, duration, priority, risk etc.
	Mission monitoring	Assigned flight plan, delays, progress, records
Status data of mission, infrastructure and maintenance	UAS facilities and infrastructure	Take-off / landing, reloading facilities, stationary navaids, mobile navaids etc.
	Equipment	On-board, ground
	Communication devices	Ground-control stations, infrastructure
	Maintenance data	Status, schedules, requests, manuals
	U-Space system	Quality of coverage, accuracy of traffic information, status of services, system and coverage
Surveillance	Individual tracking	Vehicle position, altitude, direction, speed etc. (Planned, predicted, tracked, recorded)
Detection, localizing and identification of vehicle(s)	UAS traffic tracking	Traffic count, forecast, record, capacity demand

Level 0	Level 1	Level 2 (Examples)
	Surveillance infrastructure	Technology, sites, status
Weather *Atmospheric conditions relevant for flights*	Measurements	Air pressure, temperature, dew point, wind speed, directions, gusts etc.
	Observations	Phenomena: Obscuration, precipitation, hail, snow etc.
	Forecasts	Source, time, location, probability, confidence interval etc.
	Impact warnings	UAV class, flight permission, alerts, closures
UAS *Information storage about UAS vehicles, operators and pilots*	Vehicle properties	Technical properties (mass, size, propulsion etc), owner, classification, capabilities etc.
	Associated GCS	Equipment, software, capacity etc.
	Operator database	Registry, records, fleet, certifications etc.
	Pilot database	Registry, licenses, insurance etc.
Administrative Authority *Administrative data related to the U-Space environment and provided centrally*	Regulations	Procedural rules, noise standards, airworthiness etc.
	Law enforcement	Investigative procedures, administrative actions etc.
	Restricted access	Privacy rights, noise restrictions, safety system restrictions, critical infrastructures etc.
	Authorization	Operation / flight plan approval
	Notifications	Ground-based activities (human gatherings, events etc.), operations of public safety and security, other hazards
	Alerts	Violations, individual notifications, technical warnings etc.
	Third-party risk database	Storage for risk assessment

2.5.4 Advanced Faceted Categorization of Information Packages

As the questionnaire indicated dependencies in the information requirements related to the different flight phases, mission types and operation areas, Figure 16 illustrates how this could be facilitated for a faceted classification. Additional features, such as the stakeholder type and operating business sectors, are reasonable to be taken into account for a further diversification but are difficult to be displayed in a non-digital diagram. In a later stage of this project, these attributes promise to be an opportunity to describe packages of information that are relevant to a certain type of user in an assumptive timeframe.

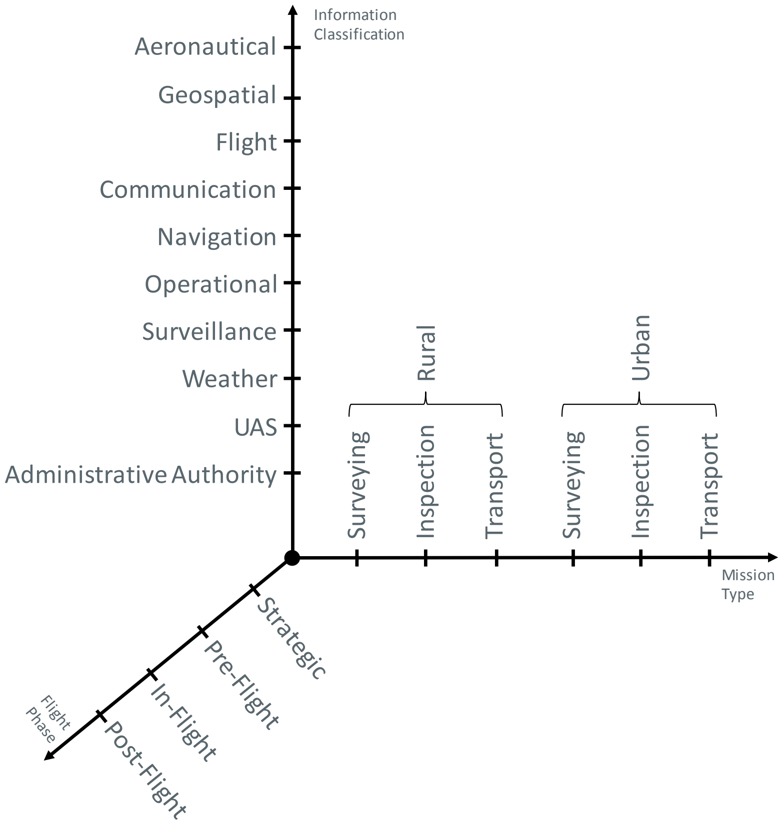


Figure 16: Faceted categorization of information packages

2.6 Current Information Services – Manned Aviation

At present the services provided to Manned Aviation are undergoing a great transformation with the implementation of the SWIM concept by the different regulatory bodies (FAA, Eurocontrol, etc.).

Today's ATM systems comprise a wide variety of legacy applications developed over decades to fit specific needs in particular regions of the world. They are characterized by many custom communication protocols, each with their own self-contained information systems realized by a combination of airborne and ground components. For the most part, these components have custom-designed interfaces, which are developed, managed, and maintained individually and locally at a significant cost. Moreover, the way ATM information is defined, structured, provided and used is specific to most of the particular ATM systems.

Building on the best practices from relevant IT communities, information standards, infrastructure and governance rules have been defined over the last decade to provide ATM stakeholders with the appropriate information in an interoperable way. This information should be of the right quality and delivered to the user place at the right time, thereby enabling the concept of net-centric ATM operations.

Thus, information services in manned aviation are now in the process to be fully offered through SWIM and this process is already in its deployment phase in many regions of the world, especially in the US and Europe.

2.6.1 SWIM

System Wide Information Management (SWIM) concerns to the development of services for information exchange. SWIM comprises standards, infrastructure and governance enabling the management of information and its exchange among operational stakeholders via inter-operable services. Information that is shared in SWIM covers the following scopes:

- **Aeronautical** - Information resulting from the assembly, analysis and formatting of aeronautical data;
- **Flight trajectory** – the detailed route of the aircraft defined in four dimensions (4D), so that the position of the aircraft is also defined with respect to the time component;
- **Aerodrome operations** – the status of different aspects of the airport, including approaches, runways, taxiways, gate and aircraft turn-around information;
- **Meteorological** – information on the past, current and future state of earth's atmosphere relevant to air traffic;
- **Air traffic flow** – the network management information necessary to understand the overall air traffic and air traffic services situation;
- **Surveillance** – positioning information of the aircraft that integrate a traffic from radar or aircraft-derived mean;
- **Capacity and demand** – information on the airspace users' requests of services, access to airspace and airports vs. the aircraft already using them.

SWIM aims at improving interoperability in ATM using widely adopted technologies, standards and best practices (e.g. AIXM, Internet Protocol, Web Services, Service-Oriented Architecture). Interoperability in SWIM is achieved through using common specifications to implement the service interfaces used in the exchanges of information among ATM stakeholders. The coordinated development of these common specifications is achieved through common governance, undertaken by SWIM stakeholders. Finally, there are common infrastructure components that support SWIM implementation (PKI - Public Key Infrastructure, Service Registry).

The registry is used for publication and discovery of information regarding service consumers and providers, the logical information model, SWIM enabled services, business, technical, and policy information. There are at the moment different registries operating under their own governance in different regions as the US SWIM registry and the European one. There are ongoing efforts to make then compatible following the guidance described in the ICAO SWIM concept document to further reduce costs and maximize competition between the providers allowing them to be fully global.

Among the most important aspects of SWIM is its definition of the stack of technologies to use for every data exchange. These stacks standardize all supporting aspects with special focus in data models and definition of services.

2.6.2 Data Models

2.6.2.1 AIXM

The objective of the Aeronautical Information Exchange Model (AIXM) is to enable the provision in digital format of the aeronautical information that is in the scope of Aeronautical Information Services (AIS). The AIS information/data flows are increasingly complex and made up of interconnected systems. They involve many actors including multiple suppliers and consumers. There is also a growing need in the global ATM system for high data quality and for cost efficiency.

In order to meet the requirements of this increasingly automated environment, AIS is moving from the provision of paper products and messages to the **collection and provision of digital data**. AIXM supports this transition by enabling the collection, verification, dissemination and transformation of digital aeronautical data throughout the data chain, in particular in the segment that connects AIS with the next intended user.

The following main information areas are within the scope of AIXM:

- Aerodrome/Heliport including movement areas, services, facilities, etc.;
- Airspace structures;
- Organizations and units, including services;
- Points and Navaids;
- Procedures;
- Routes;
- Flight restrictions.

AIXM takes advantages of established information engineering standards such as GML (Geographic Markup Language) and supports current and future aeronautical information system requirements.

Current release (5.1.1) can be found at http://aixm.aero/page/aixm-51-511

2.6.2.2 WXXM

The Weather Information Exchange Models and Schema (WXCM-WXXM-WXXS) are designed to enable a platform-independent, harmonized and interoperable meteorological information exchange covering all the needs of the commercial air transport industry.

The Weather Information Exchange Model specifications support the data-centric environment. It supports MET information collection, dissemination and transformation throughout the data chain.

It has three main components:

- The conceptual Information Model (WXCM);
- The Logical Data Model (WXXM);
- The Exchange Schema (WXXS).

The WXCM-WXXM-WXXS takes advantages of existing and emerging information engineering standards and supports current and future aeronautical meteorological information system requirements.

The major tenets are:

- Support for the latest ICAO and other user requirements for meteorological information by one single representation;
- Alignment with ISO standards for geospatial information, including the use of the Geography Markup Language (GML);
- Alignment with OGC Best Practices for geospatial information, including the Observation & Measurement model;
- Modularity to support future requirements.

The idea behind the design of WXXM is to have generic data containers (such and Observations or Weather report) that are specialized in classes that cover the present needs of the aviation industry, but can also serve as a baseline for future specifications.

In WXXM, there are top level data containers (specialized from the generic observation classes) to represent all standard airport weather reports that are in use, such as METARs and TAFs in a structured and machine-friendly way. There are also modern equivalents to the typical en-route weather reports such as the SIGMETs.

These specifications include at least the same amount of information as in the pre-WXXM era versions but with every field being tagged and strongly typed in the corresponding XML schema. In most of the cases, in order to make the transition easier, there is a field within the new container that contains the legacy representation of the report as a simple text field. This is not always the case, as this legacy representation makes it possible to produce inconsistent messages (as many pieces of information are reported twice).

Many of the providers of weather information in WXXM are also using generic standards at the service interface level making their interfaces compatible with Web Features Service (WFS).

Current version is 2.0 that can be found at http://wxxm.aero/page/documents-0

2.6.2.3 FIXM

The Flight Information Exchange Model (FIXM) is an exchange model capturing Flight and Flow information that is globally standardized.

The requirement for FIXM was identified by the International Civil Aviation Organization (ICAO) Air Traffic Management Requirements and Performance Panel (ATMRPP) and endorsed at the 12th Air Navigation Conference as part of the Aviation System Block Upgrades (ASBU) and as described in Flight and Flow Information for a Collaborative Environment (FF-ICE).

FIXM is first and foremost developed in order to enable the flight and flow information exchanges identified by ICAO as part of the FF-ICE concept. The FIXM evolution is tied to the ICAO roadmap for the development, review, approval, publication and applicability of FF-ICE packages.

FIXM is the equivalent to the Flight domain of AIXM (Aeronautical Information Exchange Model) and WXXM (Weather Information Exchange Model), both of which were developed to achieve global interoperability for, respectively, AIS and MET information exchange. FIXM is, thus, part of a family of technology-independent, harmonized and interoperable information exchange models designed to cover the information needs of Air Traffic Management. According to the ICAO SWIM concept, FIXM is one of the models that belong to the "Information Exchange Models" layer of the ICAO SWIM Global Interoperability framework.

FIXM contains flight information items that satisfy, and are traceable to, ICAO requirements for Flight information exchanges. These include Flight Plans, trajectories, aircraft information, equipment, compatibility, etc.

The latest version of the NM flight services have migrated to FIXM 4.0 for most of their data exchanges - See the flight services section below for more detail -.

Current release is 4.1.0 and can be found at https://fixm.aero/fixm_410.pl

2.6.3 Services

Making use of the data models described above, the actual Services for information exchange represent the top layer according to the ICAO SWIM concept. As the implementation depends on the region, here we describe as an example the set of services offered in the European SWIM, more specifically those of the so-called "yellow profile" as it is the biggest, most developed one and of highest interest to the IMPETUS project.

2.6.3.1 Aeronautical Information Services

The aeronautical information services are called the Airspace Services in the NM (Network Manager). The Airspace Services group is intended to provide services related to the management and sharing of Airspace data (e.g. airspaces, routes, aerodromes, etc.) as used by the NM systems.

The Airspace Services group consists of two types of services:

- **Airspace Structure Service**: for retrieving up-to-date airspace data from the CACD (Central Airspace and Capacity Database). The CACD database is the repository for the environment data (a.k.a. airspace data) used in the NM systems to perform Flight Planning and Flow Management. This data includes AIP (Airport Information Publication) concepts (such as Routes, Points and Aerodromes), and non-AIP concepts (such as Flows, RAD (Route Availability Document) Restrictions and Traffic Volumes). AIP concepts such as Airspaces may differ slightly from the AIP definition: for example when the AIP in defining an Airspace reads "follow the border between country X and Y", this must be translated into a real geometry that can be interpreted by the NM systems;

- **Airspace Availability Service**: for querying and modifying the airspace availability information. This includes the Flexible Use of Airspace – AUP (Airspace Use Plan)/UUP (Updated Airspace Use Plan) realized in Europe as EAUP /EUUP.

The Airspace Services group makes use of AIXM 5.1/ADR-E (Airspace Data Repository Extension, specific to the NM)) types when possible. This does not mean that all data types defined in this service group are AIXM 5.1 or ADR-E types, as other service groups (Flight and Flow) use non-AIXM types, and because Airspace querying services must still use, for example, traditional ICAO identifiers rather than UUIDs (Universal Unique Identifiers) that do not support wildcards.

There are different ways to retrieve (or modify, if the user is the owner of the data) this information. Most airline operators use a full dump service that the NM provides to download the full AIXM data from Eurocontrol instead of using the fine grained services - Refer to the NM documentation (https://www.eurocontrol.int/network-manager) for further detail.

2.6.3.2 Flight Information Exchange Services

Flight information shall be exchanged during the pre-tactical and tactical phases by operational stakeholders that implement services supporting the exchange of the flight information. This includes:

- **Various operations on a flight object (FO)**: Acknowledge reception, Acknowledge agreement to FO, End subscription of a FO distribution, Subscribe to FO distribution, Modify FO constraints, Modify route, Set arrival runway, Update coordination related information, Modify SSR (Secondary Surveillance Radar) code, Set STAR (Standard Arrival Route), Skip ATSU (Air Traffic Services Unit) in coordination dialogue;

- **Share Flight Object information**: Flight Object includes the flight script composed of the ATC constraints and the 4D trajectory. Operational stakeholders shall implement the following services for exchange of flight information:

  - Validate flight plan and routes;

- File, Update & Cancel Flight Plans;
- Flight plans queries, 4D trajectory prediction exchanges, flight performance data requests, flight status monitoring;
- Flights lists and detailed flight data;
- Flight update message related (departure & arrival information).

Service implementations shall be compliant with the applicable version of AIRM (ATM Information Reference Model), the AIRM Foundation Material and the ISRM (Information Service Reference Model) Foundation Material.

As an example of a complete set of flight information services, the Eurocontrol NM 21.5 release (most recent publication) includes services for validation, filing and management of flight plans and services to query for flight information by many parameters such as arrival or departure airport, operator or many others over a set of REST (Representational State Transfer) or SOAP (Simple Object Access Protocol) services, all using the FIXM format. It also includes a publish interface to subscribe to the events associated with the flight of interest of the user. These messages include information of many characteristics and, depending on the role of the petitioner, only a subset can be requested. They include the arrival and departure message or updates on the ETA (Estimated Time of Arrival) among many other things.

These services are further divided into what are called service ports that basically are clusters by functionality. For example the flight services of the NM include:

- **Flight Preparation (FP) Service Port:** Includes all services that allow an aircraft operator to prepare and validate a FP. This includes the possible requests:
  - FlightPlanValidationRequest
  - ExtendedFlightPlanValidationRequest
  - RoutingAssistanceRequest
- **Flight Filing Service Port:** This port includes all services to file a FP. This includes the possible requests:
  - FlightPlanCreationRequest
  - FlightPlanUpdateRequest
  - FlightPlanCancellationRequest
  - FlightDelayRequest
  - FlightDepartureRequest
  - FlightArrivalRequest
  - FilingStatusRequest
  - ExtendedFlightPlanCreationRequest
  - ExtendedFlightPlanUpdateRequest
- **Flight Management Service Port**: This port includes the services to query Flight Information and also to interact with many messages related to the arrival & departure including most of A-CDM related messages – For further information please concern the Network Manager documentation: https://www.eurocontrol.int/network-manager.

  This includes the possible requests:

- FlightPlanListRequest
- FlightListByKeysRequest
- FlightListByAircraftOperatorRequest
- FlightListByAerodromeRequest
- FlightListByAerodromeSetRequest
- FlightListByAirspaceRequest
- FlightListByPointRequest
- FlightListByTrafficVolumeRequest
- FlightListByMeasureRequest
- FlightListByHotspotRequest
- FlightListByAircraftRegistrationMarkRequest
- FlightRetrievalRequest
- EarlyDPIRequest
- TargetDPITargetRequest
- TargetDPISequencedRequest
- ATCDPIRequest
- CancelDPIRequest
- FlightUpdateRequest
- EstimatedAPIRequest
- TargetTakeOffAPIRequest
- TargetTimeOverAPIRequest
- CancelAPIRequest
- ATCAPIRequest

- **Flight Safety Service Port:** This port include services to access data related to the safety such as that of third countries (not included under the umbrella of Eurocontrol) in the "green list" from the point of view of Eurocontrol. This includes the possible requests:
  - ACC3AccreditationListReplacementRequest
  - TCOAuthorisationListReplacementRequest
  - TCOAuthorisationListUpdateRequest

2.6.3.3 Flow Information Exchange Services

This set of services offers information exchange capabilities in order to facilitate the flow management in a collaborative way. It includes flight counts predictions, capacity plans, airport configuration predictions and the collections of measures that are being taken (or are planned to solve any potential issue). It is a quite complex set of services and the least standardized at ICAO level. Thus, at the moment, every region is offering a different set of services using region-specific data formats in most of the cases.

The different ports that exist in the European solution are:

- **Traffic Count Port**: This service port is intended to provide querying of traffic counts according to different criteria of interest for the present day or planned for the next five days. The requests currently available are:
  - TrafficCountsByAircraftOperatorRequest
  - TrafficCountsByAerodromeRequest.
  - TrafficCountsByAerodromeSetRequest
  - TrafficCountsByAirspaceRequest
  - TrafficCountsByPointRequest.
  - TrafficCountsByTrafficVolume Request

- **Measures Port**: This service port is intended to provide the means to classify, apply and resolve the different measures that are required to accommodate all the predicted traffic while meeting all applicable restrictions (e.g. related to weather, military use of the airspace, or capacity problems). Measures in the NM are classified in different groups:

  - **Regulations**: Are events that affect to the capacity (or even no fly zones). They usually contain a description of the event, the time window of the effect and the geometry of the volume affected. Examples could be a regulation due to weather conditions or a faulty equipment in a runway that limits the airport capacity;

  - **Rerouting**: Are events that mark that a group of flights are going to be rerouted, usually to keep the expected flight counts under the planned capacity. The list of flights affected is associated to the rerouting and can be requested;

  - **McdmOnly**: are pure text coordination measures. The remark field actually describes what kind of measure is and what is expected. They allow to associate flights to mcdmOnly measures and follow the MCDM (Multiple-Criteria Collaborative Decision Making) process. However, there are no proposal flights associated to mcdmOnly measures, so no what-if counts and flight lists can be done to evaluate any potential impact.

  The list of possible requests on this port is:

  - RegulationListRequest
  - RegulationCreationRequest
  - RegulationUpdateRequest
  - RegulationCancelRequest
  - RegulationProposalListRequest.
  - RegulationProposalFilingRequest
  - RegulationProposalUpdateRequest
  - RegulationProposalRevocationRequest
  - ReroutingListRequest
  - ReroutingCreationRequest
  - ReroutingUpdateRequest
  - ReroutingCancelRequest
  - MCDMOnlyListRequest
  - MCDMOnlyCreationRequest
  - MCDMOnlyUpdateRequest
  - MCDMOnlyCancelRequest
  - MeasureOpLogRetrievalRequest
  - AddFlightsToMeasureRequest
  - RemoveFlightsFromMeasureRequest
  - ATFCMSituationRequest

- **Tactical Updates Service Port**: This port includes predictions that are useful to plan operations. Its information is mostly predictive in nature and includes data from the airport and the ATSUs to be able to know what capacity and status they are expecting to be in.

  Specifically, the sector configuration, activation plan and capacity plan can be exchanged. Also the list of hot spots (areas in which expected flight counts are over the planned capacity), which can be related to measures (as reroutings), can be retrieved.

  For the European airports, predictions of the runway configuration and the taxi times are available in this port. The requests that are possible in this port are:

- SectorConfigurationPlanRetrieval Request
- SectorConfigurationPlanUpdate Request
- CapacityPlanRetrievalRequest
- CapacityPlanUpdateRequest
- TrafficVolumeActivationPlanUpdate Request
- OTMVPlanRetrievalRequest
- OTMVPlanUpdateRequest
- RunwayConfigurationPlanRetrieval Request
- RunwayConfigurationPlanUpdate Request
- HotspotListRequest
- HotspotPlanUpdateRequest

2.6.4 Meteorological Services

The Meteorological information that is available through SWIM goes beyond that offered by the classical METAR & TAF reports for airport weather & SIGMETs (plus specific NOTAMs) for en-route. iWXXM offers primitives to map all of these in an improved and more machine friendly way but it also includes ways to exchange much more detailed information, for example about wind.

In Europe the services are not offered by Eurocontrol NM, but there are already some listed parties in the registry that offer these services. For example EUMETNET (Meteo France) was set during the SESAR GLOBAL demos serving WXXM information about both airport and en-route weather to the different partners.

There are mechanisms so that the data contained in the WXXM messages can refer to the AIXM data model when required. This means that weather information can also be easily integrated with other services.

2.6.5 NOTAM

With the SWIM era is also coming a renewed format for NOTAMs in the form of Digital NOTAMs (D-NOTAM) which evolve the technology to make it much more flexible and automation friendly.

The current NOTAM is a text note, which can be distributed by basic teletype networks such as AFTN (Aeronautical Fixed Telecommunication Network). The NOTAM is intended to be read by pilots, controllers and other operational personnel involved in flight operations.

By contrast, a Digital NOTAM is a small data set, made available through more advanced communication networks (such as AMHS (Aeronautical Message Handling System), TypeX, etc.). It is intended to be read and processed by automated systems, which in turn will convert it into text and graphical formats for presentation to humans. Digital NOTAM can be used for example in order to present an updated airport chart to the pilot or to the air traffic controller, containing graphical depictions of the work in progress areas, closed taxiways or runways, temporary obstacles, etc. A Digital NOTAM might also trigger automated actions, such as determining procedures impacted by the unavailability of a navaid.

In order to encode the NOTAM information digitally, all the data currently exchanged by NOTAM needs to be modelled and specified in a data exchange format. This was achieved with the

Aeronautical Information Exchange Model (AIXM) version 5. In addition to the model, rules and guidelines are necessary in order to harmonize the encoding of the different categories of NOTAM events.

The inclusion of D-NOTAMs data primitives into AIXM permits cross references to other aeronautical information such as sectors or any other elements within the AIXM schema. This allows for an efficient and coherent maintenance of all information in a single dataset that can be shared between different actors, sharing their AIXM sources much like in the spirit of SWIM.

Although this is yet a very new technology, there are already some D-NOTAM service providers. For example the Eurocontrol SWIM registry lists the IDS service as available. This service was shown during the SESAR Global Demo in Rome 2016.

2.6.6 Summary of SWIM and Data Exchange Services

Table 9 shows a brief summary of the previously described SWIM categories and the related state of the art data exchange formats.

Table 9: Summary of SWIM and Data Exchange Services

SWIM		Date Exchange Format			
Information	Categories	AIXM	FIXM	WXXM	NOTAM
Aeronautical	Aeronautical	X			X
	Geospatial	X			X
Flight Trajectories	Flight		X		
Aerodrome Operations	Operational	X			
Meteorology	Weather			X	
Air Traffic Flow	Flight		X		
Surveillance	Surveillance		X		
Capacity and Demand	Aeronautical/Flight	X	X		

2.7 Current Information Services – Unmanned Aviation

The ongoing global encouragement and excitation of integrated drone operations opened up diverse business opportunities for current and future information services, e.g. facing the need to manage operations, displaying no-fly zones for UAVs, scheduling maintenance and personnel training. The following section introduces a set of companies that already offer such dedicated services, based on the needs of commercial drone operators. The corporations have been selected according to information from Eurocontrol, evidence provided by the participants of our own online survey and internet research platforms.

2.7.1 Existing Service Providers

The boxes below detail a set of exemplary services which are competing on the market of drone information services. They summarize the primary information categories, a brief description of the provided services and current availability. For further details, please concern the given website addresses.

Airdata UAV

AIRDATA™ UAV

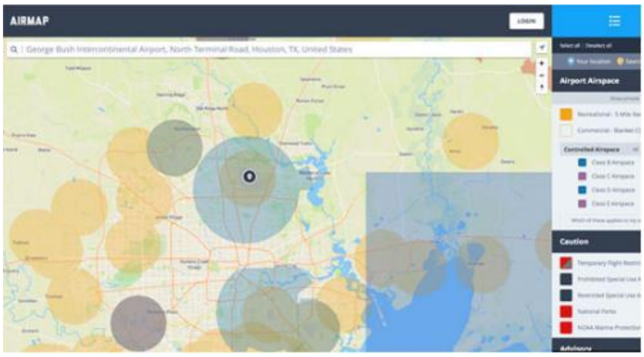
Category
UAS – Operational

Service description
Flight data recording and analysis for performance control. Proactively plan maintenance. Report and track services. Customized reports of operations. Set individual thresholds for performance alerting and potential problems.

Availability
Globally

Source
https://airdata.com

Airmap



AIRMAP

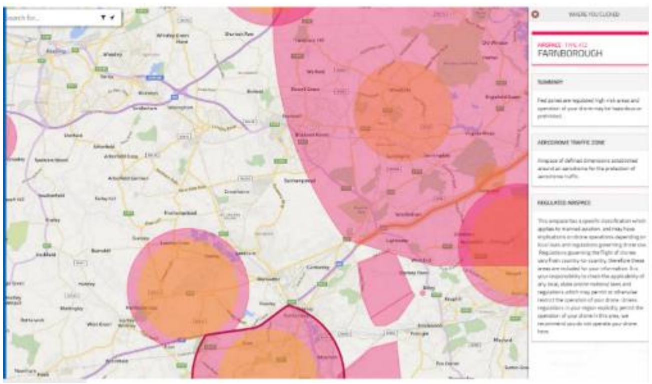
Category
Flight – Weather – Aeronautical – Administrative Authority

Service description
Real-time airspace intelligence about the operators flights, controlled airspace, temporary flight restrictions and weather changes to ensure safety and compliance with applicable regulations. Automated flight authorization for the US airspace with LAANC.

Availability
USA, Europe.

Source
https://www.airmap.com

Altitude Angel



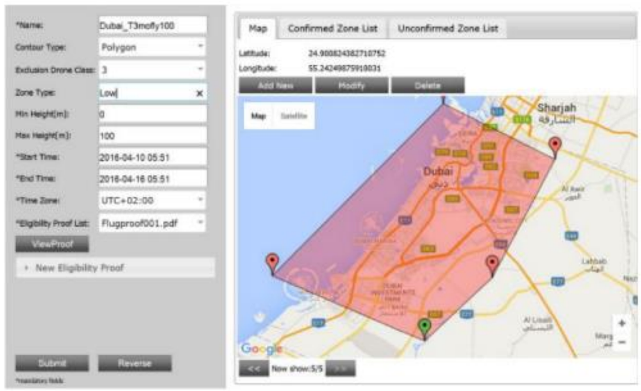
ALTITUDE ANGEL

Category
Aeronautical – Flight – Weather – Administrative Authority

Service description
Altitude Angel is an aviation technology company focusing on creating global-scale solutions that enable the safe integration and use of fully autonomous drones into airspace worldwide. Supporting both U-Space and UTM, our purpose-built cloud platform delivers class-leading services to drone operators, manufacturers and software developers by enabling them to access a rich source of real-time aeronautical, environmental and regulatory data all tailored to the individual operation dynamically.

Altitude Angel	
Additionally, the platform provides an integrated portfolio of scalable and robust digital communications services to aviation stakeholders, national drone registration solutions and integrated identification services to deliver comprehensive protected airspace management solutions. **Products Services:** **Drone Safety Map** – The Drone Safety Map provides real-time information on aeronautical, weather and ground hazards to ensure a safe and efficient conduct of flights, for instance by providing visual NOTAMS (e.g. TFRs). There is also a capability to share flight reports (flight plans) with other airspace users and maintain awareness (through Airspace Alerts) of other nearby manned/unmanned aviation, significant changes in weather and dynamic airspace closures. https://www.altitudeangel.com/drone-operators/ **Guardian Apps** (and branded versions e.g. **Drone Assist / FlySafe**) - An on-the-move application (for smart phones and tablets) providing similar capability to the online Drone safety Map with real-time notifications. https://www.altitudeangel.com/drone-operators/ **Developer Platform** – Provides API access into the underlying Guardian UTM platform for both software developers and manufacturers. Altitude Angel's open, web standards based provides programmatic access to accurate, up-to-date and relevant aeronautical, environmental, regulatory and drone-centric operation data. Beyond the provision of data, the platform can proactively notify your systems whenever important events in the airspace occur, such as changes to the classification of a region of airspace, or when a tracked manned aircraft is likely to intrude on a defined region. Both Drone Safety Map and Guardian applications rely on this underlying platform. https://developers.altitudeangel.com/docs **Protected Airspace Management System (PAMS)** - Enables national/regional management of a particular region of airspace, giving real-time communications, deconfliction and registry services for each facility. Coupled with apps and developer platform, PAMS is designed with deep integration to existing aviation systems, including airport Electronic Flight Strip solutions, PAMS is the solution required to safely integrate drones into your airspace, now - and well into the future. https://www.altitudeangel.com/authorities-infrastructure/protected-airspace-management/	
	Availability 80 countries
	Source https://www.altitudeangel.com

Colibrex Drone Management



Colibrex
Member of the LS telcom Group

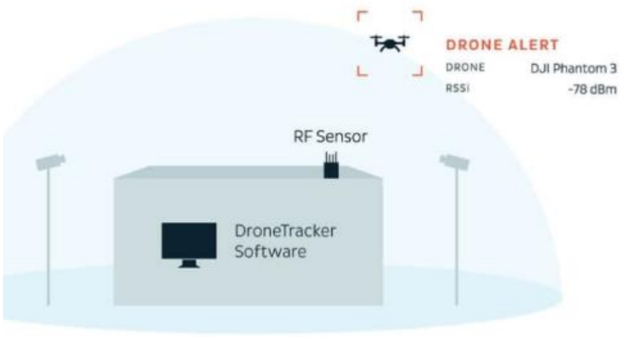
Category
UAS - Flight

Service description
Drone management portal to provide flight approval mechanisms, geo-fencing and drone traceability

Availability
Unknown

Source
http://www.colibrex.com/en/drone-management/

Dedrone



Dedrone

Category
Surveillance – Administrative Authority

Service description
Soft- and hardware solution for airspace control and non-cooperative drone tracking, including counter measurements.

Availability
Global

Source
https://www.dedrone.com/

Drone Logbook

DRONE Logbook

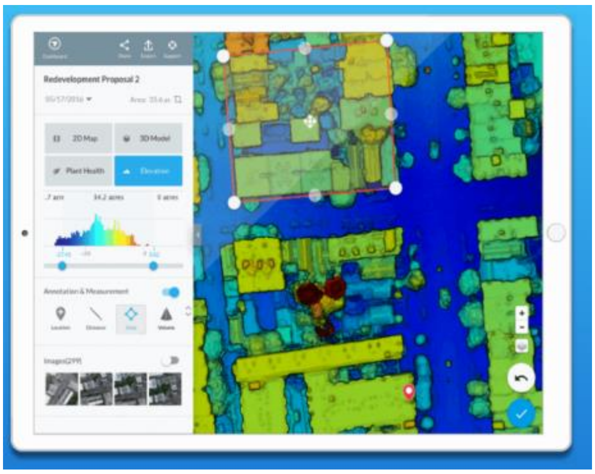
Category
Flight – Operational – UAS

Service description
Flight management platform including mission planning and report functions as well as equipment and maintenance management solutions.

Availability
Global

Source
https://www.dronelogbook.com/

DroneDeploy



DroneDeploy

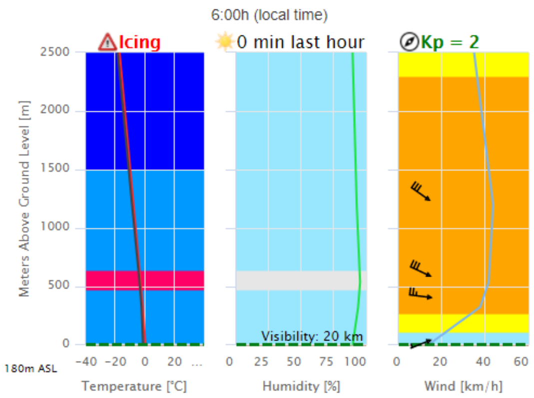
Category
Aeronautical – Flight – Navigation

Service description
Planning and execution of real-time mapping operations and in-field analysis. Improvement of operational quality with ground control points for higher navigational accuracy. Maintain visibility of previously flown routes, missions and captured data.

Availability
Global

Source
https://www.dronedeploy.com/

Droneweather Meteomatics



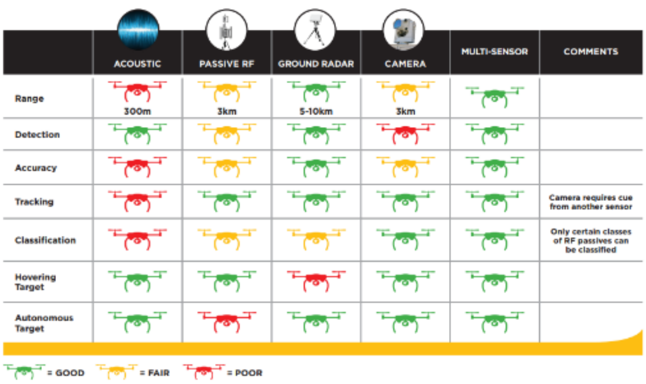
Category
Weather

Service description
Dedicated drone weather up to 2500 feet above ground level.

Availability
Global

Source
https://droneweather.ch/

Gryphon Sensors: Skylight

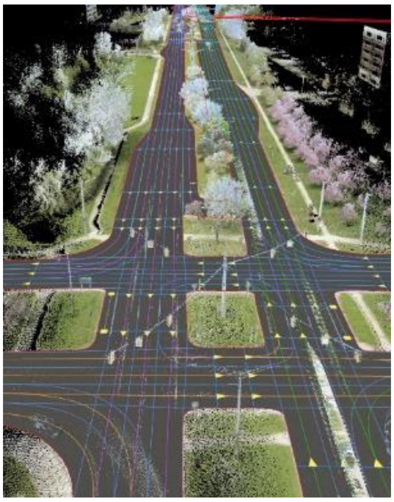


Category
Surveillance – Administrative Authority

Service description
Detecting cooperative and non-cooperative targets in an airspace by providing multiple ground-based sensor arrays and software solutions.

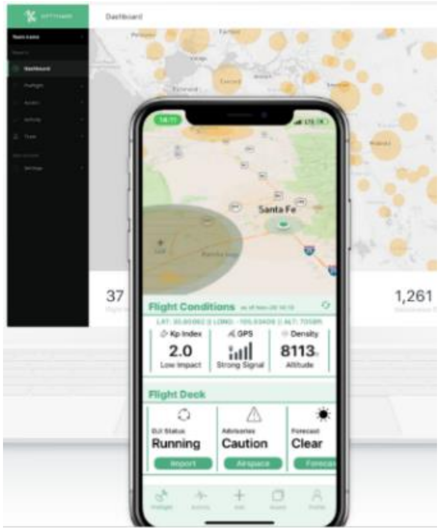
Availability
Global

Source
http://gryphonsensors.com/

HERE Technologies	
	**Category** Aeronautical / Geospatial – Administrative Authority **Service description** Airspace mapping for drones, which marks out no-fly zones, such as airports, residential areas and sensitive government installations. **Availability** Global **Source** https://www.here.com/

Hionos: Signalpack and Pulsar	
	**Category** Surveillance – Flight **Service description** Provides soft- and hardware solutions for drone surveillance, tracking and visibility (Signalpack). The second product (Pulsar) is an autopiloting solution for autonomous flights in safety critical environments. **Availability** Global **Source** https://www.hionos.com/

Kittyhawk



KITTYHAWK

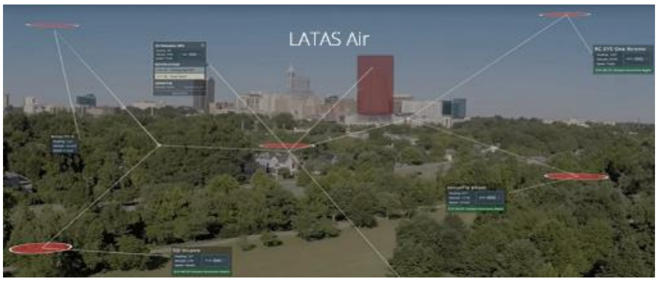
Category
Aeronautical – Flight – Operational – Weather – UAS – Administrative Authority

Service description
Provides access to weather and airspace information; solutions to plan flights and document drone data in all phases of the operation.

Availability
Global

Source
https://www.kittyhawk.io/

LATAS: Air and Ground



LATAS
FLY SAFER

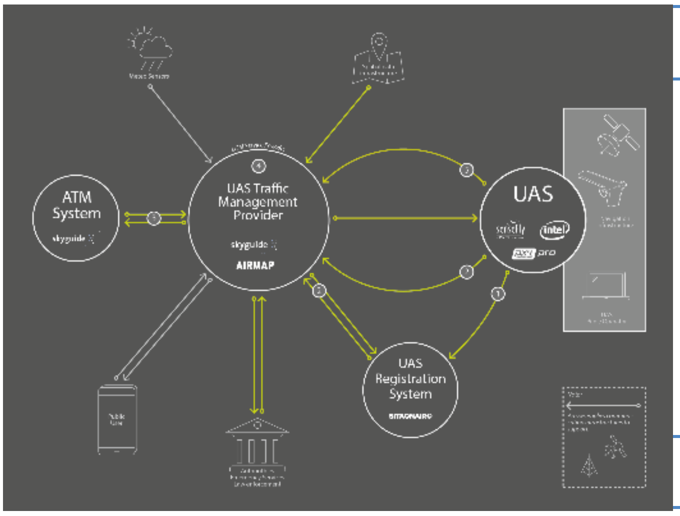
Category
Aeronautical – Flight

Service description
Latas Air displays live radar feed of aircraft traffic and provides notifications for potential flight plan conflicts and no-fly zones. Latas Ground provides a 3D obstacles data base for buildings, terrain trees and towers. To improve situational awareness these information is dynamically displayed based on drone proximity and hazard potential.

Availability
128 countries

Source
http://www.flylatas.com

SITAONAIR



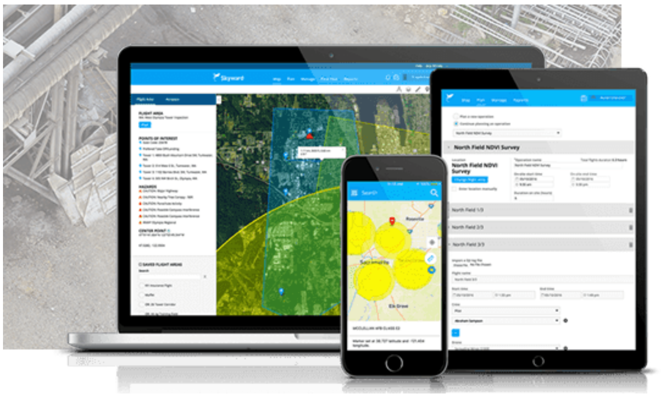
Category
UAS

Service description
System solution for a UAS registration system that is to be connected with a future UAS traffic management provider. Will enable drone operators to register themselves as pilot, and their drones for public record, linking their identity, details, and their drone serial number, model and operation modes, to unique identifiers delivered by the registry.

Availability
First live demo Switzerland, 2017

Source
https://www.sitaonair.aero/paving-way-drone-age-sitaonair/

Skyward



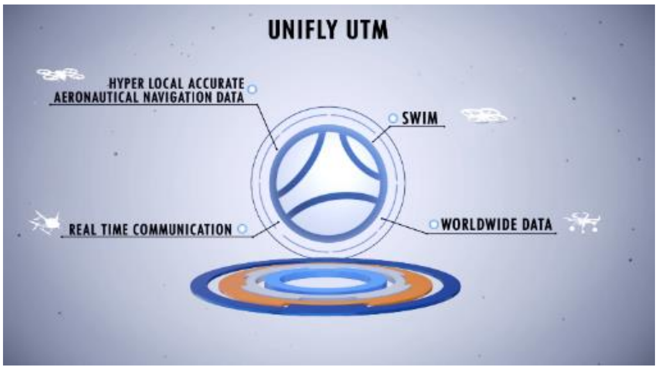
Category
Aeronautical – Flight – Operational – UAS

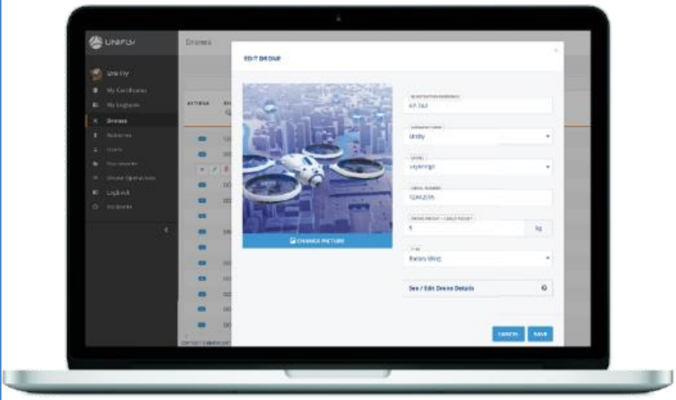
Service description
Drone operation management software for all flight and business phases: Interactive map to collaborate and plan safe flight jobs. Manage operational procedures during flight. Keep track of pilots and drone records for business and regulatory needs.

Availability
Global

Source
http://www.skyward.io

Unifly UTM





Category

Aeronautical – Flight – Surveillance – Operational – UAS – Administrative Authority

Service description

UTM platform to connect ANSPs and official entities with drone operators to ensure a safe integration of UAS into the airspace; includes several stand-alone services:

Unifly Launchpad shows airspace legislation and contains a personal UAS database.

Unilfy Pro is an application for operators to plan and legally validate drone flights. Fleet can be managed and flights records be kept.

Unifly Sentry addresses aviation authorities that need to track drone activities and manage airspace by creating no-fly zones and identify potential conflicts.

Unifly Connect offers a data-based drone application development architecture based on existing industry standards for manned aviation, such as SWIM, AIXM, ASTERIX or FIXM.

Availability

Global

Source

http://www.unifly.aero

2.7.2 Summary of Unmanned Aviation Information Services

Table 10 summarizes the introduced services that are already available on the market and shows briefly how they fit into the categorization of drone information provided in chapter 2.5.2.

Table 10: Comparison of existing unmanned aviation information services with the proposed categorization

Brand	Service	Aeronautical	Geospatial	Flight	Communication	Navigation	Operational	Surveillance	Weather	UAS	Administrative Authority
Airdata UAV	UAV Performance Control						X			X	
Airmap	UAV Safety Maps	X	(X)	X					X		X
Altitude Angel	UTM Portal	X	(X)	X		Partial	1)		X	2)	X
Colibrex	Drone Management			X	X					X	
Dedrone	Airspace Control				X			X			X
DroneDeploy	Real-time Mapping	X	(X)	X		X					
Droneweather	Weather Forecast								X		
Drone Logbook	Flight Data Management			X			X			X	
Gryphon Sensors	Airspace Control				X			X			X
Here Technologies	UAV Safety Maps	X	X								X
Hionos	UAV Safety Systems			X	X			X			
Kittyhawk	UAV Operation Management	X	(X)	X			X		X	X	X
Latas	UAV Safety Maps	X	(X)	X							
SitaonAir	UAS Registry									X	
Skyward	UAV Operation Management	X	(X)	X			X			X	
Unifly	UTM Portal	X	(X)	X			X			X	X

1) Subject to locations infrastructure capability. *2)* Subject to operators on-board drone capability.

(X) Service focuses primarily on provision of aeronautical geo-data, not ubiquitous geo-spatial data.

3 System Outline

At the moment of producing this deliverable, no logical architecture was officially documented in the European literature about UTM or in the ongoing project to define the U-Space Concept of Operation, CORUS. Thus, the IMPETUS consortium has determined to outline an **internal vision of the high-level logical architecture of the future U-Space system**. This step is necessary to build coherent use cases which will serve as the basis for the identification of gaps in current available information systems and services for their use in unmanned aviation.

The first section is focused on identifying **invariant system functions** that should exist in the future U-Space system. The second section is oriented to the identification of potential **roles and responsibilities**. The third section is addressing potential **data transfer and processing mechanism**. Inconsistencies in terminology and nomenclature between the three sections are due to the fact that no agreed terminology in the European literature was identified at this stage[3].

3.1 Invariant System Functions

This section focuses on the invariant functions that are necessary to facilitate the planning and execution of a mission, from the perspective of a drone operator and with analogy to future ATM systems for manned aviation. The processes are described for the planning and execution phases.

3.1.1 Planning Phase

In planning (Figure 17), the Drone/Mission Operator (MOP) defines mission requirements in order to plan the mission. The Mission Planning function interacts in an iterative way with the Flight Planning function to formulate a *flight intent* for each drone participating in the mission. To create this *flight intent*, the Flight Planning function draws information from a set of services - such as a Drone Service Trajectory Prediction (DSTP), a Drone Meteo (DMET) service, Drone Aeronautical Information Service (DAIS) and Drone Ground Information Service (DAIS) - and from a central Drone Aircraft Performance Model (DAPM) database. In a further step, the Flight Planning service interacts with the Unmanned Traffic Flow Management Service (UTFM) for strategic deconfliction. Once a consensus between Mission Planning, Flight Planning and UTFM has been reached, the Mission is approved for execution.

[3] The agreement on a common terminology with other on-going exploratory research projects, and in particular with CORUS, will allow solving these inconsistencies.

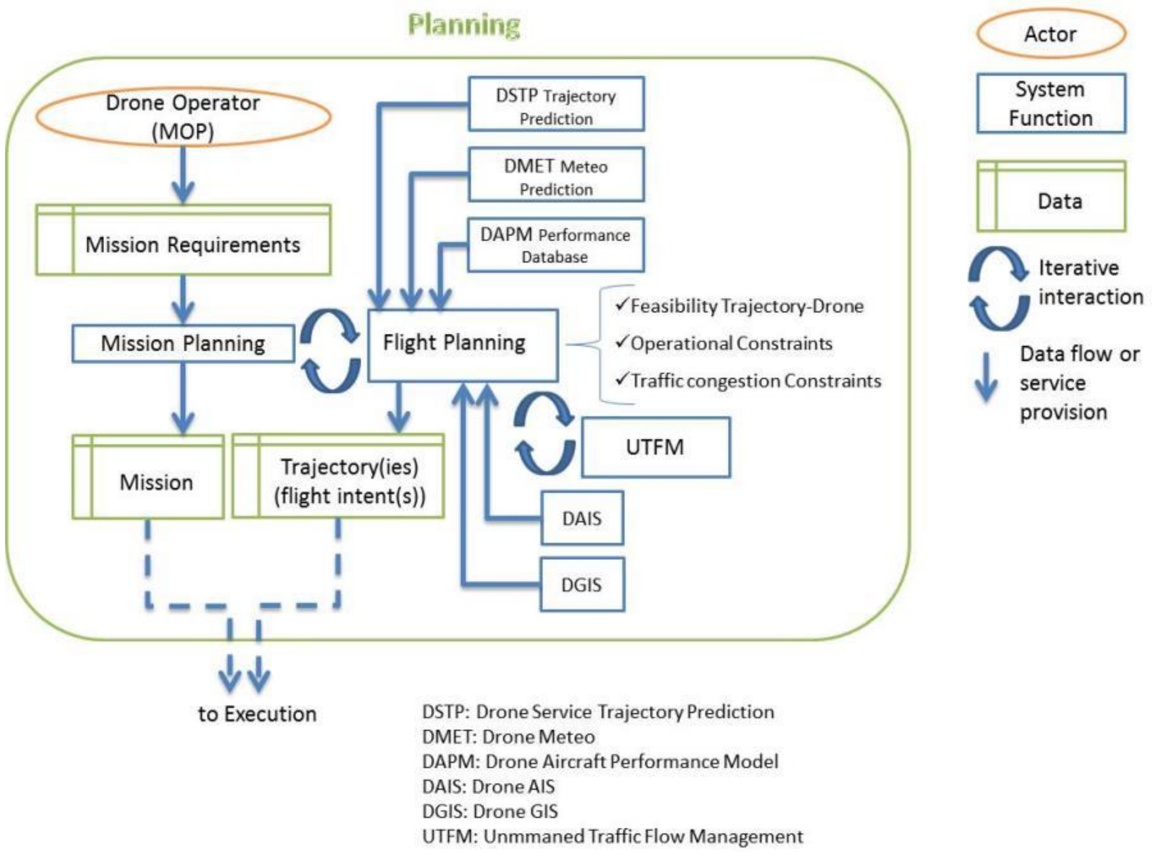


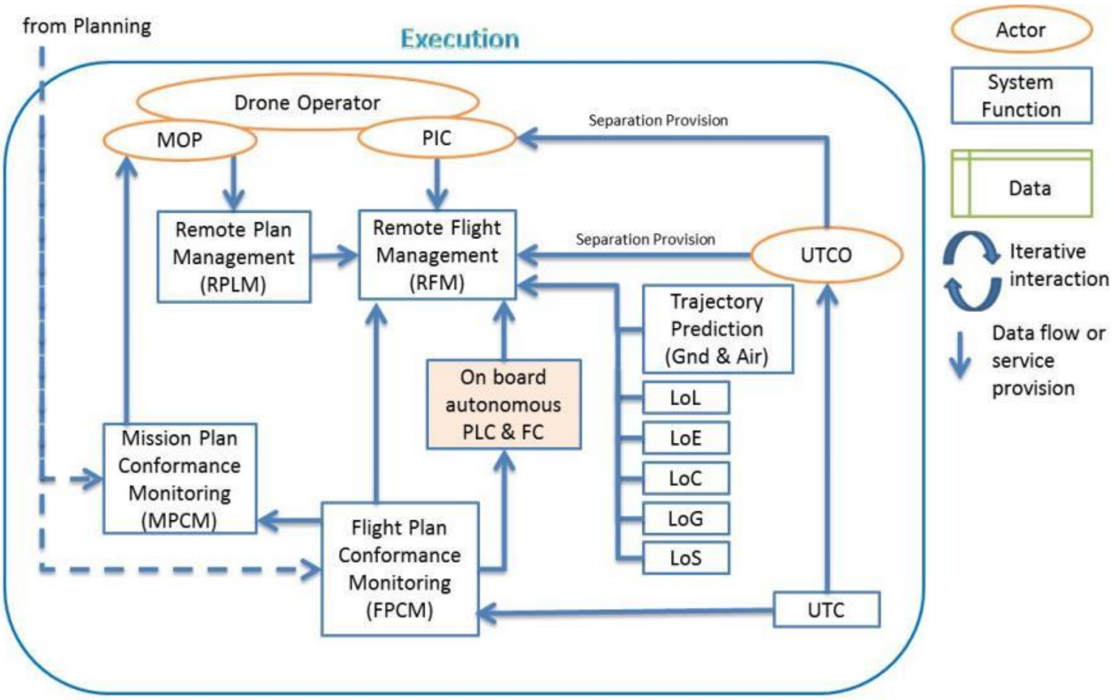
Figure 17: Overview of invariant system functions in the Planning Phase

3.1.2 Execution Phase

The mission is launched and the Drone/Mission Operator (MOP) and Pilot in Command (PIC) monitor and manage respectively the mission progress via Remote Plan Management (RPLM) and the flight progress via Remote Flight Management (RFM) services (see Figure 18).

The Flight Plan Conformance Monitoring (FPCM) service is a fundamental service which acts as a driver for RFM and Mission Plan Conformance Monitoring (MPCM). Unmanned Traffic Control (UTC) provides monitoring information and traffic awareness both to the FPCM function and to the Unmanned Traffic Controller (UTCO), which is an actor in charge of providing separation advisories towards other Airspace Users (AUs). The UTCO interacts with RFM and directly with the PIC, if necessary.

Flight contingency situations as well as trajectory predictions are managed via the RFM or via on-board autonomous Payload Control (PLC) and Flight Control (FC) management systems.



MOP: Mission Operator
PIC: Pilot in Command
UTCO: UTM Controller
PLC: Payload Control
FC: Flight Control

LoL: Loss of Link
LoE: Loss of Engine
LoC: Loss of Control
LoG: Loss of GPS
LoS: Loss of Separation

Figure 18: Overview of system function in the Execution Phase

3.2 Statement of Responsibilities

This section depicts a layered and federated system with an open and competitive market in mind. It is based on the idea of identifying and using standard interfaces with defined performance criteria and levels of certification requirements. Its main purpose is to describe how roles and responsibilities can be distributed among three main actors: the *Drone Operator*, the *Service Provider* and the central *U-space Authority*, which is in charge of orchestrating the essential parts of the system.

The end-user cannot interact directly with the U-space Authority, but instead has to use a U-space Service Provider from an open marketplace as medium interface (see Figure 19).

As in the previous section, the processes are described for the planning and execution phases.

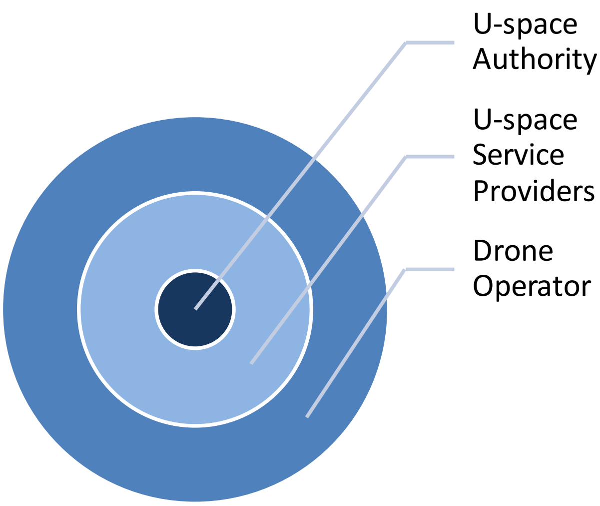


Figure 19: Depiction of the main actors inside the system outline

3.2.1 Planning Phase

In the planning phase (**¡Error! No se encuentra el origen de la referencia.**), the Drone Operator issues a *Flight Request* via a Flight Planning service, which can be provided by several actors on an open market. The Flight Planning service is connected to a Permission System, which deconflicts filed flight plans and issues or denies permissions based on capability levels of the equipment. This service is run by the central U-Space Authority. The U-Space Authority is also the single provider of the Accurate Airspace Picture (DAIS), which allows a central view of airspace usage for authorities and law enforcement to be able to understand what is happening in the skies, including potential ATM integration feeds.

Another important centralized service is the Authoritative Geo System (DGIS), which consists of a data set of restrictions and hazards that is approved and maintained by the State. This data will be served from a centralized service that is isolated from the end user by a marketplace of U-Space service providers. In consequence, a Geo-Awareness service is required so that operators and drones are aware of restrictions and hazards. This should be a competitive marketplace where service providers are able to additionally differentiate themselves by adding data to the authoritative dataset – e.g. greater range of hazards, terrain model, 3D City maps, etc.

DAIS and DGIS are directly linked to the Permission System, which iteratively interact with the Flight Planning service until the final flight plan is created.

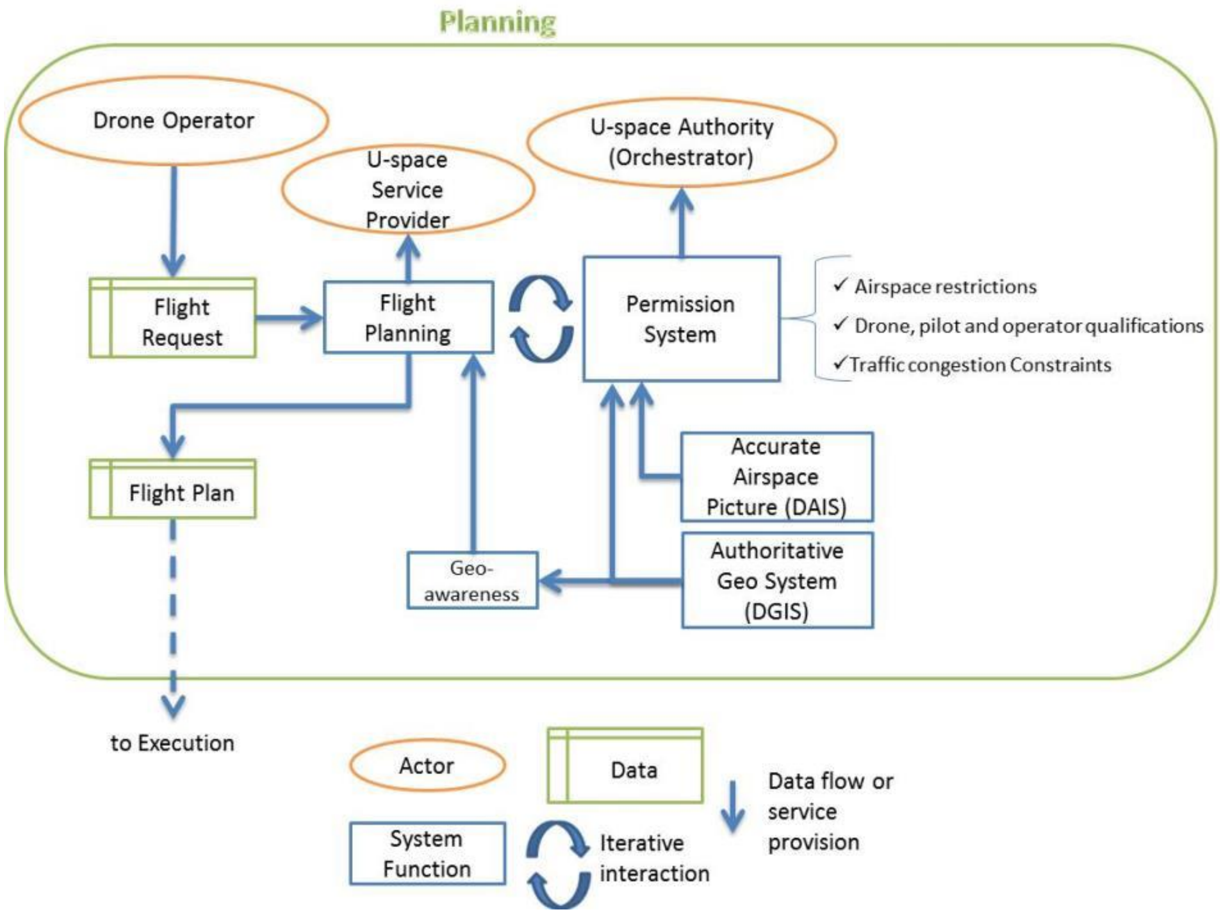


Figure 20: Overview including the distribution of responsibilities in the Planning Phase

3.2.2 Execution Phase

The permission to take-off and fly a route is given to the drone by the U-Space Authority via the Permission System (see **¡Error! No se encuentra el origen de la referencia.**). This central service should not be directly accessible by the end user; instead they will go through a U-Space Service Provider that will be able to perform flight-relevant tasks on their behalf.

U-Space Service Providers will be the central point of contact between the U-Space Authorities and the Drone Operator. For instance, a drone in flight will relay its position to the Drone Operator as well as to (or even via) a U-Space Service Provider for Flight Planning and Execution. This service provider then relays the position information to the central Monitoring service of the U-Space Authority.

In turn, the U-Space Authority provides Collision Avoidance Information/Instruction Services to the U-Space Service Provider, which forwards new instructions to the drone operator or directly to the drone. If drones are human-controlled, the Collision Avoidance Information service can warn drone pilots about potentially conflicting manned and unmanned aviation as well as changes to airspace and potentially poor weather. In the case of automated drones, they will be equipped with Sense and Avoid systems but this should not be the only means of avoiding a collision. Therefore the U-Space Authority will also run Collision Avoidance Instruction Service provides a Plan-to-Avoid system, which dynamically routes drones around hazards while they fly.

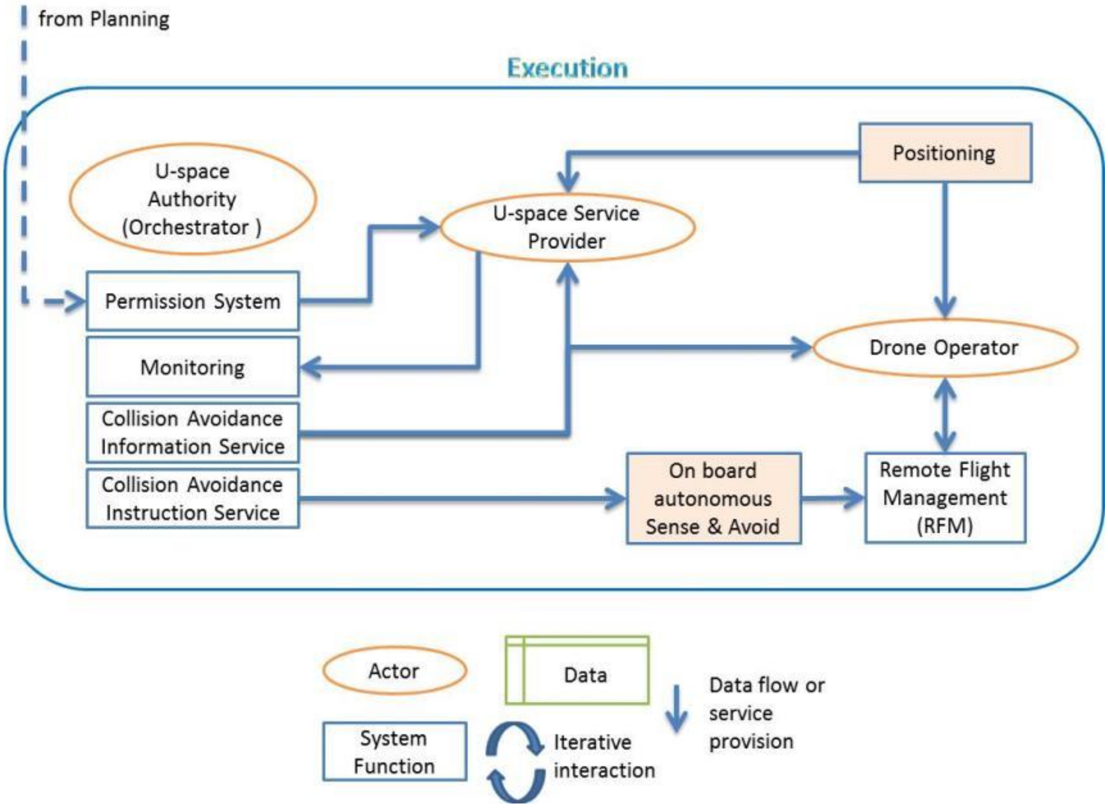


Figure 21: Overview of including the distribution of responsibilities in the Execution Phase

3.3 Data Transfer and Processing Mechanisms

This section will only provide basic information about the information management processes. The technologies to be implemented, a thorough analysis of their pros and cons, the methodology of data management and the standards adopted will be further described in WP3 deliverables.

The main goal of data management in UTM systems is the provision or transferring of information between stakeholders or services. Operational data, managed in a real-time process, is the base of a system to support the decision-making paradigm.

The minimum requirements of data management are:

- **Integrated**: the main objective of the information is defined and there is only one way to interpret it;
- **Integrity**: accurate-enough in term of accuracy and complying with business rules;
- **Accessible**: easily manageable with intuitive access and visualization;
- **Credible**: the information is reliable and has a defined value;
- **Timely**: data must be provided within the required time frame, intense use of the resources;
- **Analysis**: the information is subject to analytical tasks;
- **Heterogeneous**: data is provided from multiple sources/applications;
- **Structured**: data needs an organised structure to be used as information.

The only viable solution is what is called **Data Warehouse (DW)**, an informational environment that provides a general view of all the information stored (historical) and collected (from other sources) to enable its exploitation with decision-support technologies (transaction and analysis processes together), offering a wide range of solutions to interact with these inputs. This process will align, combine and present the relevant information to an end-user in a user-friendly interface.

Nonetheless, DW must be updated regularly using the available sources. This process is called ETL (Extracting, Transformation and Loading), which has been extended to cover the transmission and the delivery steps. The following figure represents the key principles of the data lifecycle. Further details on these processes can be found in Appendix B "Generic data lifecycle".

- **Extraction**. The desired data (depending on the requirements) are identified and extracted from different sources;
- **Transformation**. After extracting the required information, raw data must be processed to be compatible and usable in the data warehouse analytics, focusing on the principle of being used for strategic decision-making;
- **Loading**. Data is now processed and prepared to be part of the DW, storing all the information in the database;

- **Delivery**. Several mechanisms should be defined to offer potential data consumers (end users) the requested pieces of strategic information;
- **Transmission**. Data has to be transmitted across platforms, business models and users.

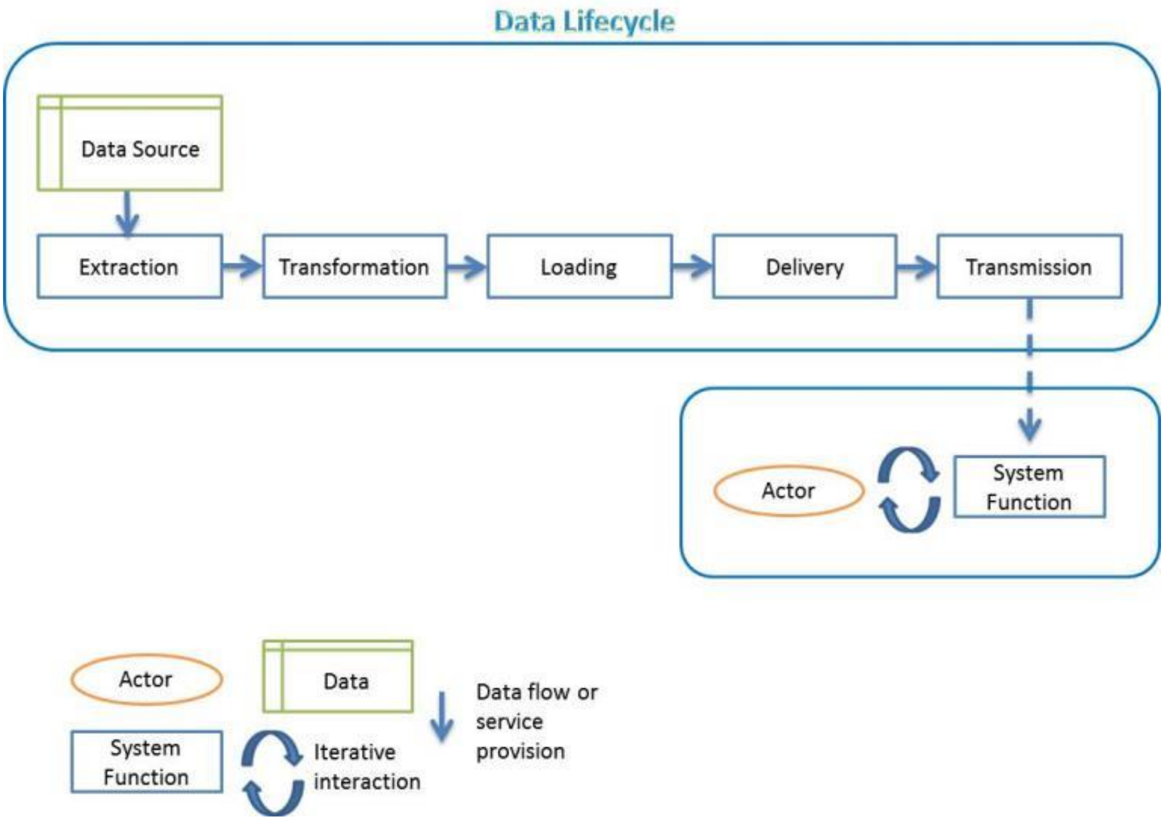


Figure 22: Generic data transfer and processing mechanisms

4 Use Case Proposal

To refine the results of the drone users' information needs identified with the online survey, use cases were described. The following chapter will introduce six use cases that were selected based on the simplified classification presented in chapter 2.2.7. As illustrated in Figure 23, they are supposed to cover all varieties that are expected to be essential in the next 15 to 20 years of the U-Space development.

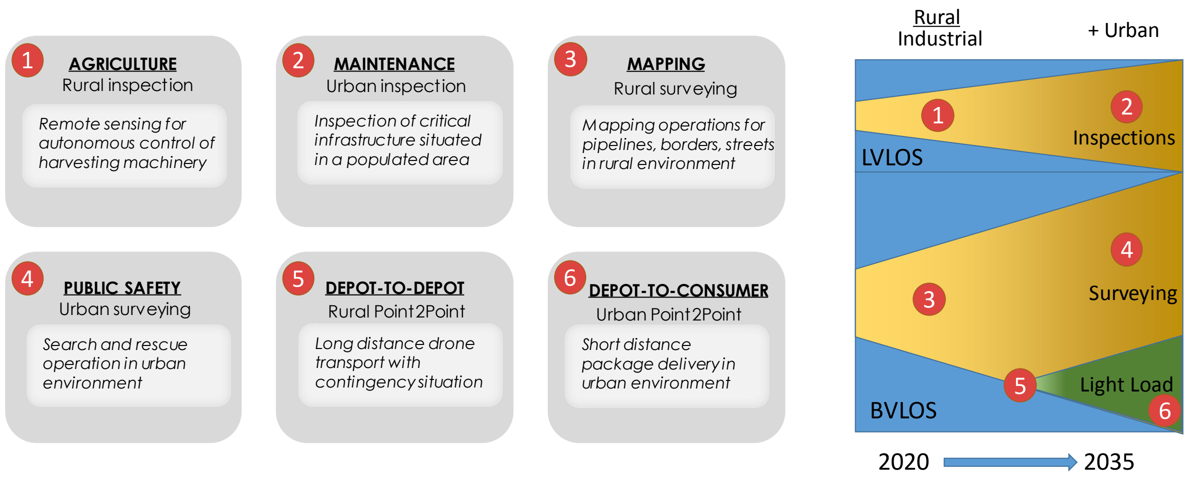


Figure 23: Overview use cases

To ensure that the envisioned use cases depict the future operations in a realistic way, topics were chosen that guarantee an internal or external review by experts of that matter.

4.1 Guiding and Supervising Autonomous Agriculture

4.1.1 Context and Assumptions

Proposal of a drone operation enabled by U-Space and inspired by current ENABLE-S3 research conducted by ULPGC and other project partners [40].

4.1.2 Summary

Operating costs and efficient use of resources are key in competitive, sustainable and contemporary farming methods. These requirements can be met by enabling autonomous harvesting machines to support precision farming on a high level. Since UAVs are capable of providing geospatial data and real-time information based on hyperspectral and thermal imaging from above, they can be utilized to a) provide agricultural information advantages; and b) command and control autonomous harvesters. Additionally, they offer a high quality, flexible and cost efficient alternative to conventional methods of aerial remote sensing.

The following use case will show, how such a long term operating procedures is conducted, including the high altitude surveying mission as well as the low level, inspection-like flights necessary to head and command the harvesting machines through the fields.

4.1.3 Actors

Drone Operator "Harvester Supervisor" – [Primary]

Operates one or more UAVs, equal to the number of individual harvesting machines in defined operating areas. In this use case also acts as the **End Customer**.

U-Space Service Provider 1 "Essential U-Space Services" – [Secondary]

Provides assistance for flight planning, assistance for authorisation and DTM services to ensure a safe, efficient and secure conduct of UAS operations.

U-Space Service Provider 2 "Agricultural Remote Sensing Data Processing" – [Secondary]

Provides software and services to transform real-time sensor data into dynamic routes and commands for the harvesting machines as well as for the UAV, including specific management tools for agricultural UAS operations.

U-Space Service Provider 3 "Short and Long Term Rural Weather Forecasts" – [Secondary]

Provides weather and information services for rural areas and with agricultural context (such as Growing Degree Days, Phytophthora Negative Prognosis or Moisture Stress Index); interacts with Service Provider 1 and 2, to facilitate flight permission calculation and tactical decision-making for cropping.

U-Space Authority "Identity Provider, Authorized Weather and Geosystem" – [Secondary]

The authority providing reliable data and updated information linked to the airspace management (restricted areas, temporary restricted zones, etc.) and in particular specific information for drone operations ("no fly" zones, drone tracks etc.).

Competent Authority – [Secondary]

The authority giving permit to fly to drone operators using a category of drones for a specific mission.

Contains registry information about the Drone Operator's licensing, drone equipment, drone contingency provisions and delivery classifications.

4.1.4 Pre-conditions

Drone Operator:

- Is licensed to operate UAVs by the **Competent Authority** (e.g. NAA);
- Is authorized to operate autonomous harvesting machines;
- Is registered by the **Competent Authority;**
- Has access to working equipment appropriate for the operation (e.g. UAVs, compatible harvesting machines, ground control stations etc.);
- Has authority over the operating areas or is commissioned to this effect;
- Has standard access to basic U-Space U1, U2 and U3 services via Service Provider 1;
- Has advanced access to context specific U-Space services via Service Provider 2 and 3;

Drone Specifications

- Positioning Capability: Level 4 (Highly accurate with redundancy);

- Datalink: Via radio modem and 5G mobile networks;
- Drone Type: Hybrid;
- Propulsion: 4 DC Motors;
- VTOL capabilities;
- Dimensions: 0,80 m x 1,20 m x 0,4 m;
- Auxiliary Equipment: Hyperspectral/thermal cameras, sonar, sunlight sensor, real-time kinematics and referencing system to the position of the harvesting machine ;
- Max. Payload: 5.5 kg.

Service Provider 1:

- Has a valid U-Space service provision license;
- Provides select U-Space U2 and U3 services (Table 11) to its customers;
- Has direct access to the **U-Space Authority;**
- Acts as Data Exchange and Management Platform;
- Can calculate automatically generated flight plans based on origin and destination coordinates and drone/operator information stored in the database;
- Has information about the capabilities, equipment and optimal operating method of all of the drones of the **Drone Operator.**

Service Provider 2:

- Has a valid U-Space service provision license;
- Provides detailed (public) Digital Elevation Maps (DEM);
- Provides data analysis tools to process hyperspectral and thermal images for agricultural purposes;
- Provides command and control features for autonomous harvesting machines;
- Provides operation management specific to the needs of the agricultural business sector;
- Stores and protects detailed mapping and remote sensing data proprietary to the operator / drone service receiver;
- Does not have direct access to the **U-Space Authority**, but interacts via **Service Provider 1.**

Service Provider 3:

- Has a valid U-Space service provision license;
- Provides short-term weather status and forecast appropriate for immediate UAV flight approval and agricultural decision making;
- Provides long-term weather forecast appropriate for strategic UAV operation planning and agricultural decision making;
- Does not have direct access to the **U-Space Authority**, but interacts with **Service Provider 2.**

U-Space Authority

- Provides strategic and tactical flight de-confliction;
- Has direct access to all registry information;
- Manages flight plan approvals;
- Provides Authoritative Geo System Service;
- Provides emergency management and tactical de-confliction in case of State incidents.

Table 11: Overview of U-Space services and service providers in Use Case 1

	Drone Operator contracts:		:
U-Space Authority	**Service Provider 1**	**Service Provider 2**	**Service Provider 3**
DAIM	DAIM		
			Weather
		Real-Time Data Processing	
		Agricultural Decision Making	
		Flight Scheduling	
		Geo-Awareness	
Tactical geofencing			
Flight plan management	Assistance for flight planning	Assistance and system input	
Monitoring	Tracking	Tracking	
Strategic de-confliction			
Tactical de-confliction			
Emergency management			
Traffic information			

4.1.5 Post-conditions

4.1.5.1 Success end-state

The use case is considered to be a success when the following conditions apply:

- Successful provision of drone service (guiding and supervising autonomous agriculture);
- Successful return of drone to its storage place;
- Efficient and safe conduct of mission;
- Data protection secured proprietary information during the whole flight life cycle.

The drone has provided aerial information with the purpose of supervising, commanding and controlling an autonomous harvesting machine. During the whole mission, no airborne or ground obstacle collisions have occurred, and precision agriculture has been performed within the capabilities of the used systems. All captured information is protected according to proprietary rights of the operator / drone service receiver.

4.1.5.2 Failed end state

The use case is considered to be failed when one or more of the following scenarios occur:

- Drone unable to perform operational intent;
- Abort of operation;
- Drone endangers other airspace users, persons or animals, airborne and on the ground;
- Drone causes damage to property, itself or other deployed working equipment;
- Drone contingency provisions fail;
- Deployed autonomous harvesting machine did intercept obstacles without evasive maneuvers provided by the drone and the related service provider technology;
- Proprietary information has not been protected.

4.1.6 Trigger

The use case starts when the **Drone Operator** files the intent of the guiding/supervising mission for a specified area by using Service Provider 2's long-term operation scheduling.

4.1.7 Flow of Events

4.1.7.1 Strategic Operation Phase

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
1	Drone Operator, Service Provider 2	The **Drone Operator** facilitates a long-term operation scheduling by using **Service Provider 2**'s system features.	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
2	Service Provider 1, Service Provider 2, U-Space Authority	**Service Provider 2** periodically transmits strategic operation planning to **Service Provider 1** to inform the **U-Space Authority**: • Date of operation • Type of operation • Area of operation	• Transmission Feedback • Airspace usage plan
3	Drone Operator, Service Provider 2. Service Provider 3	Taking into account weather information provided by **Service Provider 3** and previously recorded remote sensing data, agricultural decisions are made collaboratively by **Service Provider 2** and the **Drone Operator**, leading to adjustments in the strategic planning.	
4	Service Provider 1, Service Provider 2, U-Space Authority	**Service Provider 2** provides changes to **Service Provider 1** to inform the **U-Space Authority** (the closer to the effective operation data, the more often the information is updated).	• Transmission Feedback • Airspace usage plan

4.1.7.2 Pre-flight Operation Phase

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
5	Drone Operator, Service Provider 1, Service Provider 2	In time, an official operation request is automatically forwarded from **Service Provider 2** to **Service Provider 1**, including: • **Drone Operator's** ID • Drone ID • Declaration of intent to fly	
6	Service Provider 1, U-Space Authority	**Service Provider 1** uses this information to access a central registry of the **U-Space Authority** which provides all the data required to formulate an automatic flight plan for the drone. This flight plan can only outline flight boundaries, since the main mission intent, "guide and supervise autonomous agriculture", indicates that the drone has to fly ahead of the harvesting	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		machine and adapt the flight paths dynamically in case of evasive manoeuvres. This is assumed to be legit, as long as the operator has the authority over the operating area and adheres to the regulations defining segregation to restricted areas (e.g. crossing a highway to access another field).	
7	Drone Operator, Service Provider 1, Service Provider 2 Service Provider 3	Registry information about the **Drone Operator's** licensing, drone equipment, drone contingency provisions, operational area and classifications are accessed by **System Provider 1** and forwarded to **Service Provider 2** to be combined with advanced navigational information, such as optimal flight patterns based on limitations indicated by the drone capability levels and weather information, provided by **Service Provider 3**.	**U-Space Authority** provides general, authorized information. Such as • Licensing • Operational area • Classifications • Equipment
8	Service Provider 1, Service Provider 2, U-Space Authority	In an iterative process between **Service Provider 1**, **2** and the **U-Space Authority** the flight plan is optimally constructed to fit the requirements of the drone, the operation and system/traffic constraints.	• Transmission Feedback • Flight Plan Approval
9	Drone Operator, Service Provider 1, U-Space Authority	Upon approval of the flight plan from the **U-Space Authority**, **Service Provider 1** via **Service Provider 2** returns the flight approval and the final flight plan information to the **Drone Operator**. The flight plan contains information about operational and flight pattern limitations.	

4.1.7.3 In-flight Operation Phase

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
10	Drone Operator, Service Provider 2	The flight is dived in two legs. First, a surveying flight 120 m AGL is conducted to update the mapping and remote sensing data. Data is transmitted from the Drone	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		directly to the **Drone Operator**'s ground control station and processed in **Service Provider 2**'s system features.	
11	Service Provider 1, Service Provider 2, U-Space Authority	**Service Provider 2** uses the data to refine the operational plan of the second leg and the autonomous harvesting machine. Relevant changes in flight duration and operation boundaries are transmitted to **Service Provider 1** to inform the **U-Space Authority**.	• Transmission Feedback • Approval of minor changes
12	Drone Operator, Service Provider 2	The second leg is an inspection flight ahead of the harvesting machine in 10 – 15 m AGL and with speed equal to it. Thermal and hyperspectral sensors are now used to detect animals, unauthorized persons and various types of obstacles. The data, used to correct the route of the harvesting machine and the drone, is exchanged via **Service Provider 2** and the **Drone Operator**'s ground control station.	
13	Service Provider 2, Service Provider 3	A push transmission on behalf of **Service Provider 3** informs **Service Provider 2** about the fact that a hail is most likely for the operational area in 90 minutes. • Location / Area • Weather Phenomenon • Time • Probability • Impact Equivalent	
14	Drone Operator, Service Provider 2	With the purpose of saving crops from weather damage, the strategic decision is made by the **Drone Operator** and **Service Provider 2**, to instruct the harvesting machine to also yield crops that are not yet totally ripe.	
15	Drone Operator	The UAV is called back to the base station upon the harvesting machine to be protected from most likely weather damage. The **Drone Operator** arranges conventional control of the harvesting machine.	

4.1.7.4 Post Operation phase

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
16	Service Provider 1	The drone arrives back on its station at the harvesting machine and starts re-charging of batteries. Tracking transmission by **Service Provider 1** is cancelled.	• Transmission Feedback • End of Operation • Monitoring cancelled
17	Service Provider 1, Service Provider 2, U-Space Authority	**Service Provider 2** informs **Service Provider 1** that the UAV operation has ended without any incidents. **Service Provider 1** informs the **U-Space Authority** that the flight is completed.	• Operation Record Transmission
18	Service Provider 2	Post-operation analysis is performed by **Service Provider 2**, to optimise future operations and plan the next cycles. Relevant data is stored and protected.	
19	Drone Operator, Service Provider 1	Post-operation analysis for basic U-Space system features is performed by **Service Provider 1** by accessing unclassified flight data with approval of the **Drone Operator**.	
20	Drone Operator	When (19) occurs the use case terminates and new scheduling cycles to plan the operational use of the working equipment can start on behalf of the **Drone Operator**.	

4.2 Inspection of critical infrastructure located in a populated area

4.2.1 Context and Assumptions

Assumptions made in this use case are based upon the definitions set out in Call CEF-SESAR-2018-1 and seen in the context of the outline view provided in chapter 3, including but not limited to all the premises described in this document. In this context, the function of the "Orchestrator" is aligned with that of the "U-Space Authority" (SJU call).

Given the high level of situational awareness required in this environment, the following additional assumptions must be considered:

- Registration services must also store information about the software used during the operations and the U-Space Service Provider in charge of the communication with the orchestrator;
- The monitoring services will also warn the authorities automatically in case of operations in no fly zones;
- The Competent Authority will be responsible in the certification of all types of operators, pilots, operations, devices, equipment, software and Service Providers;
- Filing a flight intent is not enough. A flight plan must be submitted and validated for every operation. The U-Space Authority must manage and deconflict this new information and, if the validation process finishes successfully, provide permission to fly;
- Collision avoidance information & instruction services are provided to both autonomous and human controlled operations, ensuring that there will be automatic actions to manage conflicts (for instance, denying a request of flying through a no-fly zone) and that the pilot has enough situational awareness to take control of the operation in a safe manner.

4.2.2 Summary

The aim of this operation is to analyse the physical state of the structure of facilities, through detection of the wear of materials, surface and internal cracks, as well as the presence of foreign objects. The operation is part of a maintenance program, scheduled by the local authorities and/or the infrastructure owner, to anticipate problems related to the bad condition of the structure or, as an emergency measure, because of the detection of a critical defect that may affect the integrity of the building. This operation shall be performed ensuring restrictive safety conditions due to the nature of the environment.

Two different operations are possible (separately or even during the operation, VLOS and BVLOS):

- **Fully/partially autonomous flights**: the drone will follow a list of predefined waypoints and a trajectory that has been calculated previously. During the operation, it will be aware of changes in the environment that can affect the operation, and it will calculate the safest, most optimal path between two waypoints. The pilot/s will supervise the procedure. During the flight and after reaching every waypoint (or point of interest) the drone will collect data from the attached sensors;
- **Manual flight**: the pilot/s has/have planned a list of predefined waypoints (or points of interest) and the trajectory. The drone will take off and, being controlled by the pilot, will

wait after reaching every waypoint trying to detect deficiencies in the structure and collecting information that can be processed later. During the operation, the pilot is the main responsible of the operation and he must take into account the sudden changes in the environment and provide alternative, reliable and safe solutions that do not cause incidents in the area around the operation.

This use case expects U1, U2 and U3 services to be in place. With these services, the drone is able to operate nearly autonomously, making real-time decisions to assure safe operation but also allowing the operator to intervene by confirming, declining or selecting several options concerning the flight.

The following use case contains a detailed description of the actors, conditions involved and the flow of events in an operation. Safety must be the main goal, considering that it takes place in urban environment which is one of the most critical ones.

4.2.3 Actors

Client (Service Receiver) – [Primary]

As the end-customer of the analysis, he is responsible of defining the requirements of the operations (the mission goal) and should not ask for something outside the current regulation. If this is the case, the operator must refuse the offer.

Drone operator – [Primary]

This actor must comply with the current regulation (operational limitations, operator certification, operations manual, maintenance plan, drone certifications, pilot licenses and trainings, safety analysis…).

Drone pilot/s – [Primary]

As main responsible/s of the operation, he must be the head of the operation in the three phases (pre-flight, in-flight and post-flight) and the person in charge of the risk assessment study. He also must ensure safety during the operation and must take control of the device if necessary (countermeasures). Two operating states can be identified:

- State 1 – Nominal operation: the drone is operating according to the flight plan and the type of operation (piloted or autonomous) and the different services provided by U-Space ensure that all the factors involved are controlled (deconfliction systems work properly, information accuracy and integrity are within the minimum requirements of the operation, communications are available…);
- State 2 – UAS operation out of control: as defined in SORA Methodology, the operation is being conducted outside the approved conditions. There can be a wide variety of causes (technical issues with UAS, human error, deterioration of external systems supporting UAS operation…).

Competent Authority – [Secondary]

As responsible of safety, it must ensure that the operation can be done and is performed complying with minimum standards in terms of accuracy and safety that have already been set and enforced. This actor must be in charge of e-Identification and e-Registration services, providing certification to all the equipment involved in the operation (both hardware and software), the actors (drone operator, pilot…) and the flight plan (validation).

Basic Data provider – [Secondary]

Information provided must be of high quality, diversified and reliable. In case of aeronautical data, AIS from every country must be the main provider, ensuring the quality and reliability of all this information.

U-Space Authority– [Secondary]

As an actor which comprises both **Competent Authority** and Drone **Basic Data Provider**.

ATC – [Secondary]

As the main responsible of the provision of air traffic control services in the airspace in where the operation is going to take place.

U-Space Service Provider/s – [Secondary]

Providing services to ensure a safe and efficient conduct of UAS operations. This use case will comprise three different types (all of them provide connectivity with e-Identification and e-Registration services):

- **Provider 1 (USP1):** offering accurate assistance for flight planning and DTM services.
- **Provider 2 (USP2):** as a backup system, offering a cheaper and less accurate (but within the limits of this operation) assistance for flight planning and DTM services.
- **Provider 3 (USP3):** providing accurate geographic and urban data in real-time and microweather information based on different sensors from the city.

Population – [Secondary]

The operation must be focussed on protecting this group and, after that, on fulfil the mission.

Other operators/pilots & leisure drone users – [Secondary]

It is expected that a large group of simultaneous drone operations will share U-Space and they must be carried out without endangering the safety of any of them and, as a consequence, of the previous actors in this group.

Data manager – [Secondary]

This participant is in charge of processing all the information that has been collected during the operation and provide the client a reliable solution.

Equipment provider – [Secondary]

The equipment (both software and hardware) that is going to be used in this operation must be certified by the National Competent Authority to assure that the minimum requirements established are available.

Urban infrastructure/environment – [Secondary]

The city framework can support the operation providing real time information. This use case must comply with a set of minimum requirements focused on preventing collisions with infrastructure.

Insurance company – [Secondary]

Covering economic risks.

4.2.4 Pre-conditions

The restrictions of this action are described below:

- **Urban environment:**
  - Populated area;
  - Buildings with a wide variety of heights and separation distances;
  - Several locations will not allow drone operations (or may ask for permissions), such as police stations, hospitals or airports;
  - Other drone operations are being carried out (congested airspace);
  - VFR flights can appear suddenly;
  - The operation can be cancelled anytime due to emergency actions;
  - Coordination with all the authorities is mandatory;
  - Congested radio-spectrum;
  - Privacy of all the parties must be warranted.
- **Operation:**
  - The operation can be fully or partially autonomous or even manual in case of a particular interest in certain area;
  - The flight plan must be submitted and validated before the operation;
  - Geo-fencing will be defined to protect the actors in U-Space;
  - During the operation, sudden problems must be detected and avoided in complete safety;
  - Data from sources will be necessary in real-time process with a high level of accuracy and integrity;
  - Sources will provide aeronautical information (both VFR flights and drone traffic), geographic datasets, population density, emergency situations and weather changes in real time;
- **U-Space services** must be enabled, including the IMPETUS portal (and its associated micro-services) and other U-Space services.
- **Regulation** must have established the minimum requirements to ensure that the operation can be done with a high level of safety.
  - Certifications (software and equipment);

- Pilot training;
- Height;
- Distance from obstacles;
- Distance from other devices;
- Priority of the flight.

- **Drone Operator:**
  - This actor has a valid operating license and is registered by the competent authority;
  - The operator complies with all the articles stated in the regulation and can be inspected by authorities without any problem;
  - It has hired the services provided by USP1 as the main system to consume information with better accuracy than the one required by the current regulation, offering high-quality results;
  - It has hired the services provided by USP2 as a redundant system to warrant that the information with a minimum requirement of accuracy and integrity can be consumed;
  - USP3 provides accurate, up-to-date information related to the environment.
- **Drone Pilot/s:**
  - This actor has a valid operating license (approved by a certified training) and is registered by the competent authority;
  - The pilot is carrying all the documentation and is valid at the time of the operation;
  - He understands the Operation Manual of the operator and the Risk Assessment Analysis performed during the flight plan process;
  - The pilot has confirmed that the drone is in good condition and its maintenance is according the Maintenance Manual. Batteries are also in good condition;
  - He has revised the pre-flight checklist and he counts with all the items he is going to need.
- **Drone Specifications:**
  - Has a level 3/level 4 positioning capability;
  - Communications based on 5G mobile networks;
  - Rotatory-wing drone whose size and weight will depend on the payload (type of cameras, inspection method, type of detected defect…).
- **Service Provider 1/2:**
  - It has a valid access to the U-Space Authority (all the service providers must be validated) and a valid U-Space service provision license;
  - Can validate the operation by consuming information about the capabilities, equipment and optimal operating method of all drones of the **Drone Operator;**
  - Provides U1, U2 and U3 Services to its customers;

  - Can calculate automatically generated flight plans based on origin and destination coordinates and drone/operator information stored in the database;
  - Provide monitoring and tracking services with different levels of accuracy, but complying with urban operation requirements.
- **Service Provider 3:**
  - It has a valid access to the U-Space Authority (all the service providers must be validated) and a valid U-Space service provision license.
  - Can validate the operation by consuming information about the capabilities, equipment and optimal operating method of all drones of the **Drone Operator;**
  - Provides highly accurate micro-weather services within the city;
  - Provides highly accurate geographic and urban data services within the city.
- **Client (Service Receiver):**
  - Private person with no connection to U-Space;
  - Is the owner or responsible of the facility;
  - Is not aware of the regulations.
- **U-Space Authority:**
  - Provides strategic and tactical flight de-confliction;
  - Has direct access to all registry information;
  - Manages flight plan approvals;
  - Provides Authoritative Geo System Service;
  - Provides emergency management and tactical de-confliction in case of State incidents.

Table 12: Overview of U-Space services and service providers in Use Case 2

	Drone Operator contracts:		Drone Operator contracts:
U-Space Authority	Service Provider 1	Service Provider 2	Service Provider 3
DAIM	DAIM	DAIM	DAIM
Microweather			Microweather
Geographic data			Geographic and city data
Tactical geofencing			
Flight plan management	Assistance for flight planning	Assistance for flight planning	
Monitoring	Tracking	Tracking	
Strategic de-confliction			
Tactical de-confliction			
Emergency management			
Traffic information			

Final goal: the main objective of this operation is to collect as much data as possible. This information can be processed in real time or stored to be managed by data scientists in the operator headquarters.

4.2.5 Post-conditions

- Flight has been executed successfully; the drone has landed in a safety area and has been picked up by the pilot/operator. All the information needed has been collected/ processed (the pilot must ensure that data is stored) and the client is satisfied with the results;
- Some of the data will be processed in headquarters. The information related to the operation is shared with the IMPETUS platform to store it with the objective of using it as an input for other operations;
- The drone operator and the pilot must update the logbook with all the details related to the operation (flight log, incident/accident reporting or wear of batteries);
- The pilot and the operator will take care of the integrity and maintenance of the device (visual check of the drone, cleaning the dust in the components…);

- If it is the case, authorities must be informed of the incidents/accidents during the operation;
- The equipment that has been used in the operation is collected and removed from public streets;
- The U-Space platform is available to support next operations.

4.2.5.1 Success end-state

- Flight has been executed successfully: the drone has landed in a safety area and has been picked up by the pilot/operator. All the information needed has been collected/ processed (the pilot must ensure that data is stored) and the client is satisfied with the results;
- The result of the operation is according to the flight plan and any issue during the flight has been solved by deconfliction systems (both on-board and provided by U-Space) with no harm;
- The operation is done in a reasonable time using a cheaper device than other alternatives;
- The flight log has been updated and the drone has passed the maintenance plan.

4.2.5.2 Failed end-state

The use case is considered failed when one or more of the following scenarios apply:

- Safety in the environment cannot be assured: the operations must not be carried out (during pre-flight, taking off is not allowed; during the operation, the drone must land) and can cause damage to people in the ground, property, other aircrafts and itself. Contingency measures are deactivated (or not possible);
- Priority of operations: there are certain operations more relevant for the common interest, such as emergency situations, conditioning the mission and provoking an abort of operation;
- Failure of the device during the flight: this case must be considered and contingency measures should be part of the risk management plan (such as safety landing zones and the training of the pilot to control the device without navigation sensors…);
- The cameras do not work properly and data cannot be acquired with the minimum requirements of quality. The drone is unable to reach mission goal.

4.2.6 Trigger

A physical defect has been detected in the infrastructure or the time of the inspection in the scheduled maintenance plan has come. It is necessary to fly around the facility stopping in certain points of interest that can be critical for the structural integrity of the building.

The **Drone Service Receiver** (the owner of the building or the Public Authority) issues a petition to a **Drone Operator** for the inspection of the infrastructure asking for as much information as possible (inspection using cameras, thermography…). The images will be checked during the operation and the data will be stored and processed after the operation.

4.2.7 Flow of Events

4.2.7.1 Pre-flight

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
1	Owner/ Responsible of the facility (Client)	The use case starts several weeks before a maintenance revision is scheduled. The **Client** is aware of the date and has to develop and manage the revision plan and contact a drone operator specialized in urban infrastructure inspection.	
2	Drone Operator, Client	The **Drone Operator** meets the **Client** to capture all the needs of the operation (resolution, type of data collected…). Two operations have been identified: • A primary mission, consisting on an autonomous flight focused on several critical points (already identified) and different faces of the building (BVLOS). • A secondary mission may be requested in case of the detection of critical failures in the infrastructure. In that case, a piloted flight is necessary to check it. Based on these requirements, the **Drone Operator** is able to have an overview of the whole operation and is able to select an adequate drone to fulfil them and a pilot from his crew.	
3	Drone Operator, USP1	The **Drone Operator** connects to **USP1** and validates itself (capabilities, pilots, experience for this operation, drones, equipment…). A flight plan request for the first mission is developed and includes information about the type of the operation (autonomous) and aim and information about all the actors involved (operator, pilot, equipment, software and documentation). The second mission will be planned in real-time, in case of it is necessary. The **Drone Operator** and the **Pilot** must consider the following issues:	**USP1** validates the actors and sends an acknowledgement of the flight plan request to the **Drone Operator**.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		1.- Flight plan: the operation can be performed in two different ways: • Fully/Partially autonomous: drone will fly from waypoint A to B following the safest and most optimal route. The operation will be the result of a list of points of interest. • Manual flight: the operation will be focused on critical points that must be inspected but the time the drone will be pointing every target is not known. Other issues in the flight plan to be considered: • VLOS/BVLOS flight: depending on the visibility of the supervisor/pilot and the requirements of the operation. A second pilot/supervisor may also be necessary. • Operation phases: number of flights (or batteries), objectives of every part of the mission, flight time estimation, configuration/s required… 2.- Selection of the drone: the device selected for this operation suits the requirement given by the **Drone Service Receiver** in terms of configuration, flight time, payload (cameras) and immersion into the U-Space environment. 3.- Communications redundancy. 4.- Safety landing zones. 5.- Geofencing requirements. 6.-Data sources: • Aeronautical information (both VFR flights and drone traffic) in real time (NOTAMS, SWIM shared services, static datasets, traffic predictions and information that is liable to change). • Geographic datasets: digital terrain model and urban facilities, given with a minimum level of accuracy (set by the	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		regulation authorities). • Geo-fencing definition. • Population density (in real time). • Emergency situations (in real time): coordination with public authorities. • Weather changes (in real time) and forecasts. • Status of U-Space Services (availability and both navigation and radio coverage). • Previous operations: the IMPETUS platform can use the information stored from previous operations to offer an estimation of the risk indicators associated to the mission. • Regulation limitations: registration, identification, establishing the minimum separation distance and height from people, buildings, countermeasures and level of U-Space services. 7.- Certifications: • Drone certification for the operation requirements (both software and hardware verification and validation, such as communication redundancies). • Pilot certification to ensure the minimum knowledge and skills to carry out the operation in a completely secure and efficient way. • Operator certification: the operator must be certified to perform this type of operation. 8.- Risk assessment plan: the operation must ensure the integrity of people in this area, buildings, coordination with other aircraft and priority level between operations.	
4	USP1, USP3,	Using its assistance to flight planning, **USP1**	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
	Drone Operator, Drone Pilot, Authority	is able to gather this preliminary information with all the data collected from the **Drone Operator** and **Drone Pilot** (using U-Space authority database) and generates a preliminary flight plan with the most optimal paths based on the description of the environment provided by **USP3**. During this process, a risk analysis based on SORA methodology must be performed and submitted with the flight plan.	
5	USP1, USP3, Authority	The whole operation is submitted by **USP1** into the **U-Space authority** system, containing: • Waypoints. • Pre-calculated flight path (including landing locations). • Identification of actors and roles. • Countermeasures and contingency measures. • Estimated time frame. • Drone operator documentation. • Safe take off/landing locations. • Maximum allowable speed. All the information related to the actors in the operation (certifications, capabilities, equipment…) are checked and validated using the information stored in the Authority systems.	**U-Space authority** offers a revised and updated flight plan based on the restrictions in an iterative process between the **Authority** and **USP1**: • Coordination and deconfliction methods with other operations. • Traffic and population density. • Weather. • Temporary Airspace restrictions. • Events affecting the drone capability required and the mission objectives over a certain area. • Geo-fencing data. • Other risk indicators. This output consists on the final flight plan approved by the **U-Space authority** and delivered to **USP1.**
6	USP1, Drone	**USP1** returns an approved flight plan to the **Drone Operator**, containing all the details	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
	Operator	of the mission.	
7	Drone Operator, Drone Pilot	In the operator headquarters, the **Drone Operator** coordinates with the **Drone Pilot** to check a pre-flight checklist that comprises all the necessary equipment for the operation. After having verified that everything is loaded, they head to the building.	
8	Drone Operator, Drone Pilot, Client, USP1, Authority	These actors are now at the location of the facility, where they verify that all the premises and conditions expected during the flight plan process are correct. They connect their equipment, which is identified and validated automatically using **USP1** (connected to **U-Space authority**) and the flight plan is verified in real time, ensuring that unexpected events will not affect the mission. Finally, drone pilot check that all the cameras are switched on. The pilot sets the GCS and places the drone in the designated take-off location, turns it on and the device connects automatically to U-Space identification services. After the validation process, the mission is allowed to start.	**USP1** (using **U-Space authority** basic services) offers an updated permission to fly. The operation can take place.

4.2.7.2 Execution of the flight

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
9	Drone Operator, Drone Pilot, USP1, USP3, U-Space Authority	The drone automatically departs on its flight plan. The **Drone Pilot** is always supervising the operations and, together with **USP1** (and **U-Space authority**), they monitor the surrounding operations and offer information about the current operation: • Identification of the mission and all the actors involved. • *Flight Plan*.	**USP1** alerts the **Drone Pilot** of the departure and the arrival at different waypoints.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		• Drone status (i.e. "enroute to [Collection Pad ID]"). • 3D Position. • Collision avoidance countermeasures. **USP3** is providing information about meteorological conditions and all the obstacles in the surroundings and is checking that minimum separation (established by regulations) is ensured. With this equipment, the operation can avoid most of the hazards and the procedures in the risk assessment plan will contribute to ensure the safety of the airborne and ground elements. The drone has the ability to recalculate its trajectory and the risk indicators in real time and, adding the skills provided by the training of the pilot/s, the operation is performed properly.	
10	USPs, U-Space Authority, Drone Operator, Drone Pilot	There have been an emergency. **U-Space Authority** has all the information and restrictions (such as geofencing) derived from this sudden event and detect all the conflicts with the current operations. • Conflict area. • Timeframe: undefined. • Priority: very high. There is no way to provide deconfliction management as the airspace has been segregated to provide assistance to the emergency services.	The emergency service is activated and the **U-Space Authority** sends to all **U-Space Service Providers** in the surroundings a simple order: cancel your mission and land safely, informing the operator and the pilot.
11	Drone Pilot	Drone pilot is in charge of the operation and has to land the drone in the allowed, planning sites. This action can be performed autonomously (programmed in the flight plan) or manually.	
12	Drone Operator, Drone Pilot, U-Space Authority, USPs	The state of emergency is disabled and the **U-Space Authority**, via the **USPs** allow the operations to continue. The drone takes off as stated in step 9 and continues with the	**U-Space Authority** provides permission to continue with the operation.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		mission.	
13	Drone Operator, Drone Pilot, U-Space Authority, USPs	The operation has been successfully completed. The drone operator checks that the results have been stored.	**USP1** informs **U-Space Authority,** updates the status of the mission and upload all the details (pilot log, flight log, detected events…).
14	Client, Drone Operator	In a quick look of the results, a surface crack has been detected. The **client** requests the second flight to look closely at the defect.	
15	All	Steps 1-9 must be repeated for the requirements of this new mission. The new flight plan is validated in a short time using real-time data and the flight can be carried. The drone takes off.	**U-Space Authority** provides permission to continue with the operation.
16	Drone Pilot, USP1, USP2, U-Space Authority	During the flight, communications with **USP1** are lost, but thanks to the redundancies in the communication systems and the availability of **USP2,** offering the same services the operation can continue within the minimum requirements of the operation and the environment.	During the transition time, the drone has entered in State 2 (out of control) but **the pilot**, thanks to his experience and training and the capabilities of the drone (sense & avoid capabilities, for instance), has been able to manage the issue. **U-Space authority** has been informed of the problem and has managed the deconfliction process with all the current operations that are being carried in the same environment.
17	Drone Pilot, USP2, U-Space Authority, Leisure Drone	During the flight, **U-Space authority** has detected and identified a **leisure drone** piloted manually in the area. Tracking service offers its position and, based on its algorithms, a prediction of future intentions.	Automatically, it sends the information to the surrounding operations and manages the deconfliction process. This drone is registered

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
			and, no matter the nature of its mission, must comply with current regulations and restrictions of airspace. Geofencing provided by **U-Space authority** does not allow it to go through this mission.
18	Drone Pilot, Leisure Drone, USP2, USP3, U-Space Authority	The pilot in charge is aware of the presence of the leisure drone. He has been trained to avoid dangerous situation and is ready in case of the necessity of countermeasures using all the information provided by **USP2** and **USP3**.	The **U-Space Authority** must provide, via **U-Space Service Providers**, all the information to manage unexpected events in case of piloted operations and the pilot must certify the capabilities to deal with it.
19	Leisure Drone, U-Space Authority	The leisure drone lands or flies away.	The **U-Space Authority** provides this information to the actors.
19	Drone Pilot, U-Space Authority, USP2	The inspection process has been successfully completed and the pilot has to land in the previously designated safety sites.	The **U-Space Authority** is informed about the location of these places via USP2.
20	Drone Operator, Drone Pilot, U-Space Authority, USPs	The operation has been successfully completed. The drone operator checks that the results have been stored.	**USP2** informs **U-Space Authority,** updates the status of the mission and uploads all the details (pilot log, flight log, detected events…).

4.2.7.3 Mission completed

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
21	Drone Operator, Drone Pilot	Flight has been executed successfully; the drone has landed in a safety area and has been picked up by the **pilot/operator**. All the information needed has been collected/ processed (the **pilot** must ensure that data	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		is stored) and the client is satisfied with the results.	
22	Drone Operator, Client, Data manager	The result of the operation is according to the flight plans and any issue during the flight has been solved by deconfliction systems (both on-board and provided by U-Space) with no harm and in reasonable time. The **Drone Operator** confirms that the data has been stored and delivers it to the client. Data manager that is part of the operator or has been hired by the client will process these information and identify the required results.	
23	Drone Operator, Drone Pilot, U-Space Authority, USPs	The drone has passed the maintenance plan, relevant information has been stored (battery levels, incident/accident reporting, unexpected obstacles…) and the pilot log has been updated and certified by the operator.	This information must be updated in the **U-Space authority** database using a specific **USP.**

4.3 Maritime Border Surveillance

4.3.1 Context and Assumptions

Assumptions made in this Use Case are based upon the definitions set out in Call CEF-SESAR-2018-1 and seen in the context of the 'visions' provided in chapter 3.

4.3.2 Summary

Continuous maritime border surveillance is increasing in importance, in view of ongoing political, migratory and illegal trafficking dynamics. One possibility for fulfilling the assigned task of maritime border control within limited budgets is recently opening up with the use of unmanned air systems. The coast guards and border police have traditionally relied on manned aircraft and sea vessels for border surveillance. Especially manned aircraft have operating hour costs in the range of several thousand to several ten thousand Euros, without counting the costs for the associated infrastructure. Moreover, these vehicles are easily observed from the ground due to their noise and size and are less manoeuvrable than UAVs. Being smaller and hence less detectable, more manoeuvrable and above all having several orders of magnitude lower operating costs, UAS are an attractive alternative to the above mentioned traditional border surveillance vessels.

The following use case describes how the use of unmanned air systems for the above-mentioned operations can be performed safely and efficiently. To cover a wide range of issues which may affect the operating environment, the use case details requirements for operations, outlines interactions of various service providers with the U-Space system and the drone operator, and includes actions to be performed in case of ad hoc changes in-flight. The use case begins with a detailed description of the actors, lists pre- and post-conditions and describes the flow of events from pre- to post-flight. Furthermore, the flow of events is structured in a way to focus on the interactions of all the actors with the system, so as to emphasise the information requirements.

4.3.3 Actors

Drone Operator – [Primary]

Border Surveillance Unit within Maritime Border Police operates a fleet of autonomous UAS on a planned or upon-request routing and with a distinct mission goal.

Pilot in Command (PiC) is in charge of managing the operation of one or several drones in the fleet, and is the last instance of contingency, in case automation fails. This position is bound by three operating states of the drones in the fleet:

- State 1: Drone(s) is/are operating nominally, their flight(s) only need to be superficially overseen. The PiC and the accompanying Observer concentrate on the task (surveillance by EO and Infrared/thermal sensors);
- State 2: Drone(s) is/are in an abnormal state (flight plan deviations, system alerts, unforeseen events) and trying to rectify the state autonomously. The Pilot in Command should pay special attention to the drone's operation but does not interact;
- State 3: Drone(s) is/are in an abnormal state (flight plan deviations, system alerts, unforeseen events) and autonomous attempts at reconciliation have failed. The U-Space

Authority is notified. The Pilot in Command is the last line of defense and is tasked in resolving the situation.

Competent Authority – [Secondary]

The authority giving permit to fly to drone operators using a category of drones for a specific mission.

Contains registry information about the **Drone Operator's** licensing, drone equipment, drone contingency provisions and delivery classifications.

U-Space Service Provider – [Secondary]

- Provider 1: Provides assistance for flight planning, assistance for authorisation and DTM services to ensure a safe, efficient and secure conduct of UAS operations;
- Provider 2: Provider of advanced Microweather and Geo-Awareness Services within the perimeter of the coastal waters boundaries.

U-Space Authority

The authority providing reliable data and updated information linked to the airspace management (restricted areas, temporary restricted zones, etc.) especially specific information for drone operations ("no fly" zones, drone tracks etc.).

4.3.4 Pre-conditions

Drone Operator:

- Has valid operating license;
- Is registered by the competent authority;
- Has a centralized drone hub in a rural area located a few kilometers from the country border;
- Has standard access to U-Space U1, U2 and U3 services via Service Provider 1;
- Has premium access to premium U-Space services via Service Provider 2.

Drone Specifications

- Has level 3/level 4 positioning capability;
- Communication based on 5G mobile networks;
- Dimensions: wingspan 2.5 m, length 1 m, height 0.5 m;
- Type: Fixed-wing drone with mounted EO and thermovision cameras;
- MTOM: 5 kg.

Service Provider 1:

- Has a valid U-Space service provision license;
- Provides select U-Space U1, U2 and U3 services (Table 12) to its customers;
- Has direct access to the **U-Space Authority;**
- Has information about the capabilities, equipment and optimal operating method of all of the drones of the **Drone Operator.**

Service Provider 2:

- Has a valid U-Space service provision license;
- Provides highly accurate micro-weather services within the flying zone of interest;
- Provides highly accurate geo-awareness services within the perimeter;
- Does not have direct access to the **U-Space Authority.**

U-Space Authority

- Provides strategic and tactical flight de-confliction;
- Has direct access to all registry information;
- Manages flight plan approvals;
- Provides Authoritative Geo System Service.

Table 13: Overview of U-Space services and service providers in Use Case 3

Drone Operator contracts:

U-Space Authority	Service Provider 1	Service Provider 2
DAIM	DAIM	
		Microweather
		Geo-Awareness
Tactical geofencing		
Flight plan management	Assistance for flight planning	Assistance for flight planning
Monitoring	Tracking	Tracking
Strategic de-confliction		
Tactical de-confliction		
Emergency management		
Traffic information		

4.3.5 Post-conditions

4.3.5.1 Success end-state

The use case is considered a success when the following criteria apply:

- Successful provision of drone service (border surveillance);
- Efficient and safe conduct of mission;
- Successful return of drone to its hub;
- Platform available for preparation of next operation.

4.3.5.2 Failed end state

The use case is considered failed when one or more of the following scenarios apply:

- Drone unable to reach mission goal;
- Abort of operation;
- Drone endangers other airspace users or persons on the ground and sea;
- Drone causes damage to property or itself;
- Drone contingency provisions fail.

4.3.6 Trigger

The use case starts when the **Drone Service Receiver** (Border Police Command) issues a request to the **Drone Operator** (Border Police UAS surveillance unit) for a Border surveillance mission. The mission specifications are:

- Observe (boat) traffic at the maritime border;
- Same-spot observation period: 10 min;
- Thorough inspection and geolocation of suspicious vessels.

4.3.7 Flow of events

4.3.7.1 Pre-Flight

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
1	Border Police Command, Border Police UAS unit	The use case starts when the Border Police Command orders the UAS unit (**Drone Operator**) to perform the surveillance operation.	
2	Drone Operator	The **Drone Operator** prepares the Operation plan: to fly a group of 6 fixed-wing, electrically-powered drones along the country's maritime border. The drones are	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		intended to start their mission from a predefined starting point positioned 300 m inward of the country's airspace, at a 500 m AGL, then fly at constant separation from the coastal junction and along the maritime territorial border with the neighbouring country. The flight path will then be extended in a straight line for 24 more kilometres into the international waters. The drones will then return to home base along the same path with a 50-m increased altitude. The drones will be positioned in a chain-like order, with a 10-min flight time separation. The drone PiCs will not actually be piloting the drones but will be supported by automated functions and tools allowing him to monitor several drones flying at the same time.	
3	Drone Operator, Service Provider 2	The **Drone Operator** issues a request for weather update and a geo-referenced map (restricted areas) of the flight zone of interest. Upon receipt of the report, the Drone Operator adjusts the flight plan accordingly.	**Service Provider 2** issues the requested report to the Drone Operator.
4	Drone Operator, Service Provider 1	A flight plan registration request is automatically forwarded to **Service Provider 1**, which includes information about the **Drone Operator's** ID, the drone's ID, classification of the operation and the flight path.	**Service Provider 1** sends an acknowledgement of the flight plan request to the **Drone Operator**.
5	Service Provider 1, U-Space Authority, Competent Authority	The *declaration of intent to fly* is prepared according to the updated *preliminary flight plan* and filed to the **U-Space Authority.** The intent to fly contains the following information: • Preferred trajectory • Drone registry ID* • Operator registry ID* • Contingency planning* • Type of mission ID* *Registry information about the **Drone**	The **U-Space Authority** returns an updated *flight plan* based on restrictions in: • Manned traffic density • Weather • Temporary Airspace restrictions • Events affecting the drone capability required over a

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		Operator's licensing, drone equipment, drone contingency provisions and delivery classifications are stored in the **Competent Authority's** database.	certain area. The planned mission, being a Law Enforcement (LE) operation, is given a high priority, thus several other planned drone operations interfering with the operation are automatically rescheduled to give way to undisturbed operations of the LE drones.
6	Service Provider 1, Drone Operator	Upon approval of the flight plan from the **U-Space Authority**, **Service Provider 1** returns a flight approval and flight plan information to the **Drone Operator**.	

4.3.7.2 Execution of the flight

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
7	Drone Operator, Service Provider 1, U-Space Authority	Flight operations of all drones of the **Drone Operator** are supervised by internal <u>Pilots in Command</u>. The **Drone Operator** signals **Service Provider 1** when each of the flights has commenced. Position information is automatically forwarded to **Service Provider 1**, which is in charge of managing the flight progress based on its *tracking* service. The flight altitude is 500 m AGL. The drone is flying at maximum velocity towards the border junction. Separation assurance is not relying on *detect and avoid*, but is provided by **Service Provider 1.** **Service Provider 1**, in turn, sends continuous position information to the **U-Space Authority** for *monitoring*, which includes:	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		• Drone ID • *Flight Plan* ID • LAT/LON position • Height • Velocity	
8	Drone Operator, Service Provider 1, U-Space Authority	**U-Space Authority** detects a potential conflict of the drone with a manned aircraft in approach to the nearby GA and light commercial aviation airport. It automatically instructs the drones to change their path (deviate away from the airport, lower the altitude) pending an aircraft landing approach. The instructions are transmitted via the **Service Provider 1**.	
9	Drone Operator. Service Provider 1, U-Space Authority	Each drone is equipped with an EO and thermovison camera. The live video from each drone (both EO and thermos channel) is transmitted from the drone to the border police UAS surveillance unit via a 5G mobile network. At larger ranges, i.e. in international waters, the communication link is provided by 5G steered array antennas. The video is processed with machine vision algorithms in order to detect unlawful activity. In case a suspected misconduct is observed, the drone is automatically set into loitering mode, observing the object. The drones perform a 4-loop, 4-hour border surveillance mission. One potential breach is observed and triggers an automatic alarm. Within a 1-minute time span, the coordinates are sent to the closest patrol boat that will intercept and inspect the unauthorised boat. Full coverage video surveillance is provided throughout the clarification procedure. **U-Space Authority** is informed about the change of flight path (change from cruise	**U-Space Authority** checks for potential conflicts with other flying vehicles. No air vehicles are affected; therefore no contingency procedures are initiated.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		to loitering over the target).	
10		Each of the drones fulfils the mission and flies back to the take-off/landing site. The **Service Provider 1** is automatically notified that the flight has been terminated.	

4.3.7.3 Mission completed

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
11	Drone Operator, Service Provider 1, U-Space Authority	The **Drone Operator** confirms to the **Service Provider 1** that the mission has been completed.	**Service Provider 1** informs the **U-Space Authority** that the flight is completed.

4.4 Search and Rescue operations in an urban environment

4.4.1 Context and Assumptions

Assumptions made in this Use Case are based upon the definitions set out in Call CEF-SESAR-2018-1 and seen in the context of the 'visions' provided in chapter 3. In this context, the function of the "Orchestrator" is aligned with that of the "U-Space Authority" (SJU call).

4.4.2 Summary

Search and Rescue operations in an urban environment can range from a response to the report of a missing person through to a major disaster such as an earthquake or terrorist attack. Unmanned aerial systems (UAS) can support Search and Rescue efforts in these scenarios with faster results and offering significant safely benefits around risk-to-life compared with more traditional methods.

There are many supporting functions that UAS can provide, such as:

- Site inspection: An activity required before rescue teams can come safely be onsite. This activity can often take many hours and therefore limit the success of the rescue. The use of UAS can increase the speed of such an inspection. Additionally, UAS can locate good access routes for rescuers;
- Early Access: UAS can access areas which are initially too dangerous for people alongside advance sensors (e.g. IR, Video) they can help pinpoint where potential casualties are located and where help is required;
- Emergency supplies: UAS can provide supplies to casualties e.g. blankets, first aid, water, beacons for tracking or even communication devices ahead of any rescuer reaching them in person;
- Surveillance for Coordination efforts. Real time feeds from UAV mounted sensors can provide command and coordination teams a detailed and up-to-date picture of what is happening at an incident.

Using a combination of automated and human remotely piloted vehicles, UAS can support these coordinated rescue operations improving response times and ultimately saving lives.

The following use case describes how such a service could be provided, safely and efficiently. To cover a wide range of issues which may affect the operating environment, this use case details requirements for Search and Rescue operations in urban environments, outlines interactions of various service providers with the U-Space system, co-ordinating Search and Rescue team and the drone operators, including actions to be performed in case of conflicting traffic.

The use case begins with a description of the actors, lists pre- and post-conditions and describes the flow of events from pre- to post-flight.

Furthermore, the flow of events is structured in a way to focus on the interactions of all the actors with the system, to emphasise the information requirements.

4.4.3 Actors

Drone Operator 1 (Reconnaissance) – [Primary]

Operates a fleet of autonomous UAS with distinct mission expertise around reconnaissance surveys for defined Search and Rescue areas.

Pilot in Command is in charge of managing the operation of all of the drones in the fleet, and is the last instance of contingency, in case automation fails.

Drone Operator 2 (Emergency Supplies Delivery/Drop) – [Primary]

Operates a fleet of autonomous UAS with a distinct mission goal focused on dropping emergency supplies to identified casualties as prescribed by the Search and Rescue Coordinator.

Pilot in Command is in charge of managing the operation of all of the drones in the fleet, and is the last instance of contingency, in case automation fails.

Competent Authority – [Secondary]

The authority giving permit to fly to drone operators using a category of drones for a specific mission.

The authority also able to segregate the airspace where required.

Contains registry information about the **Drone Operator's** licensing, drone equipment, drone contingency provisions and delivery classifications.

U-Space Service Provider – [Secondary]

- Service Provider 1: Provides assistance for flight planning, assistance for authorisation to ensure a safe, efficient and secure conduct of UAS operations. **Drone Operator 1** is a customer of Service Provider 1;
- Service Provider 2: Provides assistance for flight planning, assistance for authorisation to ensure a safe, efficient and secure conduct of UAS operations. **Drone Operator 2** is a customer of Service Provider 2.

U-Space Authority (the Orchestrator)

The authority provides reliable data and updated information linked to the airspace management (restricted areas, temporary restricted zones, etc.) especially specific information for drone operations ("no fly" zones, drone tracks etc.).

Search and Rescue Coordinator – [Secondary]

This team entity is the Customer of the **Drone Operators** and sets the mission goal of the Search and Rescue service being conducted by the **Drone Operators**.

Casualties – [Secondary]

This is the individual(s) who are the subject of the Search and Rescue mission.

4.4.4 Pre-conditions

Drone Operator 1 (Reconnaissance):

- Has valid operating license;

- Is registered by the **Competent Authority;**
- Has centralized drone hub in an urban area near the Search and Rescue site;
- Has access to U-Space services via specialist **Service Provider 1.**

Drone Operator 2 (Supplies Drop):

- Has valid operating license;
- Is registered by the **Competent Authority;**
- Has centralized drone hub in an urban area near the Search and Rescue site;
- Has access to U-Space services via specialist **Service Provider 2.**

Drone Specifications (Drone Operator 1 - Reconnaissance)

- Has level 3/level 4 positioning capability;
- Communication based on 5G mobile networks;
- Dimensions of drone: 1,5m x 1,5m x 0,5m;
- Type: Fixed wing drone with both a video and Infra-red camera/sensor onboard with onboard;
- Max payload: 6kg.

Drone Specifications (Drone Operator 2 – Emergency Supplies Delviery/Drop)

- Has level 3/level 4 positioning capability;
- Communication based on 5G mobile networks;
- Dimensions of drone: 1,5m x 1,5m x 0,5m;
- Type: Hexacopter with standardized package attachment mount on the bottom for delivery of water, blankets, communication equipment (e.g. mobile phone);
- Max payload: 14kg.

Service Provider 1:

- Provides select U-Space Services, such as *Flight Plan*ning Services;
- Has direct access to the **U-Space Authority;**
- Can calculate automatically generated flight plans based on origin and destination coordinates and drone/operator information stored in the database;
- This is a U-space provider that is operated by the drone manufacturer to provide services optimized for their drones. It has detailed performance data on the manufacturer's drones, so is able to generate mission plans that play to the airframe strengths and capabilities;
- Has information about the capabilities, equipment and optimal operating method of all of the drones of **Drone Operator 1.**

Service Provider 2:

- Provides select U-Space services such as *Flight Plan*ning Services and Route optimization;

- Has direct access to the **U-Space Authority;**
- Specializes on providing U-Space Services to drone operators that perform package delivery in an urban environment by using high resolution 3 dimensional models of cities;
- Can calculate automatically generated flight plans based on origin and destination coordinates and drone/operator information stored in the database;
- Has information about the capabilities, equipment and optimal operating method of all of the drones of **Drone Operator 2.**

Search and Rescue Coordinator

- A Search and Rescue specialist tasked with coordination of a mission to find and bring to safety those effected by the urban disaster;
- Defines the mission goal (including operations and logistics) for locating all potential casualties, understanding the best route to help these casualties and where required directing emergency supplies to casualties that cannot be quickly reached.

Casualties

- Private person with no connection to U-Space;
- Has been caught up in the urban disaster and is in need to help.

U-Space Authority

The U-space authority is responsible for providing the following services

- Registration: Provides a single source of identity information about pilots, drones and operators including the capabilities of the equipment and qualifications of the pilots and operators;
- GeoAwareness: Provides Authoritative GeoFencing data for the region covered by this authority.

Orchestrator

- Manages flight plan approvals;
- Responsible for issuing permission to fly;
- Provides strategic and tactical flight de-confliction;
- Provides a single, authoritative, view of the airspace to relevant authorities or security services.

4.4.5 Post-conditions

4.4.5.1 Success end-state

The use case is considered a success when the following conditions apply:

- The drone service has safely identified and mapped the location of potential casualties in a defined area;
- The drone service has safely mapped all possible potential paths to the casualties;

- The drone service has safely delivered supplies to the casualties as a result of the coordinators request;
- No other airspace users or persons on the ground were endangered by the drone operations;
- The drone has not caused damage to property, itself or the delivered supplies;
- Successful return of drone to its hub;
- Efficient and safe conduct of mission;
- Platform available for preparation of next operation.

4.4.5.2 Failed end state

The use case is considered failed if one or more of the following scenarios apply:

- Drone unable to reach mission goal;
- Abort of operation;
- Drone endangers other airspace users or persons on the ground;
- Drone causes damage to property, itself or the delivered supplies;
- Drone contingency provisions fail.

4.4.6 Trigger

The Search and Rescue coordinator requests onsite drone Search and Rescue drone support for their operation. The use case starts after the commencement of a Search and Rescue mission at the request of the Search and Rescue coordinator.

4.4.7 Flow of Events

4.4.7.1 Pre-Flight

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
1	Casualties	The use case starts when the authorities initiate a Search and Rescue mission following an urban disaster.	
2	U-Space Authority	A no-fly zone is created around the incident site to prevent non-emergency/non-SAR flights. The no-fly zone is created in the *GeoAwareness* service and promulgated to all interested subscribers. This is enforced by the *Orchestrator* routing all non-approved traffic around the no-fly zone.	
3	Search and Rescue	The **Search and Rescue Coordinator** submits a request for **Drone Operator 1** to undertake	Request acknowledged or rejected by Drone

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
	Coordinator, Drone Operator 1	a reconnaissance mission over a defined urban region. The request indicates: • The boundary of the reconnaissance requirement • The time-frame of reconnaissance requirement. • The focus of the reconnaissance mission (pathfinder or casualty identification). This request is not made through any U-space services and would probably be performed via a phone call. The *GeoAwareness* service can now be updated to allow **Drone Operator 1** to enter the no-fly zone.	**Operator 1**.
4	Drone Operator 1	The request launches an automatic process for **Drone Operator 1,** which selects an adequate drone (given the characteristics of the reconnaissance mission, the required data capture - which will determine the on-board sensors and the operating conditions) to fulfil the set of mission requirements.	
5	Drone Operator 1, Service Provider 1	A request is automatically forwarded to **Service Provider 1**, to generate a flight plan from the drone's current location to the target site. As part of this request, **Drone Operator 1** gives permissions for **Service Provider 1** to access limited profile information from the **U-space authority's** Registry relevant to the mission operator(s) and drone(s).	**Service Provider 1** sends an acknowledgement of the request to the **Drone Operator 1**.
6	Service Provider 1	**Service Provider 1** creates a preliminary flight plan using the initial request information and supplementing it with: • Information from the National Registration Database for Drone Operator 1 – for which they have now been granted limited access to for the purpose of supporting the mission	*Registration* provides **Service Provider 1** with the following information in response: • Drone and Operator information relevant for the mission. The *Authoritative Geo*

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		• information from an Authoritative Geo System about any additional restrictions or hazards in the proposed operational area. • Information of the flight characteristics of the specific drone to provide an optimised route.	*System* provides **Service Provider 1** with the following information: • Geo-fencing data. • Known Flight restrictions. • Coordinates of hazards.
7	Service Provider 1, U-Space Authority, Competent Authority	The *declaration of intent to fly* is prepared according to the updated *preliminary flight plan* and filed to the **U-Space Authority.** The intent to fly contains the following information: • Preferred route including waypoints. • Take-off and land locations. • Estimated waypoint times. • Classification of mission. • Drone registry ID. • Operator registry ID. • Contingency planning.	The **U-Space Authority** returns information on whether the flight plan has been accepted: • Traffic density. • Temporary Airspace restrictions. • Events affecting the drone capability required over a certain area. If there are parts of the route that the authority has rejected, the reasoning is returned. This reasoning allows the service provider to file an alternative flight plan that mitigates the reasons for the initial rejection. This process will need to be repeated until the flight plan is accepted. Alternatively, the service provider could ask the *Orchestrator* to plan a route, but this would not include any of the optimizations that the service provider would make.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
8	Service Provider 1, Drone Operator 1	Upon approval of the flight plan from the **U-Space Authority**, **Service Provider 1** returns a flight approval and flight plan information to **Drone Operator 1**. The flight plan contains full information about the reconnaissance flight as well as digitally signed permissions to fly through any areas that have required permission to be gained.	
9	Search and Rescue Coordinator, Drone Operator 2	The **Search and Rescue Coordinator** submits a request for **Drone Operator 2** to undertake an emergency supplies delivery/drop mission over a defined urban region. The request indicates: • The target locations for the casualties to receive the emergency supplies. • The time-frame of emergency supplies drop requirement. • The specifics of the emergency supplies to be dropped.	Request acknowledged or rejected by **Drone Operator 2**.
10	Drone Operator 2	The request launches an automatic process for **Drone Operator 2,** which selects an adequate drone (given the characteristics of the emergency supplies mission, the required supplies that will be dropped as part of the mission and the operating conditions) to fulfil the set of mission requirements.	
11	Drone Operator 2, Service Provider 2	A mission plan request is automatically forwarded to **Service Provider 2**, As part of this request, **Drone Operator 2** gives permissions for **Service Provider 2** to access limited profile information from the Drone and Operator Registration Database relevant to the mission operator(s) and drone(s).	**Service Provider 2** sends an acknowledgement of the flight plan request to the **Drone Operator 2**.
12	Service Provider 2	**Service Provider 2** creates a *preliminary flight plan* using the mission request information and supplementing it with: • Information from the National Registration Database for **Drone**	*Registration* provides **Service Provider 2** with the following information in response: • Drone and Operator

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		Operator 2 – for which they have now been granted limited access to for the purpose of supporting the mission • Information from an Authoritative Geo System about any additional restrictions or hazards in the proposed operational area.	information relevant for the mission. The *Authoritative Geo System* provides **Service Provider 2** with the following information: • Geo-fencing data • Known Flight restrictions • Coordinates of hazards
13	Service Provider 2, U-Space Authority, Competent Authority	The *declaration of intent to fly* is prepared according to the updated *preliminary flight plan* and filed to the **U-Space Authority.** The intent to fly contains the following information: • Preferred route including waypoints. • Take-off and land locations. • Estimated waypoint times. • Classification of mission. • Drone registry ID. • Operator registry ID. • Contingency planning.	The **U-Space Authority** returns information on whether the flight plan has been accepted: • Traffic density • Temporary Airspace restrictions • Events affecting the drone capability required over a certain area If there are parts of the route that the authority has rejected, the reasoning is returned. This reasoning allows the service provider to file an alternative flight plan that mitigates the reasons for the initial rejection. This process will need to be repeated until the flight plan is accepted. Alternatively, the service provider could ask the *Orchestrator* to plan a route, but this would not include any of the

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
			optimizations that the service provider would make.
14	Service Provider 2, Drone Operator 2	Upon approval of the flight plan from the **U-Space Authority**, **Service Provider 2** returns a flight approval and flight plan information to the **Drone Operator 2**. The flight plan contains information about the emergency supplies drop flight.	

4.4.7.2 Execution of the flight

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
15	Drone Operator 1, Service Provider 1, U-Space Authority	Before take-off, the drone uses Service Provider 1 to request take off clearance from the *Orchestrator*. Upon gaining clearance, the drone automatically departs on its flight plan. Flight operations of all drones of **Drone Operator 1** are supervised by a company internal Pilot in Command. Position information is automatically forwarded to **Service Provider 1**, which is in charge of managing the flight progress based on its using the tracking service that **Drone Operator 1** has selected. Separation assurance is not relying on *detect and avoid only*, but provided by the *Orchestrator***.** **Service Provider 1**, in turn, sends continuous position information to the **U-Space Authority (the Orchestrator)** for *monitoring*, which includes, but is not limited to: • Drone ID. • *Flight Plan* ID. • Drone status. • Position.	**Service Provider 1** alerts the Pilot in Command of the departure.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		• Altitude. • Velocity.	
16	Drone Operator 1, Service Provider 1, Service Provider 2, U-Space Authority	**U-Space Authority** detects a potential conflict with the reconnaissance mission - **Drone Operator 1** (a mission being managed by **Service Provider 1**) and a second Search and Rescue already delivering emergency supplies to early identified casualties – **Drone Operator 2** (a mission being managed by **Service Provider 2).** The **U-Space Authority** alerts **Service Provider 1** of the potential conflict through the following information: • ID of affected Drone. • Resolution advisory. The **U-Space Authority** tells **Service Provider 1** to assign the reconnaissance drone to climb 20 meters and continue on its path. (ensuring the fix-wing reconnaissance drone stays well above the supply drop hexa-copter) **Service Provider 1** alerts the Pilot in Command. The **U-Space Authority** tells **Service Provider 2** to assign the emergency supply drone to slow down by 10 knots and continue on its path.	**Service Provider 1** accepts de-confliction proposal by the **U-Space Authority** and alerts the Pilot in Command of the flight changes. **Service Provider 2** accepts de-confliction proposal by the **U-Space Authority.**
17	U-Space Authority, Service Provider 1, Service Provider 2	The situation has been successfully de-conflicted as both affected service providers have implemented the **U-Space Authority** mandated actions.	
18	Drone Operator 2, Service Provider 2	The emergency supplies drone reaches the supply pick up point**.**	**Service Provider 2** alerts the Pilot in Command.
19	Drone Operator 2,	Pilot in Command requests landing and emergency supplies collection authorisation from the Search and Rescue Coordinator,	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
	Search and Rescue Coordinator	who approves the request.	
20	Drone Operator 2, U-Space Authority, Service Provider 2	The drone scans the landing area to assure that it is free of obstacles. The landing platform is equipped with an automatic landing guidance system. The activation of this landing assistance system is automatically forwarded to **Service Provider 2**.	**Service Provider 2** informs the **U-Space Authority** and the <u>Pilot in Command</u> of the landing.
21	Drone Operator 2, Search and Rescue Coordinator	The emergency supply is attached to the bottom of the drone via a standardised mount. The Search and Rescue Coordinator confirms the attachment of the supply to **Drone Operator 2**.	
22	Drone Operator 2, U-Space Authority, Service Provider 2	**Drone Operator 2** informs **Service Provider 2** that the flight can be continued.	**Service Provider 2** assigns the drone to take off and follow the next segment of the flight plan to the drop point, and informs the **U-Space Authority** as well as the <u>Pilot in Command</u>.
23	Drone Operator 2, Service Provider 2, U-Space Authority	At the incident site, a helicopter ambulance has started airlifting a casualty (the very highest priority Search and Rescue flight). The **U-Space Authority** alerts **Service Provider 2** and is told to its drone hover until the air ambulance has cleared the conflicting area. **Service Provider 2** alerts the <u>Pilot in Command</u>. **Service Provider 2** checks the proposal and finds that in the interim there is another causally to drops supplies to while waiting for access to the original site. A more optimal solution will be to service this new casualty first.	**Service Provider 2** instructs its drone to enter a hover as per the Authorities instruction. **Service Provider 2** generates a new flight plan to the alternative casualty and submits it to the **U-space Authority**.
24	Service Provider 2, U-	The **U-Space Authority** checks the validity of the new proposal of **Service Provider 2** and	**Service Provider 2** alerts the <u>Pilot in Command</u> of

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
	Space Authority	accepts it.	the flight changes.
25	Drone Operator 2, Service Provider 2, U-Space Authority	**Service Provider 2,** informs **Drone Operator 2** of the change.	The drone now initiates the new flight plan
26	Drone Operator 1, Service Provider 1	**Drone Operator 1** completes its reconnaissance missions and flight plan. The drone activates its landing assistance system which automatically informs **Service Provider 1** of it landing.	**Service Provider 1** informs the **U-Space Authority** and the Pilot in Command of the landing.
27	Drone Operator 2, Service Provider 2	Drone 2 completes its supplies drop mission. The drone activates its landing assistance system which automatically informs **Service Provider 2** of its landing.	**Service Provider 2** informs the **U-Space Authority** and the Pilot in Command of the landing.

4.4.7.3 Mission completed

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
28	Drone Operator, Service Provider 1, U-Space Authority	The **Drone Operator 1** confirms to the **Service Provider 1** that the mission has been completed.	**Service Provider 1** informs the **U-Space Authority** that the flight is completed
29	Drone Operator 2, Service Provider 1, Service Provider 2, U-Space Authority	The **Drone Operator 2** confirms to the **Service Provider 2** that the mission has been completed.	**Service Provider 2** informs the **U-Space Authority** that the flight is completed

The Use Case ends.

4.5 Depot-to-Depot Package Delivery

4.5.1 Context and Assumptions

This use case (UC) describes how a specific drone mission is performed in the context of U-Space, enabled by U1, U2, U3 and U4 services. The mission consists on the routine delivery of packages between sizeably separated facilities (e.g. depots) in rural or suburban industrial environments.

This use case fits to the U-Space visions provided in chapter 3. According to this vision, all airspace users (including drone operators) are responsible for planning and executing their AV trajectories (i.e. safely flying their AVs) in both nominal and off-nominal circumstances.

The description of the use case focuses on how airspace users (drone operators as well as manned AVs) interact with U-Space services (internal actors) to support the conduction of the mission. The discussion of how U-Space services are grouped/packaged and provided by one or several service providers are left out of the scope of this description.

4.5.2 Summary

Figure 24 represents the use case “Depot-to-depot package delivery” using a UML (Unified Modeling Language) use case diagram. It shows a high level decomposition of the use case considered into lower detail use cases that capture the main processes involved. Such decomposition reveals the main actors (both internal and external to the U-Space system boundary) that participate in the realization of the lower level use cases and, in turn, in the use case under consideration.

In essence, the use case at hands involves a **drone operator** (U-Space user) that offers an express package delivery service demanded by a **drone service customer**. To that end, the drone operator must plan the delivery mission and subsequently execute it in a way that, not only attains the mission objectives as optimally as possible, but also fulfills all applicable operational constraints intended to guarantee a safe, secure, efficient, equitable, privacy-respectful and environmental-friendly use of the airspace.

Such mission plan includes a flight plan that needs to be developed in concert with a number of additional flight plans that other drone operators, and, perhaps manned AVs, intend to execute, which may conflict among each other. Two interrelated processes, namely traffic planning and traffic execution, are in charge of orchestrating access to airspace and execution of multiple concurrent flight operations. As flight operations can never be guaranteed to succeed exactly as planned, planning and execution processes at both single (flight) and aggregate (traffic) levels need to work in parallel and in close loop and re-planning will always be needed to a bigger or lesser extent. This hierarchical control scheme were one traffic planning/re-planning process and one traffic execution process interact between each other as well as with, respectively, multiple flight planning/re-planning and flight execution processes is paradigmatic in ATM (Air Traffic Management) and so is expected to be in DTM (Drone Traffic Management).

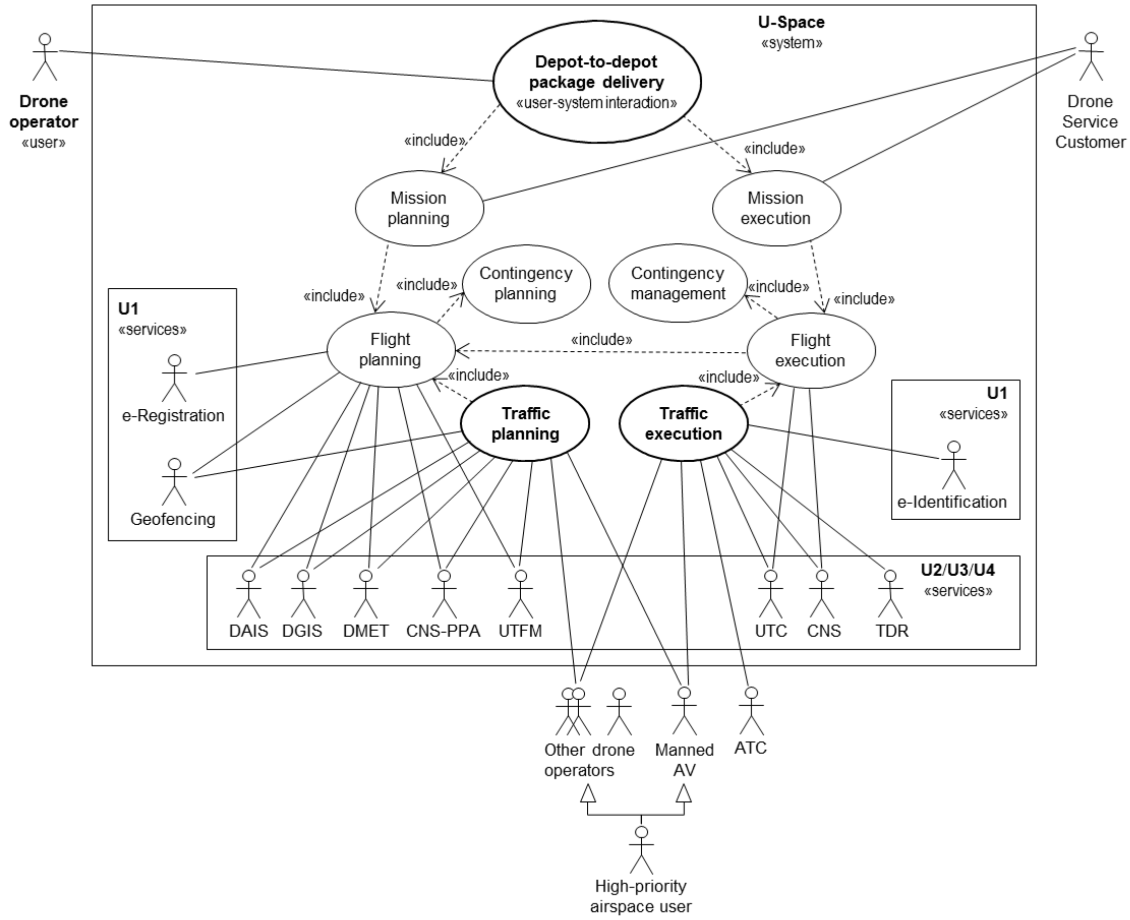


Figure 24. Depot-to-Depot package delivery use case representation in UML

When little uncertainty is present, this UTM control loop facilitates the accomplishment of flight operations nearly as planned. However, off-nominal circumstances can arise at any moment as a result of unplanned incursions of manned or unmanned flights into the operational scenario or one or more AVs experiencing single or multiple in-flight contingencies, or because unexpected airspace disruptions. An example of disruption can occur when an emergency situation requires users to not enter (or leave, if already occupying) a suddenly defined no-fly airspace volume because it has become dangerous or it needs to be occupied by higher-priority users such as emergency or Police AVs. Both flight execution and traffic execution processes need to be able to safely handle these unplanned, contingency and disruption situations, for which specific provisions may need to be made before the actual flight execution starts (i.e. at flight planning time or, much earlier, at airspace design time).

As described below in more detail, several U-space services that range across U1, U2, U3 and U4 participate in the realization of the UTM flight/traffic processes mentioned. Such services are reflected in Figure 24 as internal actors related with the lower level use cases.

4.5.3 Actors

The drone operator under consideration – [Primary]

An authorized person or organization that operates the drone under consideration following U-space regulations. The drone operator includes the whole UAS, comprising the UAV (Unmanned Aerial Vehicle) and GCS (Ground Control Station) along with the remote PIC and all additional supporting functions covering both operations planning and execution timeframes.

Other drone operators – [Secondary]

Third-party instances of the drone operator defined above that may interact with the system (U-Space) and/or with the drone operator under consideration.

Manned AV – [Secondary]

A manned aerial vehicle operating in same airspace as the drone under consideration. It includes both the AV, the PIC and, possibly, a remote mission command and control center.

High-priority airspace user – [Secondary]

A particular third-party drone operator or manned AV that has priority access to airspace, e.g. an emergency or Police helicopter.

The customer of the drone delivery service - [Secondary]

The individual or organization requesting the package delivery service. The drone service customer must provide or designate the delivery pad, an open area where the drone can land, leave the package and takeoff back.

ATC (Air Traffic Control) – [Secondary]

The standard ATC service in charge of separating manned air traffic.

U-Space Provider – [Secondary]

- U-Space foundation (U1) services, namely e-registration, e-identification and geofencing services;
- U-Space initial (U2), advanced (U3) and full (U4) services, namely Digital aeronautical Information Service (DAIS), Digital Geospatial Information Service (DGIS), Digital Meteorological (micro-weather) service (DMET), Communications, Navigation and Surveillance Predictive Performance Assessment (CNS-PPA) service, UAS Traffic Flow Management (UTFM) service, UAS Traffic Control (UTC) service, Communications, Navigation and Surveillance (CNS) services and Traffic Data Recording (TDR) service.

4.5.4 Pre-conditions

All airspace users operating in the environment – whether manned or unmanned, adhere to a standardized RF spectrum policy that avoids frequency collisions/interferences.

All **U-Space U1 and U2/U3/U4 services** listed above are in place (provided by one or multiple service providers), compliant with standards.

Drone Specifications

The drone is assumed to feature VTOL (Vertical Take-Off and Landing) capabilities[4], as well as enough performance in terms of payload, range, endurance and cruise speed as to satisfy reasonably valuable business cases characterized by the following representative figures:

- Payload: 10 Kg (rural community supplies, bulk email, emergency shipments, etc.);
- Range: 30 Km (15 Km roundtrip);
- Endurance: 30 min;
- Cruise speed: 75 Km/h.

Based on this data, MTOW (Maximum Take-Off Weight) is likely to near or exceed 25 Kg.

The drone (most likely of ***certified*** category) is in flight order (ready to fly) and duly registered using ***e-registration (U1).*** In addition to owner, operator, plate ID and assigned PIC, e-registration should include standardized information about drone capabilities (e.g. VTOL), limitations and performance characteristics (e.g. MTOW, payload type, range, endurance, characteristic speeds, etc.).

The drone equipment complies with the required MEL (Minimum Equipment List). A representative MEL suitable for the use case under consideration should include:

- A networked CNPLC solution ***(more reliable means of communications – U3)*** suitable for secure BVLOS operation (e.g. based on standard mobile telecommunications infrastructure) that complies with RCP (Required Communication Performance) (initial guidance provided by RTCA DO-362);
- A ***navigation*** means alternative to GPS (e.g. based on vision, signals-of-opportunity, triangulation via networked CNPLC solution, etc.) that complies with RNP (Required Navigation Performance);
- ***Surveillance*** means to ensure the ability to detect cooperative and non-cooperative surrounding traffic (e.g. vision, air-to-air radar, ADS-B/in) as well as being detected/tracked (e.g. ADS-B/out, in addition to the relay of telemetry by the GCS) that comply with RSP (Required Surveillance Performance) (some initial guidance on the airborne Detect function can be found in RTCA DO-365);
- An airborne *flight control* function capable of performing 4D navigation compliant with performance standard (related to RNP);
- An airborne *flight management* function capable to autonomously manage safety-critical in-flight contingencies such as loss-of-(CNPLC) link (LoL), loss-of-separation (LoS), loss-of GPS (LoG), loss-of-engine/energy (LoE) and loss-of-control (LoC) according to SARPs (Standards and Recommended Practices);
- An airborne ***flight data recording (FDR)*** function capable or recording all relevant flight information required () to support safety, security and privacy investigations;

[4] Notice that hovering capability is not necessarily required. STOL (Short Take-Off and Landing) capabilities could also potentially fit this use case.

- Redundant electrical power supply onboard to ensure continuity of service of critical avionics systems – MOPS (Minimum Operational Performance Standards).

Ground Control Station

The GCS is capable of guessing the behavior of the drone when operating autonomously in response to a contingency and describe and convey such behavior to the U-Space service in a standardized manner so the U-Space service knows what to expect.

Operating Environment

Appropriate weather/atmospheric conditions must exist that permit the safe operation of the drone.

The mission is conducted entirely within VLL (Very Low Level) airspace (below 500ft AGL) although no airspace segregation is assumed, i.e. manned aircraft such as helicopters and other drones conducting diverse UCs might be encountered during nominal mission execution.

In nominal circumstances the drone is able to perform its round trip from A to B and back to A within about 80% of its endurance, which leaves a 20% endurance margin (*energy reserve*) to cope with uncertainties and contingencies.

The drone is operated entirely BVLOS (Beyond Visual Line of Sight) nearly autonomously, although the remote PIC (Pilot-In-Command) retains the ability to intervene by confirming, declining or selecting several options concerning the flight as long as situational awareness, CNPLC (Control and Non-PayLoad Communications) link availability and response time permit.

The operational context is characterized by "business-as-usual" use of drones for many different applications and, thus, by a considerable density of drones operating within VLL. In other words, the probability of encountering drone traffic is not negligible. In that context, we assume that the operational contract between the drone operator and the DTM system (U-Space) will be a 4D trajectory, i.e. we are assuming a TBO (Trajectory-Based Operations) environment.

4.5.5 Post-conditions

From the standpoint of the **drone service customer**, the drone service is considered successfully fulfilled once the requested package has been safely and timely delivered. However, we contemplate here the whole drone operation, including the return leg of the roundtrip between the base of operations (hub) and the delivery point.

4.5.5.1 Success end-state

1) From the standpoint of the **drone operator**, the mission is accomplished only when the drone shipped has safely returned back to the base, after having successfully delivered the package and so it can be reused for the next shipment.
2) Another necessary condition to consider the mission successfully accomplished is that, at no point during the operation, the drone has violated separation minima or geofences or any other operational restriction in force, which might have endangered **other airspace users** or people or property on the ground.

4.5.5.2 Failed end state

Several post-conditions may characterize mission failure; in order of severity[5]:

1) Due to traffic congestion the drone is allocated a delayed takeoff slot that unacceptably impacts the delivery time – the drone never departs and the business opportunity is missed.
2) Traffic interactions once the drone is airborne cause unacceptable delay of the delivery.
3) After having successfully delivered the package, the drone experiences off-nominal circumstances (conflict with unplanned flights, in-flight contingencies or airspace disruptions) in its way back to the base, which are safely managed though result in failure to get the drone back ready for reuse (e.g. emergency landing requires retrieving the drone manually).
4) The drone experiences off-nominal circumstances in its way forward to the delivery point, which are safely managed resulting in a safe though unacceptably delayed delivery.
5) Same as the two previous but resulting in, respectively, drone and/or drone-package self-damage due to abnormal (forced) flight termination.
6) Failure of the drone and/or the DTM system to safely manage off-nominal circumstances resulting in violation of separation with traffic, terrain or obstacles or geofencing infringement without further consequences
7) Same as previous but resulting in material loses, damages to property or minor injury to people
8) Same as previous but resulting in fatal casualties or large environmental impact

4.5.6 Trigger

The use case starts when the **customer of the drone delivery service** issues a petition to a delivery system that, in turn, reaches the **drone operator**. The petitioner interacts with the *mission planning* process through designating the delivery pad and accepting or rejecting the proposed *delivery time*.

Flow of Events

4.5.6.1 Pre-Flight

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
1	Drone operator, Drone service customer	Mission planning. The **drone operator** plans the delivery mission considering a drone whose performances fit the purpose of the mission. If not readily available, extra time may have to be added to the estimated delivery time to allow for an appropriate	

[5] The severity order may vary depending on the nature of the package delivery mission; in typical delivery of supplies missing or late deliveries would be less severe than losing the drone, while in the case of emergency supplies the order of severity may be reversed

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		drone to become available, which would worsen the quality of the drone delivery service or even render it unacceptable (to the **drone service customer**). This, in turn, may condition user preferences in terms of time cost vs. other cost factors and, possibly, trigger dynamic requests for re-planning ongoing flights (step 1.1) in an attempt to speed up drone availability. *Mission planning* involves an iterative what-if process that includes *flight planning* (step 1.1) which, in turn, provides an estimation of the delivery time. If the delivery service with associated delivery time is accepted by the **drone service customer** within the available decision time window, the shipment request becomes firm and the mission is scheduled for execution (step 3), otherwise the *mission plan* becomes invalid (remain in step 1).	
1.1	Drone operator, U-Space Provider (geo-fencing, DAIS, DGIS, DMET, CNS-PPA and UTFM)	<u>Flight planning</u>. As part of *mission planning*, the **drone operator** tentatively plans the most appropriate 4D drone (roundtrip) trajectory to fulfil the delivery mission. Such trajectory is the result of an automated constrained optimization process carried out by the ***flight planning* (U2)** capability (a function of the GCS), where the optimality is driven by a user-preferred compromise of flight time vs. other relevant operational cost factors and the constraints are related to airspace volumes permitted/prohibited and required separation with the terrain, fixed obstacles (e.g. buildings, poles, etc.), bad weather and other AVs whose 4D trajectories have already been allocated previously. *Flight planning* iteratively interacts with *traffic planning* (step 2) until flight plan acceptability by the **UTFM service** is achieved (so-called *trajectory negotiation* process in the context of TBO). If the mission plan based on the acceptable flight plan found becomes firm, flight plan	The *flight planning* process requires information about atmospheric conditions and weather, geography, static/dynamic airspace structure, predicted performance of CNS services/infrastructures and third-party flight plans. All this information, except the third-party flight plans, is provided by the **DAIS (geofencing – U1 plus airspace dynamic information – U2)**, **DGIS**, **DMET** and **CNS-PPA** services. In fact, the *flight planning* process is never provided with third-party flight plans, which apart of inefficient, would be competition-sensitive. Instead, a neutral *traffic planning* process is

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		approval is obtained from the **UTFM service** and the approved flight plan is scheduled for execution (step 3.1), otherwise, the tentative flight plan pre-allocated is unfrozen. The flight plan finally approved/allocated represents the so-called *4D trajectory contract*. The 4D contract implies a commitment between the **drone operator** and the UTM system that the drone will be at the specified 3D positions at the specified times within a given error margin. In particular, the arrival time to the delivery pad can be exploited to, in turn, commit a delivery time with the **drone service customer**.	realized by a **UTFM (UAS Traffic Flow Management) service** with support by the same information services abovementioned.
1.1.1	Drone operator, U-Space Provider (geo-fencing, DAIS, DGIS, DMET, CNS-PPA and UTFM)	Contingency planning. Together with the nominal 4D trajectory intended to be flown, the **drone operator** also produces a companion *contingency plan* that explicitly describes the level of susceptibility of the drone chosen to foreseeable in-flight contingencies along with the predetermined way in which such contingencies would be managed by the drone, should it have to autonomously react to them.	
2	Drone operator, U-Space Provider (geo-fencing, DAIS, DGIS, DMET, CNS-PPA and UTFM)	Traffic planning. The **drone operator** feeds the **UAS Traffic Flow Management (UTFM) service** with the tentative flight plan to what-if whether the plan would be approved as planned (***flight approval* – U2**) or amendments would result necessary to ensure that, collectively, the demand of drone operations does not exceed the capacity of the **UTC service** to safely cope with their execution. Multiple instances of *flight planning* processes concurrently conducted by multiple airspace users are orchestrated by a single instance of *traffic planning*. When decision is made by the **drone operator** to allocate an acceptable flight plan within the *decision time window*, the flight plan results approved and allocated for	The **UAS Traffic Flow Management (UTFM) service** responds either with a confirmation of acceptability or with a number of amendments to the submitted flight plan. Such amendments may consist on delaying takeoff or imposing additional constraints to the nominal flight trajectory or the companion contingency plan in the expectation that, when re-planned, the new flight plan results acceptable.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		execution, otherwise it is discarded by the **UTFM service**. The **UTFM service** must not only ensure capacity vs. demand balance (*capacity management* – U3), but, to the extent possible, achieve so while guaranteeing a fair access to airspace according the accepted *fairness criterion* (e.g. first-come-first-served, capability-based, best payer, least polluter, etc.). If the flight plan submitted by the **drone operator** results acceptable, the **UTFM service** pre-allocates (freezes) the flight plan during certain time interval (*decision time window*), whose duration may vary depending on the demand of UAS operations existing at the moment.	

4.5.6.2 Execution of the flight

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
3	Drone operator, Drone service customer	Mission execution. Before the approved *takeoff time slot* expires, the **drone operator** must make sure that the *turnaround process*[6] is completed, all *pre-flight checking* successfully passed and the drone readily placed at the ramp or takeoff pad, otherwise the slot will be missed and the operation will have to be re-planned and approval obtained again. During the execution of the mission, the **drone operator** may have to re-plan the flight trajectory (step 1.1) due to operational or business reasons, which might impact the delivery time. The **drone operator** will keep	

[6] by analogy with manned air transport, including loading, refueling and/or battery recharge/replacement and any other quick maintenance process needed

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		the **drone service customer** posted on the estimated delivery time, as well as on any change that affects the quality of the delivery service being offered. Upon arrival to the delivery pad, the drone releases the package with or without confirmation by the **drone service customer** that the delivery service is completed, depending on the business approach[7].	
3.1	Drone operator, U-Space Provider (UTC service and CNS services)	Flight execution. When ready to takeoff within the allocated slot, the **drone operator** notifies the **UTC (UAS Traffic Control) service** in charge of orchestrating the traffic execution process. Upon online reconfirmation by UTC (*takeoff clearance*), the drone takes off and proceeds with the execution of the approved *flight plan*. *Flight execution* iteratively interacts with *traffic execution* (step 4). If UTC clearances are issued during the flight, the *flight planning* function (step 1.1) is used online to try and modify the drone trajectory so it meets the new constraints. If that is doable without compromising the safety of the flight then the UTC clearance is accepted by the **drone operator** with the mediation of the PIC and the *trajectory contract* is updated with the re-planned trajectory. Otherwise, the clearance is rejected, which means that the **UTC service** needs to keep searching for alternative solutions to organize the traffic[8]. As nominal flight execution proceeds, the drone reaches the delivery pad and	During flight in nominal circumstances uncertainty related with atmospheric conditions, drone performances, new flight plans and dynamic changes to existing ones (subject to nominal trajectory negotiation) may require minor trajectory amendments, which would come in the form of new constraint/s (clearances) issued by the **UTC service.** In general, trajectory amendments during flight execution can impact flight time or endurance or both in a way that may benefit some users whilst penalizing others, pretty much depending on their particular cost indexes, thereby impacting *fairness*.

[7] E.g. a particular approach may require confirmation by the drone service customer before releasing the package, otherwise the package is carried back to the hub. An alternative approach may be to release the package anyhow upon arrival to the delivery pad.

[8] E.g. if UTC requests a speed or altitude change that the drone is unable to perform or a re-routing that compromises the available endurance, all depending on the given wind conditions

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		autonomously lands, releases the package, takes off again and flies back to the hub. During the flight, the **drone operator** cooperates with the surveillance function by supplying actual drone position (from telemetry) and intent. In addition, the drone itself cooperatively broadcasts its position and intent via ADS-B as all the other AVs operating in the environment are required to do. Based on its *Detect and Avoid* (DAA) capability, the drone is able to perform *Remain Well Clear* (RWC) procedures (self-separation) to the extent delegated by **UTC** as established in the U-Space *rules-of-the-air*. Finally, all relevant information such as the actual trajectory flown, milestones reflecting changes with regard to the original flight plan, status of the critical airborne and ground systems, etc., are continuously recorded by the **drone operator** during the flight as evidence in case of safety, security or privacy investigations, as well as to create a base of experimental data from which to learn how to improve operations.	It may happen that the delivery pad is not a facility of exclusive use by the **drone service customer**, but a shared one, in which case concurrent drone takeoff and landing operations may need to be managed, depending on the density of drones using such facility. This leads to converging traffic problems that may require **UTC** to perform sequencing, scheduling and arrival-departure coordination with support of high levels of automation (**U4 services**). **Communications, Navigation and Surveillance (CNS) services** support safe flight execution.
3.1.1	Drone operator, UTC service and CNS services	Contingency management. Based on ADSB-in as the cooperative means and, most likely, a complementary independent airborne traffic surveillance means, the drone continuously monitors its separation with surrounding traffic, as part of its **DAA capability (U3)**. In case of separation infringement (LoS), the drone triggers the corresponding *Collision Avoidance* (CA) response. As part of the nominal flight execution, the drone monitors the performance of its critical systems, in particular, that of the CNPLC link, navigation function and engine/energy systems in search for potential contingencies (respectively, LoL, LoG and LoE). The drone also monitors its flight control performance in search for ill-conditions such as actuator failures or severe	**CNS services** provide, in particular, mechanisms supporting online assessment of CNS performance and alerting on abnormal service provision situations. The **UTC service** may cooperate managing the contingency (e.g. keeping traffic away from an AV known to be operating under contingency or adapting separation mechanisms to the limitations associated with contingency operation).

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		wind (e.g. gusts, heavy turbulence) that may cause LoC. As soon as the routine monitoring performed as part of nominal flight execution identifies the occurrence of an in-flight contingency, its criticality is immediately assessed and decision is made (possibly autonomously) on whether to attempt a procedure for *contingency resolution* (which may imply diverting from the original flight plan in the expectation that the nominal flight can be later resumed), *drone recovery* (with implies aborting the mission in an attempt to safely retrieve the drone operating in degraded mode), *emergency landing* (at the nearest available emergency landing facility) or *flight termination* (which sacrifices the drone to avoid greater safety or security consequences). The contingency management process includes notifying the **UTC service** about the contingency being experienced as well as the ensuing drone behavior expected. This way, **UTC** can cooperate, if necessary and possible, to safely handle the contingency situation.	
4	Drone operator, ATC, UTC service, CNS services and TDR	Traffic execution. The execution of multiple concurrent flight operations interact among each other, possibly creating conflicting situations that need to be anticipated (**conflict detection – U3**) and resolved before they actually happen. Such conflicts, or predicted separation infringements can appear even when all flight executions proceed as planned just because of the presence of uncertainties inherent to the trajectory prediction process underpinning *flight planning*. But they can also appear as a result of AVs diverting from their approved flight plans with or without the consent by **UTC**. Examples of this are, respectively, when an **airspace user** dynamically requests changing its approved trajectory due to business reasons, or when a drone autonomously engages in a contingency	In addition to the separation provision function exerted in nominal circumstances, the **UTC service** must be able to keep separating the traffic in off-nominal conditions. Moreover, to the extent possible (i.e. whenever safety or security are not critically compromised), **UTC** must consider additional quality of service merits such as *efficiency*, *environmental impact* and *fairness*. To realize its job in support

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		management trajectory that diverts from the plan without being able to communicate the reason to UTC because the concurrency of a LoL condition. Even more challenging conflicting situations can arise as a result of sudden unplanned incursions of non-cooperative AVs in the operational scenario, or U-space disruptions caused by emergencies or **high-priority user** access to airspace or **ATC** interventions.	to *traffic execution*, **UTC** relies on **CNS services** to, in particular, obtain the traffic surveillance data needed to monitor flight plan conformance, communicate operational information and decisions with concerned actors and stay aware of CNS performance. As with the *flight execution* process, all relevant information related to *traffic execution* needs to be recorded by a **TDR service** to support safety, security and privacy evidence in case of investigation, as well as to feed the base of experimental data to further learn and improve the system. Part of this information may need to be accessible online by authorized individuals or organizations for security or law-enforcement purposes, which is facilitated by the **e-identification (U1)** service.

4.5.6.3 Mission completed

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
5	Drone operator, UTC service, CNS, TDR	Upon arrival back to the base, the drone autonomously lands and the **drone operator** notifies **UTC** that the drone operation has been completed. The **drone operator** stores all relevant mission and flight data related to the drone	The **TDR service** stores all relevant traffic information related to the drone operation completed. Concerned **U-space**

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		operation completed. The **drone operator** releases all mission and flight resources related with the operation completed.	**services (UTC, CNS, TDR)** release all U-space resources related with the operation completed.

The use case ends.

4.6 Depot-to-Consumer Delivery

4.6.1 Context and Assumptions

Assumptions made in this Use Case are based upon the definitions set out in Call CEF-SESAR-2018-1 and seen in the context of the 'visions' provided in chapter 3. In this context, the function of the "Orchestrator" is aligned with that of the "U-Space Authority" (SJU call).

4.6.2 Summary

Immediate delivery of goods is a demand not only in cases of medical emergencies or for high value business transportation. Modern e-commerce customers expect to receive deliveries in a fast and convenient manner, but for a payable price. Instead of waiting for a conventional parcel delivery which might get stuck in traffic, drones will allow companies to provide direct depot to consumer deliveries by air, taking less time, emitting lower amounts of pollution and requiring less man power. The following use case describes how such a service can be provided safely and efficiently. To cover a wide range of issues which may affect the operating environment, the use case details requirements for operations in rural, suburban and urban environments, outlines interactions of various service providers with the U-Space system and the drone operator, includes actions to be performed in case of conflicting/priority traffic and includes possible business applications related to drone package delivery. The use case begins with a detailed description of the actors, lists pre- and post-conditions and describes the flow of events from pre- to post-flight. Furthermore, the flow of events is structured in a way to focus on the interactions of all the actors with the system, so as to emphasise the information requirements.

4.6.3 Actors

Drone Operator – [Primary]

Operates a fleet of autonomous UAS on a Drone Service Receiver request-based routings and with a distinct mission goal.

Pilot in Command is in charge of managing the operation of all of the drones in the fleet, and is the last instance of contingency, in case automation fails. This position is bound by three operating states of the drones in the fleet:

- State 1: Drone(s) is/are operating nominally and only need to be superficially overseen;
- State 2: Drone(s) is/are in an abnormal state (traffic density, flight plan deviations, system alerts, unforeseen events) and trying to rectify the state autonomously. The Pilot in Command should pay special attention to the drone's operation, but does not interact;
- State 3: Drone(s) is/are in an abnormal state (traffic density, flight plan deviations, system alerts, unforeseen events) and autonomous attempts at reconciliation have failed. The U-Space Authority is notified. The Pilot in Command is the last line of defense and is tasked in resolving the situation.

Competent Authority – [Secondary]

The authority giving permit to fly to drone operators using a category of drones for a specific mission.

Contains registry information about the **Drone Operator's** licensing, drone equipment, drone contingency provisions and delivery classifications.

U-Space Service Provider – [Secondary]

- Provider 1: Provides assistance for flight planning, assistance for authorisation and DTM services to ensure a safe, efficient and secure conduct of UAS operations;
- Provider 2: Provider of advanced Microweather and Geo-Awareness Services within the city bounds of the **End Customer;**
- Provider 3: Provides assistance for flight planning, assistance for authorisation and DTM services to ensure a safe, efficient and secure conduct of UAS operations.

U-Space Authority

The authority providing reliable data and updated information inked to the airspace management (restricted areas, temporary restricted zones, etc.) especially specific information for drone operations ("no fly" zones, drone tracks etc.).

Retail Company – [Secondary]

This entity is the customer of the Drone Operator and sets the mission goal of the provided service.

End Customer – [Secondary]

This is the consumer of the product delivered by the Drone Operator.

4.6.4 Pre-conditions

Drone Operator:

- Has valid operating license;
- Is registered by the competent authority;
- Has centralized drone hub in a rural area near the package distribution center of the **Retail Company**;
- Has standard access to U-Space U1, U2 and U3 services via Service Provider 1;
- Has premium access to premium U-Space services via Service Provider 2.

Drone Specifications

- Has level 3/level 4 positioning capability;
- Communication based on 5G mobile networks;
- Dimensions: 1,5m x 1,5m x 0,5m;
- Type: Hexacopter with standardized package attachment mount on the bottom;
- Max payload: 10kg;
- Auxiliary Equipment: parachute system for contingency, "detect-&-avoid" system sensors, automatic landing guidance system receiver, standardized package attachment mount.

Service Provider 1:

- Has a valid U-Space service provision license;
- Provides select U-Space U2 and U3 services (Table 12) to its customers;
- Has direct access to the **U-Space Authority;**

- Can calculate automatically generated flight plans based on origin and destination coordinates and drone/operator information stored in the database;
- Has information about the capabilities, equipment and optimal operating method of all of the drones of the **Drone Operator.**

Service Provider 2:

- Has a valid U-Space service provision license;
- Provides highly accurate micro-weather services within the city;
- Provides highly accurate geo-awareness services within the city;
- Does not have direct access to the **U-Space Authority.**

Service Provider 3:

- Has a valid U-Space service provision license;
- Provides some U2 core services (Table 12) to its customers in areas classified as 'rural';
- Has direct access to the **U-Space Authority;**
- Can calculate automatically generated flight plans based on origin and destination coordinates and drone/operator information stored in the database;
- Has information about the capabilities, equipment and optimal operating method of all of the drones of its own users, but not those of **Service Provider 1**.

Retail Company

- Retail company offering product delivery at home;
- Has a package distribution center in a low populated area outside of the city boundaries;
- Defines the mission goal of the delivery based on the **End Customer** request and its internal operations and logistics.

End Customer

- Private person with no connection to U-Space;
- Lives in an apartment building in the center of a city;
- The building has a designated landing pad for drones on its roof.

U-Space Authority

- Provides strategic and tactical flight de-confliction;
- Has direct access to all registry information;
- Manages flight plan approvals;
- Provides Authoritative Geo System Service;
- Provides emergency management and tactical de-confliction in case of State incidents.

Table 14: Overview of U-Space services and service providers in Use Case 6

	Drone Operator contracts:		
U-Space Authority	Service Provider 1	Service Provider 2	Service Provider 3
DAIM	DAIM		
		Microweather	
		Geo-Awareness	
Tactical geofencing			
Flight plan management	Assistance for flight planning		Assistance for flight planning
Monitoring	Tracking		Tracking
Strategic de-confliction			
Tactical de-confliction			
Emergency management			
Traffic information			

4.6.5 Post-conditions

4.6.5.1 Success end-state

The use case is considered a success when the following conditions apply:

- The drone has delivered package in a timely manner;
- No other airspace users or persons on the ground were endangered;
- The drone has not caused damage to property, itself or the delivered goods;
- Successful provision of drone service (delivery of package);
- Successful return of drone to its hub;
- Efficient and safe conduct of mission;
- Platform available for preparation of next operation.

4.6.5.2 Failed end state

The use case is considered failed when one or more of the following scenarios apply:

- Drone unable to reach mission goal;
- Abort of operation;
- Drone endangers other airspace users, persons or animals, airborne and on the ground;
- Drone causes damage to property, itself or the delivered goods;
- Drone contingency provisions fail.

4.6.6 Trigger

The use case starts when the **End Customer** orders a product for express delivery (within 40 minutes) on the website of the **Retail Company**. The package has the following specifications:

- Dimensions: 0.5m x 0.5m x 0.5m;
- Mass: 5kg;
- Goods classification: Food Products.

4.6.7 Flow of Events

4.6.7.1 Pre-Flight Operation Phase

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
1	End Customer, Retail Company	The use case starts when the **End Customer** orders a product for express delivery on the website of the **Retail Company**. (See Trigger).	
2	Retail Company, Drone Operator	The **Retail Company** submits a service request on the on-line delivery service of the **Drone Operator** to collect a package from its package distribution center (sub-urban area) and to deliver it to the address of the **End Customer** in a nearby city (urban area). The request indicates: • The unique ID of the collection pad at the package distribution center (where the package is to be collected automatically by the drone). • The unique ID of the landing pad at the delivery address. • The specifications of the package to be	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		delivered. • The time-frame of delivery. • The type of goods to be delivered. • The ID of the end customer.	
3	Drone Operator	The request launches an automatic process in the **Drone Operator's** drone hub which selects an adequate drone (given the characteristics of the package, the time of delivery, the type of landing facilities available and the operating conditions set out by the mission) and fulfils a set of mission requirements used to develop the flight plan request.	
4	Drone Operator, Service Provider 1	A flight plan request is automatically forwarded to **Service Provider 1**, which includes information about the **Drone Operator's** ID, the drone's ID, classification of the delivered goods, IDs of the landing fields (home base, landing pad of **Retail Company**, landing pad of **End Customer**).	**Service Provider 1** sends an acknowledgement of the flight plan request to the **Drone Operator**.
5	Service Provider 1	**Service Provider 1** uses the flight plan request information alongside the information already stored on its internal database about the drone's capability and the **Drone Operator's** preferred operating methods to generate an optimal *preliminary flight plan*. To generate it, further information must be gathered from *Registration* and the *Authoritative Geo System*. **Service Provider 1** sends the following information to *Registration*: • Landing pad IDs **Service Provider 1** sends the following information to the *Authoritative Geo System*: • Operational area	*Registration* provides **Service Provider 1** with the following information in response: • Coordinates of landing pads. • Types of landing pads. • Restrictions of landing pads. The *Authoritative Geo System* provides **Service Provider 1** with the following information in response: • Coordinates of hazards. • Flight restrictions.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
			• Geo-fencing data.
6	Service Provider 1, U-Space Authority, Competent Authority	The *declaration of intent to fly* is prepared according to the updated *preliminary flight plan* and filed to the **U-Space Authority.** The intent to fly contains the following information: • Preferred trajectory. • Departure/collection/delivery landing pad coordinates. • EOBT/EIBT (Estimated off/in-block times). • Classification of transported goods*. • Drone registry ID*. • Operator registry ID*. • Contingency planning*. *Registry information about the **Drone Operator's** licensing, drone equipment, drone contingency provisions and delivery classifications are stored in the **Competent Authority's** database.	The **U-Space Authority** returns an updated *flight plan* based on restrictions in: • Traffic density. • Weather. • Temporary Airspace restrictions. • Events affecting the drone capability required over a certain area. An iterative process is performed between the **U-Space Authority** and **Service Provider 1** until a *flight plan* is mutually agreed or a cut-off time is reached. In such a case, the *flight plan* of the **U-Space** authority will prevail.
7	Service Provider 1, Drone Operator	Upon approval of the flight plan from the **U-Space Authority**, **Service Provider 1** returns a flight approval and flight plan information to the **Drone Operator**. The flight plan contains information about the delivery as well as the return flight.	

4.6.7.2 In-Flight Operation Phase

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
8	Drone Operator, Service Provider 1, U-Space Authority	The drone automatically departs on its flight plan. Flight operations of all drones of the **Drone Operator** are supervised by a company internal Pilot in Command.	**Service Provider 1** alerts the Pilot in Command of the departure.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		The **Drone Operator** signals **Service Provider 1** that the flight has commenced. Position information is automatically forwarded to **Service Provider 1**, which is in charge of managing the flight progress based on its *tracking* service. The initial flight altitude is 120m AGL. The drone is flying at maximum velocity, as there are no airspeed restrictions in the first part of the flight plan (rural area). Separation assurance is not relying on *detect and avoid*, but should be provided by **Service Provider 1.** **Service Provider 1**, in turn, sends continuous position information to the **U-Space Authority** for *monitoring*, which includes: • Drone ID. • *Flight Plan* ID. • Drone status (i.e. "enroute to [Collection Pad ID]"). • LAT/LON position. • Height. • Velocity.	
9	Drone Operator, Service Provider 1, Service Provider 3, U-Space Authority	**U-Space Authority** detects a potential conflict of the delivery drone with that of a drone inspecting a power line, which is managed by **Service Provider 3.** The **U-Space Authority** alerts **Service Provider 1** of the potential conflict through the following information: • Drone IDs (inspection/delivery). • Conflict Area. • Timeframe for the potential conflict. • Resolution advisory. The **U-Space Authority** asks **Service Provider 1** to assign the delivery drone to climb 5 meters and continue on its path.	**Service Provider 1** accepts de-confliction proposal by the **U-Space Authority** and alerts the Pilot in Command of the flight changes. **Service Provider 3** accepts de-confliction proposal by the **U-Space Authority.**

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		Service Provider 1 changes the flight status to "State 2" and alerts the Pilot in Command. The **U-Space Authority** asks **Service Provider 3** to assign the inspection drone to slow down by 3m/s and continue on its path.	
10	U-Space Authority, Service Provider 1, Service Provider 3	The situation has been successfully de-conflicted as both affected service providers have implemented the **U-Space Authority** mandated actions.	The **U-Space Authority** informs **Service Provider 1** and **Service Provider 3** that the restrictions have been lifted.
11	Drone Operator, Service Provider 1	The drone reaches the distribution center of the **Retail Company.**	**Service Provider 1** alerts the Pilot in Command.
12	Drone Operator, Retail Company	Pilot in Command requests landing and package collection authorisation from the **Retail Company**, which approves the request.	
13	Drone Operator, U-Space Authority, Service Provider 1	The drone visually scans the landing platform to assure that it is free of obstacles. The landing platform is equipped with an automatic landing guidance system, which the drone follows to land on the platform with high precision. The activation of the landing assistance system is automatically forwarded to **Service Provider 1**.	**Service Provider 1** informs the **U-Space Authority** and the Pilot in Command of the landing.
14	Drone Operator, Retail Company	The package is attached to the bottom of the drone via a standardised mount. The **Retail Company** confirms the attachment of the package to the **Drone Operator**.	
15	Drone Operator, U-Space Authority, Service Provider 1	The **Drone Operator** informs **Service Provider 1** that the flight can be continued.	**Service Provider 1** assigns the drone to take off and follow the next segment of the flight plan to the delivery point, and informs the **U-Space Authority** as well as the Pilot in Command.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
16	Service Provider 1, Service Provider 2	The drone flies its certified maximum allowed speed for carrying cargo in suburban areas. Upon entering city limits, it reduces its speed further to the maximum allowable flight speed within city limits and maintains an altitude high enough to safely overfly buildings. The drone comes within range of navigational beacons placed throughout the city, which increases its navigational redundancy. This information is automatically sent to **Service Provider 1.** Furthermore, it is now within range of **Service Provider 2's** services.	**Service Provider 2** feeds highly accurate *Geo-Awareness* and microweather data to **Service Provider 1.**
17	Drone Operator, Service Provider 1, Service Provider 2, U-Space Authority	The **U-Space Authority** alerts **Service Provider 1** of a police helicopter with dynamic geofencing engaged, surveying the building next to the one with the destination landing site, and proposes an extensive horizontal reroute around the affected area. **Service Provider 1** changes the flight status to "State 2" and alerts the <u>Pilot in Command</u>. **Service Provider 1** checks the proposal and finds that the most optimum re-route would be for the drone to descend to near street level and cross below the helicopter, between buildings. This is justified because the following requirements are in place: • The space between buildings is wide enough to allow the drone to fly there. • Additional navigational redundancy is assured, due to the reception of signals from navigational beacons. • **Service Provider 1** receives constant and highly accurate *Geo-Awareness* data from **Service Provider 2**. • **Service Provider 1** receives constant and highly accurate microweather data	**Service Provider 1** rejects the proposal by the **U-Space Authority** and submits the counterproposal and justification.

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		from **Service Provider 2**. • The drone meets contingency requirements for the area. • The drone has sufficient detect and avoid capabilities.	
18	Drone Operator, Service Provider 1, U-Space Authority	The **U-Space Authority** checks the validity of the counter proposal of **Service Provider 1** and accepts it.	**Service Provider 1** alerts the Pilot in Command of the flight changes.
19	Service Provider 1, U-Space Authority	**Service Provider 1** orders the drone to pass below the police helicopter at near street level. The **U-Space Authority** evaluates that the situation has been de-conflicted	The **U-Space Authority** informs **Service Provider 1** that the restrictions have been lifted.
20	Drone Operator, Service Provider 1	**Service Provider 1** orders the drone to rise again to the altitude determined in the *flight plan*.	**Service Provider 1** alerts the Pilot in Command of the flight changes.
21	Drone Operator, Service Provider 1	The drone reaches designated landing pad of the **End Customer's** apartment building.	**Service Provider 1** alerts the Pilot in Command.
22	Drone Operator, Service Provider 1, U-Space Authority	The drone visually scans the landing platform to assure that it is free of obstacles. The landing platform is equipped with an automatic landing guidance system, which the drone follows to land on the platform with high precision. The activation of the landing assistance system is automatically forwarded to **Service Provider 1**.	**Service Provider 1** informs the **U-Space Authority** and the Pilot in Command of the landing.
23	Drone Operator, End Customer, Retail Company	The **Drone Operator** notifies the **Retail Company** of the successful delivery. The **Retail** Company informs the **End Customer** to ascend to the roof to collect the delivery. The **End Customer** is scans a code on the package in order to confirm reception of delivery.	

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
		After reception of delivery is confirmed, the **Retail Company** asks the **Drone Operator** to release the package.	
24	Drone Operator, U-Space Authority, Service Provider 1	The **Drone Operator** orders the drone to release the package and informs **Service Provider 1** that the flight can be continued.	**Service Provider 1** assigns the drone to take off and follow the next segment of the flight plan to the landing pad of its home base, and informs the **U-Space Authority** as well as the Pilot in Command.
25	Drone Operator, Service Provider 1, U-Space Authority	The return flight is conducted at the same initial altitude (120m) without incident. The drone reaches designated landing pad of the **Drone Operator's** apartment building**.**	**Service Provider 1** alerts the Pilot in Command.
26	Drone Operator, Service Provider 1, U-Space Authority	The drone visually scans the landing platform to assure that it is free of obstacles. The landing platform is equipped with an automatic landing guidance system, which the drone follows to land on the platform with high precision. The activation of the landing assistance system is automatically forwarded to **Service Provider 1**.	**Service Provider 1** informs the **U-Space Authority** and the Pilot in Command of the landing.

4.6.7.3 Post Operation Phase

Step	Actor(s) Involved	Actor(s) Action	System Response (optional)
27	Drone Operator, Service Provider 1, U-Space Authority	The **Drone Operator** confirms to the **Service Provider 1** that the mission has been completed.	**Service Provider 1** informs the **U-Space Authority** that the flight is completed

The Use Case ends.

5 Information Users' Requirements

This chapter yields the core results of the deliverable by first, elaborating a gap analysis based on the previously provided knowledge to state the general "supply and demand" for aviation information. Second, we are analysing through the introduced use cases if a special demand for certain "information packages" can be distinguished by types of operation, flight life cycle of stakeholder.

5.1 Gap Analysis

In a first step, we will use the results of our domain analysis to show the generally needed types of information related to drone operations. This data will then be compared to:

a) the existing data services in manned aviation;

b) identified services of unmanned aviation that are currently available;

c) the description of U-Space services taken from the recently released ATM Master Plan;

d) the particular users demand identified in the survey;

By these steps, we will identify synergies on the one hand and blank spots on the other to detect necessary action tasks and opportunities.

5.1.1 Data Comparison of Existing Data Services and General Demands

The following Table 15 represents the entire results that were extracted from comparing the existing data services among each other as previously described. Green marked boxes indicate that information in this category (according to our research) sufficiently exists for manned aviation (as summarized in chapter 2.6) and could be facilitated for unmanned traffic purposes. Yellow marked boxes indicate that available data here is probably not (yet) adequate for such usage. The column of UTM service providers shows if the described information is already available on the free market, as detailed in chapter 2.7. The arrows between both columns show which services are already interconnected (blue) or should be implemented (red). Which of these information categories are at some stage of the U-Space implementation plan essential to realize the provision of certain service is analysed in the column "U-Space Service Enabler." Finally, the results of the survey as in chapter 2.5.1.2 are taken into account to show the specific demands predicted by the interrogated stakeholder groups.

Table 15: Comparison of existing information services in manned and unmanned aviation

Information Categories		Existing Data Services		Demand		
		Manned Aviation	UTM Service Providers	U-Space Service Enabler	Survey Results	Additional sources / notes
Aeronautical	Permanent airspace sectorisation	AIXM →	X	U1	X	
Aeronautical	Non-permanent airspace sectorisation	AIXM, NOTAM →	X	U1	X	
Aeronautical	Airport reference and configuration	AIXM →	X	U1	X	
Aeronautical	Additional aeronautical data	NOTAM	X	U1	X	More detailed information will be required
Geospatial	Permanent geographical data	AIXM ⇄	X	U1	X	Missing "Material (frangibility) and "Support Technologies"
Geospatial	Non-permanent geographical data	NOTAM ⇄	X	U2	X	More detailed information will be required
Geospatial	Data verification and validation			U2		
Flight	Flight plan	FIXM ⇄	X	U2	X	
Flight	Flight monitoring	FIXM ⇄	X	U2		
Flight	Command and control (C2)		X	U2		Unmanned "communications with AUs" needed
Flight	Payload control			U2		UAS Specific
Flight	Flight management	FIXM →	X	U2	X	
Flight	Contingency management			U2		
Flight	Deconfliction	FIXM	X	U2/U3		
Communication	Payload Communication	⇄	X	U1/U2		No harmonized solution yet
Communication	Control and Non-Payload Communication	⇄	X	U1/U2		
Communication	Infrastructure	⇄	X	U1/U2		

Information Categories		Existing Data Services		Demand		
		Manned Aviation	UTM Service Providers	U-Space Service Enabler	Survey Results	Additional sources / notes
Navigation	Navigation data	AIXM	X	U2		
	Signal of opportunity (SOO) data		X	U2		UAS Specific
	Vision-based navigation		X	U2	X	UAS Specific
	Accuracy levels		X	U2		
Operational	Mission intent		X	U2		No central authority yet
	Mission monitoring		X	U2		No central authority yet
	UAS facilities and infrastructure		X			UAS specific
	Equipment		X			UAS specific
	Communication devices		X	U2	X	Limited to "Quality of coverage"; No central authority yet
	Maintenance data	NAMIS	X			
	U-Space system			U3		UAS specific
Surveillance	Individual tracking	FIXM	X	U2	X	No central authority yet
	UAS traffic tracking	FIXM	X	U2	X	
	Surveillance infrastructure		X	U2	X	
Weather	Measurements	WXXM	X	U2	X	No high resolution/micro-weather yet
	Observations	WXXM	X	U2	X	
	Forecasts	WXXM	X	U2	X	
	Impact warnings					UAS specific
UAS	Vehicle properties		X	U1	X	UAS specific
	Associated GCS		X			UAS specific
	Operator database		X	U1	X	Roll-out in progress
	Pilot database		X	U1	X	

Information Categories		Existing Data Services		Demand		
		Manned Aviation	UTM Service Providers	U-Space Service Enabler	Survey Results	Additional sources / notes
Administrative Authority	Regulations	AIXM	X		X	No central authority yet
	Law enforcement	AIXM			X	
	Restricted access	NOTAM	X	U1	X	
	Authorization			U1	X	No central authority yet
	Notifications	NOTAM	X	U1	X	
	Alerts	AIXM	X	U2/U3	X	
	Third-party risk database		X	U2	X	UAS specific

5.1.2 Identified blank spots and action tasks

According to the comparison of existing services and demands, the following action tasks are identified for a general provision of drone related information.

- **Aeronautical and Geospatial**

  Broadly covered by existing aeronautical data exchange services but missing the necessary geospatial level of detail to facilitate drone operations. Furthermore, drone operations feature various applications that require geospatial data for operational rather than aeronautical purposes. As demonstrated, various service providers are already competing in this sector, anyways there is not central authority that verifies or validates information (for drone relevant data) to assume liability. Additional information to improve and authenticate data could be received from authorized and governmental datasets such as the NASA lead ASTER Global Digital Elevation Map or the European Meteosat missions.

  - *Improve availability of high resolution and multi-purpose geospatial data;*
  - *Certify credibility of aeronautical drone information, e.g. by a central authority.*

- **Flight**

  Information that exists for describing flights in manned aviation, as in the FIXM data exchange format, guarantees a safe integration and deconfliction with unmanned aviation. Vice versa, the same kind of information should be facilitated for drone operations, even if the level of detail still needs to be determined. At the same time a digital reprocessing of drone flight plans and the actually monitored movements are necessary to elaborate several future U2 and U3 services such as the unmanned aviation internal deconfliction and contingency management procedures.

- *Interoperable exchange of flight/flight management information with manned aviation;*
- *Digital reprocessing of information needed to enable safety critical U-Space services.*

- **Communications**

  A critical piece for unmanned operations is the assurance of a communication link between the drone and the ground control station. This safety critical connection requires LOS and BVLOS communication via a ground based and satellite based communications system, as well as a dedicated and protected communications spectrum [41].

  - *Provision of dedicated, scalable and protected aviation spectrum for communications;*
  - *Communications infrastructure is not yet in place (neither ground based nor space based) and should assure adequate coverage;*
  - *Internationally harmonised communication standards.*

- **Navigation**

  This section appears underrepresented in the results. But, from an engineering point of view it is vital anyway. Availability and accuracy levels, especially in environments that are not covered by the services of manned aviation deserve special attention, e.g. in urban or isolated areas.

  - *Elaborate concepts and information provision appropriate to enable drone navigation;*
  - *Determine transferability and applicability of existing structures from manned aviation.*

- **Operational**

  In the first instance, this information is relevant for operator convenience. Consequently, the interrogated stakeholders did not see this section as part of a central information platform. De facto, various vendors already offer services processing maintenance data and supporting the efficient execution of operations. Nevertheless, an exchange with a central authority could be necessary as pointed out in the vision of future concept. Instead of asking operators for flight ready plan, they could file their actual mission intent.

  - *Discuss adequate level of centralised information for operational intentions;*
  - *Evaluate potential to increase quality of service in other information categories by processing operational information.*

- **Surveillance**

  Clearly necessary from technical position and stakeholder interests. Existing tracking information for manned aviation is already incorporated partially, e.g. accessible ADS-B data. Simultaneously, drone traffic data should be available for safety purposes of manned aviation. As in the aeronautical data, this information transfer is reasonably supervised by a central authority.

- *Centralise tracking information efforts;*
- *Provide supervision of information transfer;*
- *Determine different levels of tracking accuracy depending on operation parameters.*

- **Weather**

The atmospheric conditions feature a particular relevance for successful drone operations. Compared to manned aviation UAS are more vulnerable to the effects of weather but also more flexible in their flight execution. Thus it is indicated, that such information needs to be reliably available, especially in flight level that are commonly used by drones and areas not covered by data from manned aviation. Weather in general and microweather where it is needed are hence identified as core elements of a future drone information system, even if some of the services are externally provided. Furthermore, the data needs to be reconditioned to be convenient for drone operator and automated system functions. Data exchange should be evaluated bi-directional, since it could be of value for manned aviation to benefit from higher resolutions and more dynamic information as well, and by design UAV offer a lot potential to deliver weather data.

- *Ensure reprocessing of existing weather data for drone purposes;*
- *Secure and manage availability of weather information;*
- *Ensure reconditioning of weather information for dedicated user;*
- *Determine different level of weather details depending on operation parameters.*

- **UAS**

Has no equivalent in manned aviation, since it concerns data in conjunction with the actual drone and the connected persons. Provided information here is essential to the core U-Space services, as identification and registration. Current services are not yet publicly available in all European states.

- *Investigate readiness for market and detailed concepts of existing solutions.*

- **Administrative Authority**

As central allocation and distribution pipe for administrative information purposes, this section is identified as an enabler for several core and advanced U-Space services. Most information is not yet practically implemented since U-Space lacks a central authority and harmonisation with all European states. Therefore, existing services focus on an individual national level. An exchange of information with manned aviation in cases of alerts is of particular interest for safety reasons, whereas notifications concerning ground based activities of humans are not.

- *Allocate and distribute administrative information;*
- *Determine relevant information for an exchange with manned aviation.*

5.2 Summary of Requirements by Operation Type and Flight Phase

In this subchapter the results of the use case analysis are presented in six tables. They demonstrate in detail which kind of information has been utilized / transmitted / processed to facilitate a safe and efficient conduct of the described mission. In addition, it has also been pointed out in which phase of the flights this was relevant to the operation of the use case.

Table 16: Information requirements: guiding and supervising autonomous agriculture (rural inspection type)

Category		Flight Phase				
		Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
Aeronautical	Permanent airspace sectorisation	x	x	x		
	Non-permanent airspace sectorisation	x	x	x		
	Airport reference and configuration data					
	Additional aeronautical data		x	x		
Geospatial	Permanent geographical data	x	x	x		
	Non-permanent geographical data		x	x		
	Data verification and validation	x	x	x		
Flight	Flight Plan		x	x	x	
	Flight Status		x	x	x	
	Command and Control (C2)		x	x		
	Payload control and management	x	x	x		
	Flight Management	x	x	x		
	Contingency Management	x	x	x		
	Deconfliction	x	x	x		
Com-munication	Payload Communication			x		
	Control and Non-Payload Communication			x		
	Infrastructure			x		
Navigation	Conventional aeronautical navigation data					
	Signal of opportunity (SOO) data			x		
	Vision-based navigation			x		
	Accuracy levels			x		

Category		Flight Phase				
		Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
Opera-tional	Mission intent	x	x	x		
	Mission monitoring	x	x	x		
	UAS facilities and infrastructure	x	x	x		
	Equipment	x	x	x		
	Communication devices	x	x	x		
	Maintenance data	x				
	U-Space system	x	x	x	x	
Sur-veillance	Individual tracking			x		
	UAS traffic tracking		x	x		
	Surveillance Infrastructure		x	x		
Weather	Measurements		x	x		
	Observations	x	x	x		
	Forecasts	x	x	x		
	Impact Warnings		x	x		
UAS	Vehicle properties	x	x			
	Associated GCS	x	x			
	Operator database	x	x	x	x	
	Pilot database	x	x	x	x	
Administrative Authority	Regulations	x	x			
	Law enforcement	x	x	x	x	
	Restricted access	x	x	x		
	Authorization	x	x	x	x	
	Notifications	x	x	x	x	
	Alerts	x	x	x	x	
	Third-party risk database	x	x	x		

Table 17: Information requirements: inspection of critical infrastructure in a populated area (urban inspection)

Category		Flight Phase: Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
Aeronautical	Permanent airspace sectorisation	x	x	x		
	Non-permanent airspace sectorisation		x	x		
	Airport reference and configuration data					
	Additional aeronautical data		x			
Geospatial	Permanent geographical data	x	x	x		
	Non-permanent geographical data	x	x	x		
	Data verification and validation		x	x	x	
Flight	Flight Plan	x	x	x	x	
	Flight Status		x	x	x	
	Command and Control (C2)		x	x		
	Payload control and management	x	x	x		
	Flight Management	x	x	x		
	Contingency Management	x	x			
	Deconfliction		x	x		
Com-munication	Payload Communication			x		
	Control and Non-Payload Communication			x		
	Infrastructure			x		
Navigation	Conventional aeronautical navigation data					
	Signal of opportunity (SOO) data			x		
	Vision-based navigation		x	x		
	Accuracy levels	x	x	x		
Operational	Mission intent	x	x			
	Mission monitoring	x	x	x	x	
	UAS facilities and infrastructure	x	x	x	x	
	Equipment	x	x	x		

Category		Flight Phase				Notes
		Strategic	Pre-Flight	In-Flight	Post-Flight	
	Communication devices	x	x	x		
	Maintenance data	x	x		x	
	U-Space system		x	x		
Sur-veillance	Individual tracking			x		
	UAS traffic tracking		x	x		
	Surveillance Infrastructure		x	x		
Weather	Measurements			x		Microweather
	Observations			x		
	Forecasts		x			
	Impact Warnings		x	x		Microweather
UAS	Vehicle properties	x	x			
	Associated GCS	x	x	x		
	Operator database	x	x	x	x	
	Pilot database	x	x	x	x	
Administrative Authority	Regulations	x	x			
	Law enforcement	x	x	x		
	Restricted access	x	x	x		
	Authorization	x	x	x		
	Notifications	x	x	x		
	Alerts	x	x	x		
	Third-party risk database	x	x	x		

Table 18: Information requirements: maritime border surveillance (rural surveying)

Category		Flight Phase				
		Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
Aeronautical	Permanent airspace sectorisation	x	x	x		
	Non-permanent airspace sectorisation		x	x		
	Airport reference and configuration data					
	Additional aeronautical data			x		
Geospatial	Permanent geographical data	x	x	x		
	Non-permanent geographical data		x	x		
	Data verification and validation	x	x	x		
Flight	Flight Plan		x	x	x	
	Flight Status		x	x	x	
	Command and Control (C2)		x	x		
	Payload control and management	x	x	x		
	Flight Management	x	x	x		
	Contingency Management	x	x	x		
	Deconfliction			x		
Com-munication	Payload Communication			x		
	Control and Non-Payload Communication			x		
	Infrastructure			x		
Navigation	Conventional aeronautical navigation data			x		
	Signal of opportunity (SOO) data			x		
	Vision-based navigation					
	Accuracy levels		x	x		
Operational	Mission intent	x	x			
	Mission monitoring	x	x	x		
	UAS facilities and infrastructure		x	x	x	
	Equipment	x	x	x		

Category		Flight Phase				
		Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
	Communication devices	x	x	x		
	Maintenance data	x			x	
	U-Space system	x	x	x		
Sur-veillance	Individual tracking			x		
	UAS traffic tracking			x		
	Surveillance Infrastructure	x	x	x		
Weather	Measurements		x	x		
	Observations		x	x		
	Forecasts		x			
	Impact Warnings	x	x	x		
UAS	Vehicle properties			x		
	Associated GCS			x		
	Operator database	x		x		
	Pilot database	x	x	x		
Administrative Authority	Regulations	x	x	x		
	Law enforcement	x	x			
	Restricted access		x			
	Authorization	x	x	x		
	Notifications		x	x		
	Alerts		x	x		
	Third-party risk database		x	x		

Table 19: Information requirements: search and rescue operations in an urban environment (urban surveying)

Category		Flight Phase				
		Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
Aeronautical	Permanent airspace sectorisation		x	x		
	Non-permanent airspace sectorisation	x	x	x		
	Airport reference and configuration data					
	Additional aeronautical data	x	x	x		
Geospatial	Permanent geographical data		x	x		
	Non-permanent geographical data		x	x		
	Data verification and validation		x	x	x	
Flight	Flight Plan		x	x	x	
	Flight Status		x	x	x	
	Command and Control (C2)		x	x		
	Payload control and management		x	x		
	Flight Management		x	x		
	Contingency Management		x	x		
	Deconfliction		x	x		
Com-munication	Payload Communication			x		
	Control and Non-Payload Communication			x		
	Infrastructure			x		
Navigation	Conventional aeronautical navigation data			x		
	Signal of opportunity (SOO) data			x		
	Vision-based navigation			x		
	Accuracy levels			x		
Operational	Mission intent	x	x	x	x	
	Mission monitoring	x	x	x	x	
	UAS facilities and infrastructure		x			
	Equipment		x	x		

Category		Flight Phase: Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
	Communication devices		x	x		
	Maintenance data		x	x	x	
	U-Space system		x	x	x	
Sur-veillance	Individual tracking			x		
	UAS traffic tracking		x	x		
	Surveillance Infrastructure		x	x		
Weather	Measurements		x	x		
	Observations		x	x		
	Forecasts	x	x	x		
	Impact Warnings		x	x		
UAS	Vehicle properties		x			
	Associated GCS		x			
	Operator database	x	x	x	x	
	Pilot database	x	x	x	x	
Administrative Authority	Regulations	x				
	Law enforcement	x	x	x	x	
	Restricted access	x	x	x		
	Authorization	x	x			
	Notifications		x	x		
	Alerts		x	x		
	Third-party risk database		x	x		

Table 20: Information requirements: depot-to-depot package delivery (rural point to point)

Category		Flight Phase				
		Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
Aeronautical	Permanent airspace sectorisation		x	x		
	Non-permanent airspace sectorisation		x	x		
	Airport reference and configuration data		x	x		
	Additional aeronautical data		x	x		
Geospatial	Permanent geographical data		x	x		
	Non-permanent geographical data		x	x		
	Data verification and validation		x	x		
Flight	Flight Plan		x	x	x	
	Flight Status			x	x	
	Command and Control (C2)		x	x		
	Payload control and management	x	x	x		
	Flight Management	x	x	x		
	Contingency Management	x	x	x		
	Deconfliction		x	x		
Com-munication	Payload Communication			x		
	Control and Non-Payload Communication			x		
	Infrastructure			x		
Navigation	Conventional aeronautical navigation data			x		
	Signal of opportunity (SOO) data			x		
	Vision-based navigation			x		
	Accuracy levels		x	x		
Operational	Mission intent	x	x	x		
	Mission monitoring	x	x	x		
	UAS facilities and infrastructure		x	x	x	
	Equipment	x	x	x	x	

Category		Flight Phase				
		Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
	Communication devices	x	x	x	x	
	Maintenance data	x		x	x	
	U-Space system	x	x	x	x	
Sur-veillance	Individual tracking			x		
	UAS traffic tracking		x	x		
	Surveillance Infrastructure	x	x	x		
Weather	Measurements		x	x		
	Observations		x	x		
	Forecasts	x	x			
	Impact Warnings		x	x		
UAS	Vehicle properties	x	x			
	Associated GCS	x	x			
	Operator database	x	x	x	x	
	Pilot database	x	x	x	x	
Administrative Authority	Regulations	x	x	x		
	Law enforcement			x		
	Restricted access		x	x		
	Authorization	x	x	x		
	Notifications		x	x		
	Alerts		x	x		
	Third-party risk database	x	x	x		

Table 21: Information requirements: depot-to-consumer delivery (urban point to point)

Category		Flight Phase				
		Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
Aeronautical	Permanent airspace sectorisation	x	x	x		
	Non-permanent airspace sectorisation		x	x		
	Airport reference and configuration data		x	x		
	Additional aeronautical data		x	x		
Geospatial	Permanent geographical data	x	x	x	x	
	Non-permanent geographical data		x	x		
	Data verification and validation	x	x	x	x	
Flight	Flight Plan		x	x	x	
	Flight Status		x	x	x	
	Command and Control (C2)		x	x		
	Payload control and management		x	x		
	Flight Management		x	x		
	Contingency Management		x	x		
	Deconfliction		x	x		
Com-munication	Payload Communication			x		
	Control and Non-Payload Communication			x		
	Infrastructure			x		
Navigation	Conventional aeronautical navigation data			x		
	Signal of opportunity (SOO) data			x		
	Vision-based navigation			x		
	Accuracy levels			x		
Operational	Mission intent		x			
	Mission monitoring		x	x		
	UAS facilities and infrastructure	x	x	x	x	
	Equipment		x	x		

Category		Flight Phase				
		Strategic	Pre-Flight	In-Flight	Post-Flight	Notes
	Communication devices		x	x		
	Maintenance data	x			x	
	U-Space system	x	x	x	x	
Sur-veillance	Individual tracking			x		
	UAS traffic tracking		x	x		
	Surveillance Infrastructure	x	x	x	x	
Weather	Measurements		x	x		Microweather
	Observations		x			
	Forecasts		x			
	Impact Warnings		x	x		
UAS	Vehicle properties	x	x			
	Associated GCS	x	x			
	Operator database	x	x			
	Pilot database	x	x			
Administrative Authority	Regulations	x	x			
	Law enforcement	x	x	x	x	
	Restricted access	x	x	x	x	
	Authorization	x	x	x		
	Notifications	x	x	x	x	
	Alerts	x	x	x	x	
	Third-party risk database	x	x	x		

6 Conclusion

The domain analysis summarizes the most important aspects, relevant for the development of drone operations in the next 5 to 20 years. Resulting from this information and the conducted survey among selected drone operation stakeholders, a categorization was derived that helps to further organize research and compare special requirements from different points of view.

To establish a common understanding of a future system outline, first concepts were drawn about how the U-Space system architecture will be designed. Based on this knowledge, use cases of drone operations were detailed with a special focus on the information and data processes. The final gap analysis revealed that in manned aviation similar information is available, but not always sufficient for a direct usage in drone operations.

In addition, many UTM service providers already compete on the market, indeed they would benefit from a central U-Space authority and harmonised structures throughout all of Europe. Analysing the requirements more precisely by dividing them among the different types of generalized operations (surveying, inspections and point-to-point) indicated that differences in information demand are existing and capable of being differentiated. Consequently, further research in this direction should refine these results.

In the course of the IMPETUS project, the outcome of this study will be used in the design of services that are tailored to the exact needs of all U-space users. Furthermore, IT technologies will be analysed to determine how the notion of smart U-space concept can support the facilitation of identified information types by optimizing the effort, costs and time demand of processing large quantities of data.

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Appendix A Survey Results

A.1 Mission Summaries

Stakeholder Type	Name	Description	Already carrying out?	VLOS	BVLOS	Drone Type: Fixed Wing	Drone Type: Rotary Wing	Drone Type: Hybrid	Max. Operating Altitude	Drone Category	Automation Level: Remotely Piloted	Automation Level: Semi-Autonomous	Automation Level: Fully-Autonomous	Automation Level: Other	Operational Environment: Urban	Operational Environment: Suburban	Operational Environment: Local	Operational Environment: Rural	Operational Environment: Other	Flight Hours per Month	Additional Information
Operator	Aerial Photogrammetry	We use drone for photogrammetric survey to obtain 3D model and orthophotos.	X	X		X	X		150 m	Open		X	X					X		2	
Manufacturer	Automated inspection of critical infraestructures	- Drone operation - Design & Manufacturing of flight control electronics - Design & Manufacturing of ground control stations	X	X	X	X	X		150 m	Certified			X					X		100	
Operator	BLOS Service Provider	Sensitive Confidential Company Information	X		X		X		>150 m	Specific			X							60	Sensative
Operator	Cartografía	Levantamientos fotogrametricos, inspecciones de obras, seguimiento de obras, inventariados,	X	X	X	X	X		150 m	Certified		X				X	X	X		140	
Manufacturer	Flight testing		X	X		X			>150 m	Specific	X	X						X		5	
Operator	Fotogrametría	Vuelo fotogramétrico de una mina para la generación de ortofoto y generación de curvas de nivel. Alcance máximo de 500 metros. Altura de vuelo de 100 metros. GSD de 3 cm/pixel	X	X			X		150 m	Open		X						X		2	
Manufacturer	Mapping at low altitude		X	X		X	X		150 m	Open			X		X	X	X	X		10	
Operator	Media	close range aerial filming manually between mostly 1-60m, sometimes up to 120m Engineering application: scanning surfaces by mission or manually in mostly 20-100m - everything line of sight	X	X			X		150 m		X	X			X	X	X	X		20	
UTM Service Provider	Multi-drone U-Space/UTM Operations Research		X	X	X		X	X	>150 m	Specific	X		X		X	X	X	X	Marine	100	This is part of our new U-Space/UTM research centre
Operator	Power line inspections	The operation would be based on follow power lines for their inspection. With different kind of sensors to acquire as much information as it'd be possible.	2020		X	X	X	X	150 m	Specific		X				X				150	
ATM	Research flights, about drones and or using drones	As the developpers of a research drone system (http://www.paparazziuav.org) since 2005, we fly drones on a weekly basis, usually fixed wings, to develop the state of the art of those systems and make them available for other civil uses, mainly research (atmospheric, agriculture, surveillance). We mainly fly in VLOS, but for some project, we fly BVLOS, up to 3200m altitude, for long endurance flights, ship based operations, etc.	X	X	X	X	X	X	>150 m	Specific			X					X		20	For atmospheric research, BVLOS, we intend to carry out a one week flight in a segregated zone (ZRT in french), as we have already done in Ireland. For agriculture flights, it's in VLOS, and the flights are run during a couple of weeks every other month.
Manufacturer	Surveillance	Surveillance of large terrain extensions for different particular applications. BVLOS operation (tens of kms). Fixed wing aircraft with fuel engine. Theoretically fixed and linear flight plan, when modified is for hovering over a detected target.	2020		X	X			>150 m	Specific	X							X		100	
Manufacturer	Training	Training the customers how to operate and fly with UAS that C-Astral produces.	X	X		X			150 m	Open		X						X		12	At the time of training, attendee is not yet qualified to operate the UAS.
UTM Service Provider	UTM management	An Unmanned Aerial Vehicle situational awareness platform enabling end-to-end, bidirectional non-verbal communication, registration, identification and monitoring.	X	X	X	X	X	X		All	X	X			X	X	X	X			
Operator	Waypoint mission, Follow me mission	Mission 1: the idea is to sweep a whole crop field giving the coordinates of the corners of the field. Then while the drone is flying images are captures and then processed to get information about the status of the crop. Mission 2: while a harvester is collecting the crop, the drone is flying in front of it (about 5 meters ahead) to detect obstacles and warn the harvester if that is the case to take a detour or just stop.	2020	X			X		150 m	Specific		X						X		20	

A.2 Objective Summaries

Stakeholder Type	Name	Description	Already carrying out?	Additional Information
Law Enforcement	Regulations	CAA - civil aviation authorities	X	
Law Enforcement	SALES AND SUPPORT	CETA IS INVOLVED IN THE INTRODUCTION, TRAINING AND FLIGHT OPERATION SUPPORT OF DRONES FOR MILITARY USE	X	
Public Entity	Operation Support	We are looking for support for all tasks of crisis management, especially fire fighting: reconnaissance, logistic support (inaccessible areas), fire fighting (contaminated environment), radio relays for a emergency network, etc.	2020	we are looking for AI and swarm solutions
NAA/CAA	Air Traffic Management of drone operations in Class C airspace	Applying conditions for drone operators to fly in controlled airspace in Dublin Cork and Shannon CTRs	X	
NAA/CAA	secure and safety operation in the air space	protect a public and the State interests protect other users of the airspace ensure a progress and a development of this kind of operation	X	
NAA/CAA	Law publishing and administration	Law publishing and administration for UAV in Poland	X	
NAA/CAA	Safe and secure integration of drones in national airspace systems	Our goal is to accelerate the transparent implementation of globally interoperable UTM systems. We are therefore publishing standards and data exchange protocols. We are also working on education (internal and external, through public events). We work with relevant bodies (ICAO, European Commission, EASA, EUSCG, ...) to harmonize the definition of the U-Space concept and of any related regulatory requirement.	X	
Manufacturer	Enviromental and gases control using drones	Our company desing and produce drones with different sensors in order to get information of enviromental parameters. This kind of products have applications in agriculture, industry, minery, smart city, etc. We produce mainly small size drones for using indoor.	X	
ATM	Set the frame and manage the french U-Space	DSNA is responsible for providing Air Traffic Control services over continental France and over the open sea airspace delegated to France, as well as in overseas french territories (West Indies, Réunion, Tahiti FIR, Cayenne- Rochambeau FIR as well as TMA airspace around other smaller islands). It already provides aeronautical information for drones in these airspaces, and will be involved in the implementation of U-Space services in the same pieces of airspace.	X	U-Space services that are already implemented are: - aeronautical information, - management of flight declaration, - processing of flight authorization. E-identification will be operational in July 2018. Orchestration and tracking should be available early in 2019.
Public Entity	Safe integration of unmanned aircraft in regular airspace		2035	
Public Entity	Education		2020	
NAA/CAA	Regulation of Drone operations and the Unmanned Aviation System.	The objective of the company, which is the Civil Aviation Authority for Jamaica, is to ensure the safety of the airspace over the entire country and the safety and protection of the citizens of the country. This is accomplished by creating regulations and enforcing the same to accomplish our objective. The constraints currently being faced is that regulation takes some time to be ratified and then published. The scope of our objective is the regulation hobbyist and commercial UAV and drone operations through out the nation.	2020	
NAA/CAA	Provide flight safety, security and economic benefits of sector.	Regulate the right and optimum rules for drone sector. Balance the sector and the safety and security of the community.	2025	
UTM Service Provider	To specify, develop and operate the overall Drone / RPAS Registery system, enabling E-registration and E-identification.	SITA Lab, which explores the future of technology within SITA Group, has developed a Drone Registry prototype to demonstrate the management of the ownership and use of drones in Switzerland. This registry is highly secure using Blockchain technology, also known as DLT - distributed ledger technology. Blockchain also provides flexibility and scalability for future international development. A live demonstration took place in Sept 2017. https://www.sitaonair.aero/europe-live-drone-demonstration-u-space/ The project has now been taken over by SITAONAIR (within the SITA Group). Our objective is the productize such Drone / RPAS Registery System.	2020	SITA Group, together with the Irish Government, jointly owns Aviareto which manages the International Registry of Aircraft Assets under guidance of, and mandate from, ICAO (International Civil Aviation Authority). This registry defines the priority of interests on airframes, aircraft engines and helicopters globally. https://www.aviareto.aero/
ATM	Safety	The Integration of unmanned aircraft Systems has to be safe and efficiency. Therefore, rules and regulations are necessary. For small drones in very low level (VLL) an unmanned aircraft system traffic management (UTM) is needed.	2020	For the safe and fair integration of small drones in VLL a UTM System has to be developed and established. The first steps of such a System has to be build up fast due to the market pressure. Interfaces to the existing ATM System has to be set up. The ICAO will develop regulations for lager drones and safe integration into ATM on global Level.
Law Enforcement	Drone Regulations	Drone regulation	X	
Public Entity	Enable operations for emergency services in disaster areas	In Germany, the current regulation enables emergency services (authority/administrations and 'official' aid-organisations) a permission-free operation of drones in disaster areas. Currently we are in a process to elaborate detailed rules for flight operations in disaster areas. The planned U-space	2019	

A.3 Drone Information

Information	Description (Partially.Survey)	Stakeholder	Subcategory	Strategic	Pre	In	Post	Update	Source	Mission Type (Partially.Survey)
Aeronautical Information Publications	*Procedures, References, Competencies (GEN, ENR, AD)*	UTM Service Provider	Commercial	X	X	X	X	Continuously	CAA / ANSP	*General*
Airspace Design	*Static/Long-term Sector Information*	ATM			X	X		Continuously		*General*
Airspace Design	*Static/Long-term Sector Information*	Manufacturer	Wing, MC	X	X	X		Continuously		*Inspection*
Airspace Use	*Dynamic Sector Information*	Manufacturer	Wing, MC	X	X	X		Continuously		*Inspection*
Airspace Use	*Dynamic Sector Information*	NAA/CAA		X	X	X	X	Periodically		*General*
Airspace Use	*Dynamic Sector Information*	UTM Service Provider	Commercial	X	X	X	X	Continuously	CAA / ANSP	*General*
ANSP Data	*Relevant data input from ATMs, CNS, AIS/AIM etc.*	NAA/CAA		X	X	X	X	Periodically	NOTAMs	*General*
NOTAM		UTM Service Provider	Commercial	X	X	X	X	Continuously	CAA / ANSP	*General*
Obstacles	*Permanent and temporary structures*	ATM		X				Periodically		*General*
Obstacles	*Permanent and temporary structures*	Manufacturer	Wing, MC	X	X	X		Push		*Surveying / Inspection*
Obstacles	*Permanent and temporary structures*	Operator	Energy		X			Periodically		*Surveying*
Obstacles	*Permanent and temporary structures*	UTM Service Provider	Research	X	X	X	X	Continuously		*General*
Terrain	*Permanent Topography (DEM, DTM, DSM)*	Manufacturer	Wing, MC	X	X	X	X	On request	SRTM	*Surveying / Inspection*
Terrain	*Permanent Topography (DEM, DTM, DSM)*	Manufacturer	Wing		X	X		Continuously	ASTER GDEM	*General*
Terrain	*Permanent Topography (DEM, DTM, DSM)*	Operator	Mining / Construction	X	X	X		On request		*Surveying*
Terrain	*Permanent Topography (DEM, DTM, DSM)*	Operator	Agriculture / Research		X	X		On Request		*Inspection*
Terrain	*Permanent Topography (DEM, DTM, DSM)*	UTM Service Provider	Commercial	X	X	X	X	Continuously	CAA / ANSP	*General*
Terrain	*Permanent Topography (DEM, DTM, DSM)*	UTM Service Provider	Research	X	X	X	X	Continuously		*General*
Performance Capabilities	*Exact flight range*	Operator	Research	X		X		Periodically	Battery status / reference	*Surveying / Inspection*
Routing	*Planned routes and altitudes*	ATM			X			Continuously	Flight Declarations	*General*
Visual Detection	*Visually detected Information on aviation hazards / obstacles*	Public Entitiy	Public Safety and Security	X	X	X	X	Continuously	Internal / External Cameras	*General*
Critical Infrastructure	*Location, stucture, restrictions*	Manufacturer	Automated Control	X				Continuously	Unspecified data bases	*Inspection*
Flight Permission	*Authorization*	Manufacturer	Wing		X			Push	CAA	*Surveying*
Notifications	*E.g. Ground-based human activities*	UTM Service Provider	Research	X	X	X	X	Continuously		*General*
Notifications / Alerts	*Visually detected Information on aviation hazards / obstacles*	Public Entitiy	Public Safety and Security	X	X	X	X	Continuously	Internal / External Cameras	*General*
Regulations	*National rules, regulations and laws*	ATM	Research	X				On request	CAA / ICAO	*General*
Regulations	*National rules, regulations and laws*	ATM	ATC					On request	EASA	*General*
Regulations	*National rules, regulations and laws*	Manufacturer	Wing, MC	X	X	X		Continuously	Airmap	*Surveying / Inspection*
Regulations	*National rules, regulations and laws*	NAA/CAA						Continuously	EASA, NAA, SESAR, Gov.	*General*
Regulations	*National rules, regulations and laws*	NAA/CAA		X	X	X	X	On request	FAA, ICAO, Manufacturers	*General*
Regulations	*National rules, regulations and laws*	NAA/CAA		X				Push		*General*
Regulations	*National rules, regulations and laws*	Public Entitiy	Civil Protection / Disaster Relief	X	X	X		Periodically		*General*
Regulations	*National rules, regulations and laws*	UTM Service Provider	Commercial	X	X	X	X	Continuously	CAA / ANSP	*General*
Restrictions	*Permanent / temporary flight restrictions*	Manufacturer	Wing, MC	X	X	X		Continuously	Airmap	*Surveying / Inspection*
Risk approval	*Risk Assesment, Risk Database, Authorization*	Manufacturer	Wing	X				On request		*Surveying*
Air Traffic Data	*Manned / Unmanned Traffic*	Manufacturer	Wing, MC			X		Continuously	ATM / other e.g. air / gnd sensors	*Surveying / Inspection*
Air Traffic Data	*Manned / Unmanned Traffic*	UTM Service Provider	Research	X	X	X	X	Continuously		*General*
Drone Tracking	*Drone Position*	ATM			X	X		Continuously		*General*
Drone Tracking	*Drone Position*	NAA/CAA		X	X	X	X	Continuously		*General*
Drone Tracking	*Drone Altitude, Position, Time*	NAA/CAA		X	X	X		Continuously	Limited	*General*
Drone Tracking	*Drone ID*	NAA/CAA		X	X	X		Continuously	Limited	*General*
Information Protection	*e.g. Data Link Security, Data Link Integrity*	Operator	Photography	X				Continuously		*Surveying / Inspection*
Drone Registration / Identification		UTM Service Provider	Communication Services		X			Push		*General*
Flight permissions	*E.g. Capabilities-based certifications*	Manufacturer	Wing		X			Push	CAA	*Surveying*
Performance Reference	*Performance reference e.g. under rain, cold, payload etc.*	Operator	Media / Engineering		X			On request	Historical records	*Inspection*
Performance Reference	*Exact flight range*	Operator	Research	X		X		Periodically	Battery records	*Surveying / Inspection*
Pilot Registration / Identification		UTM Service Provider	Communication Services		X			Push		*General*
Weather		UTM Service Provider	Research	X	X	X	X	Continuously		*General*
Weather Forecast		Manufacturer	Wing, MC	X	X	X	X	Periodically	Various APIs	*Surveying / Inspection*
Weather Maps		Operator	Mining / Construction	X	X	X		Periodically	eltiempo.es	*Surveying*
Weather Radar		Manufacturer	Wing, MC	X	X	X	X	Periodically	Difficult Access	*Surveying / Inspection*
Wind Speed		Operator	Research	X	X	X		On request	Online Services	*Surveying / Inspection*

Appendix B Generic data lifecycle

The proposed 5 steps of the data lifecycle are described in the following sections.

B.1 Extraction

First of all, the desired data (depending on the requirements) are identified and extracted from different sources. Sometimes it is not possible to identify the subset of interest for the purposes of our operation, so they are filtered in the following steps. This process is based on a one-time initial full load of data followed by incremental loads and the necessity to consolidate the updates.

The extraction procedure must be effective and has to consider the following issues:

- **Source identification***:* it comprises the identification of all the proper data providers, including the verification of the source, integrity and accuracy requirements (metrics), the selection between different sources referring to the same element (preferred source), and the missing values detection and understanding of the nature of data.
- **Method of extraction***:* depending on the source and the purpose of the information.
  - ***Static Data in Operational Systems****:* these sources store data which are not expected to change in the short term or whose mean/approximated value is enough to fulfil the requirements of the user. In this case, information is easily manageable because the value of all the attributes is known within a time frame.
    - ***Current Value****:* representing the value of the attribute at a certain point and there is no information about when it is expected to change;
    - ***Periodic Status****:* the value of certain element is known and it is not going to change according to a predefined time interval.
  - ***Immediate Data Extraction****:* the extraction process is real-time, feeding the data warehouse continuously.
    - ***Through Transaction Logs****:* used only with databases. As the information of sources is modified (adding, updating, deleting or consolidating), the DBMS immediately writes entries on the log file. DW will read this transaction log and schedule and replicate the operation in its own system. There is another option in which data will be replicated in an intermediate platform and after capturing the changes, the information can be updated to DW.
    - ***Through Database Triggers****:* only compatible with database systems. Triggers are predefined, stored procedures, which are fired when an event is detected and the output will be written in a different file used by DW to extract the data. Sometimes this mechanism can cause overhead on the source system because it happens at the same time as transaction in the source.
    - ***In source Applications****:* in this case, the source application has been developed to provide certain information to DW and can be used for all type of storage systems (databases, files…). On the other hand, the performance

of the source may be degraded due to the parallel processing of these outputs.

- *Deferred Data Extraction:* in contrast to the techniques mentioned above, data extraction takes place after the transaction has finished.

  - ***Based on Date and Time Stamp:*** this method is based on a time stamp implemented in every element (and that is it weakness, the source data must implement the time of reference it cannot be part of the system). This label can be used by DW to select the records it needs to add, update and delete, capturing the latest state of the source data and correlating it with the current inputs.

  - ***By Comparing Files:*** it is based on comparing two snapshots of the source data, simply comparing the content of two files (rows, nodes or whatever).

B.2 Transformation

After extracting the required information, raw data must be processed to be compatible and usable in the data warehouse analytics, focusing on the principle of being used for strategic decision-making. For this reason, it needs to be transformed according to standards and combined (avoiding violating certain business rules) to enrich and improve its quality.

The main tasks involved in this step are the following ones:

- **Selection***:* sometimes shared with the extraction processes, it allows the system to consider data from the source that is relevant for its final purpose.

- **Filtering**: selecting only certain elements from a database.

- **Aggregation***:* data elements can be aggregated from a wide variety of heterogeneous data sources and databases.

- **Integration***:* giving each element a standard name and definition, allowing DW to reconcile different values for the same element.

- **Splitting/Joining***:* linking data from multiple sources and determining the ultimate use of every element.

- **Merging***:* combining all the attributes collected from different sources related to one sole element.

- **Conversion***:* units of measurement, dates, standardization…

- **Summarization***:* consisting of a set of predefined rules to adequate the information to its purpose (for instance, focusing the data on the drone operation).

- **Enrichment***:* simplifying individual fields to make them more useful.

- **Decoding of fields***:* used to detect the value of the same elements based on different standards. As part of the transformation process, DW will define a unique standard to be used.

- **Key Restructuring***: establishing and* comparing the primary keys of all the elements to prevent repeated elements and facilitate the updating process.

- **Deduplication***:* correlating all the information to assure that repeated elements are not stored.

- **Derivation:** after implementing business rules into the system, this transformation process allows DW to derive new calculated values from existing data.

- **Data validation:** according to certain schema and business rules, data can even be rejected.

B.3 Loading

Data is now processed and prepared to be part of the DW, storing all the information in the database. This can be done in three different ways:

- **Initial Load***: essential for the first time, all data is populated in the database.*

- **Incremental Load***:* detecting and updating the database with all the changes and the new data.

- **Full Refresh***:* the information is erased (it may be all date or a selection) and new data is reloaded.

Loading is the most critical step in the information management process, because the system has to be offline during this event. A compromise solution is splitting the load process into smaller elements and populate them at a certain time in parallel with while certain parts of the data warehouse are running.

When data is applied over an existing database, there are four modes to deploy the information:

- **Load***: consisting of detecting if the information related to the same element is already stored. If this is the case, previous data will be replaced by the incoming elements. If not, data will apply the new information.*

- **Append***: based on the operation of "Load" mode, comprises the rules of processing when the incoming data already exists in the database. For instance, if the primary key must be unique and there are two different elements (referred to different entities) with the same identifier, the new one must be rejected).*

- **Destructive Merge***:* using primary keys as identifiers of each element, this method is based on comparing primary keys of each element (defined as identifiers). If this key does not exist, the element is added and if there is already an element with this ID, it will be updated with the incoming data.

- **Constructive Merge***:* following the Destructive Merge method, this mode differs from it in how existing data should be managed, marking the added record as superseding the old record without replacing it.

B.4 Delivery

The following bullets describe several mechanisms to offer potential data consumers (end users) the requested pieces of strategic information:

- **Bulk/Batch:** supporting ETL processes, information is collected and, after being processed, a batch result is created and bulk-volume data is delivered. This method cannot provide data in real time across different platforms.
- **Data virtualization**: this solution is focused on selecting certain pieces of the information that can be layered providing a unique view of the dataset (the most relevant for the operation, for instance).
- **Message-Oriented Movements (MOM)**: used in service-oriented applications, it can provide information to a heterogeneous group of users and business models. Grouping data into messages and using events detected and triggers launched in a bus (and sometimes middleware), this technique can read and exchange data in real time between multiple environments.
- **Data replication and synchronization**: important in mission-critical (and therefore real-time) scenarios, is based on copying the relevant dataset across different platforms and locations to ensure a continuous access to the information.
- **Federated Views**: consolidating an integrated view of the relevant information collected from different datasets extracted from varied sources with high performance.
- **Data marts**: offering the same capabilities than the Federated Views architecture, data marts are developed independently and can operate in isolation or as part of a bus architecture.

B.5 Transmission

The most important principle of data management is that data has to be transmitted across platforms, business models and users. The following techniques represent the most common options to move the information and can be implemented together in many different ways (for example, Mass Data Transmission in Real Time).

- **Manual methods**: data is recorded in an external medium, which is read by the receiving platform. It is the most simple and straightforward option, but it is not recommended in a real-time environment full of changes.
- **Shared Disk**: this method is based on two different systems sharing data stored in a common platform/database. This can be the basis of data acquisition in DW environment in where the source is updated periodically by the information provider and the DW is capturing this event and updating the data.
- **Mass Data Transmission**: when a high volume of data is being processed through data ports (understood as simply interfaces to detect, manage and process small parts of the data) between two platforms. This framework is more demanding in terms of hardware, software and network components (bandwidth to transport such a high data volume).
- **Real-Time connection (Client/Server Architecture)**: the key point of this connection is that a platform is running using the resources, jobs and events provided by other platform at the same time they are created/updated/managed. This is one of the most viable choice for the architecture for the IMPETUS platform, working together with Mass Data Transmission.

B.6 Protocols

Another requirement to establish the basis of data communication is to set the rules that will allow all the participants (sources, intermediaries and consumers) to be an active part of the process. This is the definition of protocols. Among others, the most relevant could be:

- **Internet Protocols**.
    - ***TCP/IP (Transmission Control Protocol)***: this protocol splits the information into different packages that are transmitted between systems and reassembled them into the original data at the consumer platform.
    - ***HTTP/HTTPS (HiperText Transfer Protocol / Secure)***: used widespread in webpages and the associated components over the internet, it is based on TCP/IP transmissions and determines a set of rules for transferring files (and their references) between a client application and the source server.
    - ***UDP (User Datagram Protocol)***: alternative to TCP, its main characteristic is the low latency of the communications, but the integrity of the information is more likely to be affected.
- **IoT Protocols for real-time data transmission.**
    - ***MQTT (Message Queue Telemetry Transport):*** its aim is to collect data from as many small devices as possible and transport it to a central framework (cloud) where they will be managed and controlled. It is designed for lightweight M2M communications running over TCP protocol.
    - ***CoAP (Constrained Application Protocol):*** using UDP-based transmission, this protocol allow Internet communications according to the requirements of constrained devices. It is based on a traditional client/server schema.
    - ***XMPP (eXtensible Messaging and Presence Protocol):*** providing secure communication between all the participants using simple text-messages in XML format and running over TCP protocol.
    - ***AMQP (Advanced Message Queuing Protocol):*** this message-oriented protocol is based on the integrity of the information or, in other words, "not losing data" between two points. To achieve this, it implements a set of rules that relates the different components of the application, providing reliability to the communication process.
    - ***DDS (Data Distribution Service):*** its goal is to offer D2D (Device-to-Device) connection while they are consuming relevant information from a central IT infrastructure and the other actors in the environment with high performance, in a publish-and-subscribe process.

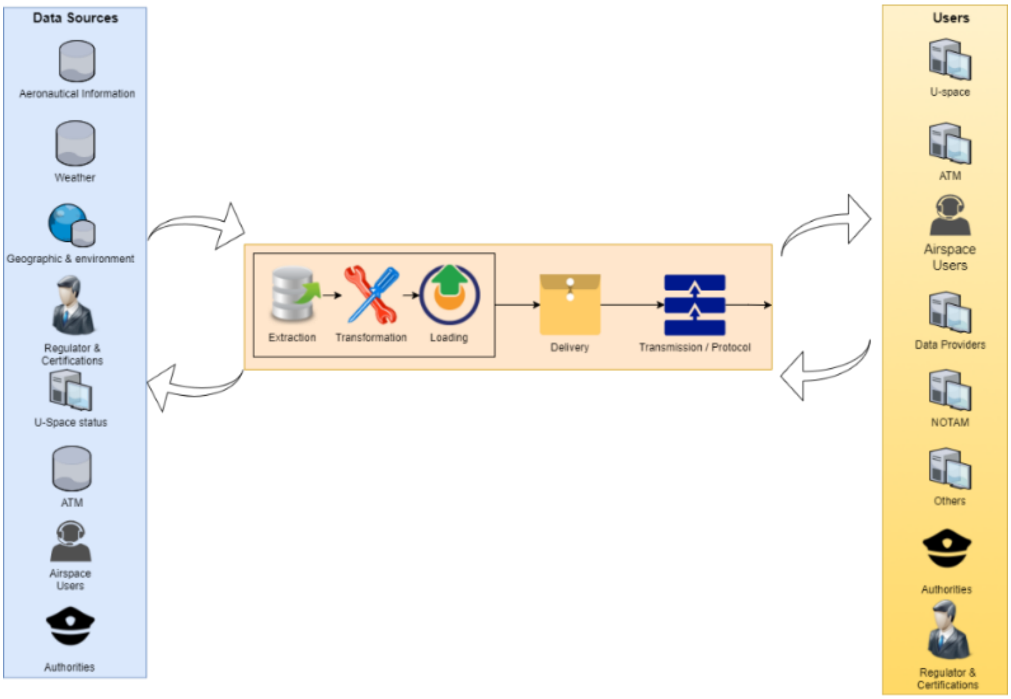

Figure 25: Data Transfer Process.