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IMPETUS

INFORMATION MANAGEMENT PORTAL TO ENABLE THE INTEGRATION OF UNMANNED SYSTEMS

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Abstract

IMPETUS D3.1 describes a set of requirements that the consortium has identified related to a certain set of services of interest and the complete architecture to support them. The approach to this definition has been performed using the use cases defined in previous deliverables as real scenarios to be analysed in terms of information management and the role of the different actors that are active and passive participants in a set of operations. The analysis reveals the necessity of a scalable and highly-efficient architecture that can be supported by the microservice paradigm.

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Executive Summary

The IMPETUS deliverable D3.1 describes the first approach to an architecture that, based on a set of requirements previously identified by the consortium partners and specific needs related to the interactions between the different roles and the scope of their application, is intended to provide an initial answer to the main objective of IMPETUS project: information management in U-Space.

In its first deliverable (D2.1 Drone Information User's Requirements [1]) IMPETUS identified the user information needs and characterized this information using predefined use cases as reference. The second deliverable (D2.2 Drone Information Services [2]) aimed to detect invariant information management functions that a conceptual drone operation lifecycle shall deal with.

The third deliverable (D5.1 Experimental Plan [3]) focused on a set of U-space services with the objective of researching on their most relevant challenges. These are:

- Drone-specific weather provision: with focus on how a better knowledge of the uncertainty in the meteorological prediction will improve the robustness of trajectory-based decision making process;
- Drone flight planning management: to guarantee the successful and safe adaptation of the initial submitted flight plan complying with the traffic management needs together with the mission targets;
- Monitoring and traffic information provision: to develop automated services to process traffic information from and to multiple users and sources;
- Dynamic capacity management (and interdependencies with tactical deconfliction for drones): exploring the services which are needed to dynamically manage the airspace and the impact on the drones' trajectories in execution phase.

Based on the use cases previously identified in D2.1 Drone Information User's Requirements [1] and the invariant information management functions from D2.2 Drone Information Services [2], this deliverable identifies, describes and characterizes the functional requirements of those U-space services selected in D5.1 Experimental Plan [3].

Additionally, this deliverable proposes a technical architecture (using micro-service architecture as reference) with a series of characteristics capable of providing a solution not only to current needs, but also to future ones (scalability, cost-effectiveness, efficiency and security).

The micro-service architecture has been designed using the same framework which IMPETUS has elaborated for U-Space: a federated logical framework. This deliverable delves into the definition of the different roles and their responsibilities and uses these outputs to support the definition of the functional requirements.

1 Introduction

1.1 Scope of the document

This document describes the requirements identified by the IMPETUS Consortium based on a specific architecture that will support U-Space Information Management. Using the use cases defined in previous deliverables [1] [3] as reference, the interactions and information needs between different roles and services is analysed, offering as a result the identification and specification of a set of functional and technical requirements, whose deployment will be supported by an architecture focused on micro-services (in its first approach).

1.2 Intended readership

This document is intended to be used by IMPETUS members, the SJU (included the Commission Services) and the community of drone stakeholders in general.

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 [4] and the project in the same research topic, DREAMS.

The requirements will be submitted to the European Network of U-Space Demonstrators to check the alignment with their demonstrations and test the implementation and utility of the requirements included in this deliverable, providing a common reference to be updated based on the findings of each project.

1.3 Acronyms and terminology

UTM acronym is used in this document for the general notion of a drone traffic management system and not for the specific system which will be designed in the USA.

Abbreviation	
ADS-B	Automatic Dependent Surveillance - Broadcast
AI	Artificial Intelligence
AIM	Aeronautical Information Management
AIS	Aeronautical Information Service
AMQP	Advanced Message Queuing Protocol
ANSP	Air Navigation Service Providers
API	Application Programming Interface
ATC	Air Traffic Control
ATM	Air Traffic Management
BFF	Backends For Frontends
BVLOS	Beyond Visual Line Of Sight
CNS	Control, Navigation, Surveillance
COTS	Commercial Off-The-Shelf

CPU	Central Processing Unit
D	Deliverable
DB	Database
DTM	Drone Traffic Management
eIDAS	electronic, IDentification, Authentication and trust Services
FPM	Flight Plan Management Service
GCS	Ground Control Station
GSD	Geospatial Domain
GUTMA	Global UTM Association
HTTP	HyperText Transfer Protocol
ICAO	International Civil Aviation Organization
ID	Identificator
JSON	JavaScript Object Notation
LoL	Loss of Link
MP	Mission Plan
MPM	Mission Plan Management Service
MS	MicroService
MTOM	Maximum Take-off Mass
NAV	Navigation
NOTAM	Notice To Airmen
QoS	Quality of Service
RAM	Random Access Memory
REST	Representational State Transfer
SC	Service Configuration
SLA	Service Level Agreements
SQ	SeQuence
STD	Standard
SWIM	System Wide Information Management
TBD	To Be Defined
TCP	Transmission Control Procotol
TD	Temporal Domain
TFR	Temporary Flight Restrictions
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UCx	Use Case x
UML	Unified Modeling Language
USP	U-space Service Provider
UTM	UAV Traffic Management
VLOS	Visual Line Of Sight
WGS	World Geodetic System
XML	eXtensible Markup Language

1.4 IMPETUS approach

As part of the requirement specification process, this document is intended to follow a top-down approach starting from the work performed in D2.1 – Drone Information User's Requirements [1], which allowed concluding a domain analysis dealing with information management in current and envisioned U-Space environment. Using them as reference, D2.2 – Drone Information Services [2] evaluated the set of functions that comprises a conceptual drone information system, identifying key requirements for U-Space services that must be fulfilled in an autonomous environment.

This deliverable goes beyond an enumeration of needs, offering the two following phases in the requirement specification process: the identification, classification and description of a set of functional and technical requirements describing 'how' the system shall behave and exposing the key principles of information management (and also the limitations with current technology) and the provision of a technological solution using an architecture that complies not only with this requirements, but with future needs of U-Space.

Three main premises have been taken into consideration:

- The definition of a set of roles and logical architecture for U-Space services, being the basis of the definition of interaction, interfaces and information flow between all the participants in U-Space;

- The selection of a set of U-Space services (considered crucial for the management of operation in a certain environment) to provide a more refined description of services, trying to focus the specification for certain use cases;

- The analysis of a microservice-based architecture in which this implementation has been proposed by IMPETUS partners to be a feasible, scalable and cost-efficient solution for information management in U-Space.

The selected set of services will be validated through several experiments, as it has been stated in D5.1 – Experimental Plan [3], in which several scenarios applying these services have been described and the implementation and testing of certain requirements (that will be described in this document) will be tested against the trials and used to refine the requirements described in the first approach of this document.

1.5 Document structure

This document is structured in the following sections:

- Chapter 2 consists on a brief description on new developments and deployments of emerging technologies;

- Chapter 3 is focused on the definition of the logical architecture of U-space, based on the clear identification of the roles involved in its operation and their responsibilities, a clear description of the services involved (not only the ones proposed by the SJU but other services identified by IMPETUS consortium) and the proposal of a logical architecture for U-Space in which the relations and interfaces between these services have been stated for different phases;

- Chapter 4 establishes a common framework for the requirement specification process, using as reference the template provided by the SJU (nomenclature, description, categories…) and applying the use cases defined in previous documents [1] [3] as a basis for specific requirement identification;

- Chapter 5 is focused on enlisting all the requirements extracted using the methodology described in Chapter 4, describing the selected use cases and the interactions between the services involved, and classifying the detected requirements using the SJU template for each service that is of interest of IMPETUS consortium.

- Chapter 6 has an initial overview of the capabilities and functionalities of a microservice-based architecture (starting from the meaning of this paradigm and following with the descriptions of Core modules to support his architecture, the means of communication between these modules and a set of examples in which this architecture is applied). After that, the relation between services and microservices is analysed and finally a set of requirements for this architecture that can be the solution to implement the U-Space information management system are described, taken into consideration the direct alignment with the requirements described for each service in Chapter 5.

2 State of the art

New technologies have been appearing in order to continuously improve the performance and capabilities of existent tasks and solve problems that before were not possible to handle due to the heavy workload. In these times of technology revolution, many different technologies have appeared trying to find a solution to all the challenges that we are facing, and these technologies have opened a new world of ideas to be implemented. Some of the more relevant examples are Big Data, AI.

The use of these technologies is compulsory, as they provide high scalability, management of huge amount of data in short period of time, even data streaming and possibility of train a neural network in order to manage or predict some events and get the best possible way to solve them, increasing the automation of the process.

As the drone market is increasing quickly, the search of a technology to cover all the previous topics is necessary. For these reasons, Big Data and distributed platforms are showing its virtues as an important option, revolutionizing the world, in both terms, data processing and analysis of this data. In the case related to IMPETUS project, the focus will be in the data management. This allows to process huge amounts of complex data from different sources in order to get an output the most valuable and accurate as possible in the minimum time.

Moreover, the sustain of a big open source foundation, as it is Apache Software Foundation, giving resources and providing with new technologies to the Hadoop environment, shows as a solid solution for both the present and future. Apache Software Foundation has implemented many technologies for its Big Data environment, Hadoop, to cover all the parts that an implementation of any Big Data solution should have. These parts are the collection of the data, then the data processing and finally a visual analysis.

As it was exposed, emerging technologies have to be studied because of the large benefits that they can offer and the great support that they have. Implementation in a proper way can give an advantage in the market and a better performance for the systems. For this reason, a wide variety of architecture paradigms have appeared, providing different answers to the different needs in information management processes. This document will focus on microservice architecture as an identified solution that will be analysed to decide if this proposal fits with U-Space requirements.

However, first, each project requiring the implementation of technologies shall be analysed to detect and clearly defined the requirements of the solution that has to be developed and, with the identification of these necessities, the technologies that will achieve the main goals of the project. To do this, this document will analyse the use cases defined in other phases of IMPETUS project and the information requirements that have been already identified in previous documents (using D2.2 as main reference) and focusing on certain services as an initial point that will lead the authorities to define their role (and the role of other actors), the communication means and the scope of the modules that will be implemented to provide a U-Space environment based on safety, security, performance and flexibility.

When implemented in the proper scenarios, these technologies can provide substantial market advantage over competitors and overall improved system performance. In this context, this document will present a possible architectural solution for U-space that enables market competition, define requirements for a selected set of U-space services that the IMPETUS consortium aims to test and elaborate the possible implementation of an architectural solution based on the microservice paradigm in order to cover these requirements.

3 U-space services' logical architecture

The framework for the IMPETUS solution is based on a federated architecture, built around the idea of a layered distribution of responsibilities with a central actor, which has a global view and the single point of truth of the airspace situation. Three layers are identified for this architecture:

- The first layer is a central actor, named the "Orchestrator", in charge of managing the essential parts (safety, security and information exchange) of the system. A Member State or a deputy thereof could run this profile, with safety culture and financial solvency to provide a set of core services necessary for U-Space to function;

- The second layer functions as an intermediate interface between the Orchestrator and the end-users of U-space, composed of U-space Service Providers (USPs) and Drone Traffic Management (DTM) providers. This will allow several providers to deliver the same set of services within the same airspace;

- The third layer is an external layer for the end-users (Drone Operators, Drone Pilots, Public Entities, etc.) to connect to U-space through the USPs and DTM providers.

In this scheme, there is no direct link between the End-user and the Orchestrator; **all interactions will be covered by the USPs or DTM providers**. Although non-explicitly represented in the figure below, the central layer also includes National Authorities and other organizations producing, storing and controlling crucial information such as the envisioned centralised registration databases.

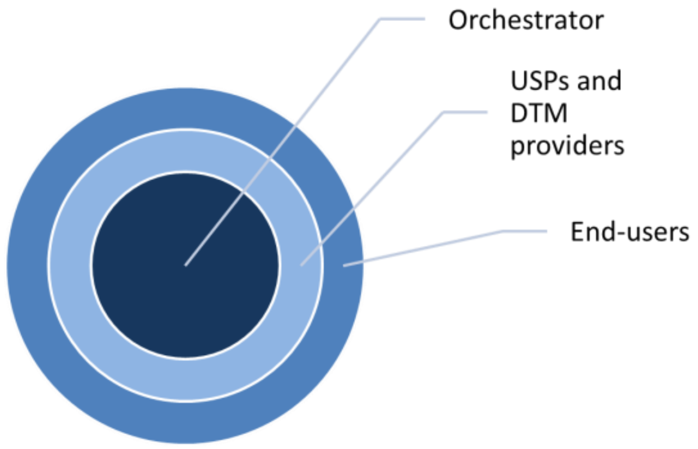

Figure 1: Simplified scheme of the main roles in the proposed U-space architecture

DTM Providers can operate in the same airspace volume, interacting with each other by means of a communications and service node acting as a central entity (the Orchestrator). This "federated approach" offers a number of advantages versus a "confederated approach", where no central node exists, or the "monolithic deployment" where a single provider manages all system functions.

In the federated architecture, End-users – specifically Drone Operators - are serviced by DTM Providers and never from the Orchestrator. Thus, the Orchestrator acts as a proxy for both the rest of the network (i.e. federated peers) and the ATM system, freeing DTM Providers from the complexity of having to interact with a large number of peers and protocols and supporting them in their computational needs. The Orchestrator also acts as a firewall between the highly critical ATM system and the network of USPs and DTM providers, and maintains a central database of airspace, mission plans, e-registry and tracking. For reasons of national security, the central repositories must reside in Member State territory, ideally being managed by the Member State itself. Otherwise, critical information pertaining to say a law enforcement investigation should be requested from a number of sources operating from different jurisdictions.

On the other hand, the proposed architecture can foster USP and DTM provider competition in a secured, neutrally governed and standardised environment. Since the Orchestrator acts as a proxy between USPs and DTM providers, it will be impossible for a particular USP or DTM provider to know highly valuable, statistically exploitable, commercial information pertaining to another USP/DTM provider. It also offers greater scalability where the Orchestrator can easily add a new USP and network it with the rest.

3.1 Roles

Based on the principles previously described, the relevant roles for the preliminary U-space architecture are elaborated in the following paragraphs. This section describes the roles of the three main actors in drone operations (Orchestrator, USPs and DTM providers, Drone Operator) and details additional roles, which are closely linked to the envisioned U-Space architecture:

- **Orchestrator:** ensures equitable access to the airspace to all users and arbitrates between the USPs and DTM providers, imposing a solution in those cases in which safety is compromised. To this end, the Orchestrator provides several centralized services assuring levels of integrity, completeness and reliability of the information needed to the provision of U-Space services. It is envisioned to be based on a highly automated and redundant system, to avoid the risk of failure. It is foreseen that its main task will be the management and approval of drone flight plans, as well as the negotiation of changes thereof with the individual DTM providers;

- **Drone Traffic Management (DTM) provider**: Provides assistance for flight planning, to obtain flight authorisation, mission planning[1] to meet a Drone Operator's mission objectives and additional DTM supporting services to ensure a safe, efficient and secure conduct of drone operations. DTM providers are the interface of the system with Drone Operators. Core interactions encompass the exchange of information, data provision and navigation services. These services will usually be consumer-oriented and can consist of all possible supplementary services not covered by the Orchestrator or Regulating Authority (e.g. flight planning assistance and drone fleet management);

- **U-space Service Providers** (e.g. Data Provider): Provides other services different to those directly related to Drone Traffic Management, such as the provision of weather data. These providers are not specific to the U-space ecosystem as they could provide data for

[1] A mission in drone operations is a specific job to be performed using drones. Given the particular objective of the mission, it might require the use of one or several drones, each one executing one or several flights.

organizations in other domains (e.g. a company providing 3D modelling of a city could provide these data for a car industry as well as drone industry);

- **Drone Operator:** Entities or individuals accountable for commercial operations of drones, which are authorized by the National Regulating Authority. Operators manage a fleet of one or several drones and employ Drone Pilots as well as other personnel to execute the authorized operations. They are users of the services provided by the system;

- **Drone Pilot**: In charge of remotely piloting, supervising and monitoring drone flights (depending on the level of autonomy). Pilots carry out drone operations for both leisure and commercial purposes, so they can be categorized by the type of operation, as well as the license they require to operate a specific drone, depending on the regulations for licensing, authorizations and identification and even their expertise (in terms of number of operations and flight time) in a certain operation;

- **Drone Owner**: 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. Owners can operate their own drones or establish commercial links with Drone Operators to do so;

- **Regulating Authority**: This actor gives drone operators their permissions to operate and use a specific category of drones for a specific business. It has centralized registries of drones (which include electronic identification, drone model, performances aligned with the standard specifications published by the drone manufacturer, emergency procedures, etc.), Drone Owners (when any drone is registered it will have a registered owner or entity), Drone Operators (legal name, business sector, air operator certificate, etc.), Drone Pilots (license type, operations approvals, etc.), Drone Traffic Management providers (type of services, points of interaction, certifications, etc.), DTM Providers (type of services, certifications, etc.) and other registries that will depend on the agreed operating methods (e.g. list of authorized landing pads in urban areas);

- **Air Traffic Management (ATM)**: A crucial actor in the U-space architecture to facilitate manned and unmanned operations and interactions in non-segregated airspace. Air Traffic Management will provide a direct line of communication between the Orchestrator and Air Traffic Control (ATC) stations so that U-space/ATM communications can be established if needed. The Air Traffic Control working stations, as part of ATM, will utilize the direct lines of communication to the Orchestrator as the single source of information about drone traffic within their area of operation, in order to assure safe separation to manned traffic and for traffic alerting purposes;

- **Orchestrator Centralized Services**: Safety-critical services that allow arbitrating between several DTM service providers operating in the same airspace. These services are unique to the Orchestrator, so that this authority is able to maintain the single point of truth in drone operations. They deal with the reception and approval of drone flight plans, the provision of reliable aeronautical and airspace data (restricted areas, temporary restricted zones, etc.) and the coordination with Air Traffic Control;

- **Regulating Authority Centralized Services**: Services that allow the implementation of the regulatory framework of drone operations in a certain airspace.

3.2 Description of services

This section provides definitions of the most relevant U-Space Services to help understand its allocation within the different roles and its connection to other services. It is important to remark that these services are described at high level, and it is envisaged to provide definitions that are more detailed when SESAR and other research programmes have been completed.

Some of these services are already identified in U-space Blueprint [5] and the European ATM Masterplan [6] and others have been identified by IMPETUS in previous deliverables [1] [2]. IMPETUS considers that the U-space system will manage the overall drone operations lifecycle, including both the processes for the design and execution of the drone flight plans and also those related to the management of the mission plans.

3.2.1 U-space Foundation Services

E-registration

The service enables the registration of the operator, drone and pilot with the appropriate information according to regulation. A level of security of the service needs to be defined.

E-identification

The service allows the identification of the Drone Operator of a drone in operation (in line with the global ICAO registry and the European eIDAS - Regulation (EU) No 910/2014). The identification provides access to the information stored in the registry based on an identifier emitted electronically by the drone. The identification service includes the localization of the drones via position and time stamp.

Pre-tactical geofencing

The service provides geo-information about predefined restricted areas (e.g. prisons and national parks) and available aeronautical information (e.g. NOTAM and AIRAC cycle) used during the flight preparation. This service requires the identification of accredited sources and the availability of qualified geo-information related to restricted areas. This information ultimately allows the Drone Operator to make use of the geofencing capability of the drone.

3.2.2 U-space Initial Services

Tactical geofencing

Compared to U1 pre-tactical geofencing, tactical geofencing brings the possibility to update the operator with geofencing information even during the flight.

Tracking

This refers to the DTM Provider using cooperative and non-cooperative surveillance data to maintain a track-identity of individual drones. The capability includes ground and air surveillance systems, as well as surveillance data processing systems. The performance requirements of the capability will vary in accordance with the specific requirements of each application.

Flight planning management

This service covers the receipt of a flight notification or a flight plan and provides the appropriate answer according to the characteristics of the mission and applicable regulations. This service will be available for any user with different levels of requirements.

Weather information

The service provides drone operators with forecast and actual weather information either before or during the flight. It can also collect and make available weather information from different stakeholders (e.g. USPs). Different levels of service provision could be considered such as:

- MET information for missions in a rural environment (based on existing aeronautical information);
- Enhanced weather information for missions in urban areas;
- Micro-weather information for urban areas (urban canyoning / autonomous vehicles).

Drone Aeronautical Information Management

This service provides relevant aeronautical information to drone operations. It will connect to the Aeronautical information service (AIS) to guarantee coherent information provision for manned and unmanned operators.

Procedural Interface with ATC

The service is a set of defined procedures for some mission types where there may be an impact on ATC, for example crossing certain types of controlled airspace under prescribed conditions. The procedures ensure clear and unambiguous drone operation, and provide an appropriate flow of information between the Drone Operators and ATC. Such procedures will allow drones to fly in controlled airspace and near airports with more flexibility. Procedural approval/rejection will be based on agreed rules.

Emergency Management

The service receives emergency alerts from Drone Pilots (e.g. loss of control) and informs relevant actors of the ecosystem, such as other Drone Pilots operating drones nearby, ANSPs, police or airport authorities, among others. The service also provides the Drone Pilot with assistance information to manage the emergency (e.g. location of landing pads).

Strategic deconfliction

The service provides deconfliction assistance at strategic level – when the flight plan is submitted, it is compared to other known flight plans and a deconfliction in time or route could be proposed. This service could be mandatory or optional according to the operating environment.

Traffic monitoring

Subject to appropriate data-quality requirements, this service retrieves data from the tracking service and fuses it with information related to non-cooperative obstacles and vehicles in order to create air situation for authorities, USPs and DTM Providers or Drone Operators.

Flight plan conformance monitoring

This service continuously compares the 4D position of each drone as 'predicted' on the basis of the approved flight plan with the 'actual' 4D position as observed by the traffic monitoring service available and triggers a 'Flight Plan non-conformance' alert if the difference exceeds the corresponding pre-established limits for each flight (depending on the type of operation/ mission).

Traffic information

This service consolidates and provides traffic information coming from any kind of monitoring services. This may include 'Forecasted/Predicted Traffic Information' to help the Drone Operator in the planning phase.

3.2.3 U-space Advanced Services

Dynamic geofencing

Compared to tactical geofencing in U2, the dynamic geofencing targets the drone itself and then this service requires data-link connectivity to a geofencing system that allows the data to be updated during the flight.

Collaborative interface with ATC

The service provides mechanisms to ensure proper effective coordination when drone operations using U-space services affect ATC. It encompasses shared situational awareness and procedures to enable a two-way dialogue supporting the safe and flexible operation of drones in airspace where ANS are provided.

Tactical deconfliction

This service provides information to ensure separation management when flying. The differences to strategic deconfliction described in U2 are twofold: the drone may receive the information and this deconfliction is set for the execution phase. It will be necessary to set the boundaries with the use of detect & avoid capabilities.

Dynamic capacity management

When drone density thresholds are defined (which can be dynamically modified), the service monitors demand for airspace and manages access to that airspace as new flight notifications are received. This service may be coupled with the flight planning management service. There should be an appropriate set of rules and priorities for slot allocation when a portion of airspace is expected to reach its capacity limits. Apart from the demand and capacity balancing, the service could manage capacity due to non-nominal occurrences, such as weather hazards or emergencies.

3.2.4 Other U-space Services

Geo-spatial Information

This service is tailored to support UAS operations in a given geographical domain, providing, as a minimum, terrain elevation and relevant cartography and/or satellite imagery. For specific UAS missions, the services might need to provide high-resolution products and/or special features such as land use, vegetation, 3D representation of buildings, population density, etc. The service might be fed with digital geographical information available from official agencies, with COTS cartography products and/or with information generated over the course of routine or ad-hoc UAS operations.

Data Recording and Post Analytics

This service, which is also named Legal Recording in other projects, registers information relevant to safety, security and privacy, such as actual trajectories flown, milestones reflecting changes with regard to the original flight plans, status of the critical airborne and ground systems, etc. This information is used to support incident/accident investigations.

Once the data has been recorded, security of the data will be paramount, ensuring the data recording system is “tamper proof” and only accessible by the appropriate authorities. In addition to supporting incident investigation, the massive traffic data recorded can provide benefits via post analytics – for example, airspace modelling for improving efficiency, understanding the impact of changes to rules of the air or simulating rule changes and studying the impact.

Mission Plan Management

The mission planning service provides automation support to mission design/re-design for single and multiple UAV missions based on the trajectory modelling capabilities supplied by a flight planning function or service not necessarily built-in, considering its feedback on the trajectories being planned to ensure safety (e.g. trajectory feasibility, availability of CNS services and airspace allocation, terrain & obstacle clearance).

To ensure mission feasibility and other QoS aspects, a modern mission planning service considers, among others, the performance characteristics of the UAV, the payloads allocated to the mission, information relevant to the context of the mission execution (e.g. weather conditions), likelihood of interactions with other UAS simultaneously operating in the area and preferred operating methods of the Drone Operator.

When dynamic mission re-planning is required due to mission, flight or traffic execution-related events, mission planning interacts with flight planning to safely accommodate mission plan changes that involve trajectory changes.

Mission Plan Conformance Monitoring

This service is in charge of up-linking the mission plan to its corresponding airborne counterpart and activating it for execution. As the mission is executed, the mission conformance monitoring service continuously analyses available mission and flight data to monitor conformance to the mission plan, working in tandem with flight plan conformance monitoring and tracking to determine if mission re-planning needs to be triggered.

Drone Emergency Management

The emergency management service for drones is required to assist the Drone Operator and the Drone Pilot in safely coping with foreseeable in-flight contingencies. Typically, it involves four steps: routine monitoring and preparation tasks, criticality assessment, alerting of concerned parties/ authorities, and execution of the corresponding pre-approved diversion of the flight plan to cope with the emergency.

A prerequisite for the emergency management logic is that its casuistry can be pre-determined at planning time so to avoid UAVs behaving non-deterministically as a result of contingencies.

Digital Logbook

Digital Logbook will be provided by the DTM Providers and contains records of the operating history of Drone Operators, the professional experience of Drone Pilots and the flight history Drones. It might be used, for example, in discussions with insurance companies or for pilot or operator accreditation.

3.3 U-Space Services allocation

This section details how specific U-Space services are allocated within the proposed architecture and defines roles for each in the planning (Figure 2) and execution (Figure 3) phases of flight. This allocation corresponds to the timeframe 2027+ (medium-term horizon), when U3 U-Space advanced services are deployed.

PLANNING PHASE

The planning phase is heavily focused on interactions between the Drone Operator, associated USPs and DTM providers, and the Orchestrator on actions related to the elaboration and approval of the Mission and Flight Plans. It is important to distinguish between the two types of plans: A Mission Plan is operator-specific and may consist of several Flight Plans for multiple drones. To this end, the Mission Planning lies with the Drone Operator’s DTM provider of choice, as Mission Planning will require more concrete information – regarding the mission objectives, drone performances, specialized weather services, preferred operating methods, licenses and registration, permissions, etc., which would be too much for the Orchestrator to handle. Therefore, the Orchestrator will negotiate with the DTM provider on the individual Flight Plans that arise from the Mission Plan.

The Orchestrator provides a Flight Planning Service to handle flight plan requests from diverse DTM Providers. This service is supported by other core services (AIM, Geo-spatial Information and Tactical Geofencing) to which DTM Providers can connect to retrieve the information they need to provide adequate services to Drone Operators. The Orchestrator will assess conformance of the Flight Plan(s) to aeronautical (i.e. prohibited areas, geofencing) and geo-spatial restrictions, the traffic situation and requirements demanded by ATC. The Flight Plan(s) are negotiated iteratively until a consensus is reached between all parties.

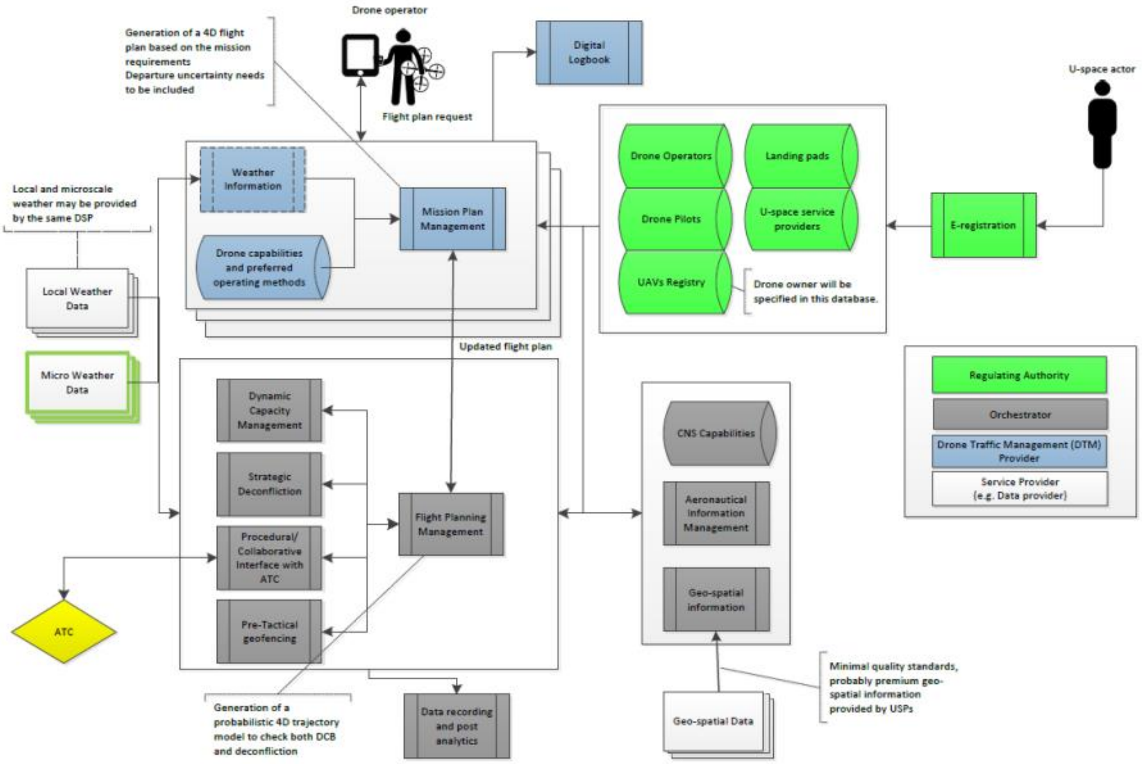

Figure 2: Overview of U-space services and interactions among providers in the planning phase[2]

EXECUTION PHASE

During the flight execution phase, new services come into play. They are related to Mission Plan and Flight Plan Conformance Monitoring, and are necessary to ensure that flight plan deviations do not threaten safety and/or accomplishment of mission objectives.

The associated DTM will continuously monitor the mission progress and report position information of the drone(s) to the Orchestrator. In turn, the Orchestrator will monitor the traffic situation, flight plan conformance and adherence to flight restrictions and interact with the respective DTM providers if necessary. These interactions will usually be limited to rectifications of deviations (conformance), deconfliction and emergency management purposes.

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[2] These services are not fully aligned with those identified in the U-space Blueprint [5]. There is on-going work to amplify the list of U-space services by CORUS [4]. The new U-space services proposed by IMPETUS in this scheme were sent to CORUS.

During the flight, the identification of any drone and associated Drone Pilot can be done via the e-identification service, managed by the Orchestrator and linked to the registries of the Regulating Authority.

Emergency Management is a critical service during flight. The proposed architecture distinguishes between two types of emergency management: The DTM provider will perform emergency management related to assisting the Drone Pilot in safely coping with foreseeable in-flight contingencies. Typically, it involves four steps: routine monitoring and preparation tasks, criticality assessment, alerting of concerned parties/ authorities, and execution of the corresponding pre-approved diversion of the flight plan to cope with the emergency. The Orchestrator, on the other hand, will perform emergency management related to coordinating with relevant actors of the ecosystem (such as other Drone Pilots operating drones nearby, ANSPs, police or airport authorities and the Drone Pilot of the drone in question).

Finally, drone's traces, performance data and event occurrences will be recorded, provided for post analytics and processed by the core services during the flight phase.

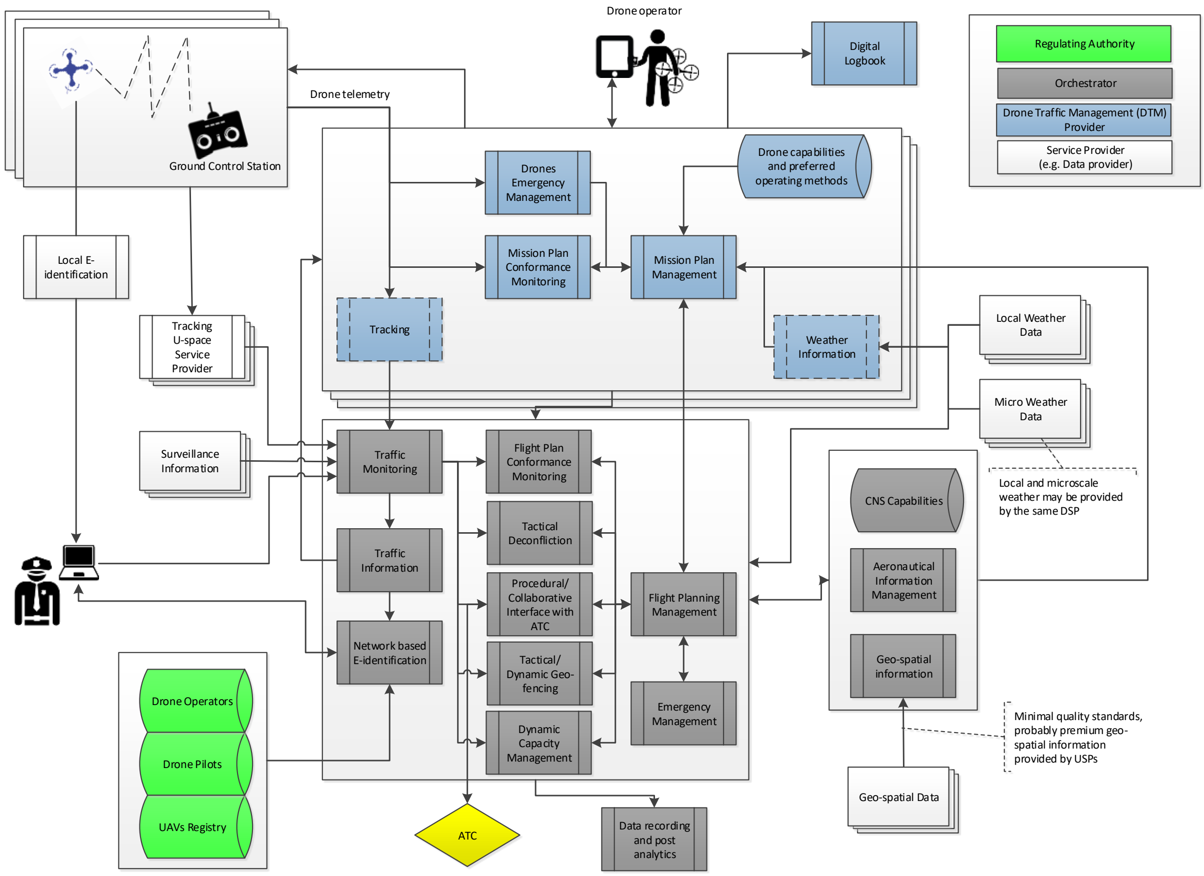


Figure 3: Overview of U-space services and interactions among providers in the execution phase

Both phases described in the architecture will depend heavily on interactions between the different actors in the system. The exercises conducted by the IMPETUS team will address specific interactions between some of the services outlined in the architecture. They will cover responsibilities of the Orchestrator as well as USPs and DTM providers, in the planning and execution phases of flight.

Not all services and interactions listed in the architecture are addressed, as this would break the scope of this project, however the framework developed in IMPETUS will serve as a basis for establishing the entire U-space architectural solution.

4 Framework for requirements' extraction

In order to elaborate the requirements of the services that IMPETUS aims to develop, many assumptions are based on expected use cases of the overall system. IMPETUS has already identified a set of high-level use cases in previous deliverables (D2.1 *Drone Information User's Requirements* [1] and D5.1 *Experimental Plan* [3]) in order to capture users' needs and characterize data requirements. They were designed to cover all types of drone applications expected in the next 15 to 20 years of the U-Space development and operating environments from rural to urban. The use cases, which have previously been elaborated, are:

- UC1: Guiding and supervising autonomous agriculture, through the use of a remote sensing drone with the capability to supervise command and control an autonomous harvesting machine [1];
- UC2: Inspection of critical infrastructure located in a populated area, which is performed using manually controlled as well as fully autonomous flights of multicopter drones [1];
- UC3: Maritime border surveillance using a fleet of autonomous drones to patrol a long stretch of coastline [1];
- UC4: Search and rescue operations in an urban environment, outlining supporting functions that drones can provide, such as site inspection, early access to dangerous areas, emergency supply delivery and surveillance for coordination efforts [1];
- UC5: Rural depot-to-depot package delivery using semi-autonomous drones [1];
- UC6: On-demand urban depot-to-consumer package delivery using fully autonomous drones [1];
- UC7: Routine wildfire surveillance in a forest by means of a fleet of fixed-wing long-endurance drones [3].

All of the fore mentioned use cases consider flight planning, flight execution and post-flight conditions, as well as interactions between actors and the U-space system. These use cases will be used as a baseline for the elaboration of the services that the consortium aims to test. However, in some cases, a higher fidelity on specific user-to-system interactions will be needed, so further details will be elaborated to fill this gap.

The table below provides an overview of the services addressed by the IMPETUS consortium and the operational use cases which were used as reference for the elicitation of requirements.

Service ID	Use cases selected
Weather information service	*UC5, UC7*
Mission and Flight planning management service	*UC5*
Monitoring and Traffic Information service	*UC5*

Service ID	Use cases selected
Tactical deconfliction service and Dynamic Capacity Management[3]	*UC1-UC7*

Table 1. Use cases used to define requirements.

Requirements related to the services tested by IMPETUS are denoted in section 5 of this document. Additionally, Appendix A shows a list of requirements extracted from D2.2 (not necessarily in a literal way) which correspond to U-space services that will not be addressed by the IMPETUS experiments. The process to define the requirements of the addressed U-Space services is described in the following steps

1. **Use case sequence diagrams**: based on the operational use cases defined in D2.1 [1] and D5.1 [3], IMPETUS describes the main sequence diagrams of each service, identifying how and in what order the processes of the service take place.
2. **Identification of requirements** by considering:
    a. Who interacts with the service;
    b. What information the service provides;
    c. Where, i.e. the geospatial context that the information is concerned with;
    d. When, i.e. the temporal context that the information is concerned with;
    e. How the service delivers its response;
    f. Why, to a big extent the answers to *why* questions are addressed in D2.2 [2], nevertheless, additional explanations about the rationale of each requirements is captured hereafter.
3. **Elicitation of requirements**: the requirements will be recognized in terms of information management, addressing aspects dealing with information exchange, compatibility of sources or performances of the system when possible. To avoid inconsistencies, requirements should be defined based in a set of premises:
    a. They must be clear to anyone involved in U-Space environment;
    b. If the requirement refers to a quantitative magnitude, it must be measurable, calculated based on similar measurements or, at least, be clearly defined to be tested and provide a reference value related to its limitations;

[3] Dynamic Capacity Management "*monitors demand for airspace, and manages access to that airspace as new flight notifications are received*" [6]. Additional functionalities not explicitly described in [6] will be included in the requirements such as how to deal with dynamic changes in the airspace that are impacting to the drones in the air, e.g. change in the required drone capabilities in a certain airspace, and how to manage these changes by rerouting drones which are affected. In this regard, these functionalities can be part of the Tactical Deconfliction service.

   c. The requirement must display a current or foreseen status and operation in U-Space environment.

4. **Requirement classification**, using the template and the guidelines proposed by SESAR:
   a. Each requirement will have a sole identifier, according to SJU structure: REQ-PROJECT-DZZ-YYYY.XXXX;
   b. Each requirement will contain a short text as a title, followed by its description;
   c. All requirements will be tagged as “service” or “capability” in the type cell;
   d. All requirements will be tagged according their related service in the service name cell;
   e. Each requirement will be classified into its corresponding category: Operational, Performance, Safety, Security, Human Performance, Information Exchange Requirement (IER), Interoperability or Human-Machine Interface (HMI);
   f. Each requirement will be tagged according to its deployment environment;
   g. The requirements may contain additional information and rationales, if necessary.
   h. Each requirement will be tagged according to its current status: Defined, Validated, Deleted. In view of the scope of this document and the nature of this project, all requirements will be only Defined.

5 Requirement analysis

5.1 Weather information service

5.1.1 Use case sequence diagrams

We consider here the weather information service within the scope of local geographical scale. Such a concept of local-scale weather information service has been described in D2.2 [2] and two use cases, namely UC5 (Rural depot-to-depot package delivery using semi-autonomous drones) and UC7 (Routine wildfire surveillance in a forest by means of a fleet of fixed-wing long-endurance drones) illustrating its usage have been developed, respectively in IMPETUS deliverables D2.1 [1] and D5.1 [3].

Here we take a step further to abstract the generic use case decomposition of the local-scale weather service in an attempt to draw its main high-level requirements. In line with the philosophy of IMPETUS, a major assumption is that the architectural approach is based on the micro-services paradigm.

Figure 4 depicts a schematic decomposition of the main use cases of the local-scale weather service using UML (Unified Modeling Language) graphic notation. As shown, the main actor interacting with the service can be classified in three categories or roles that are non-exclusive, i.e. a user can play any combination of roles. D2.2 [2] identifies the main users of the local-scale weather information identified within U-Space, namely:

- Mission planning;
- Flight planning;
- Traffic planning;
- Mission execution;
- Flight execution;
- Traffic execution;
- The micro-scale weather service;
- On-board navigation capability (as provider of local weather observations).

Essentially, any user shall interact with the service through an administrative interface to register itself and set up the corresponding service contract thereby gaining access to the service provision. Then, the service provision must be configured, which includes selecting the weather information aspects of interest to the user and defining the reminders, warnings and alerts that the service shall have to notify to the subscribed user. One important weather information aspect to be defined is how to treat the uncertainty associated with the meteorological forecasts. Once the user has defined one or many service configuration (SC) instances, it also has to define both the geospatial domain (GSD) and the temporal domain (TD) of interest. Only when three instances of, respectively, SC, GSD and TD have been defined the user can use them to make petitions to the service or register subscriptions to specific notifications. If the user is a provider of local weather observations, it can also start feeding them to the service.

To produce its outputs, i.e. the responses to the petitions and the notifications to subscribers, the service needs to compute both forecasted and now-casted weather scenarios on a continuous basis and stores the results to ensure that any petition referring to a past time can be answered. To that end, the service needs to periodically download global and mesoscale weather information from trusted sources –typically official meteorological agencies and authenticated weather stations, as well as obtain as many local observations as available from the users that act as providers of weather observations.

In principle, the geographical coverage of the service is achieved through a tiling scheme where the tiles or cells are so-called geo-cubes or intervals of longitude, latitude and altitude. An instance of a mesoscale atmospheric model runs associated with each of the cells, which requires scalable computing power.

Since the GSD requested by the users will not likely match the cells, the service needs to provide abstraction to the users with regard to the underlying tiling scheme, which involves managing the instantiation of cells as well as the corresponding computing resources in a transparent way to the requesting user.

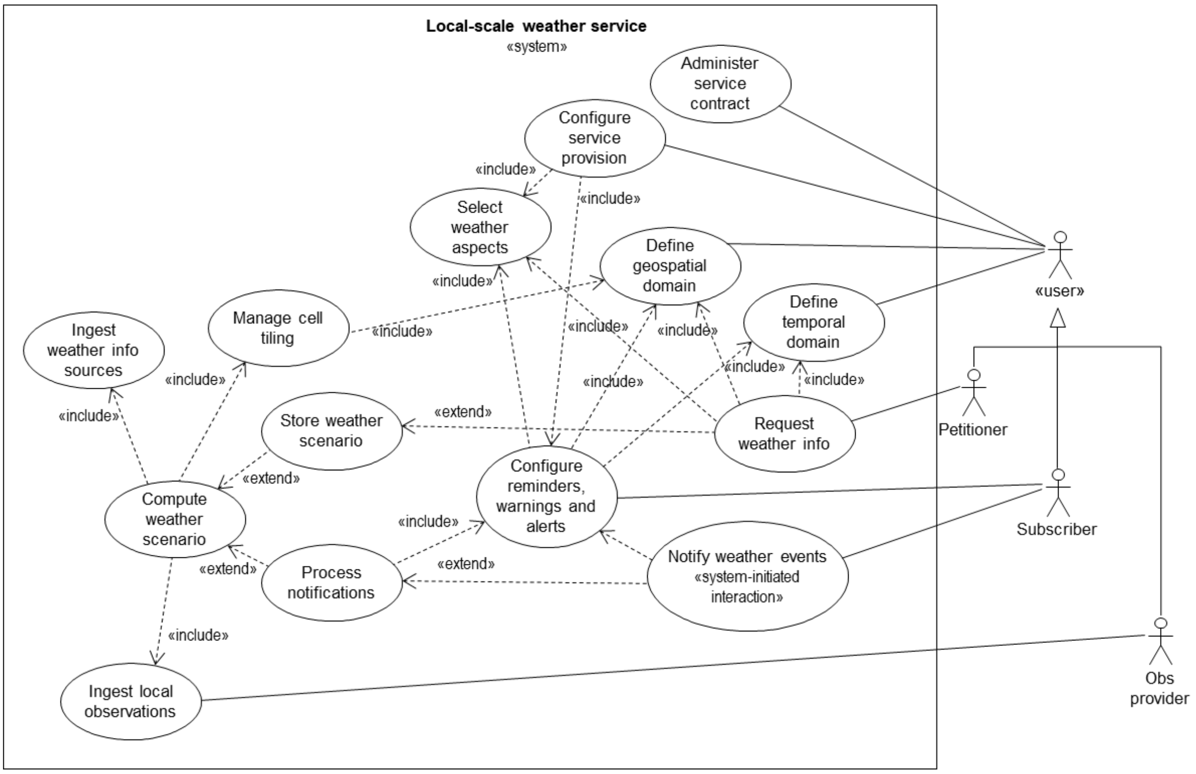


Figure 4: Use case decomposition of the local-scale weather service

The micro-services paradigm is expected here to facilitate the instantiation and management of multiple (potentially many) cells, as well as decoupling the continuous computation of weather scenarios from the provision of data to the users. In fact, we envisage a cloud of instances of atmospheric scenarios – each one associated to each cell, continuously producing data and another cloud of instances of the service-user interface –each one associated to a single user, serving its petitions, sending notifications and, possibly, receiving local weather observations.

To further clarify, a diagram is provided in figure 5 that represents the phases of the use of the Local Weather Service.

Every interaction between a client and the Local Weather Service therefore consists on at least two actions: procure the service and configure it (service contract), and the actual consumption of data generated by the service. The Service contract can be in itself subdivided in further interactions, as the figure 5 shows.

The micro-services architecture is exploited here to create an individual client agent within the Local Weather service that exchanges with the client all information relevant to create the flow of information requested, exchanging as many subscription parameters messages as required. This agent will communicate with the weather service Orchestrator to ensure the all Cells that need to be computed to cover the area requested are configured to be running producing data covering the timeframe requested (either for now-cast of predictions). The cells produce the data and place it into queues that are attended by all agents that need them. These agents are responsible for translation of the output to the format expected by the clients and to feed the subscribed client (each one as an individual client). Once the service is fully configured, the Client receives the endpoint where it can start consuming the requested flow of information.

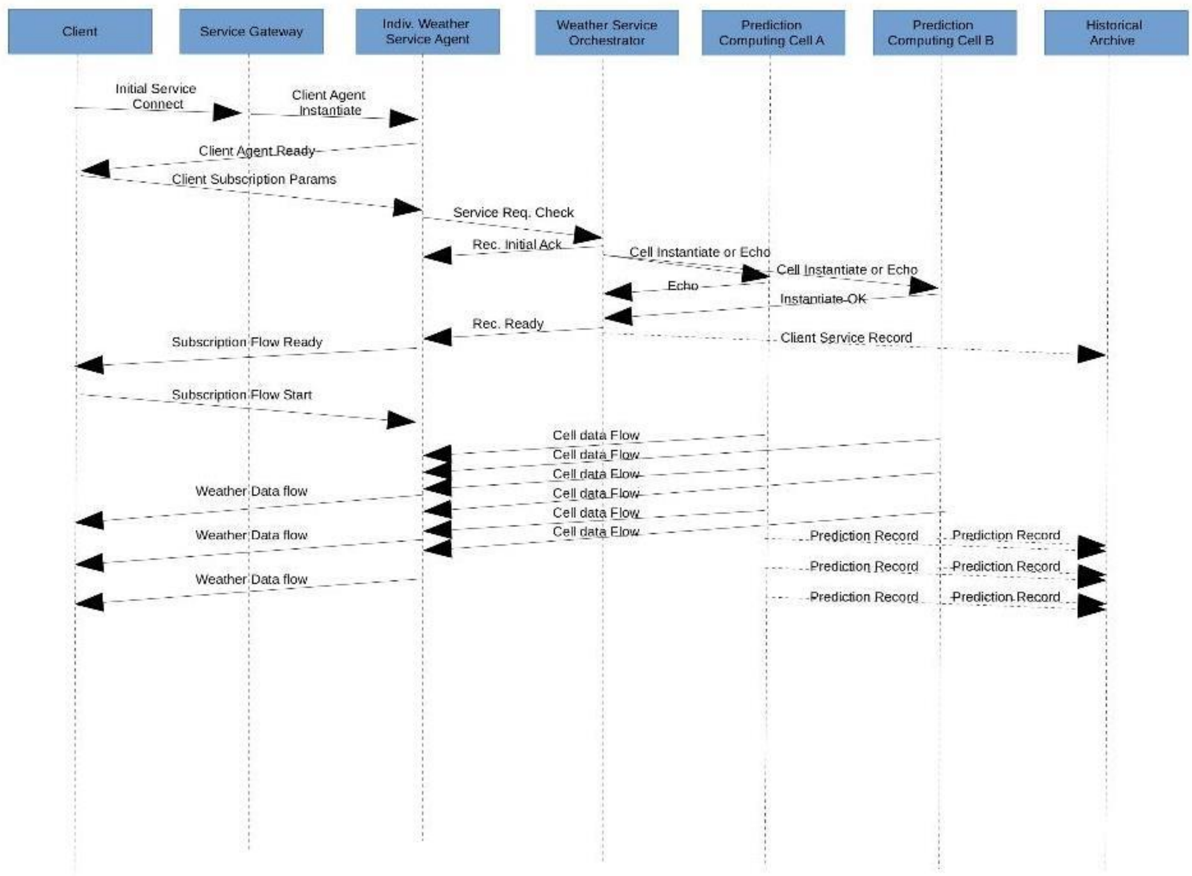


Figure 5. Sequence diagram of Weather Information Service.

5.1.2 Requirement identification

Based on the generic use case described above, we identify here the high-level requirements of the local-scale weather information service:

Who:

Identifier (R)	REQ-IMPETUS-D31-LSWS.0010
Title (R)	Service access and administration
Description (R)	The service shall feature a Service Contract Management API (Application Programming Interface) to enable authorized users (petitioners and providers of and subscribers to weather information) to access the service under well-established contract terms and conditions.
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	Operational; IER
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The Service Contract Management API includes – though it is not limited to the following functionality: 1) Searching service features, capabilities and limitations (e.g. geographical coverage supported, weather information aspects supported, etc.) 2) Registering/unregistering users 3) Registering/unregistering user roles and permissions [petitioner/subscriber/provider of local observations] 4) User authentication and access to service provision 5) Registering/unregistering and modification of service contracts 6) Notification of changes in service terms and conditions Charging/invoicing service provision costs This is the service administration interface with users
Status (R)	Defined

What:

Identifier (R)	REQ-IMPETUS-D31-LSWS.0020
Title (R)	Local-scale weather information aspects to be provided
Description (R)	The local-scale weather information service shall provide a configurable combination of the following weather information aspects (namely a subset of those listed in table 3 of D2.2 [2]): 1) Weather information provider ID [unique identifier] 2) Look-ahead type [nowcast/forecast] 3) Data generation time [Julian date & time of data generation] 4) Applicability timeframe [period of time of data applicability since data generation] 5) Temperature [K]

	6) Pressure [Pa] 7) Icing [% probability] 8) Visibility [m] 9) Precipitation [{% probability, type}; type: (freezing) rain/sleet/snow] 10) Convective precipitation [% probability] 11) Lightning [% probability] 12) Average wind (u,v,w) [m/s] 13) Turbulence [Turbulent Kinetic Energy (TKE) m^2/s^2] 14) Gusts [frequency spectrum of specific kinetic energy J/kg] 15) Thermals [% probability] 16) Forecast/nowcast uncertainties [STD associated with data items 5) to 15) or such data items are N-tuples, N being the number of members of an ensemble meteorological forecast/nowcast] 17) Reminders, warning and alerts [new dataset available, expiration of applicability timeframe, data items 5) to 15) exceeding predefined thresholds or nowcasted data items 5) to 15) deviating from the forecasted versions of the same data items beyond the estimated uncertainty]
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	Operational; Performance; Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	In general, accuracy and timely knowledge of weather information aspects listed may significantly affect and even compromise safety as well as other performance aspects such as airspace capacity or mission effectiveness and efficiency.
Status (R)	Defined

Where:

Identifier (R)	REQ-IMPETUS-D31-LSWS.0030
Title (R)	Geospatial domain
Description (R)	The weather information provided by the service shall correspond to the geographical domain specified by the petitioner. To specify such domain, the service shall provide the following geospatial primitives: 1) Geolocation [geodetic longitude, latitude and altitude in a geodetic reference system, e.g. WGS-84] 2) Geocube [interval of geodetic longitudes, latitudes and altitudes in a geodetic reference system] 3) Geoprism [base geopolygon plus interval of altitudes in a geodetic reference system]

	which the petitioner can instantiate to make the petitions of weather information.
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	IER
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	We denote GSD a geospatial domain instance. When GSD is a geolocation, the service response will be: - A single value per weather data item requested – if data item 16[4] is missing or defined as STD - A vector of values per weather data item requested –if data item 16) is defined as 'ensemble', each one corresponding to each member of the meteorological ensemble used to produce the response. When GSD is a geocube or a geopolygon, the service response will be like the one for a geolocation for each node of a 3D grid intrinsically defined by the service, cropped to the given GSD primitive. In this case, the service shall provide an interpolation API that the user can use locally to access the data and spatially interpolate requested weather aspects throughout the entire GSD of interest. Weather information aspects 5) to 15)[4] are spatially dependent; thus, geospatial primitives are needed to define the geospatial domain of interest to the user.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-LSWS.0031
Title (R)	Geospatial scalability
Description (R)	The service shall scale to any requested GSD in a transparent way to the users and without loss of QoS (Quality of Service) performance
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	Performance

[4] See REQ-IMPETUS-D31-LSWS.0020.

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	From the implementation point of view, the minimum computational unit capable of providing a nowcast/forecast of weather information is an instance of a mesoscale atmospheric model that covers a fixed cell or tile defined by a geocube. Most likely, multiple cells will be needed (may or may not be adjacent) to cover the geospatial domains for which the users request weather information. Following a microservices architecture, the instance of the microservice attending a given user shall abstract the user from the number of cells that need to be internally instantiated to cover the geospatial domain (GSD) requested. The service then shall manage the allocation of computational resources (e.g. in a cloud or a HPC cluster) and the instantiation of the geographic cells needed to attend all the users in a transparent way to them.
Status (R)	Defined

<u>When:</u>

Identifier (R)	REQ-IMPETUS-D31-LSWS.0040
Title (R)	Temporal domain
Description (R)	The weather information provided by the service shall correspond to the temporal domain specified by the petitioner. To specify such domain, the service shall provide the following temporal primitives: 1) Time [Julian date in seconds in a time reference, e.g. UTC] 2) Time interval [initial Time plus the timespan in hours, minutes and seconds] which the petitioner can instantiate to make the petitions of weather information.
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	IER
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	We denote TD a temporal domain instance. When TD is the current time or a time in the future, the service will provide its response based on the current nowcast or forecast – depending on the value set for data item 2)[4] in the petitioner's request. When the initial time of TD is past the current time, the service will provide its response partially or totally based on past nowcasts or forecasts – again, depending on the value set for data item 2)

	Weather information aspects 5) to 15)[4] are time dependent; thus, temporal primitives are needed to define the temporal domain of interest to the user.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-LSWS.0041
Title (R)	Historical data
Description (R)	The service shall record and provide upon request historical weather forecasts and nowcasts.
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	Operational; Performance; Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	It is assumed that all historical nowcasts and forecasts shall be recorded so they can be accessed by authorized users. Nevertheless, due to the huge volume of data implied, the period of availability of historical data may have to be limited to TBD months/years. To support advanced analytics and, in particular, safety investigations, the service shall have to record all past nowcasts and forecasts. This will enable answering requests of weather information where the time domain (TD) partially or totally intersects the past.
Status (R)	Defined

How:

Identifier (R)	REQ-IMPETUS-D31-LSWS.0050
Title (R)	Access to available weather data sources
Description (R)	The service shall be enabled to access weather data from the appropriate sources on a continuous basis.
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	Operational; Performance; IER
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A

Rationale (O)	External weather data is expected to be found in the Internet, though other networks may also have to be considered (e.g. ad-hoc connections to local meteo stations, SWIM, CNPLC link, etc.) The internal computation of weather scenarios considers the following sources of weather information: - Public official meteorological agencies - Private weather data providers - Networks of meteorological stations Local observations provided by users registered as local providers of weather information (e.g. drones operating in a given environment)
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-LSWS.0060
Title (R)	Configurability of weather information aspects to be provided
Description (R)	The service shall expose a Service Configuration API (Application Programming Interface) to the petitioner/subscriber/observations provider to configure the combination of weather information aspects to be provided to or acquired from users.
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	Operational; Performance; Safety; IER
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A

Rationale (O)	Of the data, items listed in REQ-IMPETUS-D31-LSWS.0020, the subset of data items 1) to 4) is mandatory and will be present in any data package provided by the service to the petitioner/subscriber. The service configuration API shall them allow the petitioner/subscriber/observations provider to describe which data items of the configurable subset, i.e. data items 5) to 17), shall be part of the service provision. We denote as SC a service configuration instance:
	SC={
	(5), (6), (7), (8), (9), (10), (11), (12), (13), (14), (15),
	({16,STD|ensemble}),
	({17,notification info})
	}
	Where:

	STD denotes estimated standard deviations associated with the data items 5-15 considered 'ensemble' denotes that such data items are N-tuples, N being the number of members of an ensemble meteorological forecast/nowcast 'Notification info' is a data structure TBD specifying which remainders, warning and alerts the user is interested about The service configuration API shall allow the user to define multiple service configurations: SC1, SC2 ... If data item 16) is missing in the SC list, the weather information provided according to such SC will be deterministic instead of probabilistic. Different operational environments/needs/timeframes may require different degree of detail and accuracy in the knowledge of the weather information aspects listed. For instance, certain drone operations may tolerate a big uncertainty about many such aspects, thereby qualitative or rough estimates of them resulting enough. However, such qualitative estimates need to be made by humans (PICs), which hampers automation & autonomy. Thus, initial drone operations conducted by human operators in simple environments will require simple weather information whereas highly automated environments will likely require more complete weather information. Configurability of service provision will enable flexibly accommodating the service to diverse operational environments, user needs and operational timeframes.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-LSWS.0070
Title (R)	Response to petitions
Description (R)	Upon sending a petition (the user acting as petitioner) making reference to a service configuration instance SC, a geospatial domain GSD and a temporal domain TD, the system shall produce a response R containing the corresponding weather information aspects.
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	IER; Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A

Rationale (O)	The petition is polymorphic in the sense that the same interface supports different types of instances of service configurations and geospatial an temporal domain definitions This is the primary interaction with a petitioner through which the weather information requested for a specific geospatial and temporal domain is provided
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-LSWS.0071
Title (R)	Notification upon subscription
Description (R)	Upon having registered to specific subscriptions (the user acting as subscriber), the service shall send the corresponding notifications to the user when the associated events happen.
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	IER; Operational; Performance; Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	Such notifications can be of the following types: Reminders: 1) Periodic updates of datasets for the registered SC, GSD and TD available 2) Administrative reminders (e.g. renew license) Warnings: 3) Expiration of the applicability timeframe corresponding to a dataset previously provided 4) Data items corresponding to a registered SC as forecasted exceeding predefined thresholds 5) Administrative warnings (e.g. scheduled/expected service discontinuation or degradation) Alerts: 6) Data items corresponding to a registered SC as nowcasted exceeding predefined thresholds 7) Nowcast of data items corresponding to a registered SC deviating from the forecasted versions beyond the estimated uncertainty (i.e. the forecast is no longer valid) 8) Administrative alerts (e.g. unexpected service degradation)
Rationale (O)	This is the primary interaction with a subscriber through which the service updates the user about relevant changes regarding weather or service statuses.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-LSWS.0072
Title (R)	Provision of local observations
Description (R)	Upon sending a dataset of local weather observations (the user acting as observations provider) making reference to a service configuration instance SC, a geospatial domain GSD and a temporal domain TD, the system shall ingest it and incorporate the data to its internal nowcast and forecast processes.
Type (R)	Service
Service/Capability name (R)	Weather information
Category (R)	IER; Operational; Performance; Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The exploitation of local weather observations provided by users as observations providers requires that the service performs an internal data validation process
Rationale (O)	This is the primary interaction with an observations provider through which the service ingests local weather observations.
Status (R)	Defined

5.2 Mission and flight planning management services

The requirements defined in this chapter are based on more elaborate versions of a general use case previously identified in D2.1 [1]. These focus on the central processes during the pre-flight phase of the operation. Subsequently, in-depth sequence diagrams are elaborated for each of the use cases in order to derive key functional requirements for the Mission and Flight Planning Management (MPM/FPM) services.

5.2.1 Use case sequence diagrams

The use case utilized for the MPM and FPM services derives from one of the standard use cases identified in D2.1 §4.6 [1], namely the depot-to-consumer use case (UC5), which defines a short distance package delivery mission in an urban environment. It was selected since it mandates high operational requirements and involves a strong interaction of relevant safety-critical services. Particularly the information management that these services require for defining a feasible mission plan is a key aspect that needs to be examined for the development of the U-space architecture.

Before examining the internal functionality of the Mission and Flight Planning Management Services and interactions between them, it is appropriate to clarify the interactions of these services with external actors of the system. The main relations of the MPM and the FPM services are depicted in Figure 6, so a description of their main functionalities is also included. It is important to remark that the FPM service is not only expected to interact with a single MPM service, but should be also able to communicate with multiple MPM services from different DTM services providers. This aspect results in higher requirements – for instance in terms of data processing and amount of storage capacity.

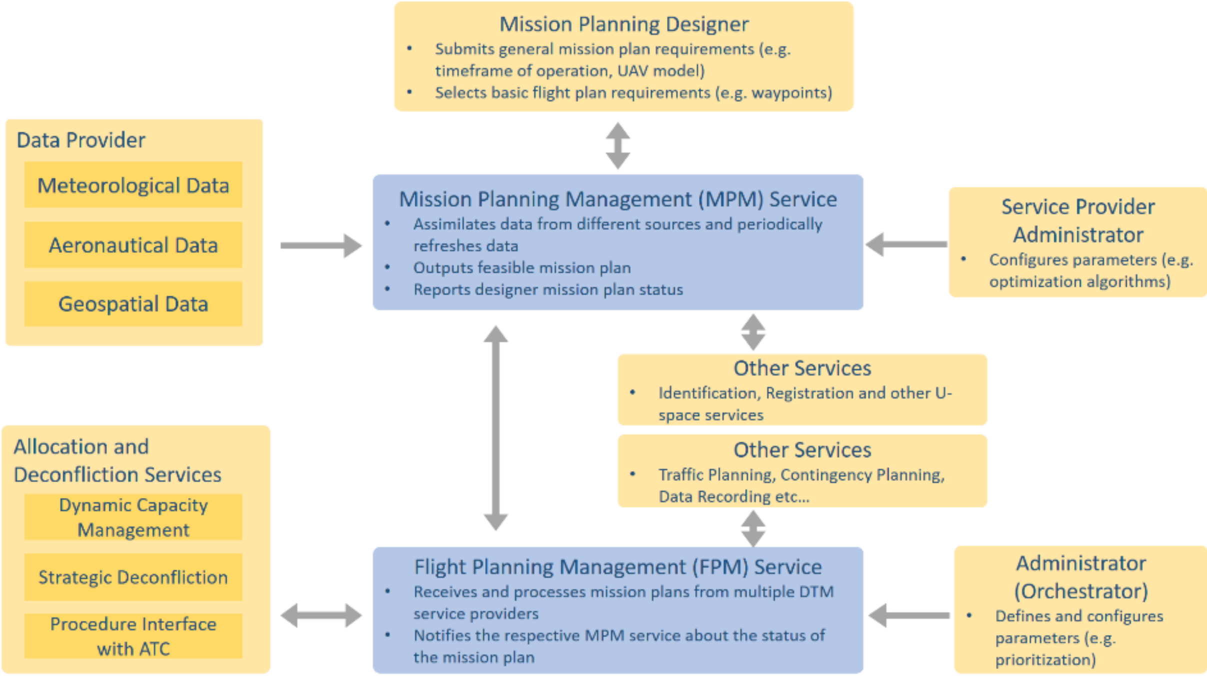


Figure 6 High-level architecture - MPM and FPM services

Furthermore, the preparation of detailed sequence diagrams requires the definition of generic functional modules as part of the MPM and FPM services. These modules enable the identification of main functions in the services and the specification of the examined processes. The internal architecture of the MPM service is shown in Figure 7 and contains five major components.

The central component of the service is the Operational Module. This module acts as the main interface of the Mission Planning Designer with the FPM service, which is responsible for the ultimate authorization of the mission plan. It is also responsible for the representation of mission details in terms of charts or maps, so as for reporting the status of the mission.

Second, the Modelling Processing Module is capable of creating a flight trajectory from mission specifications of the MP Designer. This module in particular might have very different characteristics depending of the trajectory modelling capabilities of the DTM service provider. At best, it should create a trajectory with a high level of detail (4D trajectory) and provide alternative mission specifications in case of emergencies.

The third module that might differ depending on the capabilities of the DTM service provider is the External Data Processing Module. This module is specialized in acquiring the mission specific-data from heterogeneous sources, such as geospatial and meteorological data.

Fourth, the Local Data Warehouse is in charge of storing the processed data.

Lastly, the Management Module is responsible for facilitating the administration of the service by the Orchestrator and for enabling the coordination of the internal modules.

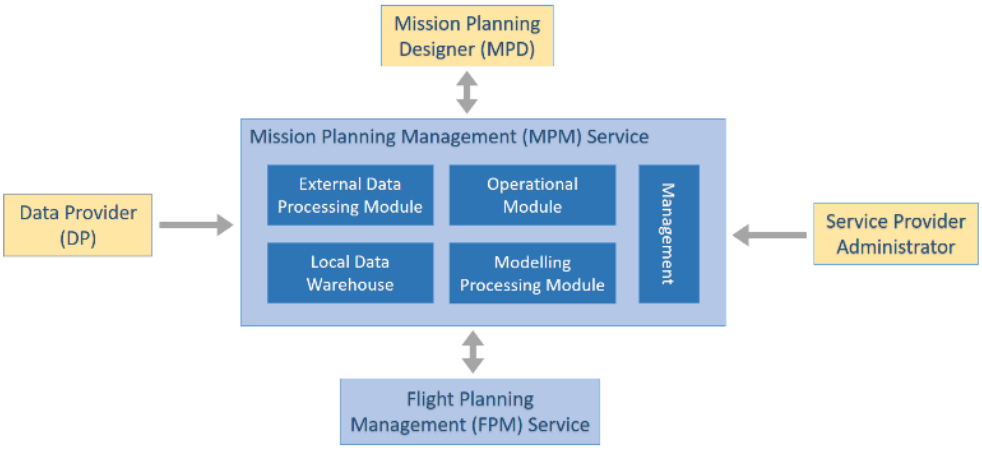


Figure 7 Internal architecture - MPM service

In the same fashion as the MPM service, the internal architecture of the FPM service is depicted in Figure 8. It also includes an Operational Module responsible for the communication not only with the MPM service but also with the rest of the services in the Orchestrator environment (e.g. traffic services). The Trajectory Processing Module is capable of extracting the individual flight trajectories from the mission plans (which could have different levels of specifications) and it prepares the necessary data for the validation process.

Additionally, the Flight Conformance Module in this service is in charge of interacting directly with the external services responsible for allocating and deconflicting the individual flight plans. Having cross-checked all relevant flight details, the Flight Conformance Module is able to approve or reject the flight plan and notify every interested party. The Local Data Manager takes care of keeping record of the processed mission plans and storing the relevant data. Finally, the Management Module serves as an administration interface for the Orchestrator.

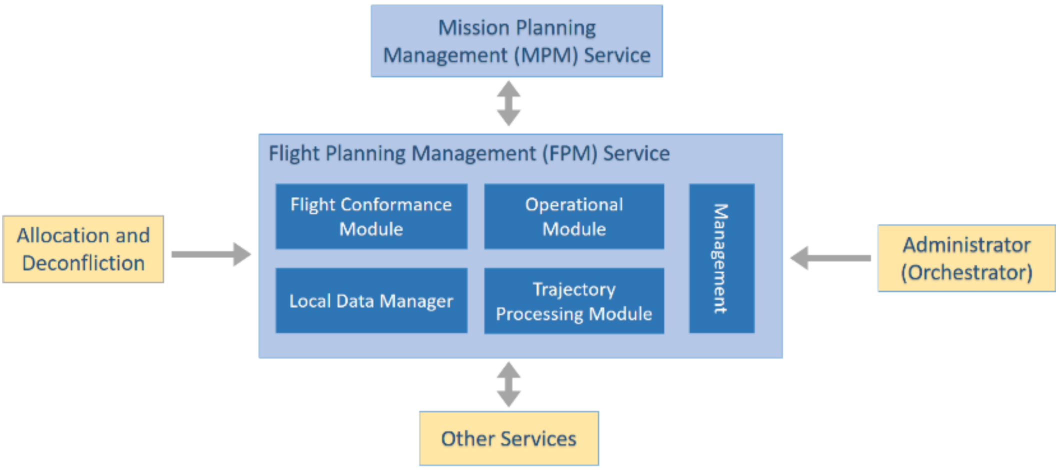


Figure 8 Internal architecture - FPM service

The use cases presented below describe in detail the main processes of the depot-to-consumer use case (see IMPETUS D2.1 [1]). As starting point, the Drone Operator receives a service request from an end customer (possibly through a retail company) and the Drone Operator employs its preferred DTM Service Provider for preparing a mission plan to be validated and approved by the U-space flight planning management capability. Depending on the outcome of the validation process, the Drone Operator is notified whether the mission plan has been approved or rejected and provided with additional details about the decision process.

It is important to highlight that although a mission plan has been approved by the Orchestrator, it is subject to modification or even, under certain conditions, cancelation due to changes of the environmental conditions related to the mission, such as a temporary restriction in the airspace or changes in the weather forecast. The Drone Operator is also directed to interact closely with the Orchestrator in case such issues arise during the planning phase of the mission.

The following system use cases are identified in the process:

- *System use case 1: Creation of supported flight plan from operator specifications*

For the creation of a flight plan the Drone Operator acting as the Mission Planning Designer is directed to use the interface of the MPM service in order to submit the specific details of the intended delivery mission, such as landing coordinates, time schedule, package type and drone model type. It is conceivable that several mission details are already pre-configured in the mission planning application since the Drone Operator conducts delivery missions on a regular basis. Under these pre-set configurations count the identification and registration details of the Drone Operator and associated drone fleet.

The Drone Operator is supported by the MPM service in the creation of individual flight plans. This support can go from the visualization of basic geospatial data and airspace restrictions up to the report of accurate micro-weather forecasts and visualization of every type of air traffic for a preferred time frame. The functionalities are ultimately dependent of the capabilities of the MPM service utilized by the Drone Operator.

For the considered system use case, the Drone Operator submits only those details relevant to the creation of the specific flight trajectory and alternative details for contingencies. Registry information about the Drone Operator licensing and drone equipment are previously stored in the DTM service provider database. Furthermore, the operational area is in the proximity of an airport.

- *System use case 2: Submission and validation of flight plan*

The submission of the preliminary flight plan to the Orchestrator's flight planning management function and subsequent validation is a complex internal process and conditioned by the response of various services within the U-space environment. Having extracted the characteristics of each individual flight plan, the FPM service interacts with allocation and deconfliction services for rejecting or approving the flight plan. The FPM service is then directed to notify all interested parties. The FPM service will constantly verify pre-approved flight plans as part of the deconfliction functionalities of U-space.

In this system use case, the flight plan initially submitted by the MPM service is rejected due to a conflict detected by the official Aeronautical Information Management Service. The MP Designer modifies the flight plan taking into account the FPM service's remarks and is consequently able to obtain the approval of the FPM service. This process takes place long before the execution of the mission, so the Drone Operator only receives a pre-approval, whose status can alter in the remainder of the pre-flight phase.

- *System use case 3: Flight plan change notification and update*

This specific system use case describes events where a pre-approved flight plan is in conflict with one or multiple trajectories. This case is the emergence of a temporary NOTAM that affects the airspace of the intended mission. The Drone Operator (through the MPM service) is required to take action in order to maintain a flight plan in compliance with the U-space system. Two possible outcomes of the change notification are examined in this system use case; either the cancelation of the flight plan or modification of the flight plan so that this does not represent a conflict anymore.

After introducing general aspects of the internal architecture of the MPM and FPM services, so as defining detailed uses cases around a delivery mission, sequence diagrams are used in this section for identifying requirements for both services. The sequence diagrams focus on the main events that originate from the individual system use cases.

System use Case 1: Creation of supported flight plan from operator specifications sequence diagrams

- *Sequence Diagram 1: Support to mission planning*

Even before defining details of the flight plan, the Drone Operator is supported by the MPM service with information relevant to the overall mission. The disposition of this information allows the Drone Operator to define specifications of the flight plan that do not only suit the requirements of the end customer but also fit the restrictions of the U-space system.

These processes involve the direct interaction of the MPM External Data Processing Module with different sources that the DTM service provider has a contract with. Ultimately, the Operational Module is directed to provide this information to the Drone Operator in user-friendly way.

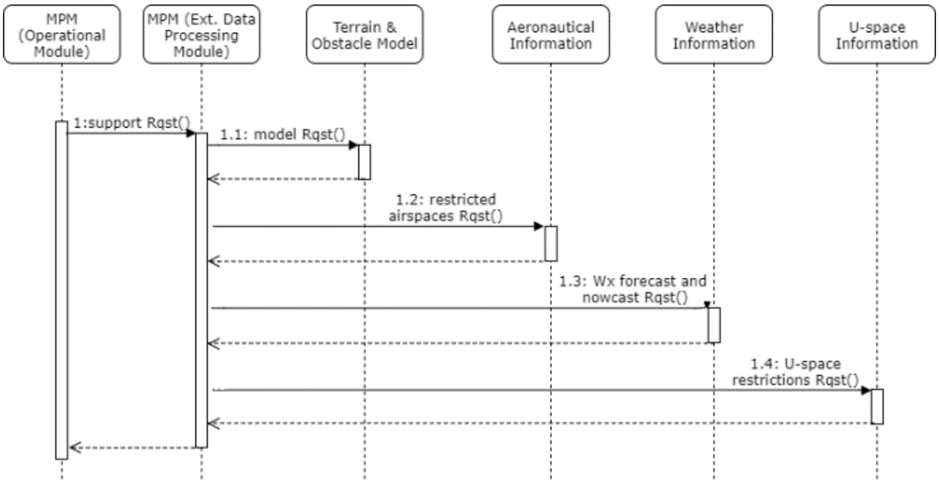


Figure 9 SQ: Support to mission planning

- *Sequence Diagram 2: Mission requirements submission*

The Drone Operator submits mission requirements through the Operational Module to the MPM service. This module is directed to process and save the data in a way that can be used later on for the creation of a flight plan.

The events depicted in the sequence diagram only show an extract of the information that the MP Designer can submit to the MPM service. Further information to be submitted includes details about the landing pads and the type of goods to be delivered.

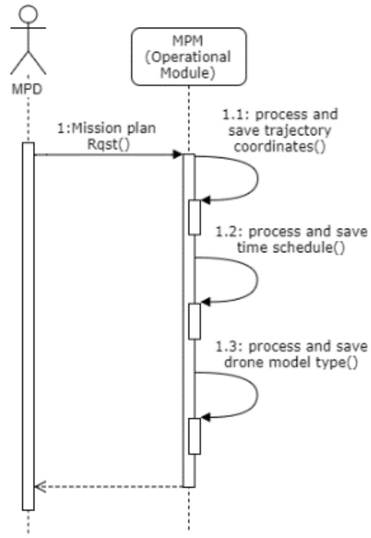


Figure 10 SQ: Mission requirements submission

- *Sequence Diagram 3: Flight trajectory creation*

The creation of flight trajectory (or trajectories) is based on the mission specifications of the Drone Operator and the trajectory modelling capability of the DTM service provider. Before the Modelling Processing Module creates a preliminary flight trajectory, basic requirements are checked. Due to the operational risk of the mission (proximity to an airport), the MP Designer is required to provide additionally alternative specifications to the mission such as contingency procedures and is also directed to provide a measure of the uncertainty associated with weather predictions und the mission itself. A trajectory is then modelled and is available for the examination of the MP Designer or for the transmission process to the FPM service.

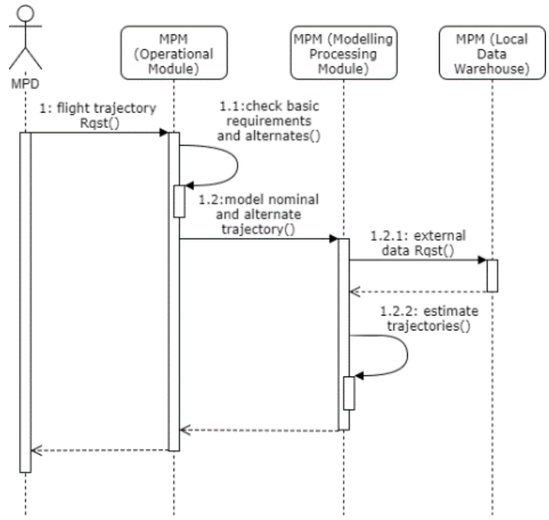


Figure 11 SQ: Flight trajectory creation

Use case 2: Submission and validation of flight plan sequence diagrams

- *Sequence Diagram 1: Flight plan characteristics validation*

This process requires a large amount of interaction with external services of the Orchestrator environment in order to validate the specifications of the flight plan. For this purpose, the Flight Conformance Module communicates with the allocation and deconfliction services in a way that it can provide the specific details that the services need for assessing the feasibility of the flight plan. After collecting the information from the various services, the Flight Conformance Module is then able to validate the submitted flight plan and inform the respective actors.

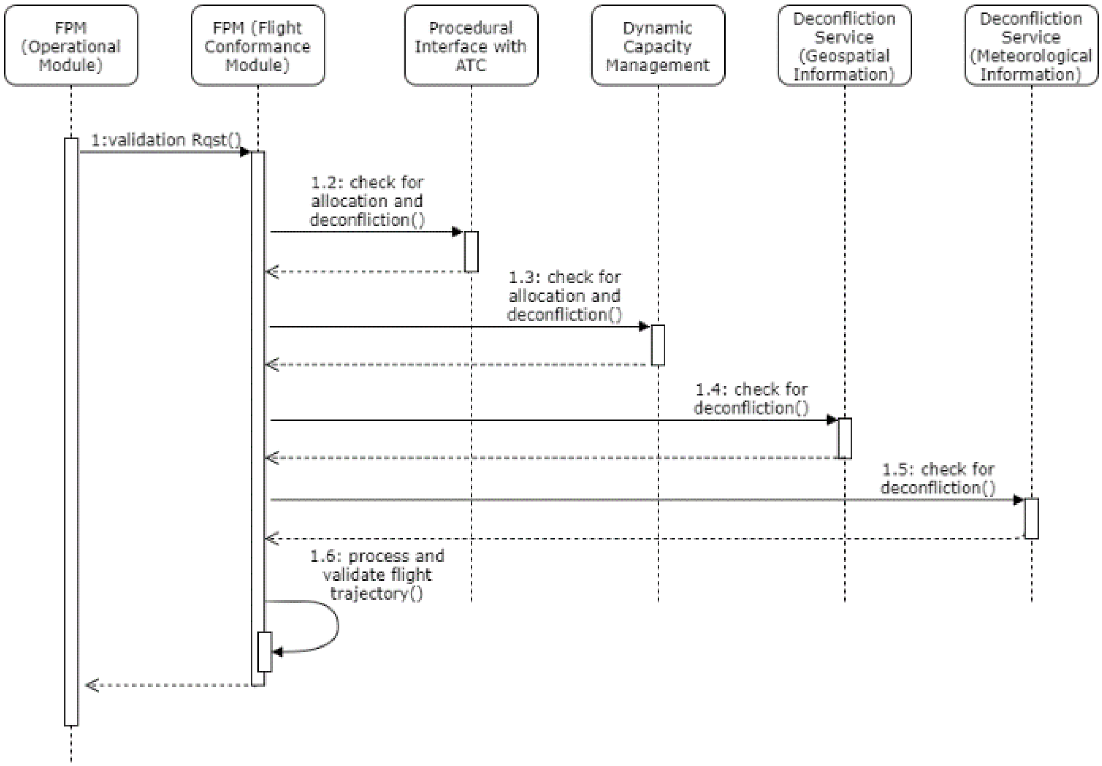


Figure 12 SQ: Mission plan characteristics validation

- *Sequence Diagram 2: Flight plan rejection*

The sequence diagram shows the flow of events that lead to the rejection of a preliminary flight plan. Since the intended mission makes use of airspace that affects regular ATC operations and insufficient flight plan specifications have been provided by the DTM service provider, the Procedural Interface with ATC Service rejects the flight plan and informs the Drone Operator through the MPM Service.

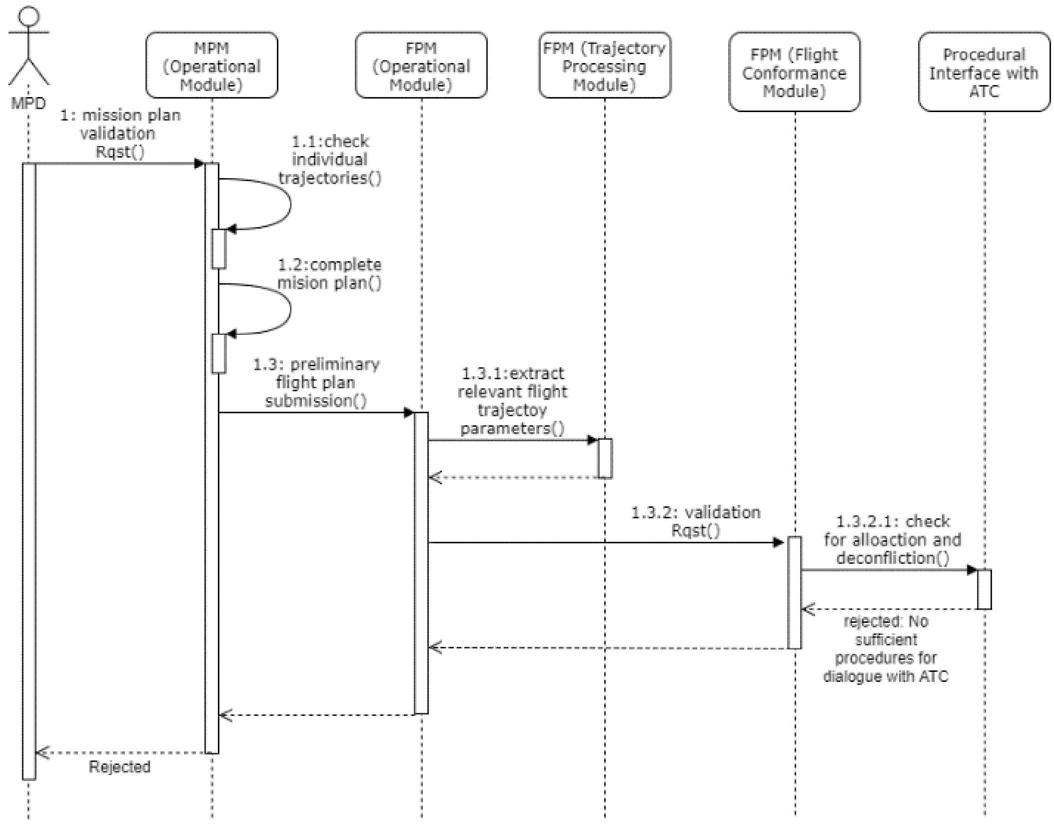


Figure 13 SQ: Flight plan rejection

- *Sequence Diagram 3: Flight plan approval*

Given the situation in which the Drone Operator undertakes the necessary modifications of the flight plan following the information provided by the Procedural Interface with ATC Service, the flight plan is validated by the Flight Conformance Module and the data are updated in the Flight Plan Database of the FPM system. From this module, this information is accessible in the remaining of the pre-flight phase and in the execution phase of the operation.

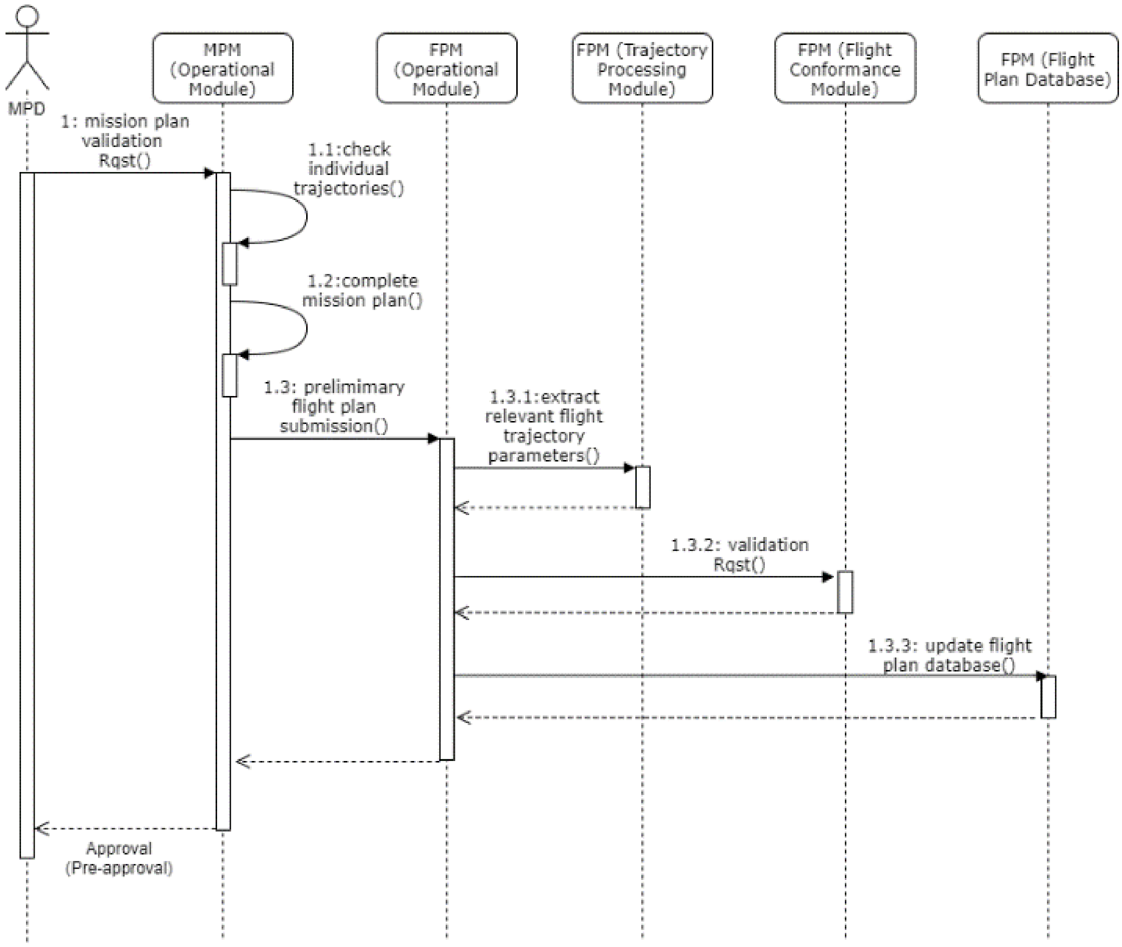


Figure 14 SQ: Flight plan approval

Use case 3: Flight plan change notification and update sequence diagrams

- *Sequence Diagram 1: Conflicting flight plan cancelation*

The cancelation of a conflicting flight plan by the Drone Operator is illustrated in the following sequence diagram. This situation is initiated with a notification of one of the allocation and deconfliction functions within the Orchestrator environment, namely the official Aeronautical Information Management Service. In this scenario, an emerging NOTAM update is communicated to MP Designer. In case that this actor cannot modify the flight plan and comply with the airspace regulations, he takes the decision to cancel the flight plan.

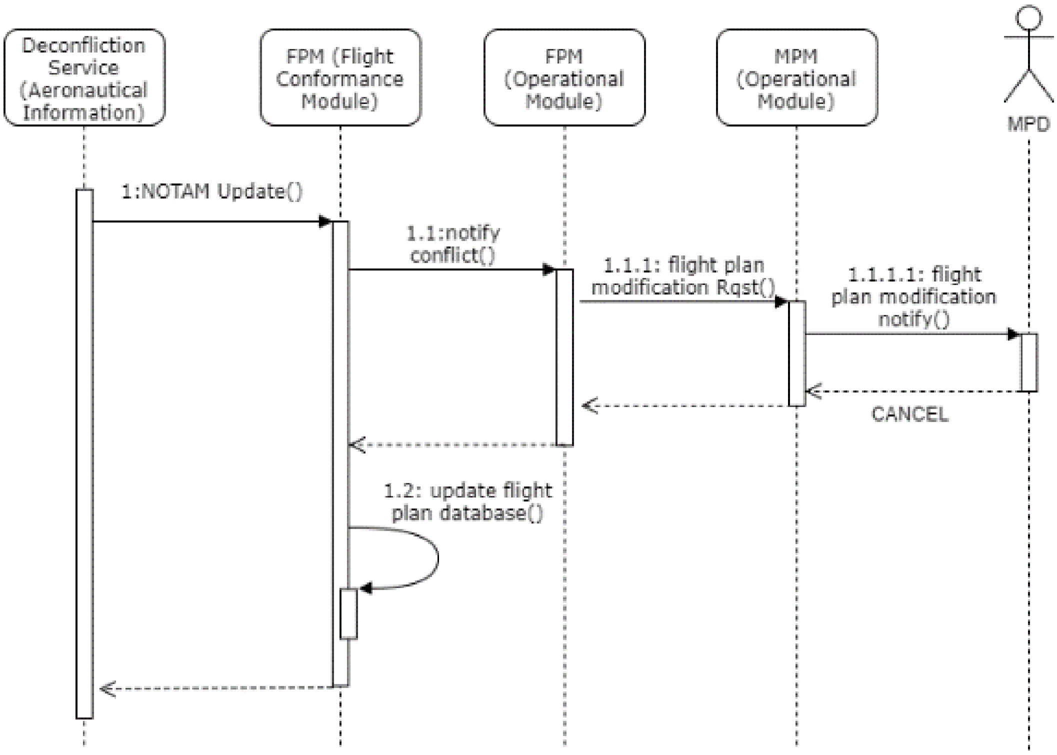


Figure 15 SQ: Conflicting mission plan cancelation

- *Sequence Diagram 2: Conflicting flight plan modification*

Similar to the previous sequence diagram, the notification of a conflict with the Aeronautical Information Management Service initiates the process. However, the MP Designer accepts the modification request and in coordination with the MPM service modifies the existing flight plan. It is important to highlight that the FPM service is directed to re-validate the modified flight plan with the same criteria as initially performed since new conflicts with other functions could be originated by the modification.

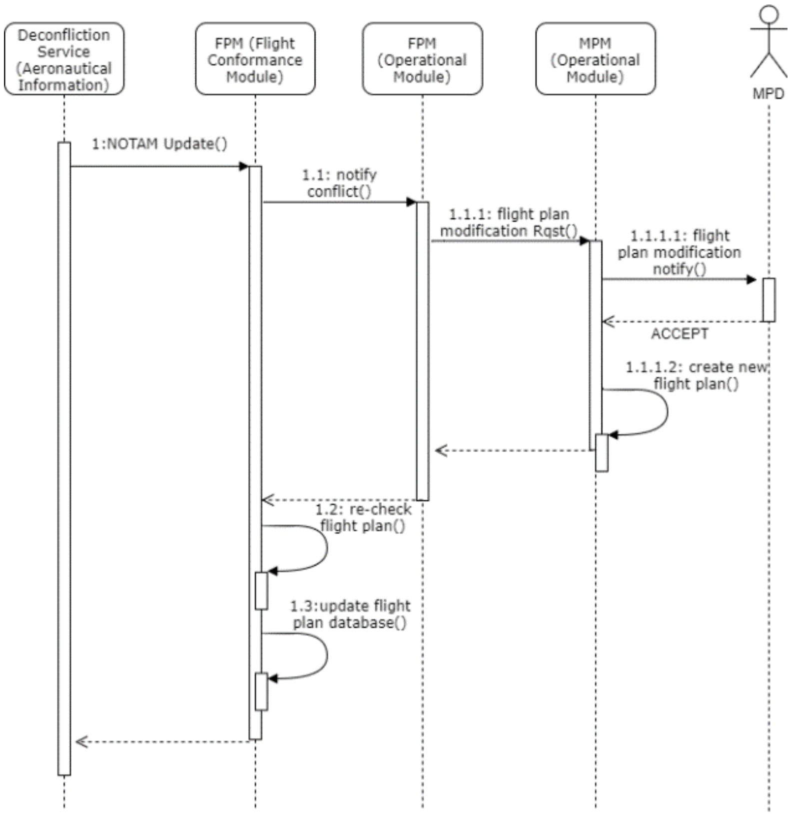


Figure 16 SQ: Conflicting mission plan modification

5.2.2 Requirement identification & classification.

The following requirements have been identified based on the sequence diagrams described above. In order to facilitate the inspection of the requirements:

Who:

Identifier (R)	REQ-IMPETUS-D31-FPMS.0010
Title (R)	Service access and administration – Flight Planning Management
Description (R)	The service shall feature a Service Contract Management API (Application Programming Interface) to enable authorized users (petitioners and submitters to flight planning) to access the service under well-established contract terms and conditions.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Operational; Information Exchange Requirement
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A

Rationale (O)	The Service Contract Management API includes – though it is not limited to the following functionality: 1) Registering/unregistering users 2) User authentication and access to service provision 3) Registering/unregistering and modification of service contracts Notification of changes in service terms and conditions This is the service administration interface with users
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FPMS.0011
Title (R)	Flight Planning Management Service accessibility
Description (R)	The FPM service shall be accessible for the Mission Planning Management Service in order receive and notify the status of submitted flight plans.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Operational;
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Status (R)	Defined

<u>What</u>:

Identifier (R)	REQ-IMPETUS-D31-MPMS.0020
Title (R)	Flight plan with minimum specifications
Description (R)	A minimum of specifications shall be acquired from the Drone Operator that enable the definition of the flight trajectory and the description of the specific mission.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management
Category (R)	Operational; Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Subset of specifications of those listed in table 8 and table 9 of D2.2: 1) Lateral path 2) Vertical path 3) Flight ID 4) Operation category 5) Range category 6) Departure location 7) Departure time slot 8) Arrival location 9) Estimated time of arrival

	10) Contingency plan 11) Flight plan status 12) Mission purpose 13) Safety category Payload information
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MPMS.0021
Title (R)	Approved mission specifications transmission
Description (R)	The MPM service shall transmit mission specifications of the approved mission plans to U-space Authority services.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management
Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	The approved mission specifications include among others the approved flight plan (see requirement REQ-IMPETUS-D31-FPMS.0020)
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FPMS.0020
Title (R)	Flight plan approval
Description (R)	A flight conformance module built into the FPM service shall be the instance responsible for approving or rejecting the individual flight plans based on defined rules and prioritization criteria.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Defined rules includes – though it is not limited to the following considerations: 1) Airspace restrictions 2) Separation from unmanned traffic 3) Separation from manned traffic Prioritization criteria considers – though it is not limited to the following aspects: 4) Technical capabilities of the drone 5) Mission type 6) Previous operations in the same airspace
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FPMS.0021
Title (R)	Flight plan rejection
Description (R)	The FPM service shall notify the MPM service of the rejection of a flight plan and provide an explanation about the existing conflict.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management; Mission Planning Management
Category (R)	Operational; Information Exchange Requirement
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Relevant traffic services include: 1) Traffic Monitoring 2) Dynamic Capacity Management 3) Flight Plan Conformance Monitoring
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FPMS.0022
Title (R)	Flight plan transmission
Description (R)	The FPM service shall transmit the approved flight plan(s) to all relevant traffic services.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Operational; Information Exchange Requirement
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Relevant traffic services include: 4) Traffic Monitoring 5) Dynamic Capacity Management Flight Plan Conformance Monitoring
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31- MPMS.0030
Title (R)	Flight plan update
Description (R)	The MPM service shall report every update of the individual flight plan status from the FPM service to the Drone Operator.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management; Flight Planning Management
Category (R)	Operational; Information Exchange Requirement
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry

Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31- FPMS.0023
Title (R)	Transmission of alternative flight plan specifications
Description (R)	The FPM service shall transmit alternative flight plan specifications of the approved flight plans to the Emergency Management service.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Operational; Information Exchange Requirement; Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Alternative flight plan specifications include – though it is not limited to the following: 1) Diverting flight trajectory models 2) Alternative landing locations 3) Flight termination protective measures 4) Redundant technical capabilities
Status (R)	Defined

When:

Identifier (R)	REQ-IMPETUS-D31-FPMS.0030
Title (R)	Flight plan approval process
Description (R)	The FPM service shall only approve the flight plan after validation through the deconfliction and the airspace capacity management functions.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FPMS.0031
Title (R)	Flight plan conflict notification
Description (R)	The FPM service shall notify the MPM service when a conflict emerges with the initially approved flight plan and provide with an explanation about the issue.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management; Mission Planning Management
Category (R)	Operational; Information Exchange Requirement

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31- MPMS.0040
Title (R)	Flight plan modification
Description (R)	The MPM service shall be available for flight plan modification after the modification request from the FPM service.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management; Flight Planning Management
Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MPMS.0041
Title (R)	Flight plan cancelation
Description (R)	The MPM service shall interact with the FPM service and the Drone Operator for cancelling a flight plan assuring that all the parties are aware of the cancelation.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management; Flight Planning Management
Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Relevant parties that should be aware of the cancellation are – though it is not limited to the following: 1) Traffic information services 2) Flight and mission plan conformance services 3) Dynamic capacity management 4) U-space Authority services
Status (R)	Defined

How:

Identifier (R)	REQ-IMPETUS-D31-MPMS.0050
Title (R)	Mission Planning Management - data assimilation
Description (R)	The MPM service shall assimilate the mission-specific data from different sources and store this data locally.
Type (R)	Service

Service/Capability name (R)	Mission Planning Management
Category (R)	Operational; Information Exchange Requirement
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Sources that should be considered for the assimilation of mission-specific data are: 1) Local weather information 2) Micro weather information 3) Aeronautical information 4) Geo-spatial information 5) Traffic information
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MPMS.0051
Title (R)	Mission Planning Management - data update
Description (R)	For every type of external data, the MPM service shall maintain the data up-to-date. This requires either refreshing the data in defined periodical timeframe or updating the data in real-time.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management
Category (R)	Information Exchange Requirement; Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MPMS.0052
Title (R)	Mission Planning Management - data visualization
Description (R)	The MPM service shall visualize the types of information to the operator that are relevant for mission planning.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management
Category (R)	Human Machine Interface; Information Exchange Management
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	Such information can be of the following types: 1) Meteorological information 2) Aeronautical information 3) Geospatial information 4) Traffic information 5) Mission objectives

	6) Vehicle performance 7) CNS performance 8) Registration information 9) Regulative information 10) Insurance information 11) Further U-space information
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MPMS.0053
Title (R)	Flight plan generation
Description (R)	The MPM service shall structure the mission and flight trajectory requirements in order to facilitate the generation of the standardized flight plan.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management
Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	The MPM service is required to translate the mission and flight trajectory specifications into specific items of the standardized flight plan.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MPMS.0054
Title (R)	Creation of flight trajectory
Description (R)	The MPM service shall include at least a basic function for the modelling of preliminary flight trajectories.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Preliminary flight trajectories shall comply with the specifications of the FPM service. Although these specifications have not been defined yet, basic modelling aspects to consider have been identified in D2.2. These are: 1) Sequence of 2D waypoints or lateral geometry primitives for lateral paths; 2) Geometric altitude AGL specified for each 2D waypoint or vertical geometry primitives for vertical path; 3) Controlled time of arrival constraints specified for each 2D waypoint or ground speed primitives.

Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MPMS.0055
Title (R)	Consideration of uncertainty in the trajectory modelling
Description (R)	The MPM service shall consider the uncertainty in the trajectory modeling associated with external factors.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management
Category (R)	Operational; Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Aspects to be considered, including but not limited to: 1) Time-dependent uncertainty 2) Pressure and wind-dependent uncertainty 3) Performance-dependent uncertainty 4) Mission-driven uncertainty
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MPMS.0056
Title (R)	Completion of mission plan
Description (R)	The MPM service shall complete a mission plan from individual flight plans and mission requirements in a standardized format.
Type (R)	Service
Service/Capability name (R)	Mission Planning Management
Category (R)	Operational; Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Mission specifications includes – though it is not limited to the following: 1) Mission purpose 2) Operation category (e.g. EASA classification) 3) Security category 4) Safety category 5) Payload type
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MPMS.0057
Title (R)	Flight plan transmission process
Description (R)	The MPM service shall transmit the flight plan to the FPM service in a common format.
Type (R)	Service

Service/Capability name (R)	Mission Planning Management; Flight Planning Management
Category (R)	Operational; Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	This format shall include information about: 1) Mission purpose. o Milestones. o Timelines. o Specific actions. o Risks. o Payload type. 2) Operation category (e.g. EASA classification). 3) Security category. o Information scope. o Countermeasures. 4) Safety category. o Emergency procedures. o Countermeasures. 5) Drone capabilities, as it has been defined in [1] [2].
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FPMS.0040
Title (R)	Flight Planning Management – data validation and integrity
Description (R)	The FPM service shall validate the consistency and integrity of the data from the flight plan(s) received.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Although a common format has not been defined yet, relevant aspects to consider are: 1) Lateral path using a character representation of the coordinates 2) Vertical path utilizing a specific Metric Level 3) Date of flight in a specific format 4) Planned date of departure using a specific format
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FPMS.0041
Title (R)	Flight Plan data extraction and structure
Description (R)	The FPM service shall extract the parameters from the submitted flight plan(s) and structure the data for the allocation and deconfliction process.

Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Information Exchange Requirement; Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Allocation and deconfliction services: Procedure/ Collaborative Interface with ATC, Strategic Deconfliction and Dynamic Capacity Management Service
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FPMS.0042
Title (R)	Flight conformance module
Description (R)	A flight conformance module built into the FPM service shall process the outputs generated from the allocation and deconfliction services and evaluate the data for the validation decision process.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Information Exchange Requirement; Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Rationale (O)	Allocation and deconfliction services: Procedure/ Collaborative Interface with ATC, Strategic Deconfliction and Dynamic Capacity Management Service
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FMPS.0043
Title (R)	Flight plan database
Description (R)	The FPM service shall include a dedicated database of approved flight plans, which can handle a large data volume.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	Submission of flight plans from multiple DTM service providers
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-FPMS.0044

Title (R)	Flight plan re-validation process
Description (R)	The FPM service shall allow the MPM service to modify the conflicting flight plan and re-submit it for a new validation process.
Type (R)	Service
Service/Capability name (R)	Flight Planning Management
Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Status (R)	Defined

5.3 Monitoring & Traffic Information service

5.3.1 Use case sequence diagrams

These services will involve information related to the execution of a variety of drone operations in the same environment (in time and position) so the selected use case should take into consideration this paradigm. For this reason, the Depot-To-Depot Package Delivery use case identified in D2.1 [1] - which defines a short distance package delivery mission in a suburban environment - has been chosen as a representative example for the intensive use of these services. Based on the assumptions initially outlined in this use case (see steps 3 to 4 of chapter 4.5.6.2 in D2.1 [1]), the Orchestrator is the entity in charge of providing access to airspace via the use of a flight plan conformance monitoring service, which uses real-time information coming from the Drone Operators.

A high-level diagram of processes and the interfaces between each actor is provided in the following picture.

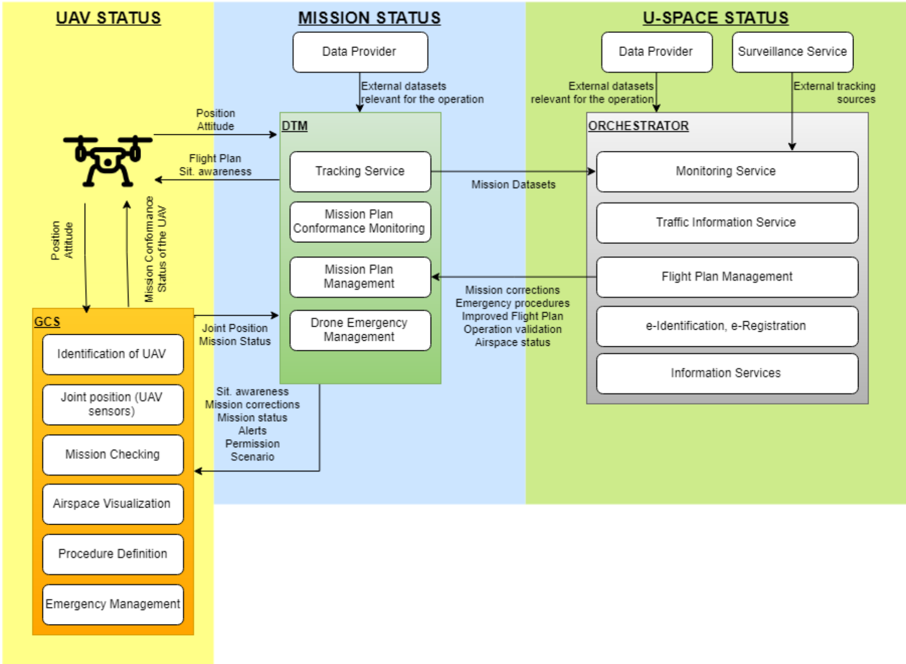


Figure 17. Information Exchange for Monitoring & Traffic Information services.

This schema reflects the key points in the bidirectional communications between actors:

- **Drone-GCS**: as part of the main control of the operation, the UAV must be constantly connected to its Ground Control Station, providing information about the sensors included in it and focusing on all the information relevant to flight safety (in which position, attitude and connectivity are the main datasets to be shared). The GCS, taking into account its location, is expected to provide better communications with the DTM than the UAV does and, for this reason, should be the main channel to provide this information. In some cases, this is not possible (i.e. when the drone flies beyond radio line of sight of the GCS), so a Drone-DTM connection shall be also implemented as a redundancy to ensure the safety in an environment full of operations. On the other hand, the GCS will act as the first interface to process the information provided by the drone and check that the operation is being executed following the flight plan uploaded in the planning phase and it could even provide an initial validation for the conformance services, identification and registration (managing their own fleets) and emergency (detecting issues during the flight).

- **Drone-DTM**: as it was described in the previous paragraph, the UAVs are expected to share their position and intentions during the flight and the interface with the DTM will be an important part of the U-Space ecosystem. Taking into account the distance from the GCS in which the operations can be carried out, the link with the GCS is not expected to be available at certain times, sometimes even at any time. For this reason, an alternative connection with the U-Space ecosystem shall be provided to ensure that the UAV will always be visible to the traffic information service. This interface may even be synchronized with the GCS via a DTM provider, completing a cyclic process of exchange, common processing and sharing of relevant information. In this interface, the compatibility with the DTM will be one of the key issues considering the heterogeneous variety of technologies and communication channels existing in the industry.

- **GCS-DTM**: sending information about the status of the UAV in a bidirectional process. The role of the DTM in this case is more relevant. As a functionality provided by a U-Space service provider, the DTM will be the first layer of information collection, processing, and comparison of the datasets obtained from the UAV, the Orchestrator and other external sources. Furthermore, it will create valuable information for the execution of the operation, by means of other services such as Tracking, Mission Plan Conformance Monitoring, Mission Plan Management and Drone Emergency Management. These valuable outputs will conform the inputs for the Orchestrator and the GCS.

- **DTM-Orchestrator**: sending the information related to the whole operation, the Orchestrator will act as the compiler of all the information provided by the DTMs, drones and other relevant sources (weather, aeronautical information, surveillance systems). Using its core capabilities, it will design a current and a foreseen scenario, detecting conflicts and inconsistencies between operations and with the environment. It will also be in charge of the identification, verification and management of conflicts, which will lead to improved flight plans, alert messages, the detection of new elements and connectivity problems and the elaboration of the new “rules of the air” to ensure safety. The consolidated information will send by the Orchestrator to the DTMs, which will be in charge of distributing to the GCSs and drones.

Based on the description of these interfaces, two main interactions have been identified, following a bidirectional (bottom-up and top-down) approach:

- Provision of monitoring data from a single UAV in operation to the Orchestrator. This process will involve the provision of position and attitude (speed, navigation angles…), the status of the mission considering this information and the impact on the status of the U-Space environment. In this case, the delivery drone shall communicate its position to the GCS and to the DTM, which will validate the operation in terms of mission conformance. The DTM interacts with the Orchestrator, which has a global overview of the airspace and can detect conflicts during the flight.

- Provision of traffic information data from the Orchestrator - the entity in charge of managing the U-space environment - to the drone in operation, which will perform maneuvers in response to the traffic around it.

The micro-service paradigm plays a crucial role in the interaction with Monitoring and Traffic information services. Micro-services provide scalability in a system whose workload may vary in a certain timeframe and geographical areas, offering an on-demand solution that fits the information requirements for different demand levels. The flexibility of using backup services and redundancies also complies with the requirements of U-space in terms of availability.

The whole architecture works as a communication bus in which the information from a set of sources can be obtained, processed and provided to other services and users. Therefore, users are always connected to the whole system that gives them access to a wealth of information.

Its modularity offers a solution to integrate a heterogeneous set of sources (drones, sensors, etc.) collecting information with no dependencies with a sole purpose, offering a joint solution.

The Orchestrator needs to be involved in the management of information regarding operations, interactions with other drones and manned flights and provision of information relevant for future operations. The definition of each one of these functionalities will be based on the micro-service paradigm and the information exchange between them looks like a relatively simple challenge for micro-service infrastructures.

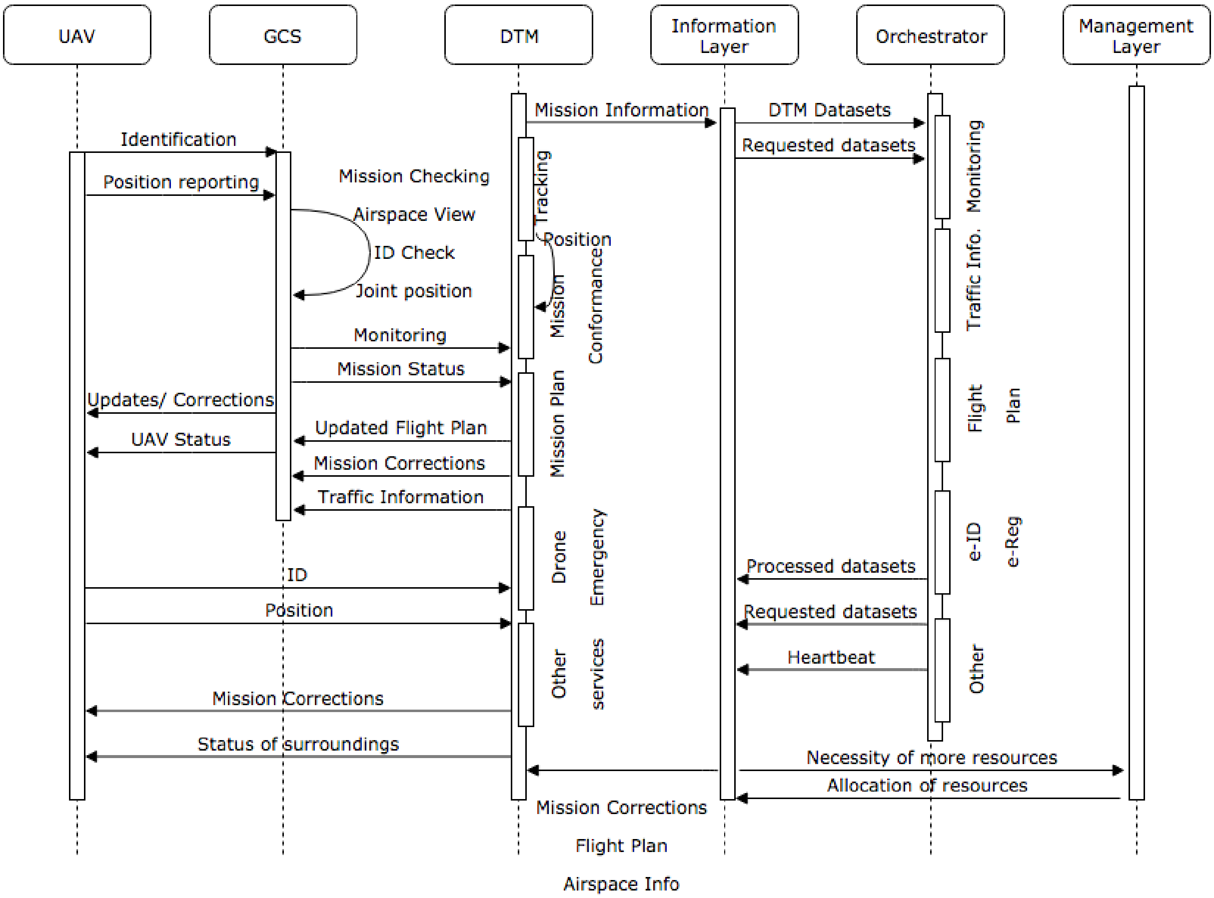


Figure 18. Information Architecture in Monitoring and Traffic Information Services.

5.3.2 Requirement identification & classification

Who:

Identifier (R)	REQ-IMPETUS-D31-INTR.0010
Title (R)	GCS-DTM Interface
Description (R)	The Ground Control System (GCS) shall act as an intermediate between the drone and DTM system, processing the information collected by the drone and offering it in an understandable format for the DTM system.
Type (R)	Capabilities
Service/Capability name (R)	Telemetry, Tracking, CNS, Operations Management
Category (R)	IER, Interoperability, Data, Design

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The interface between GCS and DTM systems involving command and control capabilities offers the user the ability to manage their own operation and execute it according to the management system to which they are subscribed, in a way that security is not compromised and where user orders can be blocked by the DTM for the benefit of the whole environment.
Rationale (O)	GCSs constitute the first layer between UAVs and U-Space services having a vital importance in the control of the operation and the provision of first-hand information to the user.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0011
Title (R)	GCS-UAV Interface
Description (R)	The drone shall provide continuous information about its position to the GCS, which will be also in charge of providing simple commands to the drone to ensure that the operation complies with the defined flight plan.
Type (R)	Capability
Service/Capability name (R)	Telemetry, Tracking, Command and Control
Category (R)	IER; Reliability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	This requirement is already integrated into drone operations but, the technology will evolve to improve the hardware, software, communications and safety. Improvements in the availability and quality of the information, together with the performance of the system, will increase automation and safety of the operations.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0012
Title (R)	DTM-UAV Interface
Description (R)	The UAV shall provide continuous information about its position to the DTM, ensuring that at least this direct link with U-Space is not compromised.
Type (R)	Capability
Service/Capability name (R)	Telemetry, Tracking, Command and Control, CNS
Category (R)	IER, Reliability

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The wide variety of operations includes BVLOS and other type of flights in which the link with the GCS cannot be ensured. This requirement intends to ensure the provision of information via other communication channels directly to the DTM in a certain environment, which will redirect the information to the Orchestrator and the GCS. The availability of information is the key feature for autonomous operations and management of U-Space.
Status (R)	Defined

What:

Identifier (R)	REQ-IMPETUS-D31-TRCK.0010
Title (R)	Mandatory tracking
Description (R)	Each drone that is going to operate in non-segregated areas shall provide information about its current position to the whole system. If this is not possible, these UAVs shall operate in segregated or allowed areas.
Type (R)	Capability
Service/Capability name (R)	Tracking
Category (R)	Safety, Security, Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	Drone operations are expected to rise in number and complexity and so the system to coordinate all of them. U-Space services will be capable of managing and solving conflicts but, when an unexpected actor steps in and, more important, in an unexpected (not predefined) trajectory, the whole system and its safety is compromised. For this reason, information about the position of drones in non-segregated areas is necessary for traffic deconfliction and advisory purposes. Being part of an automated system means: - Being automated and compatible with the infrastructure. - Not being automated but the system is able to detect and manage conflicts automatically. The variety of devices expected makes impossible the complete management of all the conflicts caused by unexpected actors without affecting the performance of the whole environment.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DINT.0010
Title (R)	Data Interoperability in the GCS
Description (R)	The systems (hardware, software applications and interfaces) implemented in the GCS shall be able to collect information from the different sensors implemented in the drone related to the same magnitude and operation (identified by a unique ID) and processing it to obtain each value separately and as part of a derived value offering a more accurate result than using independent sensors.
Type (R)	Capability
Service/Capability name (R)	CNS; operations management; tracking
Category (R)	Functional; Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	A wide range of compatible tracking sources can be implemented in a UAV (telemetry, ADS-B, satellite communications, GSM network… as described in [2]), offering different performances and characteristics. The capability level of each system separately and the joint performance will define the characteristics of the operation that a certain device and operator can execute. Complex operations will require a combination of sensors to ensure safety, availability of different data sources and emergency management procedures (in case one of them is faulty, alternatives can be proposed based on the available capabilities of the UAV).
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DINT.0011
Title (R)	Data Interoperability in the DTM
Description (R)	The systems (hardware, software applications and interfaces) implemented in the DTM shall be able to collect information from different sources (including the variety of sensors in drone and the available GCSs) related to the same magnitude and operation (identified by a unique ID) and processing it to obtain each value separately and as part of a derived value offering a more accurate result than using independent sensors.
Type (R)	Service
Service/Capability name (R)	Tracking, Monitoring (U2)
Category (R)	Performance, Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A

Rationale (O)	A wide range of compatible tracking sources can be implemented in a UAV (telemetry, ADS-B, satellite communications, GSM network… as described in [2]) and a GCS can offer different outputs (UAV data, joint and enhanced positions…), offering different performances and characteristics. The capability level of each system separately and the joint performance will define the characteristics of the operation that a certain device and operator can execute. Complex operations will require a combination of data sources and availability in the communication of the position of UAVs through different means.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DINT.0020
Title (R)	Data stream management layer
Description (R)	A common layer to collect all the data sources shall be defined and provided by the Orchestrator. This interface shall be in charge of gathering information from different DTMs, external data sources and surveillance sources and distributing it to the services that demand it.
Type (R)	Capability
Service/Capability name (R)	CNS, Tracking
Category (R)	Interoperability, Data, HMI, Design
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	To simplify the system, all information regardless of its type must pass through this layer, offering a single interface that will be able to understand the nature of the data source and redirect it to the service that will use it. In the same way, it will also serve as an exchange bus between different services and with the DTM, which will be connected to a single interface.
Rationale (O)	A complex system with independent interfaces is likely to suffer from more failures due to the incapacity of providing strong links between interfaces, hence a common layer is preferred.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0030
Title (R)	Scope of provided information
Description (R)	The Orchestrator shall ensure that UAVs exchanged data (in the Traffic Information service) is provided in such a way that commercial strategies cannot be deducted.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2), Traffic Information (U2)

Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The Orchestrator will have all the information related to the drone operation and will use it to create outputs using the Traffic Information Service. These datasets shall provide information that is related to U-Space management, ensuring that findings relevant to the commercial value of the operation cannot be deducted. This will allow a complete coordination of U-Space without losing the innate competitiveness of UAV operations.
Status (R)	Defined

Where:

Identifier (R)	REQ-IMPETUS-D31-TINF.0010
Title (R)	Geographical extension of the information
Description (R)	The Traffic Information service shall provide all the relevant information about traffic within a geographic bounding volume dimensioned large enough to ensure the safety of all the operations contained within.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Interoperability, Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	As a main coordinator and with the aim of providing situational awareness to the users, the Orchestrator must act as the key data source to provide information about the position, intents and future situation of all the operations in a certain environment, ensuring that this information is successfully delivered and used for users to reduce the risk in their operations. Depending on the congestion in the airspace, the capabilities of the actors involved and the emergency situations, the extension of this volume can be expanded or reduced dynamically.
Rationale (O)	The information that is provided by U-Space services must be filtered by relevance for a certain operating environment, avoiding superfluous information that can be counterproductive for the user by not focusing on its operation and the specific actions that must be executed.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-TINF.0011
Title (R)	Bounding volume for emergency procedures

Description (R)	The Traffic Information service shall extend the information area for a certain operation in case of the activation of emergency procedures in the surroundings of its bounding volume.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Interoperability, Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	Emergency procedures of other UAVs in the vicinity of a user's UAV may represent a risk for the operation in progress. The user must be informed of this incident.
Rationale (O)	Emergency procedures are urgent activities with maximum priority that will limit the operations if there is any possible incidence with them and, due to their nature, they must be duly informed to the affected users and those that may represent a risk.
Status (R)	Defined

When:

Identifier (R)	REQ-IMPETUS-D31-TINF.0020
Title (R)	Real-Time collection of information
Description (R)	The Traffic information service shall be fed by real-time information related to the operations being executed in U-Space.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Interoperability, Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	In order to effectively and safely coordinate all aircraft, the traffic information service must be provided with real-time information (or near real time including shipping and processing times) by all drone operations within boundaries of airspace which requires the provision of such information.
Rationale (O)	As part of a safety-critical service, the flow of information to the Traffic Information service shall be continuous and without delays that may compromise the set of operations that are being executed in a certain area due to the lack of information of one or more systems.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MONT.0010
Title (R)	Real-time provision of information

Description (R)	The Monitoring service shall provide real-time information about the operation that is managing.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2)
Category (R)	Interoperability, Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The information that is collected from the operation must be instantly processed, sent to the Monitoring service in the U-Space Service provider infrastructure and then to the Orchestrator. The Traffic Information Service will gather this information from all drone operations and ensure the coordination between them. The safety-critical nature of this service entails the need of a high performance infrastructure with practically continuous and instantaneous processing.
Rationale (O)	The key requirement of the Traffic Information Service to be fed by real-time information defines the necessity of real-time sources to be connected with and the continuity in the availability of the flow of information.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0030
Title (R)	Low latency in stream lifecycle
Description (R)	The time between the occurrence of a certain event relevant to the Traffic Information service (change of position, loss of communications, activation of an emergency procedure, etc.) and its collection by this service shall be reduced at the minimum level and below 20 milliseconds [7] ensuring that updates in the U-Space ecosystem are provided in real-time.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Interoperability, Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The system must be able to perform message transmission and processing avoiding costly intermediates in the critical processing path.
Rationale (O)	Delays in information management and processing shall not compromise the safety of operations.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0040
Title (R)	Decomposition of functionalities

Description (R)	A low-latency and highly efficient service shall be based on the partition and decomposition of functionalities into simple procedures to facilitate the swift processing of information.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2); Traffic Information (U2)
Category (R)	Interoperability, Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	Splitting a complex functionality in simple processes will improve the performance of the complete system and will streamline information management based on a wide variety of sources and consumers. Delays in information management and processing shall not compromise the safety of operations.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0050
Title (R)	Detection of loss of information periods.
Description (R)	The role in charge shall be able to detect time frames in which the position of a certain UAV is not available and raise an alert that will scale to the Orchestrator, which will be in charge of activating the emergency procedure if necessary.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2); Traffic Information (U2)
Category (R)	Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The lack of information issue shall be detected by each actor in U-Space environment involved in a certain operation and the main objective is to inform the Orchestrator (or ensure that it is able to detect it) to include it in the Traffic Information Service that will coordinate this uncertainty with the rest of drone operations and it will inform the Emergency service about the incidence.
Rationale (O)	The relevant information required in a coordination and decision-making process shall be provided in the appropriate time to ensure a highly efficient scheduling of activities.
Status (R)	Defined

How:

Identifier (R)	REQ-IMPETUS-D31-TRCK.0020
Title (R)	Redundant tracking
Description (R)	The UAV shall ensure redundancy of information that is use for the traffic monitoring service. Redundancies are mandatory for all operations as it is necessary to ensure that the position of a certain UAV is always known in a certain volume.
Type (R)	Service
Service/Capability name (R)	Tracking, Monitoring (U2)
Category (R)	Operational, Performance, Safety, IER, Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The data stream will be composed of: - A unique ID, provided by a serial number, the e-Registration service or the authority. This ID will be used to identify the drone, allow the operation and relate it with a certain flight plan. In case of an emergency, the security corps can also use it. - The position of the drone, stressing the sensor used to provide it, the communication channel used and the performances of this location provider. This information must be followed by a reference system to locate the UAV. - The UAV attitude, which will be necessary to foresee the trajectory and check the flight plan conformance. - The units of measurement. - Information about the performance of the data generator. For the automation of U-Space services and the complete coordination between the UAVs, manned aviation and the actors involved, the information about the position, intentions and mission shall be shared with the Orchestrator.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-TRCK.0021
Title (R)	Performance in tracking
Description (R)	Tracking information shall include information about the performance of the sensor used to generate that type of information.
Type (R)	Service
Service/Capability name (R)	Tracking, Monitoring (U2)
Category (R)	Operational, Performance, Safety, IER, Interoperability

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The variety of sensors and means to transmit the position of a UAV and the different capabilities required for each operation reflects the necessity of knowing the bounding volume in which the position of the device can be perfectly located. For the automation of U-Space services and the complete coordination between the UAVs it is necessary to also compute the performance of the involved sources and the uncertainty in the measurements, that must be aligned with the requirements for a certain operation being executed in a defined airspace and with specified capabilities.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0060
Title (R)	Standard definition
Description (R)	Connections between a Ground Control Station (GCS) and a DTM shall be based on compatible systems and information exchange standards. This requirement shall be checked in the planning phase of a drone operation, ensuring the communications coverage between these two roles and that the implemented sensors can provide this communication. The format of the datasets shall also be defined (information required, structure, coordinate system…).
Type (R)	Capability
Service/Capability name (R)	Telemetry, , Tracking, CNS, Operations Management
Category (R)	IER, Interoperability, Data, Design
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The variety of configurations, tracking devices and communication channels together with the obligation of providing tracking information means that the DTM, as main interface between the operation and the Orchestrator, shall be capable of collecting and managing the information provided by the mission. The key issue in data management is related to the interfaces between two different modules. Using standards will make U-Space service providers to be compatible with them and ensure that the communication is understandable.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31- INTR.0070
Title (R)	Orchestrator's standard
Description (R)	The Orchestrator shall define, make use of and provide to end-user a standard to be able to receive information from the DTMs.
Type (R)	Capabilities
Service/Capability name (R)	Telemetry, Tracking, , CNS, Operations Management
Category (R)	IER, Interoperability, Data, Design
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	All the information that will be required by the Orchestrator to coordinate the U-Space in a certain environment will be provided in a common language, easy to understand, implement and code and using data streams as short and specific as possible, also defining mechanisms to validate the received datasets. Using a sole standard to information exchange with a manager will reduce the complexity of the system (by not needing customized developments) and will promote the automation of all processes using the lowest data consumption and avoiding information loss.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0080
Title (R)	Loss of link
Description (R)	In case of system failure in the provision of monitoring information, the GCS or the DTM shall be the first actor to detect the issue and notify to the DTM the current status of that aircraft. The DTM also shall also be capable of informing the Orchestrator about the issue, which will be in charge of offering the correspondent procedures to prevent and avoid the conflict. This issue is also applicable to the communication between DTM-Orchestrator, escalating the responsibilities of each interface.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2), Emergency Management, Traffic Information (U2)
Category (R)	Operational, Safety, Performance, Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The speed of reaction to such detection will be key when activating emergency procedures and to inform the rest of the users of the problem,

	so U-Space must offer a solution according to the airspace and the complexity in the coordination of the actors. Communications shall be constantly checked to avoid compromising the availability of monitoring and other sources. Redundancies and different communications means are recommended to avoid a complete loss of tracking information.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0081
Title (R)	Service Interoperability
Description (R)	The information shall be shared between services demanding an input to process their valuable outputs. This connection must be standardized in the system in which they are implemented (DTM or Orchestrator).
Type (R)	Capability
Service/Capability name (R)	CNS, Operations Management
Category (R)	Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The relationships defined in pre-flight, execution and post-flight phases are, in terms of information management, communication channels that shall be available to allow the correct and efficient functioning of the system. The added value of U-Space services and the need of coordination in U-Space makes the processing of information and the analysis and production of datasets with conclusions and recommendations essential.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31- INTR.0082
Title (R)	Service availability
Description (R)	Monitoring and Traffic Information are key services for U-Space coordination. The operation of these services should not be compromised by the workload or the failure of any functionality. In addition, it must be adapted to the needs of each moment, thus promoting an efficient solution in costs.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2), Monitoring (U2)
Category (R)	IER, Operational, Safety, Performance

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The services must be supported by a scalable system which will be in charge of: - Monitoring the availability of services. - Detecting the current workload and the expected calculations. - Adapt to the demand in a certain timeframe. - Offer redundancies of the same functionality.
Rationale (O)	Workload peaks, the number of users and the information necessities must be supported by a robust system whose demand is going to increase exponentially.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-PERF.0010
Title (R)	Service workload
Description (R)	The system shall offer an alternative if a service is incapable of processing all the inputs and outputs for a certain environment.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2), Traffic Information (U2)
Category (R)	Performance, Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	U-Space service shall not be supported by a monolithic architecture. To ensure the availability and efficiency of a certain service, they shall be provided via the same functionality in different modules that will be activated when required, providing redundancies for the same service and ensuring the availability of crucial functions. A system based on security must have redundancies in both hardware and software that can be used in case of failures or increases in demand.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MONT.0020
Title (R)	Contents of monitoring information
Description (R)	Monitoring datasets shall comprise information related to the position, attitude, status, milestones and detected conflicts of a certain operation.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2)
Category (R)	Operational

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	Datasets shall be structured in a compatible format that can be processed by the orchestrator, including but not limited to: - ID. - Position (3D). - Spatial reference system (horizontal and vertical datum). - Timestamp. - Speed. - UAV Status. - Tracking sources. - Mission Status. - Mission Milestones. Following Milestone. This information is mandatory for a coordination system in which the answers to "who", "when", "where" and "how" shall be provided.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-TINF.0030
Title (R)	Provision of traffic information
Description (R)	Traffic information service shall provide datasets to users that allow them to understand the current status of the environment, their relative status and, in case of an emergency, the procedures to be followed and the change of rules.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	Datasets shall be structured in a compatible format that can be processed by the orchestrator, including but not limited to: - Relative position (3D) of the UAV. - Position (3D) of the other aircraft in the surroundings. - Spatial reference system (horizontal and vertical datum). - Timestamp. - Planned trajectories.

	- UAVs Status. - Tracking sources and performances. - Mission Status, milestones and intentions (in terms of positions). - Foreseen conflicts. - Detected conflicts and involved devices. - Active countermeasures. - Aeronautical information (static and temporal). - Automatic commands. Alert messages. This information is mandatory for a coordination system in which the answers to “who”, “when”, “where” and “how” shall be provided.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0090
Title (R)	Top-down hierarchy in the activation of emergency procedures
Description (R)	The conflict detection process shall start in the Orchestrator services (although the DTM can provide information about mission conformance) and the countermeasures (including automatic commands) shall be transmitted via DTM and GCS to the UAV (and the Drone Operator).
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2), Monitoring (U2)
Category (R)	Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The main manager must be the one who provides the main emergency procedures, warnings and transmission of countermeasures, so the behaviour of all the participants of the system will be predicted.
Rationale (O)	The Orchestrator, as the main coordinator of the system, shall have the last word in deciding deconfliction procedures.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-PERF.0020
Title (R)	Integrity of data
Description (R)	The Orchestrator shall validate all the information that is collected by the Monitoring and Traffic information service.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Interoperability, Performance, Security

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The information that is provided to the services shall be validated in terms of: - Integrity of information (with respect to previous inputs, the operation limits and the expected inputs from the planned flight). - Temporary instant and validity (delays). - Uncertainty and accuracy of the provided information. The Orchestrator can raise an alert when the information performance is compromised by one or more U-space users. This information shall be validated by each service prior to using it.
Rationale (O)	Processing and coordination with false information will cause the provision of an inconsistent U-Space system that can put at risk all those participating in a certain environment
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-PERF.0021
Title (R)	Safety limits
Description (R)	The Orchestrator must define a set of numerical limits for the information provided by the operations to consider that the datasets can be included in the U-Space environment.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2); Traffic Information (U2)
Category (R)	Performance, Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The safety-critical nature of these services shall be supported by a reliable group of data providers that must ensure that the information provided is within certain limits related to: - Integrity: the information is consistent with the operation in progress and previous measurements. - Accuracy: the uncertainty of the information will not compromise the operation. - Availability: the information is provided at the proper time.
Rationale (O)	Services that are critical for drone operations shall not be compromised by the use of wrong information.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-PERF.0030
Title (R)	CNS Performance

Description (R)	The information about the performance of the information generators shall be collected and processed by the DTM and the Orchestrator and this information will also be an input for the Emergency Services.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2); Traffic Information (U2)
Category (R)	Performance, Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	As first collector of tracking information, the DTM shall validate the inputs from the operation with the defined limits of the environment in which it is taking place and, if they are violated, warn the Orchestrator about this issue. The Orchestrator must also be a consumer of this type of information that will be needed to coordinate the degree of uncertainty for a certain operation with respect the other flights that are being executed in the same environment and, if necessary, raise and alert that must be transmitted to all the roles.
Rationale (O)	Services that are critical for drone operations shall not be compromised by the use of low-accurate information and the position of each participant shall be perfectly known or, at least, perfectly fenced.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-TINF.0040
Title (R)	Alerts when quality limits have been exceeded (orchestrator).
Description (R)	The Orchestrator shall raise an alert when one of its services (especially safety-critical services) detects inconsistencies in the information used as source of U-Space management.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Interoperability, IER, Performance, Security
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The information infrastructure shall be monitored (jointly and individually per service) ensuring the validity of the information that is going to be processed and, when this may become a risk, inform immediately the users of U-Space.
Rationale (O)	As part of a critical information management system necessary to obtain a valid output, the quality of the input information must be checked and inform users about detected inconsistencies.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-INTR.0100
Title (R)	Alerts when quality limits have been exceeded (DTM).
Description (R)	The DTM shall raise an alert when one of its services (especially safety-critical services) detects inconsistencies in the information. This alert shall be sent to the operator and the Orchestrator, which will distribute it as part of the Traffic Information outputs.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Interoperability, IER, Performance, Security
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The information infrastructure deployed by the DTM shall be monitored (jointly and individually per service) ensuring the validity of the information that is going to be processed and provided to the Orchestrator.
Rationale (O)	As part of a critical information management system necessary to obtain a valid output, the quality of the input information must be checked and inform users about detected inconsistencies.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-CERT.0010
Title (R)	DTM certification
Description (R)	The DTM shall be registered by the Orchestrator (as part of the e-Registration service) as a certified tracking source.
Type (R)	Service
Service/Capability name (R)	Monitoring (U2)
Category (R)	Interoperability, IER, Performance, Security
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	To ensure the validity of the information that is provided by the DTM, especially tracking, the Orchestrator will implement a registration system in which its capabilities of integrity, availability, accuracy and nature of the information can be tested and measured, providing a proof of its viability in its integration in U-Space ecosystem. The integration of an unknown system with low capacities in an environment of great complexity, demands and changes must be controlled by an authority.
Status (R)	Defined

Why:

Identifier (R)	REQ-IMPETUS-D31-PERF.0040
Title (R)	External data validation
Description (R)	The information provided by all of the sources must be validated before being part of the U-Space ecosystem.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Interoperability, IER, Performance, Security
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	To ensure the consistency and quality of information that it accepted by the Orchestrator (which is in charge of providing situational awareness to all users), these datasets shall be validated prior entering the processing phase. The attributes to be validated are: - Device: sensor that is creating the information. - Source: the origin of the data stream that has been sent. - Data Consistency with previous measurements or mission status. - Data Structure: using the standard for information exchange. - Time in relation to other operations. A coordinated system shall completely integrate the information provided and it must be compatible and admissible as valid data.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-PERF.0050
Title (R)	Performance in traffic information provision
Description (R)	The robustness of the Traffic Information service shall be focused on providing a scalable system capable of gathering a range of different sources in a time frame in which safety is not compromised, providing a series of accurate datasets to provide restrictions, commands and limitations of a set of drone operations and information to the rest of users.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Performance, Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A

Rationale (O)	The architecture that will be proposed for U-Space management shall provide autonomous modules that must be self-monitored, providing different KPIs to assess the performance of the system and the requirements of incremental improvements to fulfil the existing and foreseen demands and requirements. This is part of the key requirements for an autonomous system that will be able to manage a huge workload composed of a variety of sources.
Status (R)	Defined

5.4 Tactical deconfliction and airspace capacity service

5.4.1 Use case sequence diagrams

To ensure safe separation alongside all airspace users, whether manned aviation or drones, a deconfliction capability will be required. Therefore, as part of this experiment, the deconfliction and airspace capacity service will utilise all the “use cases” defined in D2.1 [1] and demonstrate how information received through U-Space Services, providing a critical situational representation; and will play a critical part in tactical deconfliction calculations and the resulting airspace capacity and therefore route efficiency.

As an example, taking the concept of “UC2: Inspection of critical infrastructure located in a populated area, which uses a manually controlled as well as fully autonomous flights of multicopter drones”, there are differing types of drones, with differing capabilities and performance criteria, all needing to operate in highly complex and dynamic environments and the need to mix with other airspace users.

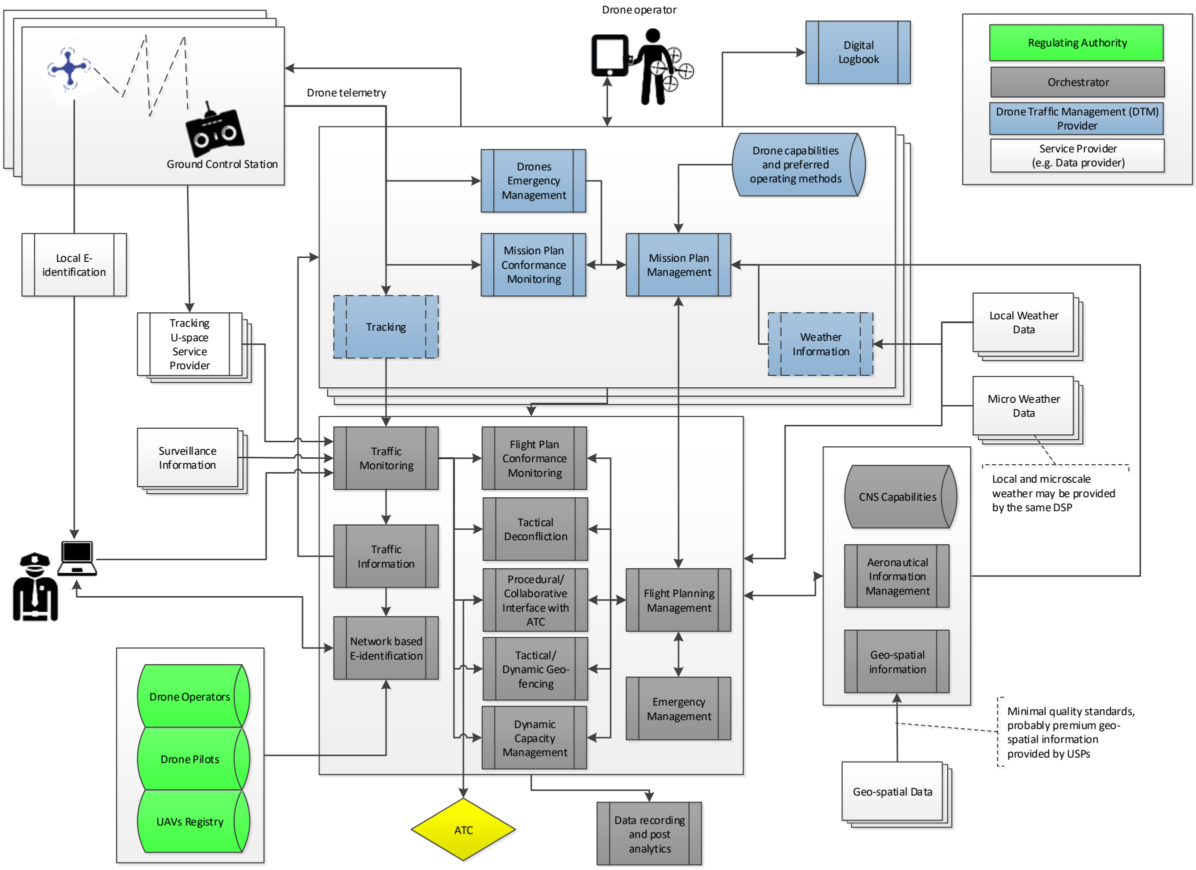


Figure 19. High-level architecture - U-space services used to inform tactical deconfliction and airspace capacity.

The Deconfliction Service will build a continuous situational awareness picture, utilising a set of environmental feeds as well as feeds from each cooperative drone flight in the system. This service will continually modify separation criteria for each object in the system in near real-time, depending on the data being received from U-space services and then evaluate which co-operative drones need re-routing based on the separation requirements.

A set of experiments will be required to evaluate the separation criteria (field size of each object) based on data inputs and the quality and performance of such inputs.

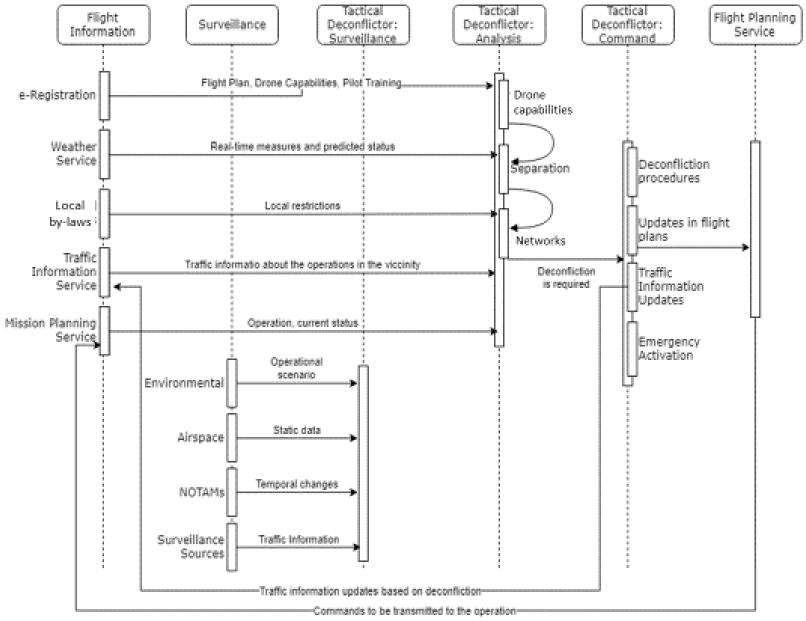


Figure 20. Airspace capacity and tactical deconfliction sequence diagram.

Focusing on the defined "use cases" allows the tactical deconfliction service to utilise U-space services demonstrate how differing environments, networks and capabilities affect the capacity of the airspace.

Based on the drone concept of operations, from mission planning to the mission execution and conformance to mission data recording, several high-level requirements and sub-requirements have been identified.

5.4.2 Requirement identification & classification

What

Identifier (R)	REQ-IMPETUS-D31-DECO.0020
Title (R)	Flight Information
Description (R)	The service shall programmatically access the flight information for each drone undertaking an active flight within the Deconfliction Region. The flight information must include the flight identifier, flight plans (where approved and are already strategically deconflicted) and where applicable, live track information of the drone flight. The system must also receive information from the U-Space registry about the drone and where applicable Drone Operator/pilot.
Type (R)	Service

Service/Capability name (R)	Traffic Information (U2)
Category (R)	IER, Operational
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	Access to Flight Information is a requirement for each cooperative drone that is to be managed by the tactical deconfliction service. The flight electronic identifier must be reused from the flight plan and assumed to be unique. The flight plan provided is assumed to be strategically deconflicted and approved prior to the flight execution. When flights real-time location is appropriate[5]), the deconfliction service must remain agnostic to specific e-conspicuity technology, and instead should define a number of supported technology adaptors (which could be further advanced overtime): • Drone GPS location over LTE; • Drone GPS location over LTE through GCS; • Drone GPS location over Satellite Communications; • Drone GPS location over Satellite Communications through GCS; • ADS-B transponder; The service will provide an endpoint for this information to be sent to. Where information does not exist or is not provided, the Deconfliction Service must assume the “least advance” capability which will lead to a larger separation requirement around the flight. For the tactical deconfliction to be able to function effectively, it must have information about cooperative drone flights operating in the deconfliction region.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0040
Title (R)	Dynamic Assignment for Field Size and Weighting

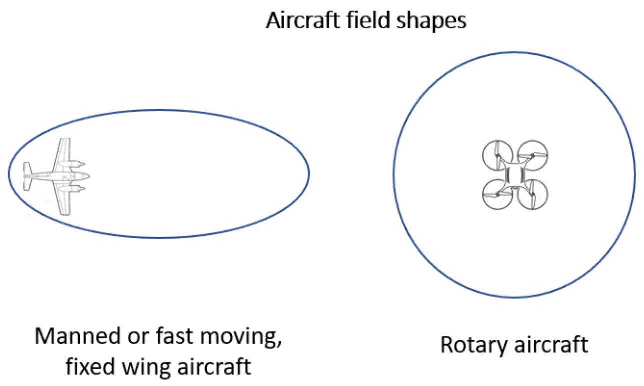
[5] A real-time location is preferred but not critical to tactical deconfliction. In deconfliction regions where this is not available/required, tactical deconfliction will deconflict against the flight plans during the flight and assume compliance. Compliance may still be verified through surveillance.

Description (R)	The Service shall assign and updates weighting and sizes to each object in the deconfliction region at defined intervals (e.g. 10 Hz). All objects within a deconfliction region or sub-region will be given a weighting and size, establishing a bounding volume. Object include airspace, hazard, manned and unmanned air traffic as well as both cooperative and uncooperative. There is a requirement to define the specific algorithm to determine the weighting and size based on all the information available to the deconfliction service. Applying fields to all objects allows the service to vary the separation between objects, providing tactical deconfliction within the Deconfliction Region.
Type (R)	Service
Service/Capability name (R)	Dynamic Capacity Management; Tactical Deconfliction
Category (R)	Operational; Safety; IER
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A

Rationale (O)	The management of the size and weighting of the fields around each drone is a key function or managing the airspace efficiently. The service relies on a number of dependencies to maintain safe levels of traffic and efficient routing. The system will utilise information received via a number of U-Space services:
	○ Weather information service
	○ Mission and flight planning management
	○ Monitoring and traffic information
	○ Aeronautical information
	○ Temporal airspace
	    ○ NOTAMS
	    ○ Local by-laws
	    ○ Short-notice emergency airspace closures
	○ Surveillance, sensor coverage, capability
	    ○ Primary radar
	    ○ Secondary radar
	    ○ Optical sensors
	    ○ Acoustic sensors
	    ○ ADS-B
	○ Ground hazards, obstacles, terrain and city maps
	○ Cellular coverage and latency
	○ GPS overage and latency

	Each of the U-Space services listed above will have an associated size and weighting. The size and weighting will depend on the information received from each U-space service which directly affects the airspace capacity and tactical deconfliction. **Weather information service** is critical to all drone operations, from planning a mission to the completion of the flight. The weather will determine the trajectory of the drone, the ability to maintain track, traffic sequencing, diversion landing sites; all of which effect the weighting and size of the fields around each of the objects. The great uncertainty of the predicted weather means the bounding volume size will vary greatly depending on the quality of the weather; the more localised or hyper-localised the weather the smaller the size and weighting of the bounding volume. This in turn directly affects the airspace capacity. **Mission and flight planning management**. Certain missions will require differing dimensions of airspace. For example, a land survey may require a large volume of airspace where as a short delivery flight will require less airspace, however it is likely to be a short notice operation. Both types of operation will need varying sizes and weighting of field to protect the operation. The survey activity not only requires a field to protect the drone, but an additional larger field to protect the survey area; quite possibly generating a complete no fly zone whilst the survey takes place. The opposite would be true for the drone delivery flight. Short notice, highly automated drone only needs a small buffer, therefore only the drone that requires the protection of the bounding volume. **Monitoring and traffic information**. Real time traffic information is needed to ensure the bounding volume sizes are kept to a minimum. Not having an ability to monitor the activity taking place within the deconfliction region would significantly affect the airspace capacity. To ensure safe drone operations, the field size and weighting would effectively be the size of the deconfliction region, thus only individual operation could take place at any one time. As previously mentioned, bounding volumes do not just effect drones, all objects within the deconfliction region will have a bounding volume or affect the size and shape of the other bounding volumes within the region. **Aeronautical Information** will provide the baseline information for other airspace data to be measure against and therefore affect the size and weighting of the bounding volume. **Local Regulations** will enforce a number of restrictions over and above the restrictions highlighted by the Aeronautical Information. The size of the field around the restriction will mimic the size of the airspace, however the weighting associated to the local restriction will be at the maximum, preventing all access to the airspace. **Temporal Airspace** could affect the Bounding volume in numerous ways. A NOTAM or by-law could come into force which only limits the drone movements therefore although the size of the field would mimic the size of

	the restriction, the weighting could vary significantly depending on the NOTAM or by-law. On the flipside, a short notice emergency closure would be a strictly enforced no-fly zone, thus the weighting would be at a maximum level possible. **Weather** can affect the size and weighting of the bounding volume in two ways. Firstly, certain types of weather may have their own Bounding volume. An example is extreme wind or thunderstorm; each would create a no fly zone for most drones and therefore the size of the field would be equal to the hazard and weighting of the field would be very high, preventing drones from entering the airspace. Secondly, the weather can affect the size and weighting of a field around an object. If the general wind speed increases in a deconfliction region, the ability for drones to maintain course and direction could become difficult therefore to ensure safe separation between objects, the field size and weighting around each object would need to increase. **Surveillance, sensing coverage, capability** all would affect the size and weighting the fields around the objects in the deconfliction region. The effects on the fields would depend on the characteristics of the surveillance sensors; the update rates, the coverage, etc. **Ground Hazards, obstacles, terrain and city maps** will all have their own bounding volume. A hazard to the flight of a drone must have a Bounding volume to prevent a drone from hitting the obstacle/hazard. The size of the field would be bigger the obstacle and the weighting of the field would be very high; for safety reasons the drone should not be allowed to penetrate the field. **Cellular and GPS coverage** and associated network latency. If the cellular or GPS networks is used by the Deconfliction Service, the coverage and the latency of the network will affect the fields around each object, which in turn will affect the airspace capacity. The time it takes for the tactical deconfliction service to receive 'traffic information' the bigger the field needed around each object and each hazard. Any rerouting decision made by the Deconfliction Service will take longer for the information to be received by the drone and therefore longer for the drone to react. In addition to certain types of environmental conditions and obstacles having their own bounding volume, all aircraft will also have their own fields. The size and shape of the field around each aircraft will vary depending on the type of aircraft and/or the type of operation being undertaken. Manned aircraft in most cases have priority over unmanned aircraft, therefore the weighting associated to the field will be very high, ensuring no drone it able to fly close to the manned aircraft.

	Furthermore, the type of drone will play a key role in the shape of the field. For example, a fast moving drone is likely to have an elliptical shaped field, protruding in the direction of travel, where as a rotary aircraft is likely to have a more even shaped field. The size also depends on the aircraft equipage levels and the performance.  Note: Each input taken into the system must be available through an “open-standard” interface, utilising industry standards where available e.g. GUTMA [8]. This requirement allows for dynamic performance-based separation in the deconfliction region.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0050
Title (R)	Re-routing analysis
Description (R)	The Service shall analysis the situational picture alongside the weightings and sizes of the bounding volume applied to each object to determine which cooperative flights require re-routing.
Type (R)	Service
Service/Capability name (R)	Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Operational; Safety; HMI
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The system will continually receive information about all participating flights either directly from the drone or through their respective GCS.

Rationale (O)	Married the drone information with the information received from other U-Space micro services, the service will be able to assess if any flight needs to be rerouted. The timeliness of the information received from the numerous U-Space services will significantly affect the safety, capacity of the airspace and possibility the success of the overall mission.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0030
Title (R)	Navigation / Command
Description (R)	The Service shall programmatically communicate with a service which is able to send the Drone Operator (for manual flight) or drone (for automated flights) navigation commands based on the deconfliction and re-routing output.
Type (R)	Service
Service/Capability name (R)	Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Operational; Interoperability; Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	To maintain 'control' of the region or to effectively manage the traffic within a region, the service needs to be able to send a command directly to the drone or to the drone pilot. Once a command has been sent, the service needs an acknowledgement that the instruction has been carried out. The acknowledgement could be addressed using a monitoring service; passing a control instruction and monitoring the compliance (a period of track observation) or the command can be acknowledged by pilot. N.B. The time it takes for a drone to respond to the instruction will directly affect the airspace capacity; the slower the response the larger the field size needed around each object, which in turn effects the capacity. Therefore, this response time needs to be fed back into the system so the drones/pilots conformance rate. Once the Tactical Deconfliction analyses the situation and determines that a re-routing is required for a specific flight, this re-routing needs to be communicated to the drone or Drone Operator.

Status (R)	Defined

Where:

Identifier (R)	REQ-IMPETUS-D31-DECO.0010
Title (R)	Environmental Information
Description (R)	The service shall programmatically communicate with other U-Space Services to determine environmental / airspace conditions for The Deconfliction Region[6]. The services available for each Deconfliction Region or sub region (and the detail of information for each) will be identified using the U-Space Discovery Service[7]. Examples of environmental information are detailed in subsequent 'sub-requirements'.
Type (R)	Service
Service/Capability name (R)	Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Performance; IER
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The data types, localisation, performance (e.g. update rate, accuracy thresholds) of environmental information can vary for each Deconfliction Region or Sub-Region. In a simple example, a weather forecast can be regional in some areas or hyperlocal local in others). Regardless of the quality of the data received from the U-space services, the deconfliction service needs to manage drone operations and be capable of adapting the level of separation accordingly. There is a requirement that the service for each environmental information category, includes an 'information service contract' defining

[6] The Deconfliction Region is an area of airspace that is managed by the tactical deconfliction service. The Deconfliction Region maybe broken down into sub-regions to support optimization of resources.

[7] U-Space Discovery Service is a U-Space Service defined outside of the scope of deconfliction to support the Microservices paradigm implementation, and essentially provides a look-up for available U-Space Service.

	the types, localisation and performance of the data their respective services provide. To ensure the effectiveness of the tactical deconfliction, the service must draw information from numerous sources to maximize the situational awareness. The quality, update rate and the numbers of microservices providing critical information will play a key role in the airspace approvals. Poor data quality, or data with a slow refresh rate will directly impact the separation requirement around each drone and therefore the airspace capacity.
Status (R)	Defined

When:

Identifier (R)	REQ-IMPETUS-D31-DECO.0013
Title (R)	Temporal Airspace
Description (R)	Real time information is needed for effective airspace management. The system shall programmatically check all updates to airspace prior to any flight taking place.
Type (R)	Service
Service/Capability name (R)	Traffic Information (U2)
Category (R)	Operational; Safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	To ensure safe drone operations, the system needs access to the most up to data airspace information. This information needs to be available throughout all phases of the drone operation; pre-flight / flight / post flight and should include: - NOTAM - Temporary Flight Restriction), navigation warnings or (de)activations of airspace volumes. - Local bye-law changes around a sports ground - Short notice emergency airspace closures initiated by the NAA's Without access to the most up to date information, drones may operate in restricted airspace and potentially become a hazard to other airspace users, such as emergency service aircraft. NOTAMs is the current tool used by manned aviation to access the most up to date aeronautical information. The NOTAM system should be adopted to ensure all airspace

	users use the same, correct information and therefore a 'single point of truth'.
Status (R)	Defined

How:

Identifier (R)	REQ-IMPETUS-D31-DECO.0011
Title (R)	Aeronautical information
Description (R)	Aeronautical data to be used for the tactical deconfliction service will be updated on a regular basis, in line with the current the AIRAC cycle.
Type (R)	Service
Service/Capability name (R)	Drone aeronautical information
Category (R)	Operational; safety
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	Current aeronautical data for manned aviation is updated every 28 days. This information will provide the basic but fundamental airspace data for a given deconfliction region.
Rational (O)	The AIRAC cycle provides an update to the traditional airspace data across the world. It ensures that all airspace users are using the same information, therefore operating from a single point of truth.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0012
Title (R)	Local regulations
Description (R)	To manage the airspace correctly and ensure drones only operate in authorised/appropriate airspace, the system shall programmatically communicate with U-Space services to update local regulations and real-time limitations).
Type (R)	Service
Service/Capability name (R)	Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Safety

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	It is expected that changes to local regulations will occur on a less predictable basis to aeronautical data. Therefore, a robust process needs to be established to manage the changes enabling the system to a continual access the environment and update the separation requirements for all objects in the deconfliction region. Unpredictable changes to local regulations could potentially allow drones to operate in airspace without the appropriate approval of equipage. In addition, the changes to local regulations may affect the separation minima and the airspace capacity.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0014
Title (R)	Weather
Description (R)	Weather has a direct impact on drone operations and the types of drones authorised to carry out a task. The system shall programmatically access the most up to date and accurate weather information to assess airspace capacity and operational safety.
Type (R)	Service
Service/Capability name (R)	Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Operational; IER
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The system can expect to receive various levels of weather data depending on the available sensors in a deconfliction region. Information received from the sensors will range from regional forecasts / measurements of wind speed, temperature and precipitation, through to hyper-localised weather calculated for an exact latitude/longitude/altitude.
Rational (O)	Weather information is critical to all drone operations, from planning a mission to the completion of the flight. The weather will determine the trajectory of the drone, the ability to maintain track, traffic sequencing, and diversion landing sites. Therefore the more localised or hyper-localised the weather or the more accurate the weather forecast, easier to calculate the separation requirements and airspace capacity,

Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0015
Title (R)	Surveillance capabilities
Description (R)	Surveillance capability shall be used for tracking and monitoring the activity taking place in a deconfliction region, or sub region and provided to the tactical deconfliction service.
Type (R)	Service
Service/Capability name (R)	Traffic information (U2)
Category (R)	Operational; Safety; Performance; Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	Traditional airspace surveillance technologies will only provide limited radar coverage; drones on the whole are too small to be detected. Depending on the drone equipage, and/or the location of the drone flight, other sensors are needed to provide a comprehensive air picture. A number of different sensors can be used to provide a complete surveillance picture: • Primary/Doppler radar • Secondary radar • Optical sensors • Acoustic sensors • ADS-B transmit/receive • RF The operational environment will dictate the suite of sensors needed in a deconfliction region or sub region. For example, using a Doppler radar in an urban environment would have a limited use, due to the 'shadows' created by the building. Therefore, other sensors such as optical or RF would be needed to cover the airspace. However, in a maritime environment a doppler radar could be very effective.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0016
Title (R)	Geospatial information

Description (R)	The service shall programmatically access geospatial information to enable drones to carry out safe operations. The data set should include both airborne and ground hazards. Therefore the service requires access to geospatial data, which needs to include some or all of the following; ground hazards, obstacles, terrain, city maps, etc. in addition to airspace restrictions such as airspace classifications
Type (R)	Service
Service/Capability name (R)	Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Performance; Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	Geospatial data is essential for safe drone operations. Without this information, only drones with the appropriate detect and avoid capability would be allowed operate in a deconfliction region or sub-region. To ensure the effectiveness of the tactical deconfliction, the system must draw information from numerous sources to maximize the situational awareness, thus optimising the separation requirements of a given Deconfliction Region, this in turn will lead improved airspace capacity.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0017
Title (R)	Legacy networks
Description (R)	Legacy networks such as cellular and GPS networks shall be used to support drone operations and provide communications between different roles. The networks can be used to communicate U-space services needed to carry out safe drone operations. The system will programmatically communicate with these networks for facilitate safe drone operations.
Type (R)	Capability; Service
Service/Capability name (R)	CNS; Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Reliability; Performance; Data; Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry

Additional information (O)	N/A
Rationale (O)	Legacy networks have their limitations. A drone operation taking place in a rural area, has a strong, reliable, GPS signal. However when the drone operation takes place in a urban area, the GPS signal can become corrupt, (GPS signal reflexed off building and urban canyoning restricting the signals) therefore making the service unreliable. Another concern is the latency of the GPS signal. This needs to be clearly understood before the information becomes a trusted source. There are also pros and cons to cellular networks. Often the signal is stronger and more reliable in urban areas than rural areas. Therefore, regardless of the location, network coverage mapping is needed for both lateral and vertical coverage before cellular and GPS networks can be 'trusted'. The information being supplied by the U-Space services has a direct impact on the separation minima and therefore the airspace capacity. The quality, update rate and the numbers of microservices providing critical information will play a key role in the airspace approvals. Poor data quality, or data with a slow refresh rate will directly impact the separation requirement around each drone and therefore the airspace capacity.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0021
Title (R)	Drone and Operator registration
Description (R)	To ensure drone and drone pilots only access areas where authorised to do so, the service shall programmatically access information about the drone and the Drone Operator/pilot from the U-space registry.
Type (R)	Service
Service/Capability name (R)	Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Security; Interoperability
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The following Drone Information is required: • Type of drone (e.g. fixed wing or rotary); • Performance limited of a drone (e.g. max. wind speed); ○ Mass ○ Lateral and vertical speeds

	• Range of Drone
	• Payload of Drone
	• Drone E-Conspicuity method
	• Drone's Command and Control interface
	  ○ Make, model serial number of GCS
	• Insurance
	  ○ Date of validity
	  ○ Policy number
	  ○ Limits of cover and exemptions
	• Drone unique identification number/code.
	• Drone make and model
	• Equipage
	
	Where the drone is piloting the drone (over automated/autonomous operation), details of:
	• Drone pilot's qualifications
	  ○ Validity
	  ○ Policy number
	  ○ rating/limitations (e.g. max weighting of drone allowed to operate)
	• Drone pilot's exemptions
	• Drone pilot's conformance history
	• Drone pilot's flight hours
	• Drone pilot's unique identification number/code/licence
	• Drone pilot contact details
	• Drone pilot name and address
	• Operator details; air operator certificate
	
	Where information does not exist or is not provided, the Deconfliction Service must assume the "least advance" capability which will lead to a larger separation requirement around the flight.

Rationale (O)	For the tactical deconfliction to be able to function effectively, it must have information about cooperative drone flights operating in the deconfliction region.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-DECO.0070

Title (R)	Situational Representation
Description (R)	The service shall include a situational representation of the deconfliction region. The service shall also provide a visualiser of this situational representation. A situation representation of a region is key to tactical deconfliction. It must correlate all information from both the "Environmental Information" and "Flight Information" requirement in order to build a single airspace picture.
Type (R)	Service
Service/Capability name (R)	Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Operational; HMI; Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	The full situational representation brings together information from U-Space Services to form part of the deconfliction service. The complete airspace picture must not only include manned and unmanned aviation but also both co-operative and non-cooperative air traffic. In order to deconflict a region, it is critical to have a current airspace picture so that the location of all object in the region can be identified.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D22-DECO.0060
Title (R)	Data Recording and Auditing
Description (R)	The Service shall record all activity. All activity must be recorded for post analytical review, this includes all inputs, analysis, and rerouting decisions and commands.
Type (R)	Service
Service/Capability name (R)	Tactical Deconfliction; Dynamic Capacity Management
Category (R)	Safety

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	N/A
Rationale (O)	As previously stated in the European ATM Master Plan [6], "RPAS operations must not degrade the current level of aviation safety or impair manned aviation safety or efficiency". For this to happen we must make sure that any accident can be properly investigated and that all decisions made by a UTM can be properly analysed, not too dissimilar to how it is done in manned aviation. Once the data has been recorded, security of the data would be paramount, ensuring the data recording system is tamper prove and only accessed by the appropriate authorities. In addition to supporting incident investigation, traffic data recorded can provide additional benefits. For example, airspace modelling for improving efficiency, understanding the impact of changes to rules of the air; simulate rule changes and study the impact. Utilising modern machine learning techniques to exploit the data in unprecedented ways. Recording all the drone data would be easier to manage if safety-critical decision making was carried out by a centralised system, a single overarching authority coordinating airspace activities and UTM service providers. All traffic-related information relevant to safety, security or privacy would need to be continuously recorded by U-Space traffic management services as evidence in case of the corresponding investigations, as well as to create a base of experimental data from which to learn how to improve operations.
Status (R)	Defined

5.5 Next steps in requirements specifications

The previous sections have been the preamble of the analysis of the different functionalities required by both the researched services and the general structure of U-Space in terms of information management. As a result, an architecture that is compliant with all these needs can be proposed.

The following steps will focus on establishing a relationship between these requirements and the real measures that will be taken in the IMPETUS experiments, so it can be ensured that each one of them is tested and validated.

Finally, once the experiments have been tested, it is expected that more reliable quantitative and qualitative information will be available in order to make a more refined description of requirements focused on real data. This document will be updated with this new information in order to offer a specification of requirements as complete as possible and in accordance with existing technologies (and possible improvements).

6 Implementation of the architecture based on micro-services

6.1 Description of microservice paradigm

The impressive progress in the systems that are part of current infrastructures is a fact, not only in their development but also in our expertise in them. Several technologies, architectural patterns, and best practices have emerged over those years. Microservices paradigm is one of those architectural patterns that has materialised from the world of domain-driven design, continuous delivery, platform and infrastructure automation, scalable systems, polyglot programming and persistence.

The microservices architectural style is an approach to develop a single application as a suite of small functionalities, each one running in its own process and communicating with lightweight mechanisms, often an HTTP resource API. These services are built around business capabilities and independently deployable by fully automated deployment machinery. There is a bare minimum of centralized management of these services, which may be written in different programming languages and use different data storage technologies.

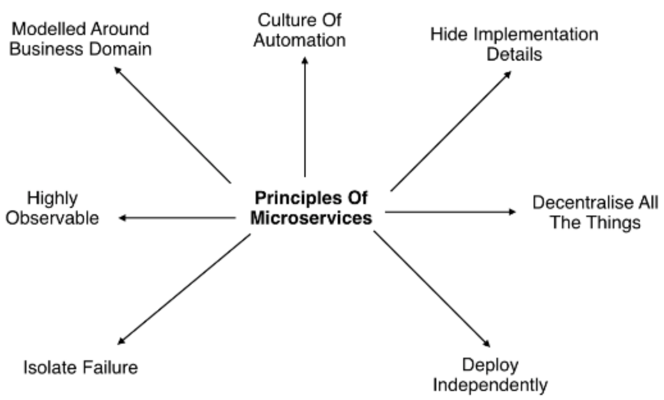


Figure 21. Main principles of microservices.

Implementation of microservices can deliver many benefits to a project application [8], including:

- Easier deployment process: when deploying updates to a particular feature, the entire application does not need to be redeployed, just the service that has to be updated, shortening implementation times and favouring rapid and independent development;
- Use of varied programming languages and technology stacks: Microservices give the ability to use different technology stacks across the services. In huge projects with different teams working on it, this is a clear advantage as every team can work in the programming language that are more confident with. Additionally, this makes it much easier to migrate to different technology stacks than a monolith application;

- Better failure detection: with microservices, it is easier to monitor and detect when one of your services has an issue;
- Enhances continuous integration and deployment: Spreading the application across many different code repositories makes it easier for developers to constantly push changes to their microservices, and also makes easier automation testing.

Surrounding this architecture exists an ecosystem who supports and provides the mechanisms to make it scalable and robust. All these technologies are implemented in some different ways (similar to standards) and the developers just have to decide between which infrastructure fits their requirement (they are offered as a package of modules, ready to be implemented), making easier the development in a microservices architecture.

Some of the characteristics of this paradigm supported by these technologies are the following [9]:

- Autonomous: services are isolated in software containers and virtual machines and the environment manages their continuous deployment and management.

- Decentralized database that can be synchronized with a central DB or a common information exchange layer.

- Failure Resistant: the system is capable of manage the failure of a microservice providing inspection functionalities and reaction mechanisms to failures (automatic deployment, load balance…).

- Evolutionary and scalable: independently developable, the system is not affected by specific modifications.

- Interoperable: Microservices are independent and a common channel is provided to exchange queries, datasets and status reports. This architecture provides that, in case of failure of an intermediate functionality, the entire system does not fail.

- Focused on an objective: developed to fulfil a certain requirement and functionality, leaving other tasks to other microservices or the manager of the architecture.

- Contract of service: communications between services (through the communication layer) are clearly defined and the scope of this exchange is limited.

- Reusable services: the management layer is common to different architectures and the services are independent, so they can be used in different applications (in this case, the architecture of several functionalities can be used in other frameworks, such as the DTM API).

- Known status: the services must send a status message ("heart beat") to the manager of the architecture with their current state.

- Virtualization: services can be deployed in cloud systems and virtual environments.

As any architecture, microservices have advantages and drawbacks that have to be considered before to decide starting the development. The size of the project, resources available, scalability and technologies are some of the topics that must be covered before to take a decision of the architecture chosen. In the next paragraphs, advantages and drawbacks of a microservices architecture will be exposed in comparison to monolithic architectures:

ADVANTAGES	DRAWBACKS
Gives developers the freedom to independently develop and deploy services	Due to distributed deployment, testing can become complicate and tedious
Development by a fairly small team	When number of services increases, integration and managing whole products can become complicated
Easy integration and automatic deployment	Developers have to deal with the additional complexity of a distributed system and communication between services
Services built around business capabilities	More resources are needed to ensure the correct operation.
Better understanding the functionality of a service	As part of a complex system, the communication means are already defined and the flexibility decreases.
Easy to scale and better fault isolation.	The role of the system manager must be clearly defined.

Table 2. Advantages/Drawbacks of microservices.

Benefits of the Microservices paradigm are extensive in front of a Monolithic architecture, but it has to be well-defined in order to get the maximum profit to all the system.

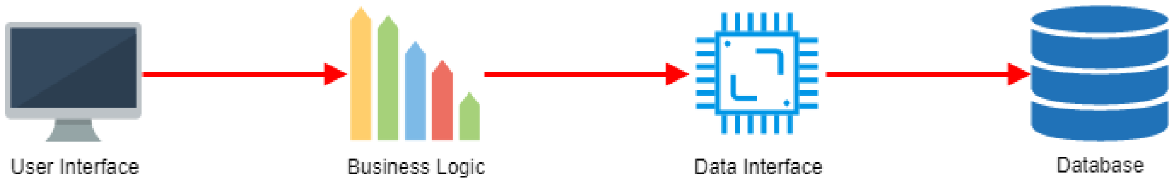


Figure 22. Monolithic Architecture.

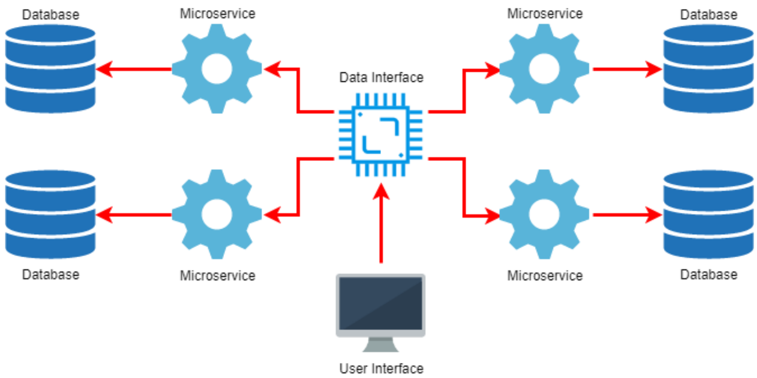


Figure 23. Microservice Architecture

In the following sections, core modules of the architecture will be presented. These modules are a common point in any system that uses the paradigm. They are the support modules that ensure all the described benefits and advantages in front of another solution, and most of them are transparent to the developer (in a programming language, this expression is related to existing applications that are ready to be implemented).

6.2 Core modules

Microservices architecture is supported by a set of standard modules to provide the advantages exposed previously and make the development easier, extracting capabilities as fault tolerance, service discovery, etc. from the actual code that has to be develop [10].

There is a suite of capabilities that make Microservices powerful without taking into account the final technology chosen to deploy it.

MODULE	DESCRIPTION
Service Discovery	Allowing the architecture and other services to find and communicate with each other without hard coding hostname and port.
API Gateway	A proxy, gateway, an intermediate layer between the users and your services.
Load Balancer	It is an Inter Process Communication (IPC) cloud library that primarily provides client-side load balancing algorithms.
Automatic deployment	Automatic creation of instances in case of any fault in the monitored service.
Maintenance	Logging checks in order to detect failures in the past and get a control of the entire system.
Real time metrics	Information at real time of the status of the services, as CPU, RAM, Storage, etc., and number of requests per second that the platform is receiving and activities to prevent failures.
Security	Providing security to access the microservices platform as well as the consistency of the platform in terms of user profile.
Fault tolerance	Platform behaviour in case of failures like unreachable or overload services. If a microservice is not working properly or is overloaded, another instance is automatically implemented to solve the problem.

Table 3. Core modules in microservice architecture.

All these modules can be used by different technologies, but what it is implicit is a Microservice architecture will have the above modules to support the Microservices implemented [8].

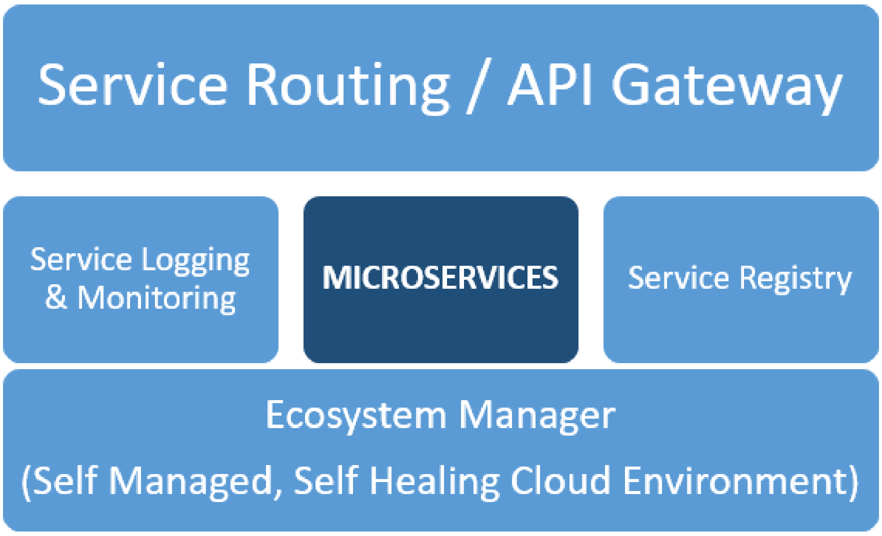


Figure 24. Core Modules in Microservice framework.

The most optimal option of chosen technologies will depend on too many factors, as resources, scope of the implementation, licenses, etc.

The following figures show two different approaches of a microservices architecture. The first one is the actual Netflix architecture, using their own set of technologies developed and implemented by their TI technicians, as Netflix is one of the reference companies using this paradigm and its main precursor. The image shows some of the options that they use, as Ribbon as Load Balancer, Eureka as Service Registry, and so on.

However, this is not the only option; there are so many approaches and tools to implement a project using the Microservice paradigm. Another one could be the second architecture, using Kubernetes to control the creation and monitoring of the dockers linked to the microservices and the cloud to locate the system.

Both are useful approaches with their advantages and drawbacks. The correct decision of the technologies to use in the project must be careful analysed, as it is an important part that will compromise the development or scalability of the entire system.

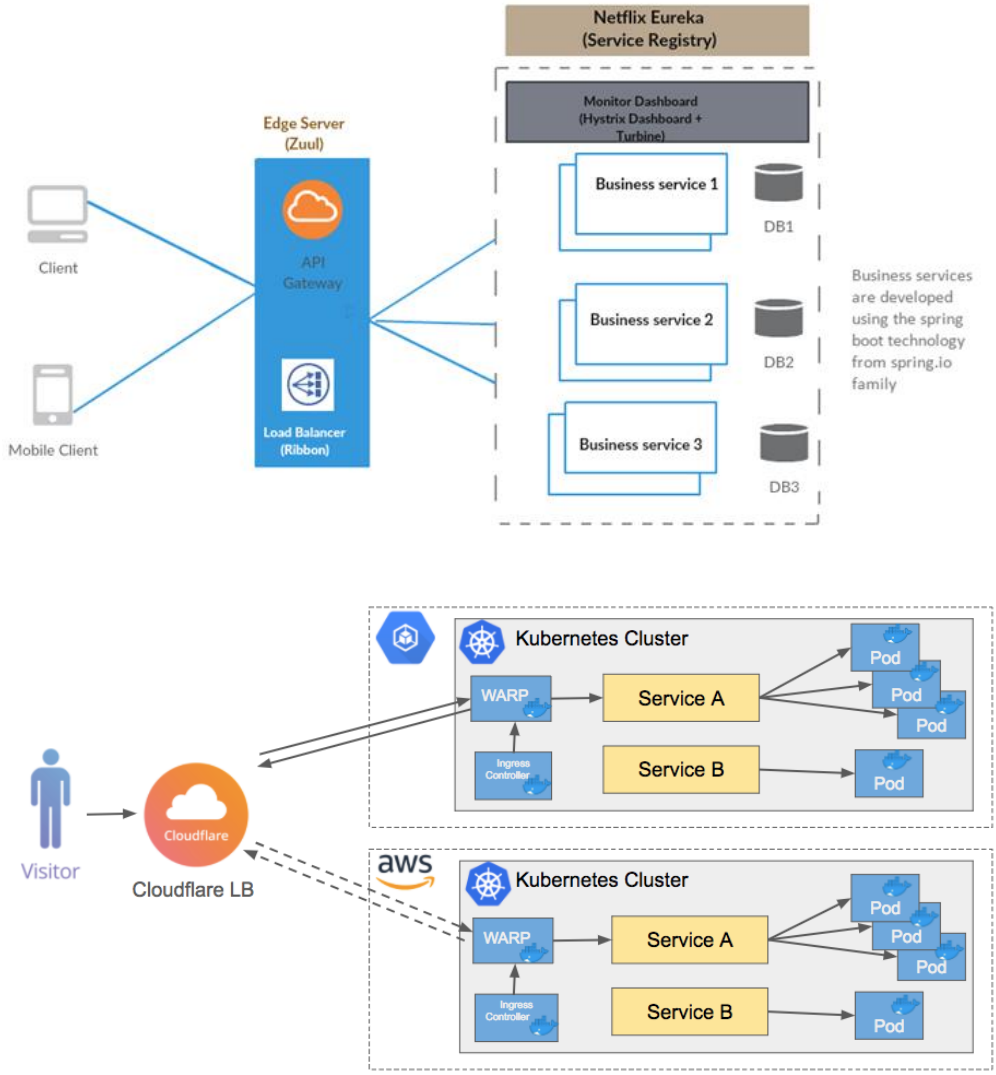


Figure 25. Approaches to Microservices Architecture [11].

6.3 API Gateway

In a microservices architecture, each microservice is exposed to the rest by a specific connection layer [12]. A possible solution is using an architecture of direct communication client-microservice. This allows to users connect directly to the microservice requesting a determine output from them, as it is shown in the following figure.

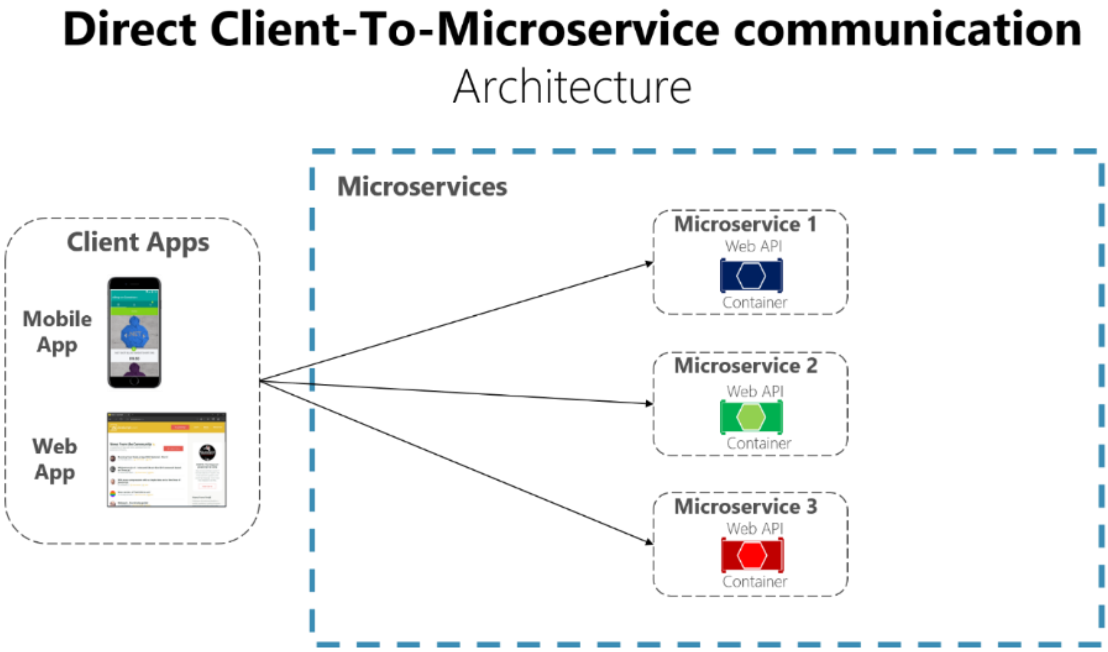


Figure 26. Direct Client to Microservice communication solution [9]

This architecture can be a starting point for a small application. However, when the project grows and requirements are focused on big applications who need complex compilations based on microservices, this solution faces big problems in terms of security, the use of different protocols between services or the development of new versions such as mobile version.

In a microservices architecture, services usually need to use functionalities from one or more microservices. If that request comes directly from the client side, that one is who has to control the access to the connection points of all the microservices. If the application grows and the number of microservices raises, trying to control all this connection points from the client side would be problematic and can become in a very complex process.

In order to solve this problem, an intermediate level, or gateway, was created. An API Gateway is based on a service that allows a unique entry point for a set of microservices, for this reason the gateway is between the client side and the microservices. It works as an inverse proxy, routing the requests from the clients to the services and, on the other hand, redirecting a certain request from services to an identified user. The following figure clearly shows the implementation of this kind of architecture with a gateway.

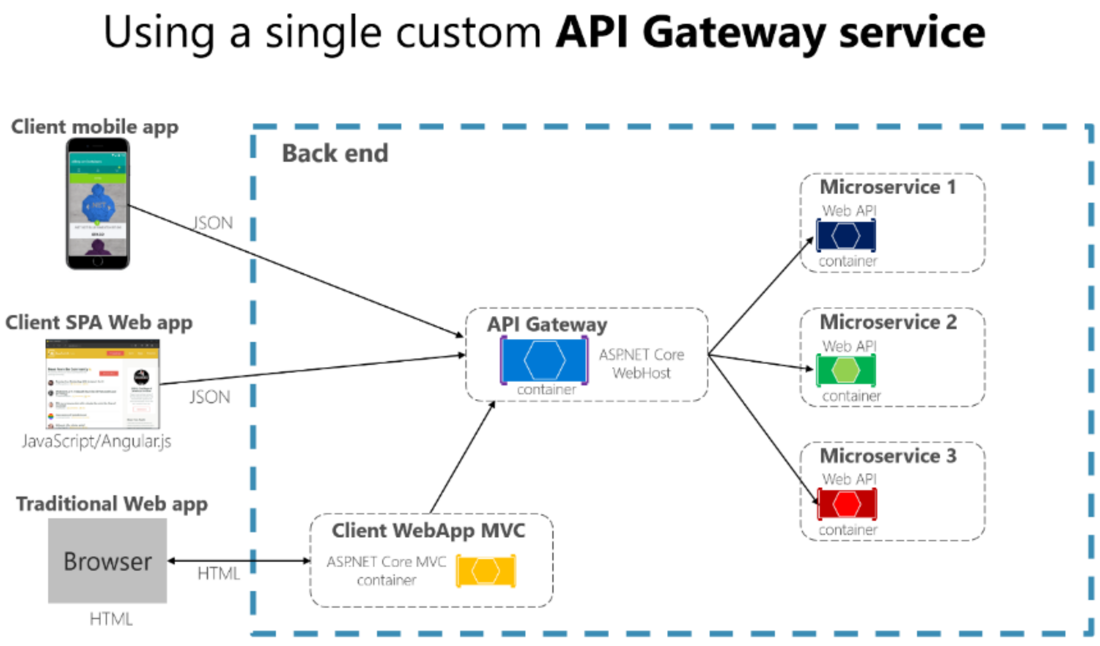


Figure 27. Single API Gateway architecture [13]

The above diagram shows a unique single entry point, API Gateway, customized with connections to different client applications. This can suppose an important problem in the future, because the API will be increasing based on incoming requirements from the client and it will become overloaded with all the requests. For that reason, it strongly recommended the division of the API Gateway in different small gateways, for instance, based on business rules or different types of client applications.

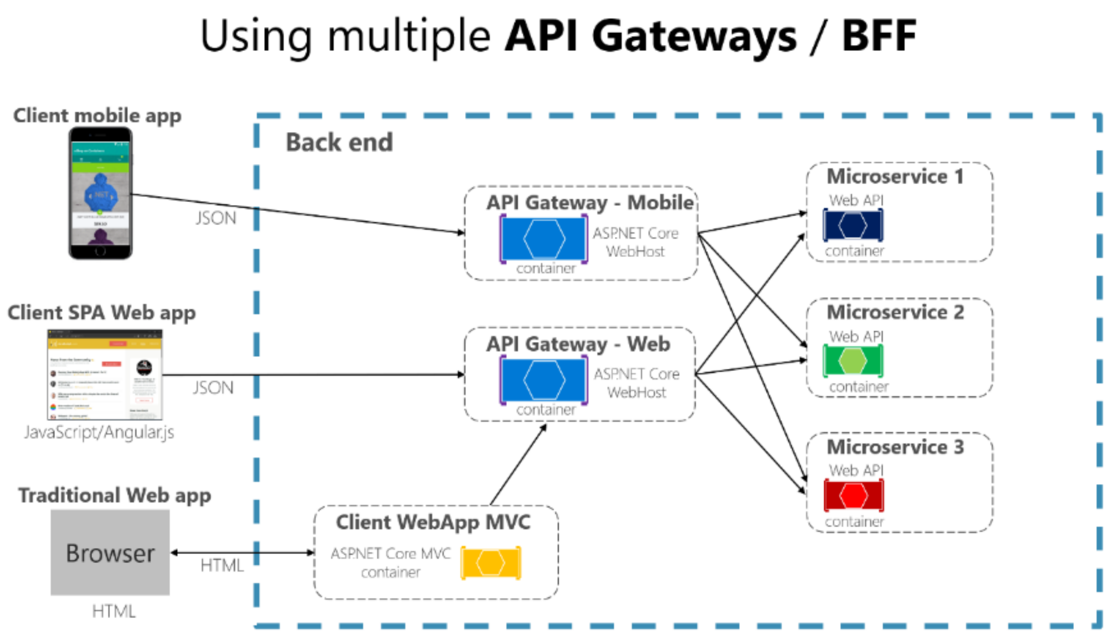


Figure 28. Multiple API Gateways on a microservices architecture [13]

The previous figure shows a model based on this idea. There are different gateways in order to split the incoming requests and avoid overloading in any of them, and then redirecting those requests to the correct services. As the diagram shows, there are different gateways based on client applications, but if the project scope increases, the creation of gateways as a second entry based on business rules is an optimal solution that will improve the performance of the entire system.

API Gateway is a powerful tool that can offer several capabilities and depending on the defined requirements, can offer complex capabilities or just simple ones. The most important and useful characteristics for any API gateway are the following points:

- Inverse proxy or gateway rooting: API Gateway works as an inverse proxy to communicate to the connection points of the microservices. Gateway assigns a unique entry point or URL for the client application, and then, internally links the requests to a set of microservices.
- Aggregation of requests: the possibility of grouping several client requests that need some microservices, in a single request. This is especially useful when a website needs information from different microservices in order to show all the content to the client. In that example, the client application sends a single request to the API Gateway that converts the single request in a set of requests for the different microservices, converting back the solution in a single amount of data that is sent back to the client.
- Simplify service functionality: The Gateway is capable to use some functionalities in order to simplify the implementation of each microservice and consolidating for the whole system some problems, as:
    - Authentication
    - Caching requests
    - Balance load
    - Registration
    - QoS

Therefore, the API Gateway is a crucial module in a microservice architecture that provides an entry clear point from the client and allows and improve the communication between services.

Moreover, it can simplify the microservices implementation and gives the necessary scalability for the incoming requests by developing more than one gateway [12].

Despite these advantages, some drawbacks must be considered when implementing an API Gateway. The most important inconvenient is the connections with the microservices. A not well connection protocol can derivate to huge problems for the application. Another problem that has to be considered, as it was mentioned before, is the scalability of the gateway by creating more than just one entry point, based on the different client applications and business rules. This can become in a bottleneck in the system if the gateway is overloaded. Similar to the last one, if the gateway is being developed by a single team, it can derivate in a bottleneck as well in the develop of the whole system. For this reason, the creation of multiple gateways is a useful point.

6.4 Transmission of information between microservices

In a monolithic application, the modules use function calls or methods in order to communicate directly between them. They can invoke using references to abstract classes instead of instance a determine object. Anyway, objects are executed in the same process. This can provoke inconsistencies in the operation of a certain application, provoking its fail when one of the modules is not able to communicate with the other ones.

Communication in a microservice architecture is far more complicate than a monolithic application. A project based on microservices is a distributed system who is executed in different process or services, usually even in different servers or hosts. Commonly each instance of a service is a process. For that reason, services have to interact using protocols, as could be HTTP, AMQP or a binary protocol as TCP, depending on the behaviour of each service.

The most common protocols are HTTP with API for the communication to the client, and asynchronous messaging to cover the communication between services. In the next paragraphs both systems will be explained.

Client and services can communicate through many types of communication, each of them focused of a determine scenario. Those communications can be classified in two types.

- Synchronous or asynchronous protocol:
  - Synchronous protocol as HTTP: a client sends a request and waits until the response get back. This is independently from the code execution that can be synchronous or asynchronous. Anyway, client cannot continue without the response.
  - Asynchronous protocol as AMQP: client code or the service do not wait any response, it simply sends the message to a queue, waiting to be accepted and processed.
- Communication to a single or multiple receptor
  - Single receptor: each request must be processed by a single receptor or service.
  - Multiple receptor: each request must be processed by a zero or multiple receptors or services. This kind of communication must be asynchronous. An example of this mechanism is the subscription to an architecture of events that will be detail explained in the next paragraphs.

A system based on a microservice architecture often use a combination of communication protocols. The most common is a single receptor using a synchronous protocol as HTTP/HTTPS to invoke a service HTTP Web API. In addition, an asynchronous protocol for the internal communication between microservices.

Ideally, the communication between services must be minimize at a minimum required. However, sometimes that is not possible, so the main rule is to use asynchronous protocol to cover those cases. The objective of every microservice is being autonomous and ready for any client request at any time, so if the system uses a synchronous protocol, the service can be unreachable until the request is process, or can affect to the performance of the service, provoking the cascade of the error to all the services.

One of the most common cases is the need of data from another microservice. To try to avoid the synchronous communication between those services, a good idea is the duplicity or replication of the data that is need by the service to its own database, so this will improve the entire performance of the system and reduce the amount of communication internally. Anyway, the use of a cache to process real-time information and the replication of the databases of all services (as another microservice of the architecture) can also be proposed to provide a common information point for all the functionalities implemented.

Usually, communication of the services outside the docker host or microservices cluster will be using synchronous protocol as HTTP and REST and using message formats as JSON or XML.

The following figure [12] represents the communication with HTTP and REST (representational state transfer). Client sends a request to the system, this process it and send it back. This is really useful to query data in real time from client application.

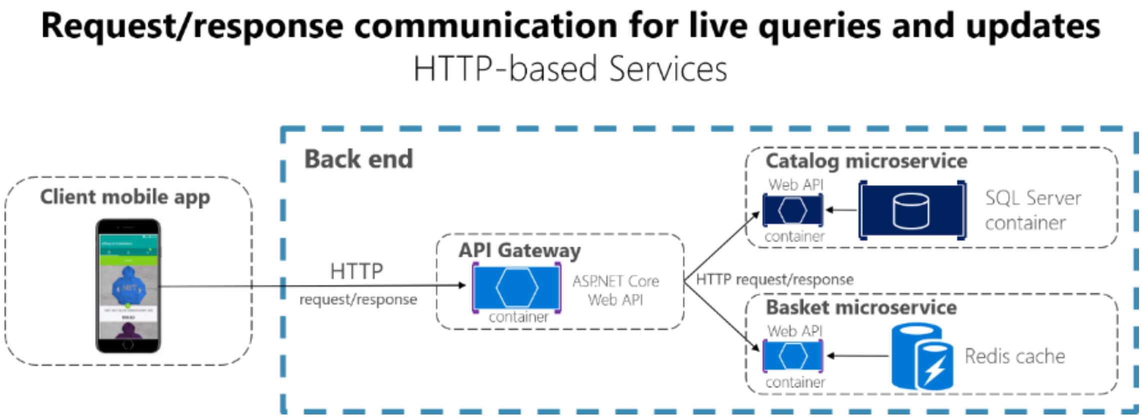


Figure 29. HTTP Communication. [13]

REST is pretty similar and is based on HTTP, because it adopts capabilities as GET, POST and PUT, exactly equal as HTTP. REST is one of the most used communication architecture, used in extensive deployments such as the World Wide Web.

On the other hand, there is the asynchronous communication and the event-driven communication that can be used to propagate changes between microservices.

There are two types of asynchronous communication, based on messages to a single receptor and based on messages to multiple receptors.

- Communication based on messages to a single receptor: there is a communication point-to-point that sends the message to one of the consumers who is reading the channel, and the message is only processed once. This is ideally implemented to send asynchronous command from one microservice to another, as it is shown in illustration 10.

- Communication based on messages to multiple receptor, as it was mentioned before, this is event-driven communication. A microservice publish an event when something has happened. The other microservices are subscribed to any change in order to receive information when something changes. Once this happen, the information will be propagated to all the services subscribed, so all the microservices will have the information updated. The illustration 11 shows an example of this type of communication.

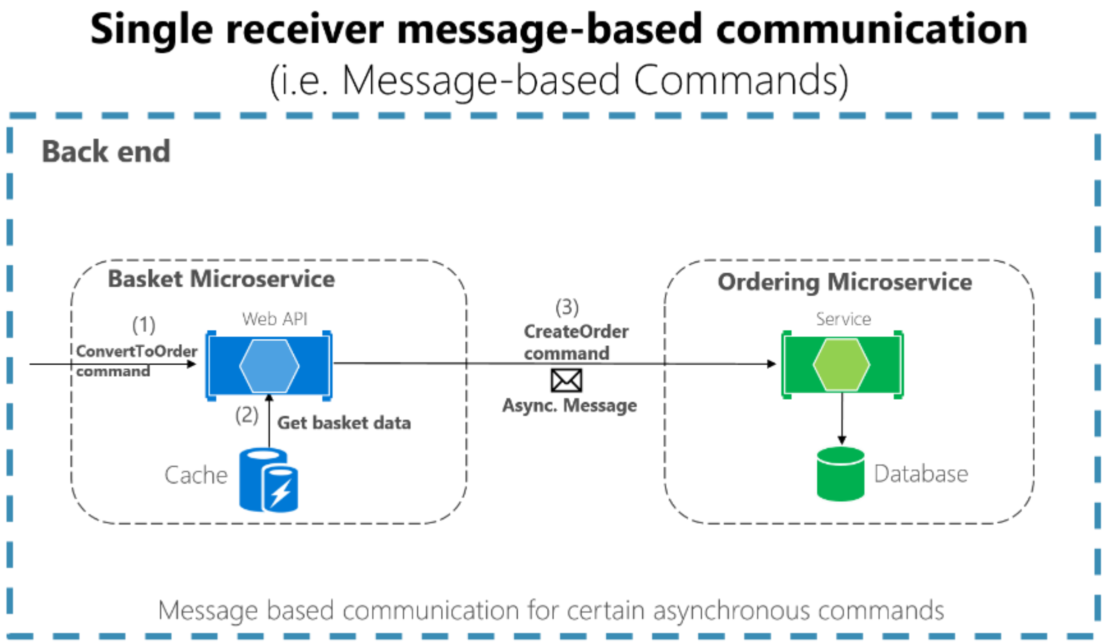


Figure 30. Asynchronous communication [13]

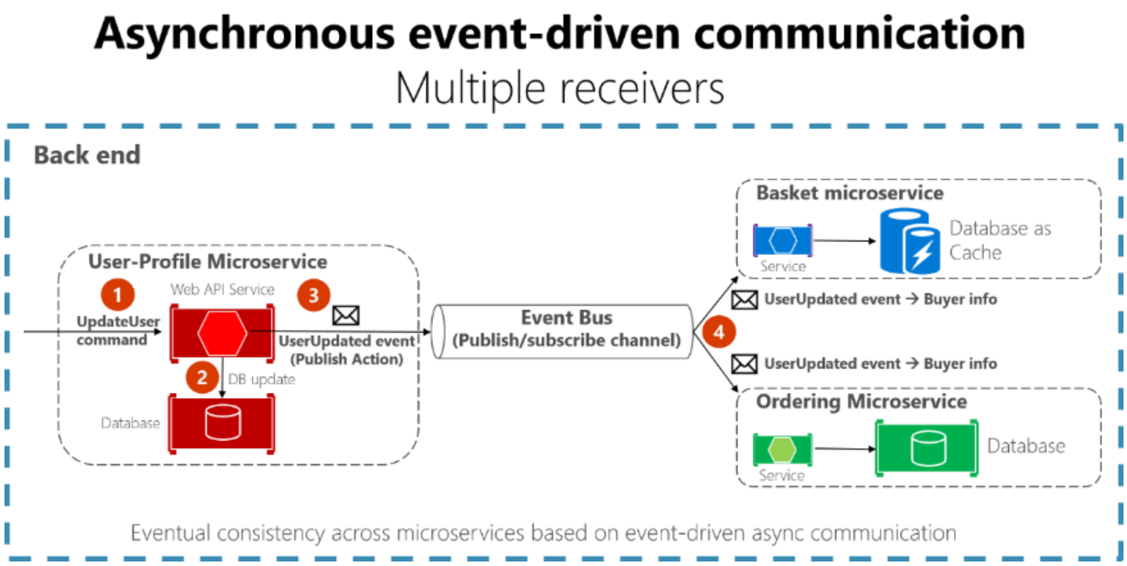


Figure 31. Event-driven communication [13]

6.5 Information management examples in Microservice architecture

6.5.1 Microservice Registration

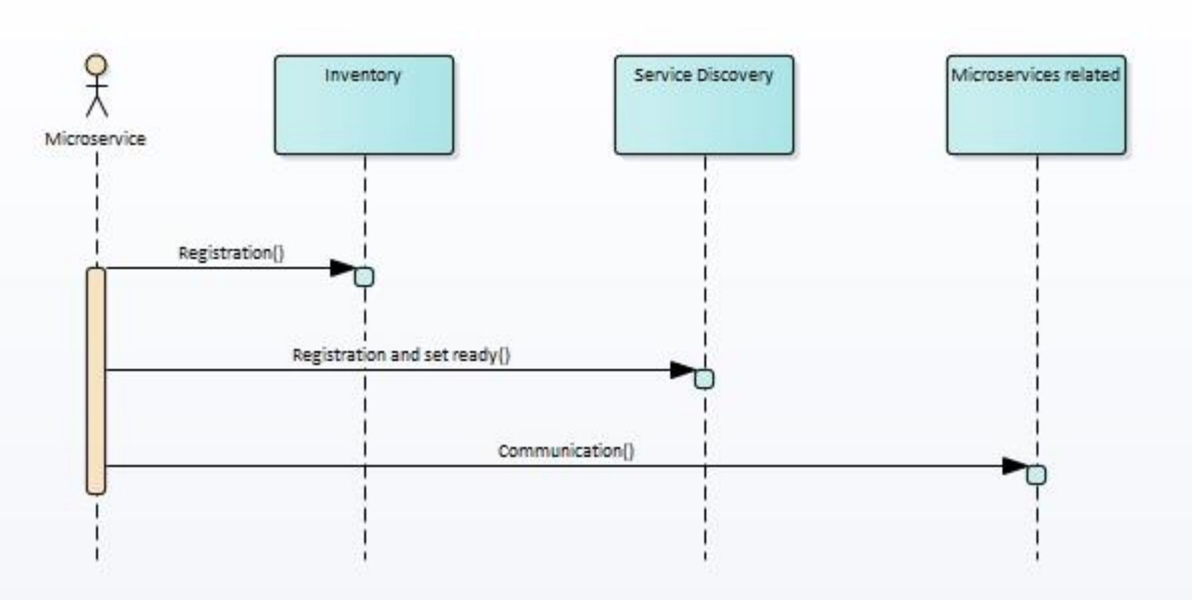


Figure 32. Microservice registration process.

1. **Registration**: the microservice is registered in the inventory.
2. **Registration and set ready**: once the microservice is ready, it will be communicated to the Service Discovery module.
3. **Communication**: the microservice will communicate to the rest of microservices belong to the same service that he is operative and can start processing data.

6.5.2 Information request to another service

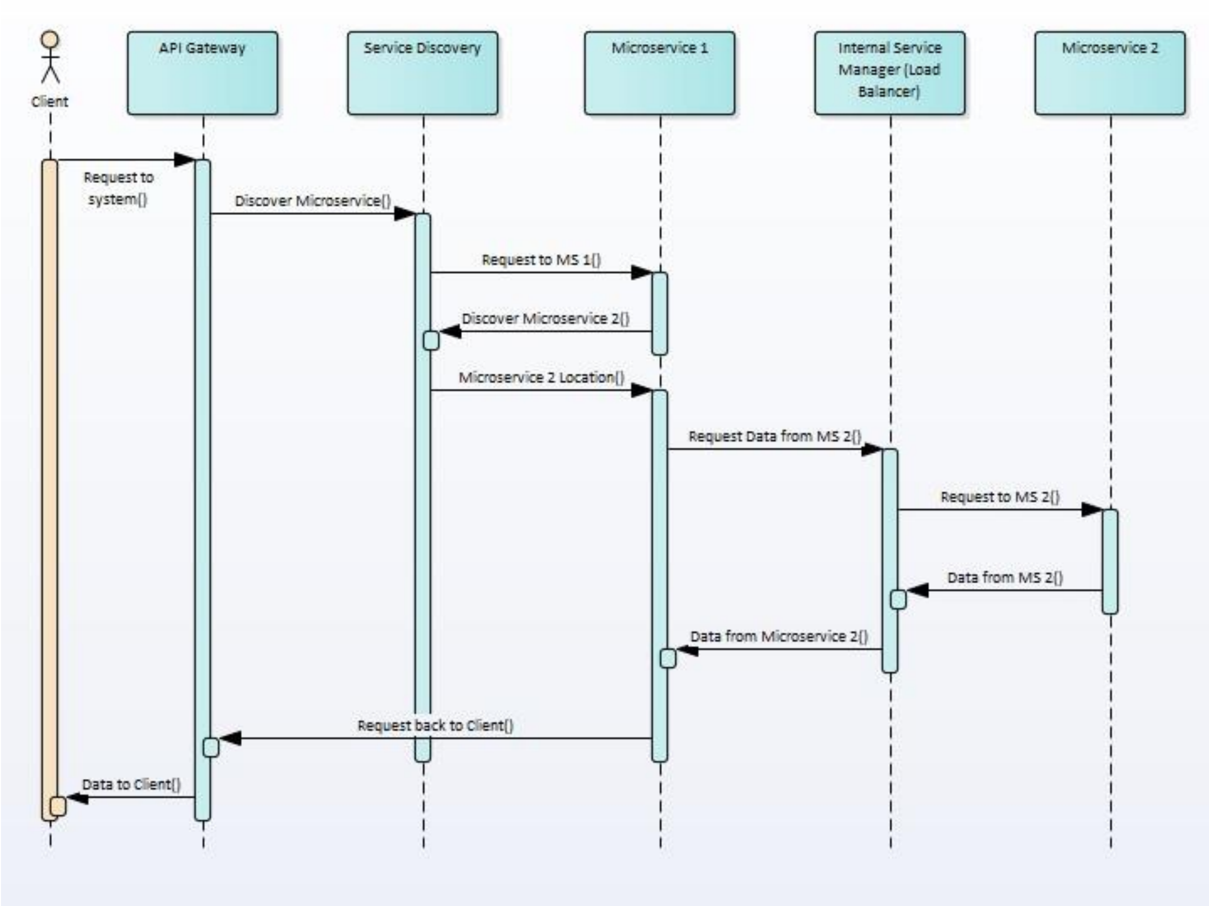


Figure 33. Information request in microservice architecture.

1. **Request to system**: the client sends a request and it is managed by the API Gateway.
2. **Discovering the Microservice**: API Gateway is the responsible of the security and resends the request to the proper microservice.
3. **Request to MS 1**: service Discovery handles the request for the microservice and check in its system the instances raised in order to choose the proper one and send the task.
4. **Discovering Microservice 2**: microservice 1 needs information provided by another microservice, so it will get the location from the Service Discovery.
5. **Request Data from MS 2**: the microservice requires data from another service. It raises the request to the Internal Service Manager.
6. **Request to MS 2**: internal Service Manager takes the request and send it to the proper microservice, taking care of the load of each instance.
7. **Data from MS 2**: microservice 2 gets the task, process and send it back to the microservice 1 who asked for it.
8. **Request back to Client**: microservice sends the data for the request back to the Gateway.

9. **Data to Client**: client gets the data.

6.5.3 Microservice failure

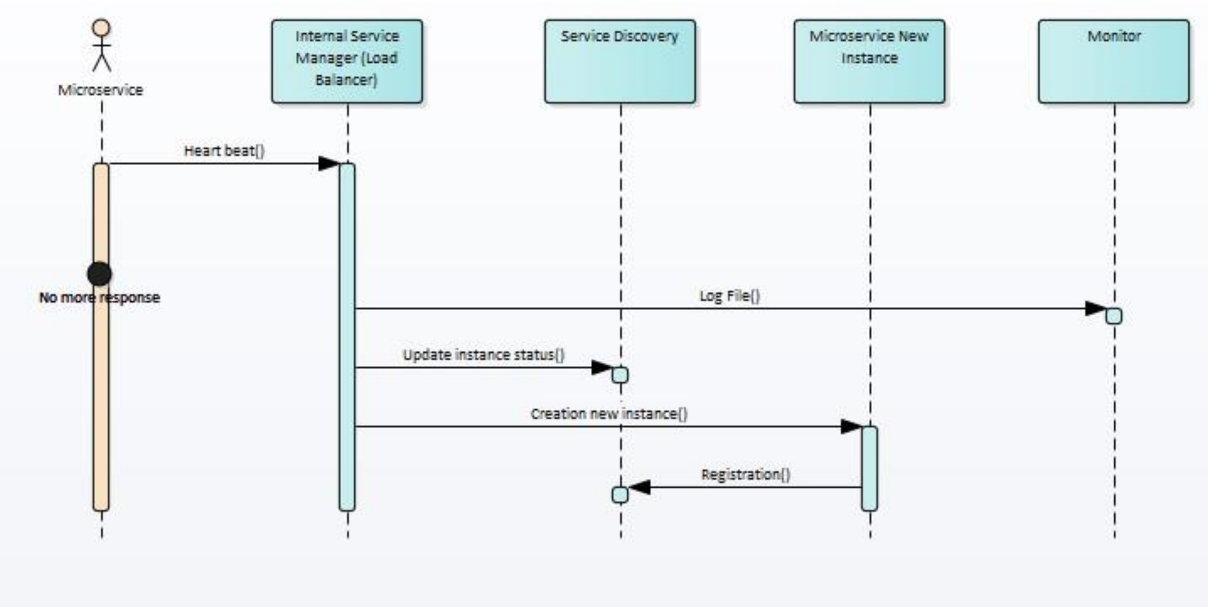


Figure 34. Microservice failure detection.

1. **Heart beat**: constantly Internal Service Manager is monitoring the status of the microservices.
2. **No more response**: microservice starts to not response anymore and it is unreachable
3. **Log File**: meanwhile, monitor service will keep the log file from the microservice, monitoring at real time all the process.
4. **Updating instance status**: Intern Service Manager communicates to the Service Discovery the status of the current instance and the Manager updates its own list.
5. **Creation of new instance**: Intern Service Manager detects the failure and instantaneously creates another instance exactly equal to the microservice.
6. **Registration**: manager registers the new microservice and refer it for the new requests.

6.6 Identification of U-Space services with Microservices

Microservices paradigm is a powerful architecture that can improve the performance of most of the systems. Moreover, it provides a huge scalability to support the big amount of data that nowadays is generated. However, it has to be created carefully in order to not compromise the system that can result in a low performance in some cases or even a performance lower than a monolithic implementation. For this reason, the architecture concept is a large and deep analysis that need to consider so many points such as the quality of the network, hosts configuration, technologies and especially the creation of the microservices themselves.

In the above paragraphs, the characteristics of the microservices have been exposed. They have to be autonomous, scalable, focused on an objective, etc. In the same way, communication between them should be minimized to reduce the latency that the network can produce, though it is not a bad practice, and it is quite common, if that happens inevitably.

In order to give more clarity to this paradigm, and associating it with the IMPETUS project and the identification of U-Space services, some examples will be presented as possible microservices. That not means the examples are a final solution, but indeed can shed light on a possibly architecture of the project.

U-Space contains a suite of services working together. Services have been identified and explained deeply during the project, identifying its capabilities and sources. Translating them to a microservice architecture does not means a direct conversion. One service does not mean a microservice. Instead, a service can be split in different microservices, depending of the functionalities and complexity that the service itself has. In the same way, sometimes a service can become in a microservice, corresponding exactly with the service identified in the U-Space. This fact can be shown in the following figure. Traffic monitoring can be split in a set of microservices, each one with their own functionality and working autonomous, and this information can be used by more than one microservice.

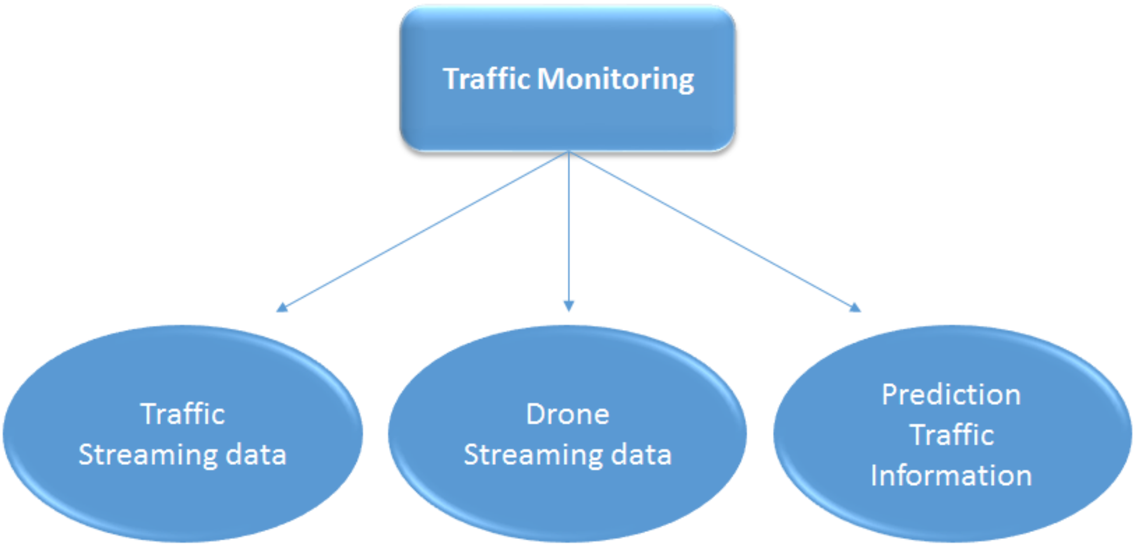


Figure 35. Possibly implementation Traffic Monitoring service in a microservice architecture

6.7 Requirements for a microservice-based U-Space architecture

Based on the previously defined capabilities and their clear relevance with U-Space environment, several requirements for this architecture has been identified:

Identifier (R)	REQ-IMPETUS-D31-MSAR.0010
Title (R)	Access to a service

Description (R)	The architecture shall provide a common entry point to the system and then the request will be redirected to the proper microservice. This requires an API Gateway to be the entry point and handle all the requests.
Type (R)	Service
Service/Capability name (R)	Information Management (API Gateway)
Category (R)	HMI, Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	A client access to the service for any purpose, like could be a request for a mission plan, log in or check the mission plans history, due to the heterogeneity of the needs and protocols must be standardized using a common entry point that will be in charge of defining the appropriate rules and communication means for being part of the information exchange process.
Rationale (O)	The architecture supporting the core modules of U-Space ecosystem must be designed to provide a fair access to all users under the same conditions.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0011
Title (R)	API Gateway
Description (R)	An architecture based on the deployment of API Gateways shall be the core module of the architecture, acting as a management layer in charge of redirecting the different messages between the microservices and roles involved in the communication process.
Type (R)	Service
Service/Capability name (R)	Information Management (API Gateway)
Category (R)	HMI, Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	Establishing common information exchange layers for all the participants in the transmission and reception of information is required in a coordinated environment in which this information will be used to establish the main status of the whole system for all of them.
Rationale (O)	This requirement is the result of the variety of information, roles, processes and the permissions of accessing certain datasets by the users.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0020
Title (R)	Intercommunication microservice-microservice and microservice-client.

Description (R)	The service shall handle the communication between microservices with a high-level performance in order to do not affect the system and discover the proper instance that can solve the request.
Type (R)	Service
Service/Capability name (R)	Information Management (Service Discovery)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The information exchange process between microservices and clients shall be supported by a robust platform with the capacity of adapting its functionalities to the current situation for a certain area and number of data providers and consumers, ensuring the quality, integrity and traceability of the information.
Rationale (O)	The development of a fully-autonomous platform, a self-managing and self-sufficient system is essential It is necessary to measure the information that is collected, the information that is provided and the behavior of the system in relation to all the possible states.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0021
Title (R)	Time delay microservice-microservice and microservice-client
Description (R)	The time of a complete lifecycle of the information (starting from a request, being processed by one of more microservices and, finally, provided to the user) shall not compromise the purpose of that request.
Type (R)	Service
Service/Capability name (R)	Information Management (Service Discovery)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	As one of the key parameters in information exchange, the time delay between a request and a provided dataset shall be enough to avoid emergencies, act to them and provide a complete view of the environment in a time in which these changes are relevant to the user. Low latency will be ensured by atomizing the functionalities of a service in modules without a costly storage operation and ensuring in-stream communications.
Rationale (O)	The necessity of real-time for certain services and the expected status of U-Space based on predictions are key requirements of most of the services in the orchestrator's platform and the communication interfaces with clients.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0022

Title (R)	Inputs of microservices
Description (R)	Each microservice shall define the parameters that is able to process and use to provide a valuable output and this information will be available for the information management system.
Type (R)	Service
Service/Capability name (R)	Information Management (Service Discovery)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The information management layer is in charge of redirecting the requests to the proper services, modifying them to ensure that all the inputs are covered and the input format is also compatible with the service in question.
Rationale (O)	The Technical description of each information exchange architecture shall provide a clear view of the information exchange process in terms of interfaces, inputs, outputs and required algorithms to implement a certain functionality.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0023
Title (R)	Outputs of microservices
Description (R)	Each microservice shall define the parameters that is able to provide after processing the inputs from data sources and this information will be available for the information management system.
Type (R)	Service
Service/Capability name (R)	Information Management (Service Discovery)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The information management layer is in charge of collecting the outputs of these services and redirect the requests to the proper services, modifying them to ensure that all the inputs are covered and the used formats complies with this layer and, as a consequence of the previous requirement, with the service that has executed the request.
Rationale (O)	The Technical description of each information exchange architecture shall provide a clear view of the information exchange process in terms of interfaces, inputs, outputs and required algorithms to implement a certain functionality.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0024
Title (R)	Information format
Description (R)	The formats of information exchange shall be defined to provide a complete communication process and ensure that no dataset is lost during the process.
Type (R)	Service
Service/Capability name (R)	Information Management (Service Discovery)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	For both environments, microservice-client and microservice-microservice communications, a common standard framework is necessary and must be adopted by all the participants to ensure that all the information that is requested and sent is following the same rules and providing the expected information.
Rationale (O)	As part of an information management system, the rules of information shall be defined prior to the development of it and the different cycles shall be defined, covering all the participants (current and foresee) and, if necessary, the evolution in the information datasets.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0030
Title (R)	Microservice overloading
Description (R)	The service shall identify when a microservice is overloaded and, in that case, create another instance in order to handle the incoming requests until the other instance will be able to take more.
Type (R)	Service
Service/Capability name (R)	Information Management (Load Balancer)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The status of microservices will be measured using predefined metrics and limited to a certain (o a variety of) service level. As a support, it is possible to include other core modules that will have an update list of the microservices and their instances that currently are available to receive requests
Rationale (O)	Redundancy in safety-critical architectures is an essential part of these systems, enabling them not only to ensure the availability of information, but the replacement of a module with no affection to the integrity of the whole framework.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0031
Title (R)	Status monitoring
Description (R)	The architecture shall be supported by a module in charge of detecting issues in the execution of the services, informing the system when there is an issue that can compromise the performance.
Type (R)	Service
Service/Capability name (R)	Information Management (Status Monitoring)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	All the modules shall provide to this service periodic reports about their status, in which the following information shall be included: - Service ID. - Associated Functionality (U-Space service in this case). - Metrics. - Current status. - Time between the request of the status and its provision.
Rationale (O)	A self-managing system shall be able to detect using, its own implementations, any inconsistency in the information process between all its modules, providing auto-reporting capabilities and autonomously solving the existing incidences.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0040
Title (R)	Control of the available instances.
Description (R)	The service shall raise new instances of any microservice if it is necessary, and reduce them, even to no one, when there are no requests
Type (R)	Service
Service/Capability name (R)	Information Management (Automatic deployment)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The flexibility in the demand of U-Space and its future evolution will lie in the scalability that the system that supports it can provide and its cost will be associated with an intelligent management of resources.
Rationale (O)	A self-managed system, after measuring the necessary metrics, is able to detect which elements are in operation and their status, in such a way that it can enable or disable those modules that it deems necessary and, therefore, adapt to the demand of the whole by optimizing both the effort as the cost.

Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0050
Title (R)	Request to microservice
Description (R)	The service shall check the availability of the microservice and send the request to the best instance in order to do not affect the system and the client.
Type (R)	Service
Service/Capability name (R)	Information Management (Service Discovery)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The service discovery module is in charge of redirecting the information to the appropriate service taking into consideration the global status and performance of the required functionalities and requesting, when necessary, the provision of new (duplicated) modules.
Rationale (O)	Requests between microservices shall avoid any interaction with other microservices in order to get data or process any information, being as most independent as possible and the system shall be in charge of redirecting these request to the appropriate microservice based on expected outputs, performance indicators and service availability. Anyway, sometimes it cannot be avoided, and the communication shall be precise and short to not compromise the performance of the whole system.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0060
Title (R)	Metrics of the system
Description (R)	The service shall provide metrics of the whole system (including external modules) continuously with all the instances of the microservices created and their performance, network and identifying the status of the modules that control the system.
Type (R)	Service
Service/Capability name (R)	Information Management (Real time metrics)
Category (R)	Security, Performance, HMI
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	Real time metrics will be available for the platform and for administrators of the system. Moreover, in case of any problem or loss of performance of the system, before crashing, an alert shall be raised to alert the administrator depending on the criticality and the creation of a new environment shall be implemented.

Rationale (O)	The performance of the complete system lies in the measurement of internal parameters (referred to the architecture itself) and external parameters (referred to the additional modules and the interaction with the client), which must be measured and monitored to prevent failures especially in operating architectures critical.
Status (R)	Defined

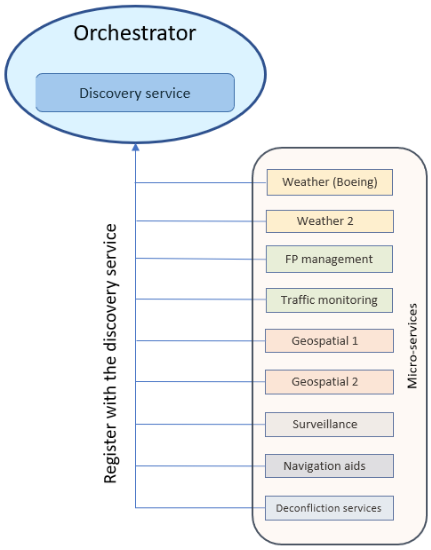
Identifier (R)	REQ-IMPETUS-D31-MSAR.0070
Title (R)	New registration of a microservice
Description (R)	The service shall register to the system as a new microservice in order to be contacted when a request needs some data or process from it.
Type (R)	Service
Service/Capability name (R)	Information Management (Service Discovery)
Category (R)	Performance
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	Once a new service (internal, redundancies or external) has been deployed and is ready to be part of the information exchange process, this service will be able to register in the Core architecture as a data manager and will be part of all the processes involved in this platform, providing not only a methodology to include new capabilities but the possibility for external clients to provide valuable datasets for the system and their clients. This requirement is linked with the e-Registration for USSP services.
Rationale (O)	The platform that will be the Core of U-Space shall fulfil two main requirements. - Quality assurance: ensuring the performance of the complete system by collecting metrics and detecting the inconsistencies. - Evolution in time: atomizing the functionality and ensuring the standardization will provide the scalability system that will allow the addition of new modules and new needs.
Status (R)	Defined

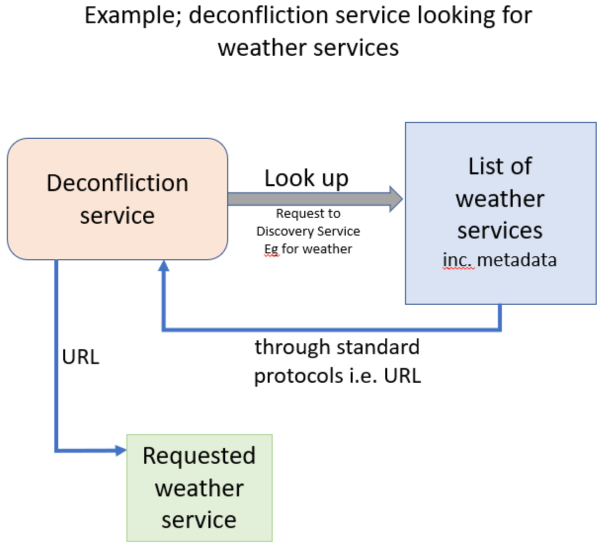
Identifier (R)	REQ-IMPETUS-D31-MSAR.0080
Title (R)	Microservice unavailability
Description (R)	There shall be service in charge of detecting, send an alert to the administrators and raise another instance as soon as possible.
Type (R)	Service
Service/Capability name (R)	Information Management (Fault tolerance)
Category (R)	Performance

Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	All the instances create log files with real time information of all the processes. In case of a microservice is not reachable, an alert shall be sent to the administrator and the module shall create another instance.
Additional information (O)	The rules of the architecture shall be defined in terms of performance (processed datasets/time), time delays, integrity of the information, loss of information and workload. If one of these issues becomes important, the system will not work properly threatening its operation.
Rationale (O)	As part of the monitoring process, microservice architecture shall have a module (or modules) to collect the metrics from all the available services and another module (or modules) that will use them (being fed by the API Gateway) that will address the consistency and integrity of these measurements and raising and alert when necessary.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR.0090
Title (R)	User levels
Description (R)	The service shall provide different accesses and perspectives of the system based on the user groups.
Type (R)	Service
Service/Capability name (R)	Information Management (Security)
Category (R)	Security
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	The main manager of the system, together with the authorities responsible for the validation, identification and registration of each of the participants, will have more extensive access to the information contained and external agents should be limited, except for rules established through different contracts, to the information necessary for its operation.
Rationale (O)	A set of roles must be defined in an information exchange environment in which the level of access to datasets should be identified, the possibility or not of modifying them, the scope of this access, the limitations envisaged, the communication methodology and the measurement of the integrity in the different interactions. These roles can be identified, in this case, by the level of authority over U-Space of these roles.
Status (R)	Defined

Identifier (R)	REQ-IMPETUS-D31-MSAR-0100
Title (R)	Discovery service
Description (R)	A solution is required to enable the discovery of micro-services with the U-space system. Each micro-service needs to be registered with the nations

	U-Space Discovery service so that consumers of this service can seemly (and in a standard manner) access the value they bring.
Type (R)	Capability
Service/Capability name (R)	Operations management
Category (R)	Functional, security, reliability, performance, data, design
Environment type (R)	Rural; Suburban; Urban; Maritime; Forestry
Additional information (O)	There is a requirement for a management service to (manage and even control the available micro-services offered. In this implantation, there will be a single centralised discovery service, however there is scope for a competitive (discovery) marketplace model. Each micro-service will need to register their service capabilities (and other information) with the Discovery Service, enabling potential consumers of services to select a best fit. Discovery service registration 
Rationale (O)	There is potential for companies to offer numerous services to facilitate safe and efficient drone traffic management. All the services on offer could have differing levels of service at different costs (for different use cases), therefore a company requiring the services of a micro-service will need a clear understanding on what's being offered, by whom and for how much. An example of this would be weather services; these services could vary greatly, from very basic weather information such as wind and pressures to highly complex, hyper localised weather information.

	The registration by the micro-service providers of their service capabilities, service contract (Service Level Agreements (SLAs)) and price will allow the customer to take decisions about which service provider to connect with. 
Status (R)	Defined

6.8 Example of a microservice-based architecture

A practical implementation of the previously described requirements and the relation between the different modules can be seen in the following picture.

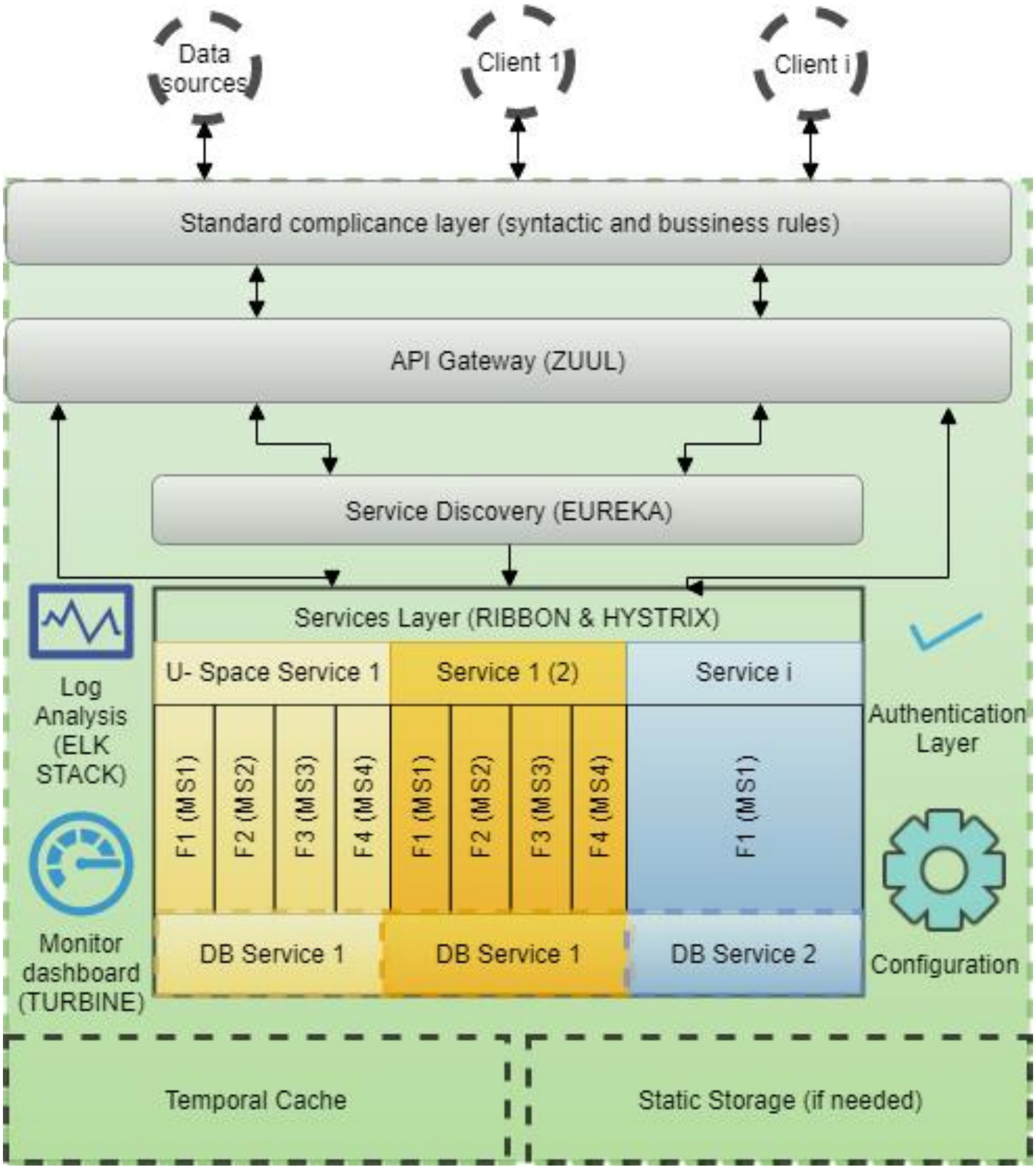


Figure 36. Microservice architecture for U-Space

The technologies used in this example are:

- **Eureka (Service Discovery)**: allowing services to find and communicate with each other without hard coding hostname and port;
- **Zuul (API Gateway)**: an intermediate layer between the users and your services acting as the information exchange layer, ordering requests and redirecting them to the proper consumer;
- **Ribbon (Load balancer):** as an Inter Process Communication (IPC) cloud library that primarily provides client-side load balancing algorithms, fault tolerance and provides configurable load-balancing rules;

- **Hystrix + Turbine (Real time metrics)**: library created to improve the behavior of the microservices system in the face of falls in some of its services and avoid cascade failures.

The key features integrated in this architecture are described below, establishing its analogy with U-space requirements.

- The capability of offering **a common interface** for clients and data sources based on a defined standard that will be implemented in a validation layer (as first step to the definition of a common standard for information exchange by the Orchestrator and the provision of a communication interface with its services through its validation rules);
- The existence of a common information exchange layer (API Gateway) which is receiving the information and, based on a set of predefined rules, datasets and requests are redirected to the proper consumer of information (information exchange between services and the different roles involved using a well-defined standard). This layer can be instanced in terms of the operation levels (scalability of the system, ensuring the availability of U-space services);
- The Service Discovery module in constant communication with the API Gateway as a support to detect the new services available (not only from the Orchestrator, but from USSPs that can be part of U-Space ecosystem) and the most appropriate one to be the processor of the information (same instances of the same service can be activated, focused on a certain area or time frame), the manager of the instances to be used and the main connector with other services that can be part of the architecture (related to overload and information exchange between U-space services);
- A service layer in which containers are deployed, offering a certain functionality (or set of capabilities) in each module. These modules can be focused on a certain U-Space service (in case of simple actions), a certain functionality of a U-Space service (offering a structure that will be part of this U-space service) or a redundancy in the same service implemented to balance the load of the system;
- The U-space services included in the service layer are not restricted to a certain architecture. If they are able to connect with this layer, their internal structure can be implemented using different business approaches, depending on the interests on the USSP;
- The storage units, divided into a temporal cache for real-time processing (ensuring the availability of information and low latencies for crucial U-Space services) and static datasets to be stored in databases and used for the services to provide outputs based on historical and statistical data (to predict future status and store information about planning phases);
- An authentication layer, acting as a registration module in which the services (both existing and new ones), the clients and data sources must be validated to be part of the ecosystem (which will provide e-Registration and e-Identification functionalities);
- A configuration layer, in which the rules of the architecture are defined and the configuration parameters are set (providing the Orchestrator with information management capabilities), so the system is capable of self-managing its own operation, including the creation of new instances of a certain functionality (or service for simple tasks), redundancies and the sharing of workload (autonomous framework that is flexible enough to adapt itself to the current demand and prevent issues in its operation);

- Monitoring and log analysis modules, in charge of detecting issues and inconsistencies in the information management in the architecture and the incidences in the operation of the set of modules (not only services but also other layers in the system) implemented.

Standardization of these types of architectures is providing a simple deployment based on well-known interfaces and rules and a wide variety of self-configuring applications, together with a continuous evolution, findings and active support in these type of developments.

7 Conclusions

In this document, the information needs of the future U-Space information system (defined in [1] [2]) have been analysed from different points of view: generation, content, transmission, processing, time, performance, interfaces, contract requirements, criticality of the data, expected outputs, nature of the information, time frames or spatial location. The focus was on a set of previously decided services and operational use cases, which has helped the consortium **to elicit the requirements in specific cases** and with immediate application, allowing a more precise approach to their needs and short-term evolution as well as the identification of common requirements transversal to critical services (e.g. scalability and redundancy of functionalities).

On the other hand, as a key objective of the IMPETUS project, an **information management architecture based on microservices** has also been analysed. Based on a federated framework for the assignment of the U-space roles and responsibilities, this document has established the basis of the different layers that compose this type of architecture, the flow of information between the different modules, the role played by both the sources and the consumers of information and a first approach of its implementation in U-Space, establishing an analogy between services in a microservice architecture and U-space services to be implemented. In this way, a series of requirements that this type of systems must fulfil have also been indicated.

As a result, a certain alignment between the real needs of U-Space (from both services and the different roles participating in U-Space) and the objectives that the architecture of microservices aims to achieve (and that, using the proper configuration, can be implemented) can be observed. The information processing capacities (real time, based on a functionality, with certain levels of restrictions and completely defined information flows), the high performance required (not only in information quality through its validation, but in scalability and availability), the connection with the segment that is not part of the Orchestrator (as consumers and data providers that will be able to connect and disconnect from the system and whose status will be controlled) **can be supported with an architecture based on microservices** in which each functionality can be atomized as estimated.

However, this consortium recommends that this architecture should be submitted to demanding, high performance tests in both simulated and real environments in order to reliably verify that the capabilities and benefits projected by this architecture are as expected. In addition, due to the high demands that this type of systems entails, the hardware infrastructure that will serve as support must not only provide a solution to this level of information exchange, but must also be scalable in such a way that it can respond to the exponential growth of the expected demand.

As next steps of the IMPETUS project, a deeper analysis on these requirements will be performed by WP04, providing the identification of technical aspects related to a microservice architecture and the selected services. In parallel, part of these requirements (the ones that are more relevant for the experiment) will be analysed and implemented in small prototypes of these services. These solutions will be tested using the experiments specified by IMPETUS, providing an idea about the level of demand in terms of information (not only datasets, but performance, latency or availability) that is expected in U-Space and promoting the use of certain technological solutions in response to these needs.

The results obtained in these tests will be used to obtain not only a refinement of these requirements, but also the identification of new needs based on the experience and on the demand measures.

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Appendix A Other U-Space service requirements (D2.2)

The table below shows a list of requirements extracted from D2.2 (not necessarily in a literal way), by indicating the relevant page and line (from the document). A second table classifies per service each requirement according to the definitions described in this document.

Requirements written in italics are referred to technical capabilities and infrastructure and, therefore, not included in second table.

ID	REQUIREMENT	PAGE	LINE/S
1	The traditional airspace structure shall be changed into a dynamic airspace (where rules of access could potentially change hour-by-hour or even minute-by-minute) to allow drone operations.	52	9
2	Airspace Managers shall be able to change the 'access rules' at peak times of the day.	52	11
3	A registration system linked to a UTM server shall be enabled.	52	18
4	The registration system shall contain detailed information about the UAS (e.g. type of drone, performance capabilities, operational limitations, pilot licensing, etc.)	52	19-20
5	To improve the airports' situational awareness about drone activity, all drone activity shall be approved by the airport, or if it is not, co-ordinated with the airport and supported by the operator.	52	31-33
6	*A centralized authority shall be created in order to manage and maintain all of the potential stakeholders.*	*52*	*43*
7	The centralized authority shall instantly announce a change of rules to the organizations providing UTM services or airspace management.	52-53	45-46
8	The centralized authority shall be in charge to allow drone information to be shared with manned aviation thus ensuring safety.	53	1-3
9	A drone airspace data format shall be created, that is aligned to manned aviation.	53	9-10
10	The drone airspace data format shall be able to produce the geofencing primitives involving complex geometries.	53	8
11	*Coordination between the drone port and the UTM shall ensure the reception of a drone by the port.*	*53*	*29*
12	*Coordination between the drone port and the UTM shall ensure that the drones arriving are deconflicted from the departing traffic.*	*53*	*30*
13	*The coordination between the drone port and the UTM shall be managed around a central managing capability, or if it is not, by an act of negotiation between the port/recharging point and the UTM server.*	*53*	*32*
14	*The UTM shall request information about the order of arrival/departure, the position and the 'state' of each drone to the*	*54*	*1-5*

ID	REQUIREMENT	PAGE	LINE/S
	drone port in order to ensure safety while any commercial agreements are met.		
15	*Diversion ports shall be identified before the drone received a clearance.*	*54*	*10*
16	*The use of ad-hoc deployable ports shall be adopted where the appropriate ground infrastructure is not in place to support certain drone operations.*	*54*	*12*
17	The UTM system shall be aware of the launch/recovery location of the deployable ports, and also its availability timeframe in order to provide the appropriate airspace access.	54	20-22
18	An information monitoring system shall filter and highlight information affecting drone flights and manned aviation.	54	42
19	Airspace restrictions and automated geo-fencing shall be broadcasted through UTM.	55	1
20	Terrain data shall be provided to all participants in the U-Space context (operators, central authorities, service providers, etc.).	56	24
21	All terrain datasets shall be accurate and current enough to serve the safe and efficient conduct of operations.	57	1
22	A likelihood of moving or shape changing obstacles shall be determined based on statistical distribution of sightings and records.	58	10
23	The centralized authority shall validate and verify obstacle data by means of standardized procedures.	58	18
24	Cartographic information shall contribute to situational awareness of the operator.	58	38
25	Cartographic information shall be extracted from aeronautical charts and specified for operational context.	59	4
26	Cartographic information shall support the navigation via ortho-imagery.	59	6
27	Cartographic information shall fulfil the requirements in resolution, depending on typical altitudes, speeds and sensors of the UAS.	59	6-7
28	The local-scale weather service shall notify subscribers of updated weather forecasts instantaneously.	60	12
29	The local-scale weather service shall continuously maintain a nowcast of the atmospheric situation for subscribers.	60	14
30	The local-scale weather service shall issue appropriate warnings and alerts to subscribers when deviations are exceeding certain thresholds.	60	16
31	The local-scale weather service shall record historical weather forecasts.	60	19
32	The micro-scale weather service shall support forecast and nowcast of average wind and adverse wind effects (turbulence, guts, and thermals).	62	17-18

ID	REQUIREMENT	PAGE	LINE/S
33	Information exchange on UAS characteristics shall be limited to the needs of operational safety, its investigation or the legislative control of security, privacy and environmental policies.	64	6
34	The UAS characteristics dataset shall provide technical specifications such as the aerial vehicle ID, the vehicle model (including manufacturer and model identifier), the vehicle type (in terms of its take-off and landing performances), MTOM, the vehicle's wake vortex category, the vehicle's weather susceptibility category and the UAS airworthiness certificate.	64	10-22
35	The UAS characteristics dataset shall describe key features of the communications, navigation and surveillance (CNS) solutions adopted by the UAS for both nominal and foreseeable off-nominal operating conditions.	65	4-6
36	The UAS characteristics dataset shall include data characterizing the UAS flight/contingency planning and management capabilities.	65	25
37	The UAS characteristics dataset shall list tactical mitigation capabilities, such as flight termination systems, energy absorbing devices or disintegration solutions.	66	12-16
38	The UAS characteristics dataset shall provide the AV payload characteristics.	66	21
39	The UAS characteristics dataset shall capture information about the maintenance status of the UAS.	66	27
40	The UAS capabilities shall be encoded alphanumerically and assigned to each UAS, so that it would be both human and machine-readable.	66	33
41	The registration service shall maintain two different databases, one for Drone Operators' information and another for drone pilots' information.	67	13
42	The registration service shall manage input and edition of the data stored in the databases, including security, integrity and authentication of the information.	67	15
43	The registration service shall control the access to the information to authorised users, based on a well-established access permission policy.	67	17
44	The registry service shall offer standardised functionalities to facilitate online applications for Drone Operator licenses and submission of pilot credentials.	68	14
45	Exchange of registry information shall be limited to acknowledged recipients by the need-to-know principle (U-Space authorities, traffic management services, official agencies designated to control safety…).	68	22-25
46	The registry service shall include essential information related to liability and insurance, such as the declared type of activity for which the Drone Operator license has been issued and the type and status of the insurance coverage.	68	27

ID	REQUIREMENT	PAGE	LINE/S
47	*The G/G datalink connecting UTM services with all the GCS instances shall enable direct communication between operators/PICs.*	*69*	*16-18*
48	Essential contingency management-related information shall be permanently synchronized, such as contingency planning information (uplink), contingency management operational information (downlink /uplink), traffic surveillance collected on the ground (uplink), UAV position derived from ground surveillance (uplink), downlink of on-board observations of atmospheric conditions and uplink of predicted atmospheric conditions relevant to AV trajectory.	72-73	10-31; 1-10
49	*CNPLC solutions shall be scalable to fit platform-specific SWAP requirements, mission-specific range, flight altitude and operational context and safety requirements.*	*73*	*18-20*
50	All the relevant performance-related events shall be recorded by both, the airborne and ground pieces of the communications performance monitoring function.	75	9
51	*Standard radio-navigation means shall be resorted by small drones fitted with the appropriate equipment to acquire and exploit their signals to perform GPS-denied recovery trajectories or as signals of opportunity.*	*76*	*16*
52	A navigation service shall constantly assess the permission and performance for vision based navigation - based on terrain characteristics and the current or foreseen atmospheric conditions (visibility, turbulence, flight altitude and speed, …).	80	18-21
53	*Performance based navigation principles shall be adopted from manned aviation.*	*82*	*10*
54	*Airborne and ground-based navigation devices shall monitor and record their performance to support evidences in case of safety investigations.*	*82*	*28*
55	*Non-conventional traffic surveillance shall guarantee acceptable surveillance performance levels, according to operational needs.*	*83*	*2*
56	The surveillance detect function shall provide a measure of the uncertainty associated with the intruders' estimated positions and speeds.	83	32
57	*Traffic surveillance capabilities shall have to account for the specific traffic surveillance equipment featured by all UAS (and manned AVs in its case), as well as for the infrastructures that such equipment relies on.*	*85*	*3*
58	*Traffic surveillance capability shall assist flight planning and the individual DAA capability of each UAV.*	*85*	*13*
59	All the relevant performance-related events shall be recorded by both the airborne and ground pieces of the surveillance performance monitoring function to support evidences in case of safety investigations.	85	37-39

ID	REQUIREMENT	PAGE	LINE/S
60	The flight planning services shall provide the requesting operator with feasible trajectories that can be assessed whether they fit the mission objectives or further tuning is needed.	86	35-37
61	The flight planning services shall interact with the traffic planning service to schedule the mission trajectory in space and time and get approval for execution as scheduled, during planning-time.	87	4
62	The flight planning service shall interact with flight execution, traffic execution and mission planning to accommodate the changes in the intended trajectory safely with minimum impact to the mission, if possible.	87	6
63	The Flight Planning Management service shall activate the flight plan for execution, so that it is started on each UAV that takes part in the mission.	88	13
64	The ground flight management shall continuously analyse available telemetry data to monitor conformance to the flight plan alerting of and recording flight non-conformities if the case arises.	88	16
65	The Flight Planning Management service shall report flight execution progress relevant to the mission in nominal situation.	88	18-20
66	The Emergency Management Service shall be able to activate the contingency plans as a result of contingency events	88	20-21
67	The ground flight management shall automatically generate trajectories for contingency management and propose them to the PIC (Pilot in Command).	88	21
68	*The on-board flight management shall execute flight guidance and control functions based on the applicable tolerances to stay inside the intended trajectory.*	*88*	*30*
69	The on-board flight management shall feature capabilities for autonomous generation and execution of contingency trajectories.	88	32
70	The on-board flight management shall interact with the corresponding airborne mission execution system to report nominal mission progress as well as the activation of contingency plans.	88	35
71	*The on-board flight management shall feature advanced autonomous flight management capabilities, such as autonomous generation of holding patterns, trajectories to a destination point avoiding NFZs (No-Fly Zones) or mission-driven trajectories.*	*88*	*38*
72	The flight management services shall ensure the coordination of all stakeholders for flight re-planning.	89	4-7
73	The contingency plan shall capture all the data that parameterizes the contingency management logic.	90	19
74	*The UAV shall continuously monitor its separation with surrounding traffic, as part of its DAA capability, based on the traffic surveillance means available on-board.*	*91*	*4*
75	UAV behaviour shall remain predictable to all stakeholders, even when diversion from the approved flight plan is needed to cope with the contingency.	91	42

ID	REQUIREMENT	PAGE	LINE/S
76	The predicted contingency trajectory shall be shared by either the RPS or the UAV itself, if operating in LoL.	91	44
77	The sequence of the contingency management logic shall be predetermined at planning time to avoid UAVs behaving non-deterministically as a result of contingencies.	92	12
78	The Drone Operator shall record all flight-related information relevant to safety, security and privacy as evidence in case of the corresponding investigations during the flight.	92	23-26
79	The airspace segregated for UAS operations shall be released as soon as the corresponding UAS mission that was allocated such piece of airspace is over.	93	7
80	Traffic planning services shall assist a concurrent flight planning by multiple Drone Operators that ensures availability of access to airspace, adequate balance between system capacity, demand of UAS operations and fairly prioritized access to airspace.	93	15-17
81	Traffic planning services shall coordinate with the airspace management authority (ATM) to allocate segregated airspace and distribute the corresponding aeronautical notification.	93	18
82	Traffic planning service shall prioritize the requested access to airspace based on a well-established prioritization policy.	93	20
83	Traffic planning service shall provide feedback to the requesting Drone Operator on airspace and timeframe availability to re-schedule the requested mission.	93	20
84	A flight plan shall be submitted by the U-Space user and approved by U-Space flight planning services before the drone flight can take place.	93	23
85	The flight plan shall be approved by all relevant authorities along its entire route before the drone could be issued with a clearance.	93	30
86	The centralised system shall manage or be closely integrated with the registration services to ensure a drone only operates in the airspace where it has all the capabilities and permissions to do so.	93-94	42; 1
87	A flight plan shall be updated with any change to a UAV's route	94	8
88	The UTM service shall be kept up to date with any changes made to the intended trajectory.	94	14
89	The Drone Operator shall negotiate with the UTM service to ensure that the drone is able to carry out its mission or have to return to base, in case of changing any aspect of flight.	94	17-19
90	The flight plan conformance monitoring shall continuously compare the 4D position of each AV as 'predicted' on the basis of the approved flight plan in force with the corresponding 'actual' 4D position as observed by the traffic surveillance service available.	95	10-11
91	The flight plan conformance monitoring shall trigger a 'FP non-conformance' alert if the deviation from the approved flight plan exceed the limits of the containment volume.	95	12-13

ID	REQUIREMENT	PAGE	LINE/S
92	The positions of all the AVs participating in a certain traffic scenario shall be known within, at least, the time horizon for which the separation assurance function is required.	95	42
93	The position of each AV shall be surrounded by a protection volume with a size depending on the separation minima applicable in the particular situation.	96	2
94	The UTM shall provide information to allow the pilot to discharge their responsibility to maintain safe separation.	96	41
95	The UTM system shall have knowledge of the intent of all drone operations taking place within its area of responsibility.	97	6
96	The UTM system shall ensure that the data recording system is tamper prove and only accessed by the appropriate authorities.	97	21
97	Mission planning capabilities shall include support for automated mission design/re-design for UAV missions.	97	36-38
98	The mission planning service shall create a plan that includes the trajectory as well as designated tasks to be performed in concurrently by the mission and trajectory execution resources.	98	5-8
99	In the case of multiple UAV missions, the mission planning service shall output a consolidated plan that breaks down into a valid, specific flight plan for each UAV.	98	9-12
100	Mission planning shall interact with flight planning to safely accommodate (if possible) mission plan changes that involve trajectory changes.	98	13
101	Mission planning shall interact with U-Space to share relevant mission-specific details that U-Space should be aware of (purpose of the mission, nature of the payload being carried, its operating status …).	98	15-17
102	Mission planning shall interact with insurance services to ensure that appropriate coverage is granted for the mission at an affordable cost, based on the risk of the operation being planned.	98	24
103	The mission plan management service shall activate the mission plan for execution, so that it is started on each UAV that takes part in the mission.	99	9
104	The mission conformance monitoring service shall continuously analyse available mission and flight data to monitor mission conformance to plan.	99	10-11
105	The mission conformance monitoring service shall alert on and record mission non-conformities and decide whether to continue the mission or abort it in view of the situation.	99	15
106	The mission conformance monitoring service shall interact with and provide automation to the mission operator.	99	16
107	The airborne mission execution service shall supply all the necessary automation in payload management and control for the payload to fulfil its assigned mission tasks.	99	26
108	The airborne mission execution service shall interact with the airborne navigation function to access aircraft state information	99	30

ID	REQUIREMENT	PAGE	LINE/S
	(position, speed, attitude, etc.), which may be relevant to payload performance		
109	The airborne mission execution service shall interact with the airborne flight execution capability: a) to get updated on whether the flight plan proceeds as planned or any contingency manoeuvre has been activated, which requires making mission-related decisions. b) To listen to the relevant trajectory execution milestones, and c) To request the flight management function to engage/disengage autonomous flight modes conceived to support missions that require dynamically changing the flight trajectory.	99	32-37
110	The mission execution services shall make sure that special constraints imposed by U-Space on the missions are met.	99	38
111	Mission execution service shall report specific milestones to U-Space as they are reached (passenger boarding/de-boarding, special cargo load/unload …).	99	40
112	All mission-related data that is relevant to U-Space for audit trail purposes shall be recorded by the Drone Operator responsible for the UAS operation and made available to U-Space authorities upon request.	100	1-3
113	Drone flights shall be tracked and the relevant data submitted to the U-Space Authority's historical record storage by traffic management services (DTM or other third party service provider) with access to it.	101	2-4
114	The U-Space Authority shall assure maintenance, integrity and correctness of data provided in 'Historical Records'.	101	5
115	A dedicated U-Space 'Data Management System' shall manage the petition of all data relevant for the prosecution of the law by Law Enforcement.	101	7
116	Data Management System shall provide all relevant information to the petitioning entity (Law Enforcement).	101	8
117	Data Management System shall have access to the Drone Registry, Drone Pilot Registry, Drone Operator Registry and Historical Records databases.	101	10
118	Data Management System shall manage any submissions of information about previous violations by Law Enforcement.	101	12
119	In the case of a loss of a UAV with or without prior notice of an emergency situation being experienced, the circumstance shall be notified to a sort of Alert service analogous to the one in place in manned aviation.	102	38-40
120	Alert service shall provide alerts to the concerned parties, emergency services, search and rescue services and accident investigation authorities, as applicable.	102	42

ID	REQUIREMENT	PAGE	LINE/S
121	E-registration shall include a field to check that all UAVs with MTOM equal or greater than 20 kg shall be insured for third-party liability.	103	9
122	U-Space shall feature a service that would allow Drone Operators filling non-compliances or deviations from the applicable regulations (operation by exception) or requesting drone operations in a harmonized way.	104	18
123	U-space shall initially support the Special Operational Risk Assessment (SORA) through a standardized methodology for risk assessment as related to drone operations.	104	23

Table 4. U-Space requirements from D2.2.

SERVICE	REQUIREMENTS
FOUNDATION SERVICES	
E-registration	3, 4, 33, 34, 35, 36, 37, 38, 39, 40, 42, 43, 44, 46, 86, 115, 116, 117, 118, 121
E-identification	34, 75, 95
Pre-tactical geofencing	9, 10, 93
INITIAL SERVICES	
Tactical geofencing	93
Tracking	50, 88, 90, 91, 113
Flight planning management	60, 61, 62, 65, 72, 73, 80, 81, 82, 83, 84, 85, 87, 89, 100, 109, 122, 123
Weather information	28,29,30, 31, 32, 33, 48, 52
Drone Aeronautical Information Management	8, 33, 101
Procedural Interface with ATC	5, 81
Emergency Management	48, 66, 67, 73, 76, 119, 120
Strategic deconfliction	12, 77
Monitoring	18, 59, 64, 65, 70, 75, 90, 91
Traffic information	33, 48, 92, 95, 101
ADVANCED SERVICES	

Dynamic geofencing	19, 93
Collaborative interface with ATC	5, 81
Tactical deconfliction	12, 56, 65, 69, 94
Dynamic capacity management	1, 2, 7, 79, 82
OTHER U-SPACE SERVICES	
Geo-spatial Information	17, 20, 21, 23, 24, 25, 26, 27, 33, 52
Data Recording and Post Analytics	22, 33, 50, 78, 96, 112, 113, 114
Mission Plan Management	89, 97, 98, 99, 100, 101, 102, 103, 107, 109, 110, 111
Mission Plan Conformance Monitoring	104, 105, 106, 108, 109
Drone Emergency Management	36, 48, 76
Digital Logbook	45, 117

Table 5. Requirements per service from D2.2.