Validation of Integrated Multi-stakeholder Architecture for UAS Traffic Management

GOF 2.0 Integrated Urban Airspace

White Paper

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GOF 2.0

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CONTENTS

Executive Summary

The number of air operations over cities is expected to increase over the next 5-10 years. Already now, manned and unmanned aircraft share the skies at low level with helicopters and drones operating in mixed airspace over cities and elsewhere below 500 feet. GOF2.0 demonstrated a unified air operation traffic management with high levels of automation serving both manned and unmanned aircraft in a safe, interconnected, distributed, interoperable, efficient, scalable and environmentally optimized manner. Highly automated separation assurance in dense airspace – specifically in areas where urban mobility and aerodrome traffic is expected - is becoming a critical capability to efficiently manage a unified airspace. Integrated trajectory management service based on flight plan information and real-time surveillance combined with a digitally connected environment provide the basic safety net for all aviators.

The main objective of GOF2.0 was to build on GOF USPACE project and other SESAR projects to validate the orchestration and operation of available state-of-the-art COTS components and services to create a dynamic operating environment for manned and unmanned aircraft to operate safely in a shared airspace along with the provision of enhanced safety net/deconfliction functionalities to maintain separation between aircraft and to lower air and ground risks.

The overarching target for GOF2.0 was to contribute to achieving Single European Sky's High-Level Goals formulated in 2005 with a vision to deliver following performance improvements by 2035:

1. Enable a three-fold increase in capacity which will also reduce delays both on the ground and in the air,
2. Improve safety by a factor of 10,
3. Enable a 10 % reduction of the environmental impact of flights,
4. Reduce the cost per flight by 50 %

Therefore, the GOF2.0 architecture provided a framework for actors in and connected to ATM and UTM domain, adhering to SWIM and common principles for U-space architectures, described in the SESAR U-space reference architecture, ICAO 10039 [1] and ongoing regulatory work. Information exchange services were introduced to facilitate standardized data exchange. They enable a modular, interoperable and highly resilient system of systems, allowing for technical variants in implementation. The architecture ensures a flexible, yet strong technical framework to ensure continuous evolution of U-space.

GOF2.0 was built around two main waves of combined trials in 4 different countries, including transnational operations. Both the waves involved UTM and ATM stakeholders in Austria, Poland, Estonia and Finland. The variety of countries was meant to multiply the learnings and explore the range of possible interpretation of a given situation. In addition to the two waves of trials, the GOF2.0 system of systems was integrated with local AIM and CNS data in three countries outside the GOF2.0 consortium with the aim to understand and demonstrate the scalability of the GOF2.0 solution.

The live demonstrations focused on validation of the GOF2.0 architecture for highly automated real-time separation assurance in dense airspace including precision weather and telecom networks for air-ground communications. These flight trials have contributed to understanding how the safe integration of UAM and other commercial drone operations into ATM Airspace can be materialized without degrading safety, security or disrupting current airspace operations.

1 Introduction

1.1. The call for UAM

Although slightly flattened through the recent COVID-19 crisis, the trend towards larger population in cities and urban environments has never stopped. By 2030, 60% of the world's population will be urban. This significant population growth is expected to create a real need for innovative mobility options as ground infrastructure becomes increasingly congested. Providing people with a safe, sustainable and convenient solution that leverages the airspace above cities could be a solution.

While the ground sees competition of usage, companies and operators have explored the possibility to use the lower part of the airspace to develop additional services and to speed up delivery services and public transportation using drones and eVTOLs. The aerial vehicles come with benefits of higher safety, lower environmental footprint, lower noise and lower maintenance than traditional VTOLs.

The European Commission identifies an increasing demand for a non-segregated use of airspace which is being driven by a rapidly growing market of Very-Low-Level (VLL) airspace users, most of which are expected to be drones. Via the Roadmap for the safe integration of drones into all classes of airspace within the European ATM Masterplan, the European Commission seeks to ensure that this rapid growth of airspace use happens in a safe and controlled manner.

When those services become mainstream, the complexity of operating multiple flights in a relatively thin layer of the atmosphere will be very high. The GOF2.0 Integrated Urban Airspace VLD (GOF2.0) very large demonstration project aimed to demonstrate operational validity of serving combined operations safely, securely, and sustainably in a unified, dense urban airspace using current ATM and U-space services and systems. Both ATM and U-space communities depend extensively on the provision of timely, relevant, accurate and quality-assured digital information to collaborate and make informed decisions.

1.2. The GOF USPACE project - “GOF1.0”

The GOF U-space project demonstrated in 2019 how connected U-space service provider microservices enabled the collective and cooperative management of all drone traffic in the same geographical region. GOF U-space further demonstrated how a Flight Information Management System (FIMS) enabled sharing situational awareness between manned and unmanned aviators. GOF U-space also demonstrated international end-to-end flight in U-space by interconnecting two FIMS in Finland and in Estonia to allow a drone to be serviced by one USSP from beginning to end.

GOF U-space did not demonstrate real-time ATC collaboration or algorithmic deconfliction schemes. Yet the consortium was able to conduct advanced beyond visual line of sight trials combined with manned aircraft operating in same airspace through alignment on common data and procedures.

1.3. Integrated airspace management and the U-space regulation

The European Commission identifies an increasing demand for a non-segregated use of airspace which is being driven by a rapidly growing market of Very-Low-Level (VLL) airspace users, most of which are expected to be drones. Via the Roadmap for the safe integration of drones into all classes of airspace, within the European ATM Masterplan, the European Commission seeks to ensure that this rapid growth of airspace use happens in a safe and controlled manner. The first regulation on U-space in

Europe will come into force on January 26, 2023. It will still require segregation of manned from unmanned air traffic. This formed the reference scenario for GOF2.0 demonstrations.

In practice, air traffic at low level is already integrated with VLL shared by drones, general aviation, and military flights. The growth of both unmanned and manned air operations in the urban environments requires digital air traffic management, where both manned and unmanned aircraft share the same safety data, tailored to individual operational needs. Integrated airspace management require functional tactical deconfliction. This integrated airspace management, including tactical deconfliction, has always been the main focus of GOF2.0.

1.4. Airworthiness requirements higher for UAM vehicles

UAM often takes place in controlled airspace. This poses some excellent challenges for more advanced unmanned operations.

Open category operations (VLOS, below 120m altitude, up to 25 kg MTOW) can be conducted without special regard within entire FIRs, as long as the operation is not restricted by a UAS zone or other airspace restriction. Many airspace restrictions may be possible to navigate with the permission of the relevant Air Traffic Service Provider.

Specific category operations in controlled airspace in or near instrument flight sectors are classified as SAIL VI by SORA, the highest risk level in the category, almost irrespective of flight altitude. This requires at least Restricted Type Certification according to Part 21 by EASA. Another risk assessment framework than the standard SORA one may be used, such as traffic heatmaps based on historical surveillance data, but to date such data is not commonly available.

BVLOS operations in populated environments come with significant ground risk, leading to any UAM BVLOS operation being regarded as medium- to high-risk operation, requiring either a Design Verification of relevant airworthiness by EASA or a Restricted Type Certification. No operator participating in GOF2.0 opted to pursue Design Verification for BVLOS flights over populated environments. Therefore, BVLOS operations over populated environments were not demonstrated.

1.5. GOF2.0 Integrated Urban Airspace VLD

GOF2.0 VLD consisted of two waves of demonstration exercises called Wave 1 and Wave 2. Wave 1 demonstrated that the GOF2.0 system of systems was operational and established a baseline functionality with only strategic (pre-flight) conflict resolution while Wave 2 added more automation. Each wave contained trials in three types of operating environments:

1. Trial 1 – Dense operations in CTR (in VLL airspace)
2. Trial 2 – Entering and leaving airspaces (including controlled/uncontrolled airspace as well as U-space airspace/non-U-space airspace both in VLL and above)
3. Trial 3 – Cross-border operations in all types of airspace in VLL and above

In addition, a roadshow was completed in three countries outside GOF2.0 consortium - Denmark, Latvia and Sweden, to demonstrate the scalability of the GOF2.0 system of systems through a limited set of scenarios involving both local unmanned and manned aircraft operators.

In this document, a blueprint architecture for all the flight trials is explained. Information exchange services based on SWIM Standards within the defined Architecture are also identified and the GOF2.0 architecture is put into context with the ongoing regulatory work. The document also gives an overview about the GOF2.0 demonstration approach including the reference test scenarios, the deconfliction methods and the success criteria used for evaluation. The key findings from all the flight trials have also been summarized here.

Furthermore, multiple IAM stakeholders have been interviewed within the scope of this deliverable and based on their feedback, the business models and strategies employed in different business segments of the IAM industry have been presented. Finally, the strategies for exploiting the GOF2.0 technologies and learnings have been listed.

2 Operational Requirements for Drones and Passenger eVTOLs

2.1. The three horizons of drone services

We expect drone operation concepts to experience three horizons of development: VLOS (visual line of sight), BVLOS (beyond visual line of sight) and finally full and automatic integration with all other modes of civil aviation traffic.

Drone services under the **first horizon** are well-established and routine everyday operations. As long as all drone operations are conducted within visual line of sight, there is no or very little benefit from traffic management solutions, as multiple drone operators easily can share the same airspace with other drone operators, and even manned aviation based on proven see-and-avoid principles.

In 2022, like in 2020 and in 2021, drone operators stand on the threshold of the **second horizon** of drone-enabled services with BVLOS flights. Some of the technologies to enable reliable flight operations beyond visual line of sight has existed for more than five years. Customers expect drone operators to further cut costs for large area sensor data collection in a wide range of industries ranging from infrastructure inspection, construction, mining, surveying and mapping to agriculture, forestry and environmental protection. More recently, also healthcare, B2B and B2C companies are willing to commit large sums to acquire fast, sustainable and cost-effective drone logistic services in the strive to cut both emissions, costs and service time from current logistics chains. However, the industry has not yet been able to deliver on expectations, mainly due to added regulatory requirements[1] when moving from first VLOS development horizon to second BVLOS horizon.

At the same time, millions of Euros have been invested in eVTOL and air taxi technologies. The technical complexity to achieve the levels of airworthiness required to carry humans in the air is slowly maturing in time with regulations, that are maturing along the technical development. A unified air operation traffic management system based on digital infrastructure will be key to welcome those passengers carrying eVTOLs when they are certified.

2.2. Operating Requirements for Drone and eVTOL Operators

Both drone and eVTOL operational requirements align in that operators need to:

- Predictably get access to initially the very low-level airspace (VLL) without see-and-avoid requirements

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[1] (EU) The application in Europe of SORA in (EU) 2019/947 [2] combined with the EASA monopoly on airworthiness assessments has created a large bottleneck moving from SAIL II to higher risk operations. The drone regulations were intended to be risk- and performance based. However, EASA has taken an extremely conservative view of risk, where airworthiness requirements for a single flight is the same as for a fleet of drones performing multiple flights an hour. This has led to a standstill of a couple of years for the European drone service industry with very little de facto need for U-space services.

- Share the VLL with incumbent aviators, such as Emergency, Rescue or police helicopters, General Aviation without need to pre-coordinate with each helicopter operator
- Operate with tight flight schedules.
- Adapt the flight schedule on a moment's notice, be it to delay or accelerate take-off or to respond to changing operating conditions.
- Receive support for flight preparation in unfamiliar environments

2.3. Requirements for U-space to support Operating Requirements

The main objective of GOF2.0 is to validate the orchestration and operation of available state-of-the-art COTS components and services to create a dynamic operating environment for manned and unmanned aircraft to operate safely in a shared airspace and the provision of enhanced safety net/deconfliction functionalities to prevent collisions between aircraft and to mitigate the air and ground risks taking into account also detailed weather and connectivity information.

U-space and digital airspace management is needed to support scalable growth of operators offering BVLOS services. The core purpose of U-space is to enable access to the airspace for a large number of drones. One of the core U-space functionalities towards that goal is the ability to ensure that manned or unmanned aircraft do not collide while in flight.

- All flights operating in the U-Space need to be digitally conspicuous.
- Multiple operators can share same landing infrastructure 'vertiports' for concurrent flights.
- When manned operations, such as helicopter flights, need to fly in proximity of drone operations, the operations must be kept at safe distance.

Drone flights differ vastly in nature from commercial airline traffic and general aviation. Whereas a general or commercial, motorized aviator rarely makes multiple flights in an hour, the volume of drone operations is expected to consist of many flights, which are relatively short in duration; from less than 10 minutes to less than an hour. For example, a drone logistics operation may see 4-6 flights in a single hour. It is clear that for a vast majority of drone operators waiting more than a minute for a new operation plan to be approved and activated is out of question. Emergency drone services should be able to get permission to fly in a much shorter time, say within 15 seconds from filing a new operation plan. It is not what most human-served procedures can consistently achieve.

- Operation plans must be digitally processed end-to-end to meet time constraints.
- Operation plans may change in-flight, or a flight may not conform to the filed one. So, system must allow for dynamic, in-flight events, whilst ensuring separation of drones and aircraft.

Drone operations rely on digital infrastructure to function reliably and the data from digital twins is also foreseen to assist in drone operations. Reliable digital data links are needed between ground and air systems, ground risk data must be digitally available, and weather reports must correspond to nature of drone operations and be current. A drone operation can often utilize short time windows in weather, which needs much more current weather products compared to traditional aviation. There is even a new term, nowcasting, which is used for current weather information including a forecast up to 30 minutes into the future. Several services are needed for mission planning:

- Digital, 3D or even 4D communication network service level "coverage" data are needed

- Up to date ground risk data, including population density and ground obstacles are needed
- Nowcast of weather with relation to wind and precipitation in addition to icing condition predictions are needed
- Common for all connected parties, DTM/DSM model to convert declared heights (relative) to absolute altitude

For operations in controlled airspace, ATM stakeholders need to maintain digital situational awareness of drone operations and need to coordinate with the UTM stakeholders. The nature and frequency of rapidly changing drone and eVTOL operations in a dense airspace is very difficult for a human to try to overview and control manually.

- Conformance monitoring is needed to automatically check which flight operations are nominal, and which ones need to be managed separately.
- Alerts related to conformance monitoring, separation distances and emergency status are needed to allow humans to focus on the part of drone and eVTOL operations, which may require human decision making to be safely returned to normal, considering the cascading effects of disturbances in a dense, high-frequency system.

The requirements for the third horizon of drone and eVTOL services, where manned and unmanned aircraft safely share the same airspace are still partly on the drawing board. However, three key requirements are already clear:

- All aircraft need to be digitally conspicuous
- All aircraft need to be able to share information digitally during all phases of flight
- Separation needs to build on both strategic and tactical deconfliction, with conflict resolution presented digitally to all actors.
- All aircraft should use Common Altitude Reference System (CARS)

3 GOF2.0 System of Systems: Architecture

3.1. Design Principles / SWIM

GOF2.0 is following U-space architecture principles as described by SESAR. Based on all those principles, one major design approach considered is decoupling conceptual and technical matters, providing guidance while allowing for flexibility in implementation and future extensibility.

It is based on SWIM principles laid out in ICAO's Doc 10039, Manual on System Wide Information Management (SWIM) [1]. Paragraph 2.3.5 summarizes:

Interoperability is achieved on a global scale through the use of common information exchange models for information elements of interest, the use of common services for information exchange, and the use of appropriate technology and standards.

Summarizing SWIM principles, information services should be described, by defining

1. Harmonized conceptual and logical data models including definition of logical format, structure and data elements
2. Service lifecycle, behaviour & performance levels
3. Means to look up and access services

This enables information to reach and keep a state where it is "known and managed". The described conceptual/logical information services can be realized in different technical implementations, "thus enabling an architectural approach based on one logic and multiple potential solutions". It allows to keep concepts stable while technology changes and evolves.

On a conceptual level, following the SWIM principles laid out before, information should be described technology agnostic, e.g., in UML or by comparable means. The aim is to document the key aspects of a dedicated service at the logical level.

An example of this approach can be studied in EUROCAE ED-269 [3], where a conceptual definition and its implementation in a standard data encoding are defined in one document.

A Common Information Service Provider for a U-space Airspace shall

- Maintain a Service Registry, allowing all stakeholders to look up service-related information, as described below.
- Provide Information Exchange Services for the U-space Airspace, by maintaining Information Exchange Service Instances.

The Service Registry (maintained by a Common Information Service Provider) shall offer the following service-related information:

- A list of U-space Service Providers that are offering U-space Services for the U-space Airspace.
- Access information to U-space Service Instances provided for the U-space Airspace.
- Access information to Information Exchange Service Instances provided for the U-space Airspace.
- Technical information about U-space Services and Information Exchange Services provided for the U-space Airspace.

- High level service specifications for U-space Services and Information Exchange Services provided for the U-space Airspace.

A U-space Service Provider provides one or several U-space Service(s) for the U-space Airspace via dedicated U-space Service Instances. A U-space Service Instance is the technical means (hosted by a U-space Service Provider) to provide a U-space Service. Such a service instance is characterized by the technical and administrative access details (e.g., URL, authentication mechanism, …). A service instance represents the implementation of a Service Technical Design.

Information Exchange Services facilitate data exchange for information provided and consumed by U-space services. Information Exchange services aim, for example, at publishing the „single truth“ of certain U-space related information to interested parties. The following Information Exchange Services have been identified and specified in the SESAR GOF2.0 project as key enablers for U-space:

- Traffic Telemetry exchange service
- Operation Plan exchange service
- Aeronautical information (Geozone) exchange service
- Operational Messages (Alerts) exchange service
- Registration exchange service
- Network coverage and population density exchange service
- Weather Information exchange service
- Drone Flight exchange service

An Information Exchange Service Instance is the technical means (hosted by a Common Information Service Provider) to provide an Information Exchange Service. Such a service instance is characterized by the technical and administrative access details (e.g., URL, authentication mechanism, …). A service instance represents the implementation of a Service Technical Design.

Technical aspects are described in form of Service Technical Design documents. The Service Technical Design describes, for example, the access protocols or the detailed data encoding rules and exchange formats (XML, JSON, …) used for a certain service implementation as implemented by a specific service instance.

The high-level logical aspects of a service are described in form of Service Specification documents. At this level, Information Exchange services as well as U-space services shall be specified and described in a technology-agnostic way, providing the following kind of information for each service:

- Requirements
- Service interfaces
- Service operations
- Service data model
- Dynamic behaviour

3.2. Architecture Blueprint

GOF2.0 integrates systems of project partners utilizing Information Exchange service based on SWIM principles in a service-oriented architecture.

Partners act in roles (or provide applications and services for roles simulated in trials):

- UAS Operator
- USSP
- Supplemental Data Provider
- CISP
- ANSP
- Authority
- International System
- Administrative Unit

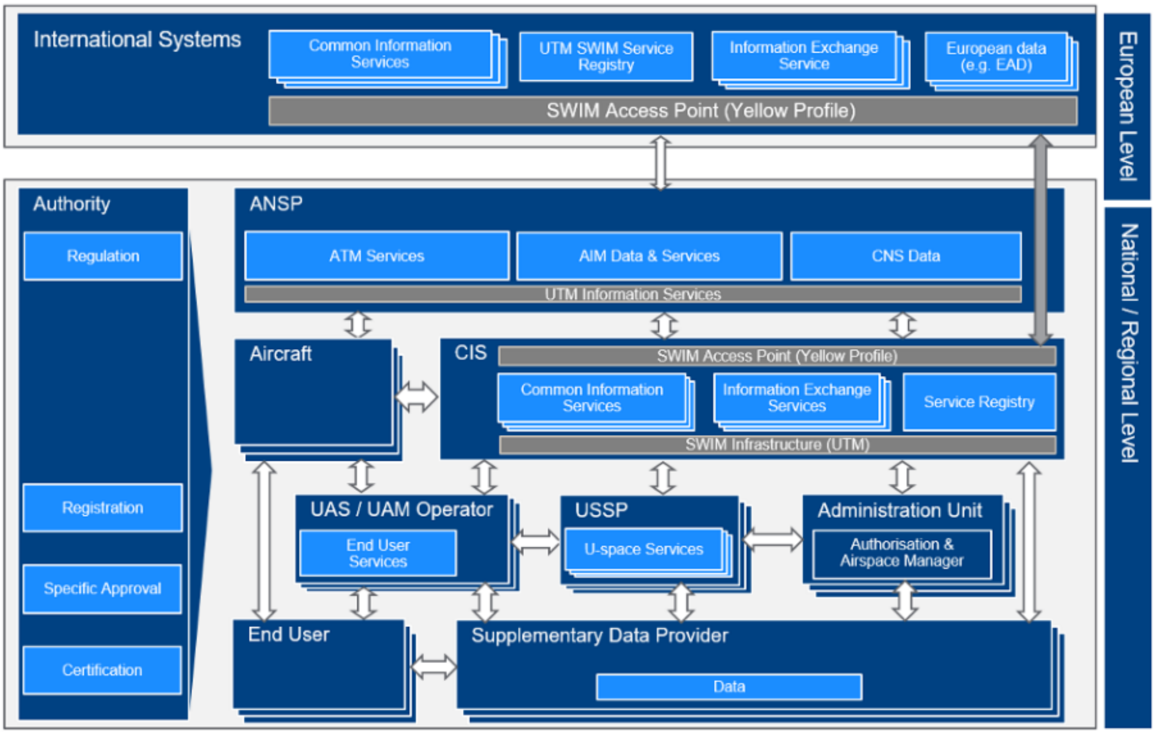

Figure 1: GOF2.0 High Level Architecture

Any information exchange between partners is based on service specifications on conceptual level, based on SWIM principles. Services provided by partners offer interfaces, which are mapped (traced) to the service specifications. Information exchange is decoupled from business services. Where necessary, conversion services are developed to achieve technical interoperability.

A multi-step approach is used

1. Operational needs and KPIs based on trials and project objectives are defined
2. Services required to meet the needs and KPIs are identified
3. On conceptual level, any information exchange between those services is documented and specified
4. On technical level, APIs and services are mapped to the conceptual level
5. Conversion services are developed where necessary.

As an example, the need to exchange aircraft position data between ANSP and UAS operator is identified. All relevant stakeholders in the digital data chain discuss and agree on how this position data is described, and which service operations are necessary to cooperate.

UAS operator and ANSP use different data formats, the UAS operator utilizes ReST services providing data in JSON Format, whereas the ANSP provides surveillance data in ASTERIX. Involving all roles that connect UAS operator and ANSP (e.g., USSP and CIS), all attributes required are identified and described in a technology agnostic way, including requirements (e.g., for data quality and latency).

Together they create a service specification, documenting that a position must have an Identifier, Latitude, Longitude, Altitude and information on data precision.

Once this specification is agreed, both partners map their technical interface. Relevant elements of the JSON structure are traced to attributes in the service specification by the UAS operator. The ANSP traces the applicable elements of an ASTERIX record to the service specification. Both ASTERIX and JSON structure could hold additional information not listed in the service specification.

Finally, a conversion service must be deployed, it is agreed that this service is provided by a CIS, allowing all stakeholders to use it.

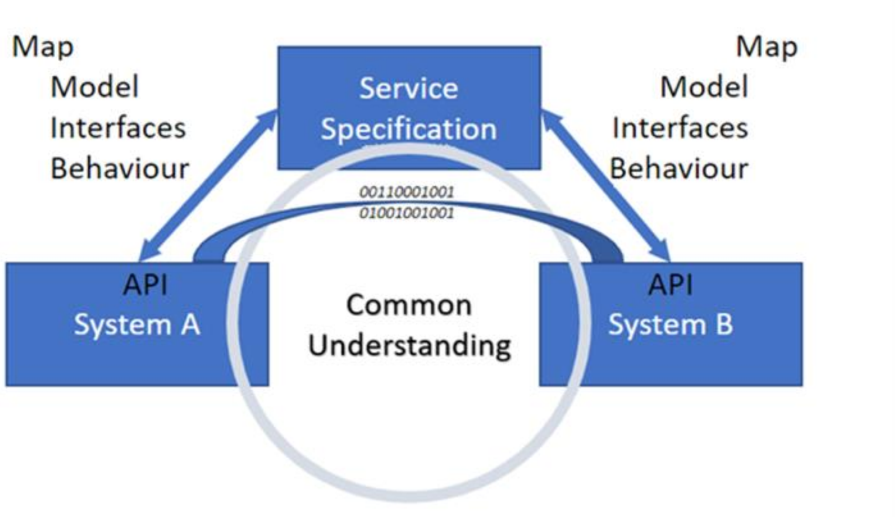

Figure 2: Multi-step approach to achieve technical interoperability

To allow a flexible setup for deployments, a service registry is foreseen both on international and trial level. Service providers register their provided services in the service registry, providing

- Service endpoints (e.g., IP Address or Domain Name)
- The geographical area in which this specific service is provided (e.g., Tallin CTR)
- Technical Documentation (API Specification, Webservice Descriptor...)
- The service specifications implemented (e.g., Traffic/Telemetry, Operation Plan…)
- Means to identify the service provider

In a deployment, the service registry is used by stakeholders to locate:

- CIS
- USSP
- UAS Operators
- Supplemental Services
- .. other relevant stakeholders

3.3. Architecture and ongoing regulatory work

SESAR's principles for U-space architecture, Chapter 2 [4] states:

U-space is a set of federated services and associated functions within a complete framework designed to enable and support safe and efficient multiple simultaneous drone operations in all classes of airspace. These services can be provided by different providers, but such service providers will need to interoperate to performance requirements that are yet to be defined. The need to guarantee a seamless and safe operational environment will necessitate timely and accurate data transmission between implementation systems.

It furthermore introduces the need to support unique and neutrally/centrally provided services as well as multiple service providers cooperating to operate in the same volume of airspace at the same moment:

The architecture must then ensure that all the U-space service providers have the same situational awareness, and the traffic is de-conflicted (i.e., strategic or tactical deconfliction). This will require cooperation and exchange of data between the various service providers: connectivity and interoperability of the U-space services and related systems will be then essential.

However, the nature of some services is so safety or security and data privacy critical that they might require to be unique and neutrally/centrally provided (e.g., registration, identification, geoawareness, interface with ATM). The architecture must allow this as well.

This concept of a hybrid architecture is reflected in the initial U-space regulation. Paragraph 9 and 16 in the preamble define

- Stakeholders
- Which should establish connectivity methods amongst each other
- Using common, interoperable open communication protocols
- Based on requirements for data quality, latency, and protection
- To deliver standardised services

Preamble (9): Harmonised rules for UAS operations in the U-space airspace, standardised services delivered to UAS operators as well as connectivity methods between providers of the common information services, the U-space service providers, the air traffic service provider and the UAS operators should be established to ensure the safe, secure and efficient operation of UAS, while facilitating the free movement of services linked to UAS as well as U-space service providers in the Union.

The initial U-space regulation requires U-space service providers to cooperate, they shall "exchange any information that is relevant for the safe provision of U-space services amongst themselves".

For so called common information, Common Information Services are introduced, required to allow access "on a non-discriminatory basis", unique and neutrally/centrally provided:

Article 5 (5): Access to common information services shall be granted to relevant authorities, air traffic service providers, U-space service providers and UAS operators on a non-discriminatory basis, including with the same data quality, latency, and protection levels.

The GOF2.0 architecture is built to provide a strong & flexible framework to realize such hybrid architectures. U-space deployments can be shaped by member states within the boundaries the U-space regulation provides.

A key enabler of U-space in GOF2.0 are the service specifications for information exchange services, which are described in this deliverable and delivered in D2.2. Providing guidance and definitions on conceptual level, they allow to integrate interfaces from different system providers and stake holders using different technologies.

An API or service could be proprietary or open, using new or established technology. If a trace / mapping to the conceptual definition is available, interoperability can be achieved. Even though technical conversion might be necessary, the complexity and cost of such conversion services is expected to be low.

The information model and service interfaces defined are foreseen to be used to exchange information between all stakeholders. E.g., a position record and its substructures defined in the Traffic/Telemetry specification will be used to between UAS operators and USSPs, USSPs and USSPs, USSP and CIS, CIS and ANSPs, SDSP and …, no matter which roles two stakeholder have in in an information exchange, they can always rely on a well-defined standard. This lowers the entry barrier for new services and stakeholders, like the Supplemental Service Providers and Administrative Units participating in GOF2.0 demonstrations.

Ultimately, this facilitates the free movement for USSPs and UAS operators described in the initial U-space regulation.

International regulatory and standardisation work was considered for the GOF2.0 architecture as well. E.g., models and architecture foreseen in the United States (FAA, ASTM) and Asia were analysed and taken as input. Related work in the mobile network domain is ingested based on input from other research projects and standardisation activities (e.g., related to Network Coverage).

The concept of Information Exchange Services was embraced in the latest available draft of Guidance Material and Acceptable Means of Compliance for (EU) 664/2021. They use *EUROCONTROL Specification for SWIM Service Description (SD)* [5] and *EUROCONTROL Specification for SWIM Technical Infrastructure (TI) Yellow Profile* [6] as formal frame to describe information exchange services.

The Network Coverage Service described in D2.2 contributed to a Service Definition by ACJA, the *Interface for Data Exchange between MNOs and the UTM Ecosystem* described in [7].

Summarized, the GOF2.0 architecture can be considered in line and compliant with ongoing regulatory work in Europe[2]. Its strong & flexible approach focussing on conceptual service definition and SWIM principles will allow for efficient alignment and integration with international UTM deployments.

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[2] Please note, at the time of writing this deliverable, Guidance Material and Acceptable Means of Compliance have not been released. While significant changes are not expected, it is recommended to compare this chapter with current versions of relevant documents.

4 Demonstrations and Results

GOF2.0 was built around two waves of trials in 4 different countries of Austria, Poland, Estonia and Finland and even included transnational flight operations. The variety of countries proved instrumental to multiply the learnings and explore the range of possible interpretation of a given situation. The preparation wave 1 allowed voice communication to be used during trial runs. All actors had full knowledge of all planned flights, and only deconfliction of monolithic operations was available.

In contrast, the main wave, “wave 2”, was built around an “onion concept”, the drone operators not aware of details beyond their own operation plans, all communication and deconfliction happening through the GOF2.0 Systems of Systems. Trial leaders and safety coordinators were the ones who had full knowledge of the plans and expected deviations built in to test the reliance of the systems.

In addition to the two waves of trials, the GOF2.0 system of systems was integrated with local AIM and CNS data in three countries outside the GOF2.0 consortium with the aim to understand and demonstrate the scalability of the GOF2.0 solution. This integration was the main goal of the “International Roadshow” and described as “trial 4” in this document.

GOF2.0 had identified eleven scenarios that represent a majority of the most relevant early UAM use cases. Low-level logistic drone flights were partly operated with real drones, and partly augmented with simulated drones, which, however, showed up as real assets for all integrated GOF2.0 users, but which did not need to exhibit the high level of robustness and airworthiness required to operate in and out of active airports or over densely populated areas.

Each scenario was demonstrated with one or more missions, so that each flight mission belonged to only one specific scenario. No multi-scenario missions were planned in GOF2.0. The interaction between the missions of different, concurrent scenarios was the focus of the GOF2.0 trials. Therefore, three sets of scenarios had been combined into trials, that were demonstrated in different operating environments.

4.1. Demonstration Approach

Most European large cities have an aerodrome nearby with parts of the city consequentially residing in controlled airspace, CTR. Therefore, GOF2.0 focuses on CTR as an operating environment.

Urban Air mobility can be split into three principal operation types: intra-urban, peri-urban and inter-urban. Intra-urban operations happen within a city, whereas peri-urban operations link city-centres with suburbs and surrounding areas. Inter-urban (or inter-city) operations connect different cities together. The trial structure in GOF2.0 mirrors these principal operation types, and resides either partly or fully inside CTR:

1. Trial 1 focused on dense operations in CTR (intra-urban)
2. Trial 2 focused on entering and leaving airspaces (peri-urban)
3. Trial 3 focused on cross-border flights linking two cities in different countries (inter-urban)
4. Trial 4 was the scalability demonstration outside GOF2.0 consortium countries

Trial number and type	Preparatory “Wave 1”	Int’l Roadshow	Main “Wave 2”
Trial 1 – Dense operation in CTR	**x**		**x**
Trial 2 – Entering and leaving airspace	**x**		**x**
Trial 3 – Cross border operations	**x**		**x**
Trial 4 – International scalability		**x**	
Status	**Completed (4 countries, 7 locations)**	**Completed (3 countries, 2 locations)**	**Completed (4 countries, 5 locations)**

Table 1: GOF2.0 Project Validation

Reference Scenarios

The following UAM use-cases and scenarios were implemented during the live demonstrations.

Scenario	Reference scenario (EU) 2021/664
1a. Large number of automated parcel delivery drones operating <120 m AGL inside and in and out of CTR (drone warehouses can be close to air cargo terminal)	Strategic deconfliction through flight authorisation U-space suspended (dynamically reconfigured) when trying to operate close to active manned aircraft, for example at airport.
1b. Individual automated parcel delivery drones below and above 150m; flights in U-space end-to-end in two different CIS	A separate flight authorisation may be required in the part of each CIS. A U-space corridor in controlled airspace must be dynamically reconfigured whenever crossing manned air traffic in CTR and TMA. In uncontrolled airspace and over international waters all manned aircraft are required to be conspicuous directly to USSP when in the U-space corridor.
2a. Drone surveillance flights "long endurance" above 150m	Strategic deconfliction through flight authorisation U-space suspended (dynamically reconfigured) when trying to operate close to active manned aircraft, for example at airport.
2b. Drone surveillance flights in urban area <120m (Multiple drones monitoring facilities)	Strategic deconfliction with unmanned operations Suspended operations when manned aircraft operates (too) near
3. Drone mapping flights <120 m (construction, infrastructure, agriculture)	Strategic deconfliction with unmanned operations Suspended operations when manned aircraft operates (too) near

4. Unexpected "HEMS" -type GA flights	Generates alert of reconfiguration of U-space airspace leading to flight authorisation withdrawal with need for all UAS to land. No traffic information on unmanned operations available to HEMS pilot
5. Tourist drones doing ex tempore photography flights up to 120m AGL (and may be higher = rule violation)	Needs to file for flight authorisation and separately to activate and terminate it.
6a. e-VTOL intra-urban and peri-urban flights	Either flight in U-space airspace with information on unmanned operations or VFR/IFR flight in dynamically reconfigured ATC-controlled airspace with separation service. Not both.
6b. eVTOL intercity international flight	A separate flight authorisation may be required in the part of each member state.
7. Airline traffic ARR/DEP from int'l airport	Dynamic reconfiguration of U-space airspace inside CTR.

Table 2: Reference scenarios considered in GOF2.0 Project to reflect main UAM use cases

Deconfliction Methods

During the trials of the main "wave 2", the GOF2.0 consortium attempted to resolve conflicts on both a strategic and tactical level. Wave 1 showed, that monolithic operation plans cannot successfully be deconflicted without "blocking" the airspace for the duration of a single flight. Due to this restriction, all flights must be done sequentially and without the slightest overlap. Such a segmentation in time and space proves to offer a very poor use of the airspace, because some flights exceeded one hour in duration and stretched for 90 km distance and up to nearly 1 km in altitude.

The main "Wave 2" demonstrated deconfliction of segmented Operation Plans. Operational Plans were represented by four-dimensional trajectories by a means of waypoints defining the volumes in latitude, longitude, altitude, and time. Each UAS/aircraft operator provided segmented plans for authorisation and each segment could be deconflicted individually in 4D. Furthermore, only take-off and landing segments occupy a volume reaching the ground. En-route segment has a minimum and maximum height, enabling other operations to be routed below. Initial wave 2 trials were expected to exhibit time-shift as the deconfliction method, with potential for more advanced schemes to be demonstrated in the later trials. This implies that if a conflict of known missions (Operation Plans consisting of a set of operational volumes/segments) was detected at a certain instant in time, then the said missions did not receive an approval. Consequently, the system prompted one rejected mission (Operational Plan) to postpone in time, so that it could then obtain Operational flight approval for the next available "time slot".

Time-shifting conflict resolution can be treated as first-come, first-served, or first-requested, first-served rules. This method does not consider the activation of flight plans i.e., it does not consider whether the first flight that was booked finally took place or not. It is expected that different operators can provide different sized segments for deconfliction.

GOF2.0 did not demonstrate tactical deconfliction schemes, nor contingency/emergency procedures, as conformance monitoring was not implemented.

Objectives and Success Criteria

Prior to the trials Objectives (OBJ) and Success Criteria (SC) were defined based on their associated functional requirements, actors, roles and interaction with both U-space/ATM services as well as with urban infrastructure. Success Criteria have been kept on a general level with supporting Key Performance Indicators (KPI) linked to each Success Criteria, forming a three-tier evaluation framework.

Trial success criteria are set for nominal, non-nominal and emergency conditions and formulated for:

1. Operational and regulatory acceptability of GOF2.0 solution
2. Safety of GOF2.0 solution considering air and ground risk
3. Integration to airspace (ATM, U-space)
4. Effectiveness of tactical and strategic deconfliction/separation procedures
5. Integration to urban infrastructure (including landing infrastructure)
6. Security of scenario (data confidentiality, data integrity, …)
7. Performance assessment of the demonstrated services and capabilities
8. Scalability assessment (including economic scalability)
9. Integration to 3rd party services
10. Acceptability of U-space services under nominal, non-nominal and emergency conditions in all environments

4.2. Significant findings from GOF2.0

Prior to each trial, the objectives were covered in the trial briefing. Also, a debriefing systematically took place after the trial giving a chance to each stakeholder to express their perspective on the trials and hear each other's opinions on improvements before next trial. Learnings did not necessarily come from the success criteria themselves, sometimes from the surprises that came on the path to the trial.

Wave 2 was organized around an "onion principle". Operators were aware of only their own missions and goals. Only the creative and Trial leads and the safety coordinator knew all details of the trials and the expected interactions in the 60-90 minute trial runs. This enabled relying on systems and stress testing the GOF2.0 solution.

The main takeaways are presented in the table below.

	Lessons in Wave 1 (2021)	Lessons in Wave 2 (2022)	Takeaway (Wave 1 takeaways in *italics*)
Situation awareness	*N/A*	The UAS operators, who had integrated U-space services Operation Plan, Alerts and Traffic Information into their Ground/Fleet management systems experienced much better situation awareness and dramatically improved workflow effectiveness compared to operators,	Separate HMI (a USSP-supplied application) may be easier to implement technically but is from a human performance perspective inferior to an end-to-end integrated solution.

		who relied on HMI from USSP's.	
Operation plan deconfliction	Drone operation plans can be both large (for example 90 km long, 5 km wide) and long duration (2 hours). Strategic deconfliction of operation plans on a 'first-come-first-served' -basis would not have worked for a single of the GOF2.0 trials in wave 1.	Wave 2 demonstrated ops plans broken down in to smaller 4D segments. This improved the number of concurrent drone operations from one to several. However, a number of problems remain: the smaller the segments which allows denser operations, the more a single delay in take-off or a miscalculated mission timing will invalidate the assumptions in the strategic deconfliction logic. GOF2.0 did not demonstrate tactical deconfliction.	*Strategic deconfliction or Operation Plan authorisation cannot be based on simple 4D overlapping geographies. Operation plans need to be limited in size and broken up into some segments of a certain maximum size.* However, too small segments easily make a flight non-conformant as even a small delay makes a flight consistently miss its strategically deconflicted, series of segmented time-windows.
System integration in a multistakeholder environment	Lack of precise deadlines and deliverable leading to trial day prevented the early detection of planning issues.	Pre-testing was employed. Still, a rapidly evolving multistakeholder ICT environment without a fully stable service test environment means that lack of full integration is to be expected, and workarounds need to be prepared.	*Preparation protocols to be implemented and monitored by task and work package lead.* U-space and other multistakeholder integrations would benefit greatly from a "plug test" environment with predefined test scripts, which are constructed to weed out weaknesses.
Mobile network connectivity	Mobile network connectivity was unreliable in several locations. Issues with roaming SIM cards not working properly in another country added to issues.	Mobile network connections were less of an issue but could still not be discounted. The takeaway remains valid.	*Lack of reliable digital connectivity on the ground for drone operators remains one of the biggest obstacles to scaling up U-space adoption.* Valid takeaway.

Operation Plan vs Flight Object	All GOF2.0 trials conducted with Air Traffic Controllers uncovered the need to distinguish between an activated drone on the ground and a drone in the air (In-flight or Airborne). In other words, the system should be able to clearly distinguish between UAS turned on (motors are rotating and telemetry transfer is on) and a UAS that that is already flying, or a drone that has landed. In general flight plan status approval (strategic) and activation (tactical) do not provide this information. A non-conformance status on the Operation Plan does not allow to unequivocally determine whether the drone has landed or not.	*There is a need to associate the flight plan with a new object, tentatively named: "Flight Object". The Flight Object contains information about Flight Status.* *Analyses of ASTM3458 "RID" and ADS-L standards (currently in consultation) shows that RID and ADS-L will provide telemetry information on whether the UAS is on the ground or in the air (ON GROUND, AIRBORNE). However, the system should enable to pass the information about Flight Status independently of telemetry used (ADS-B, FLARM, OGN, 3G / LTE, 5G) especially if a single UAS is equipped with more than one source of conspicuity, or multilateration is used to locate a drone.* *Information about the drone altitude cannot alone be used to clearly determine whether the UAS is in flight (airborne) or landed due to the need to compare the altitude with the known DSM / DTM model, which may introduce an unknown error.*

Table 3: Key Learnings from GOF.0 Demonstrations

Other take-aways, not relevant to U-space, but to arranging VLDs in general:

Nature	Lesson in wave 1 (2021)	Lesson in wave 2 (2022)	Takeaway (wave 1 takeaways in *italics*)
Roles and responsibilities	Division of roles between task leader and trial leader lacked clarity for some trials	Wave 2 acted on the wave 1 takeaway. It is recommended that the local trial leader also coordinate communications and visitor coordination activities, possibly with strong support from other partners.	*Wave 2 will see more detailed definition of roles with the introduction of (local) Trial leader, Creative leader (planning scenarios) and Communications leader coordinating visitors and media.* The recommended clarified roles worked well in Wave 2.
Safety briefing	Safety briefing was not understood by one drone operator in one trial due to both language barrier as well as lack of detailed operations manual and internal division of roles.	Safety briefing in wave 2 was simplified, and thereby also more effective.	*Air safety coordinator to explicitly assert understanding of key concepts of all participants.* Still valid.
Ground communication	Skype was used for ground communication across the teams. Initial trials experienced a lot of talk related to manual coordination. In later trials the talk died down, as the actors started to rely on system interactions to do the coordination as intended.		Establish a clear procedure for what information should be reported immediately and in what format.
Conspicuity	Manned aircraft participating in trial had three sources of conspicuity: ADS-B, mobile network tracker and SSR. Only SSR worked, but it had a fault in the altitude reporting, so only position report was available to ATC, but not to GOF2.0 system of systems.	Wave 2 included pre-testing, and conspicuity was not an issue.	*Need to include pre-testing of all participating aircraft, and not assume that hook-on dongles work out of the box.* Still valid.

Table 4: Main Takeaways about VLD set-up in general

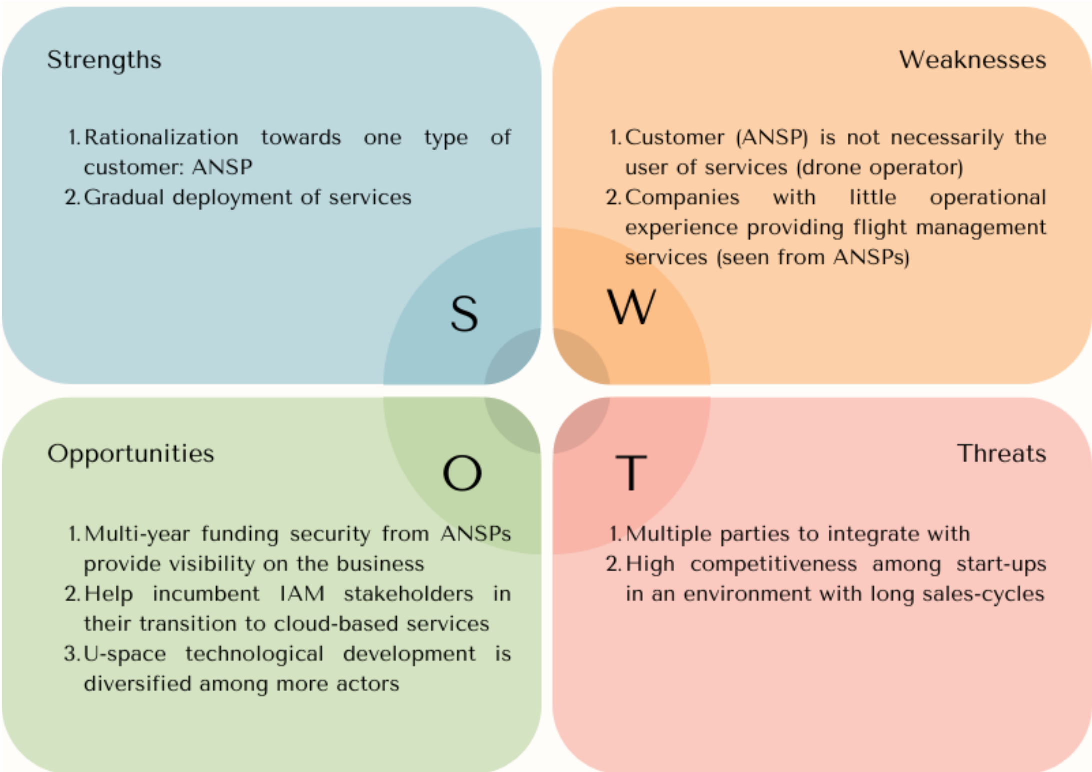
5 Innovative Air Mobility Ecosystem

Having synthesized different technologies developed during GOF2.0, this part is an opportunity to look again at the various roles and strategies of companies involved in this very large demonstration project. In particular, GOF2.0 system architecture sets a frame when it comes to relations between different parties. This U-space architecture therefore sets a business relation, or a U-space value chain that dictates the roles of producer and consumer. Towards the end of 2022, a review of this architecture was conducted in the form of interviews with different participants, where each was asked to share their future ambition, strategy and business opportunities. We write here some of those findings.

5.1. Different Stakeholders of UAS Traffic Management

U-space Service Provider (USSP)

There has been a rationalization of U-space Service providers after many start-ups started to develop UTM platform-based services for drones and quickly tried to deploy them. Ultimately, the sharp increase in drone flights and willingness to pay for U-space services materialized slower than expected, mostly because of the difficulties to fly BVLOS in a systematic, scalable way. USSPs trying to digitize airspace services also faced difficulties accessing data traditionally managed by incumbent ANSPs. Furthermore, missing regulatory framework and lack of willingness from drone operators and USSPs to self-fund at risk new developments has further slowed the growth in business.



In the meantime, the ANSPs have positioned themselves to keep control in the early stages of development and have exceptionally provided funding, so the USSPs have turned to ANSPs to secure early revenues though jeopardizing future market position. In such a way, ANSPs and regulators (which can sometimes be the same entity e.g., in Austria) could also dedicate more resources to shape regulations related to drones and implement associated services.

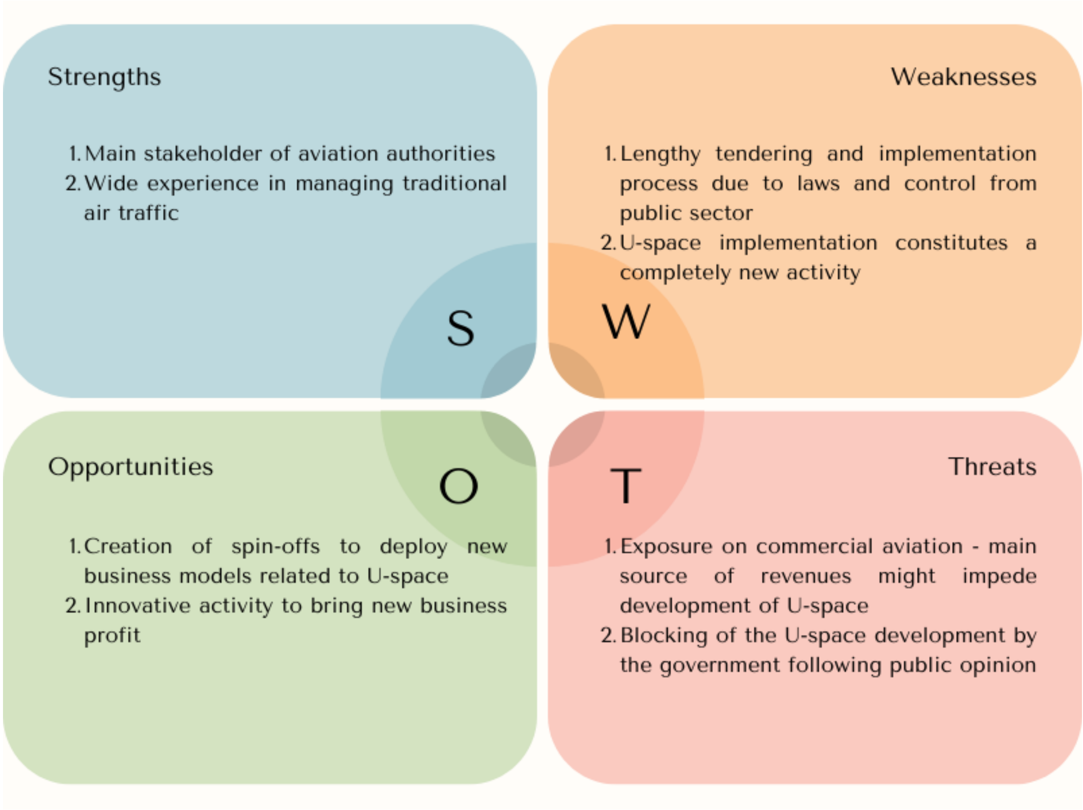
Today, it appeared to us that USSPs see ANSPs as their main growth lever. However, U-space is planned to be a free market where USSPs can freely compete, to the benefit of the drone operators. Different types of business models are foreseen from the USSP view:

1. Drone operators pay USSPs for services used
2. ANSPs subsidize the development and deployment of U-space services
3. USSPs pay a "concession right" to ANSPs

Overall, options (1) and (3), which would be respectively sources of revenues and costs for USSPs, were deemed less likely than (2). Many interviewees made a parallel with general aviation, where traffic services (NOTAMs, weather, flight plan deposition) used recurrently are paid for by the ANSPs and are usually available for free to the final user. In order to democratize drone usage, ANSPs plan to follow the same path with U-space services and fund these services for the USSPs. This business model could also be a basis for safer development of the activity.

Air Navigation Service Provider (ANSP)

The way ANSPs earn money is regulated in the EU by Commission Regulation (EU) 2019/317 of 11 February 2019 laying down a performance and charging scheme in the single European sky. For example, at the moment of submission of this deliverable in Poland, PANSA incomes were also regulated by the Performance Plan Poland Third Reference Period (2020-2024).

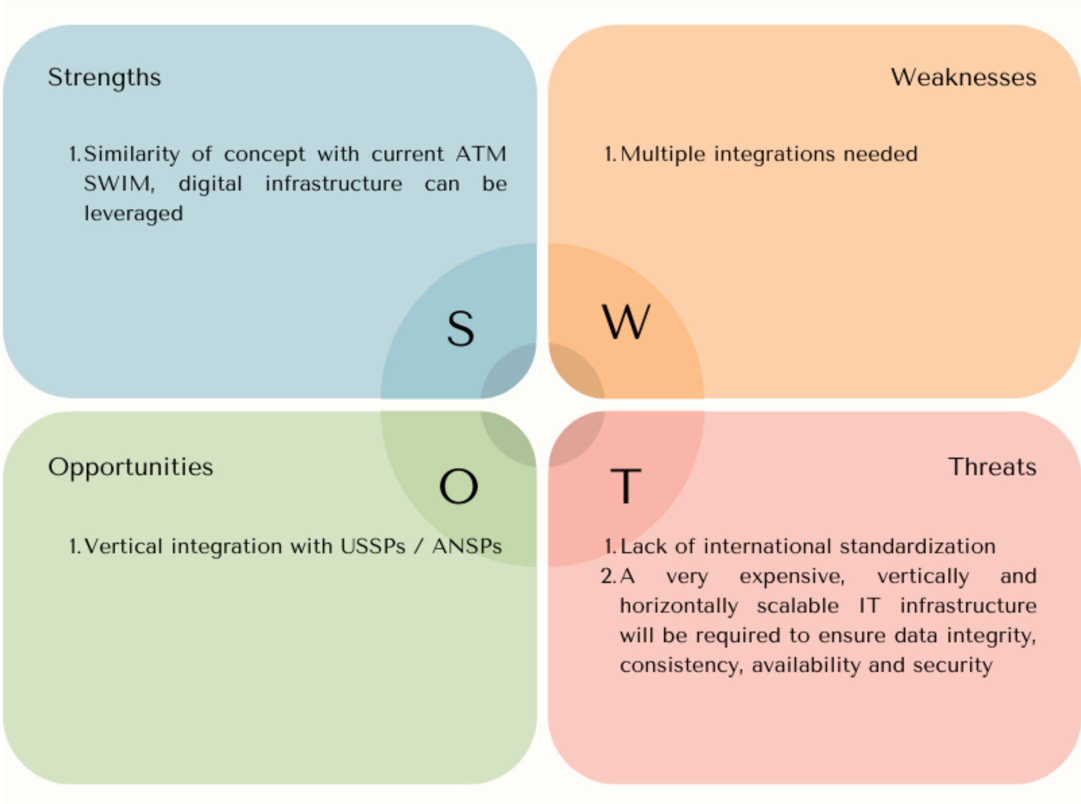


In such a case, the EU legislation does not fully take care of U-space development. Allowing drones to fly in controlled airspaces will introduce more workload for ATC, however solutions worked out by GOF2.0 and PJ34 are developed to increase safety of operations and provide ATCOs with better situational awareness. In the long term, U-space systems should become more and more contextual so that with increasing traffic, ATC attention should only be engaged in exceptional situations. ANSPs today must reconcile their mandate of keeping the sky safe with the development of new aerial vehicles mostly at their own expenses. In the long term, U-space systems should become more and more contextual so that with increasing traffic, ATC attention should only be engaged in exceptional situations.

Some ANSPs shared with us that no revenues from the drone industry are expected in the next 5 years. Billing too early could encourage illicit flying. On the contrary, the goal is to promote a safety culture, making services available at no cost to foster the safe development of the industry. Monetization will come later and the question is when.

Thus, a key question remains as to who finances U-space developments in the first place. Many ANSPs are reactively pitching their governments or budget owners to unlock funds to promote the use of drones. As with anything that flies, the idea of sovereignty is often put forward: a government that encourages drones thinks about its future economy. All along, efforts from the industry must be made to show utility when the public debate sometimes tends to classify it as an intrusive technology. And finally, one must relate the ability to invest.

Common Information Service Provider (CISP)



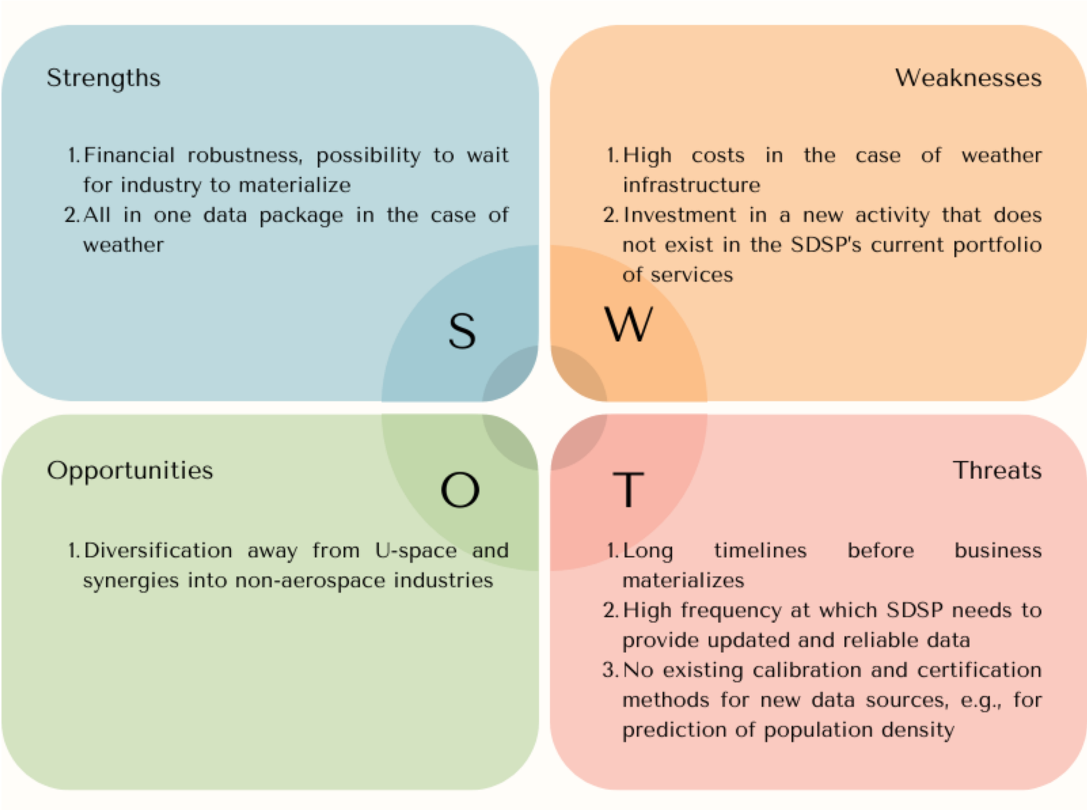
The CISP aims to be the single source of truth for U-space airspace characterization information and merges information from various players of the U-space infrastructure. Due to the inherent safety nature of the activity, many ANSPs, being liable for air safety, expressed their willingness to become a CISP. During GOF2.0, Frequentis managed this role.

In front of the GOF2.0 system architecture proposed, having a USSP also fulfilling the role of CISP is a sign of vertical integration. It can be seen by ANSPs as a simplification of tendering process, reducing the number of U-space stakeholders. However, this vertical integration could pose a threat of creating monopolistic behaviours, where access to CISP information could be favoured towards the USSP that handles it. Regulations can play a vital role in preventing such monopolies.

Supplementary Data Service Provider (SDSP)

SDSPs can be of various sorts and provide the key data needed for safe implementation of U-space services. A particular example is weather, where flying drones in urban areas brings its own constraints.

As part of GOF2.0, Vaisala deployed its wind LIDAR technology for accurate mapping of 3D wind fields around take-off and landing locations. Currently, wind LIDARs are widely used e.g., in the renewable energy applications where capability to measure wind field remotely is valuable. By applying same technology in other applications such as the emerging U-space ecosystem is a potential business diversification opportunity. The long-term promise is the deployment of wind LIDARs at each landing infrastructure but so far, such an opportunity needs to be further evaluated.



Would such wind LIDARs only be used for site installation decisions, or permanently? Can the cost of technology be afforded by an industry that promotes cheap access to flight with drones? On that last question, some SDSPs shared being open to considering new business models such as leasing of infrastructure.

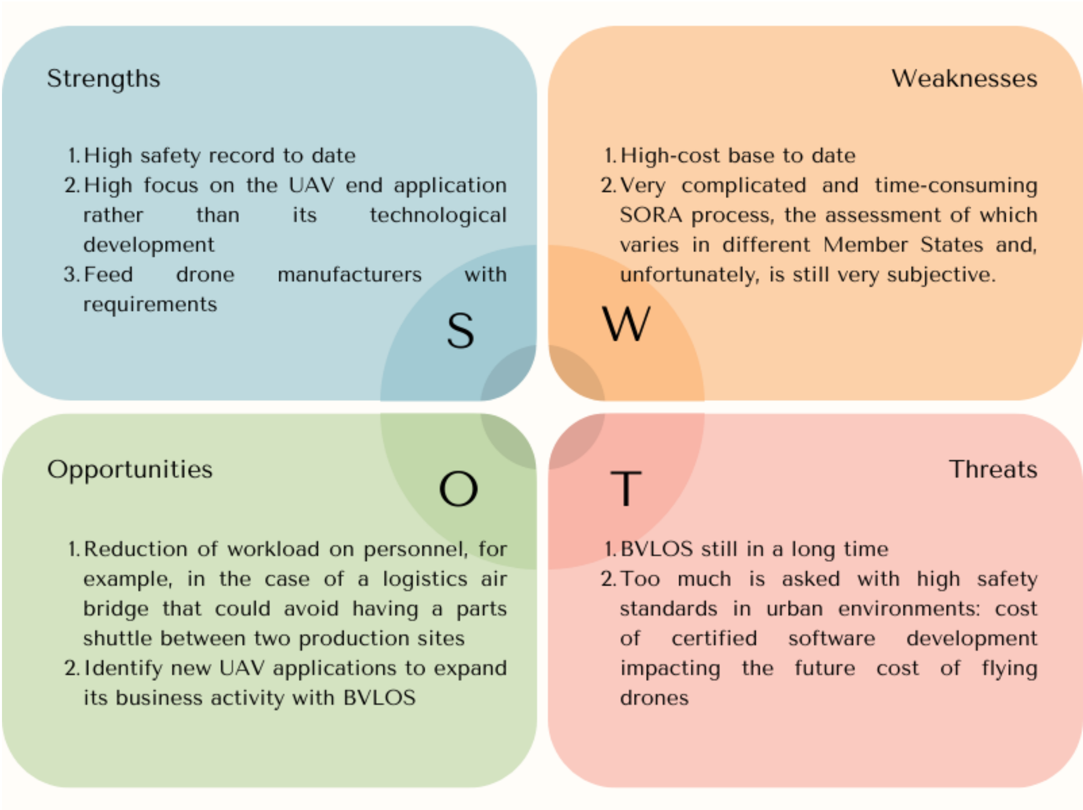
The business segment of SDSPs makes sense if the companies can diversify, otherwise the investment cost only for UAM or UAS may not be justifying the deployment of infrastructure. GOF2.0 provided an opportunity to integrate wind and turbulence field data in the context of the demos and feed it to USSPs.

Another example would be a source of population density information. While there are already advanced methods of population density estimation (data from telecommunications operators, satellite data, data from city cameras), there are no specific data calibration methods for them yet, so the time for official acceptance of the data by the Member States may be significantly extended.

Drone Operator

In the case of GOF2.0, drone operators were mostly manufacturers as well, thus leveraging their technical knowledge to have a drone ready on the day of the demonstrations. For operators in general, a major enabler still to come will be the authorization to perform BVLOS flights above populated areas in a scalable way. It is the very goal of VLD such as GOF2.0 to show a system architecture at work that could be the basis of that future.

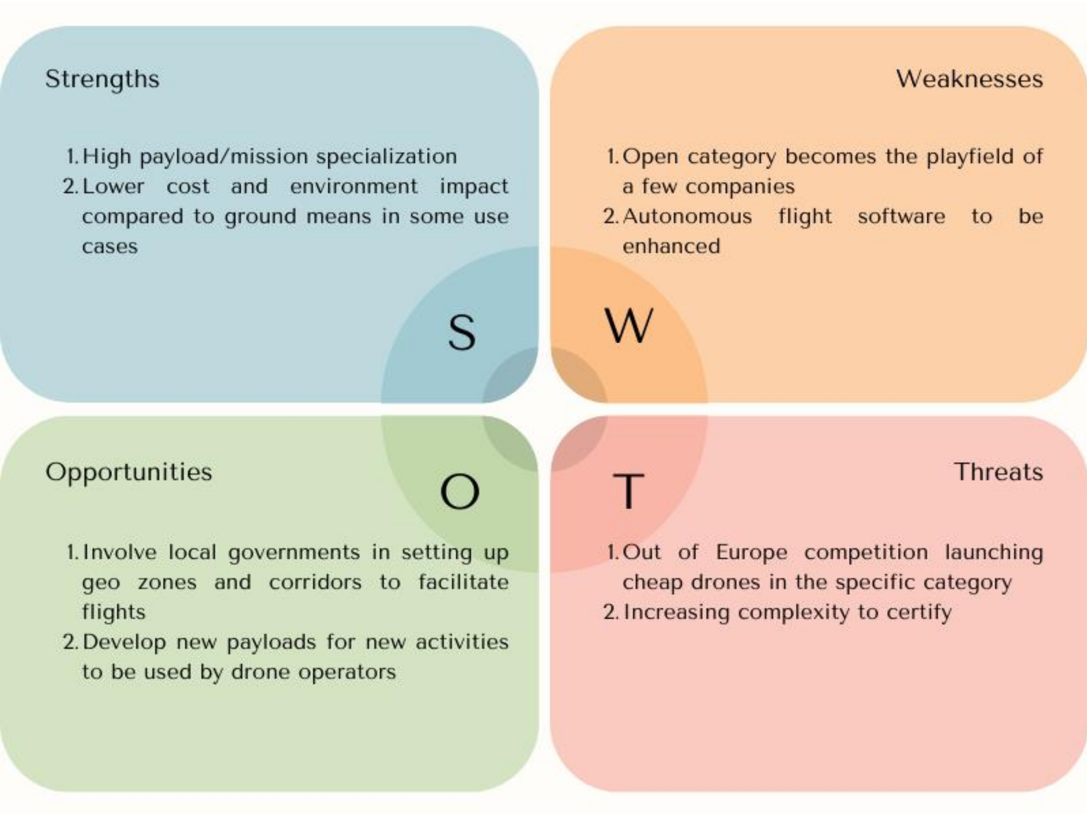
In waiting for such a future, drone operators acquiring aircraft have rather focused on specific market segments such as infrastructure inspection (airport runways, powerlines, pipelines) where airspace segregation can be assured, and specific payloads are needed for drones. For example, cameras in a specific bandwidth to detect a particular trace of chemicals. The type of mission results in being quite specific, if not niche, but service performed can be charged at higher prices because of its specificity.



Drone Manufacturer

Drone manufacturers face a competitive environment. Over the recent years, the democratization of low-cost open category drones built by Asian companies have pushed prices down. A striking example is DJI, claiming to have a 76% market share today (source: Statista).

As a result, European manufacturers have been pushed to differentiate by developing more complex aircraft in the specific category. They notably got attention from the military as the payload capabilities of their drones kept increasing. Eventually, the VTOL capability also became a strong requirement to prevent having to launch the drone manually, or in the case of heavier ones, to use a launching infrastructure.



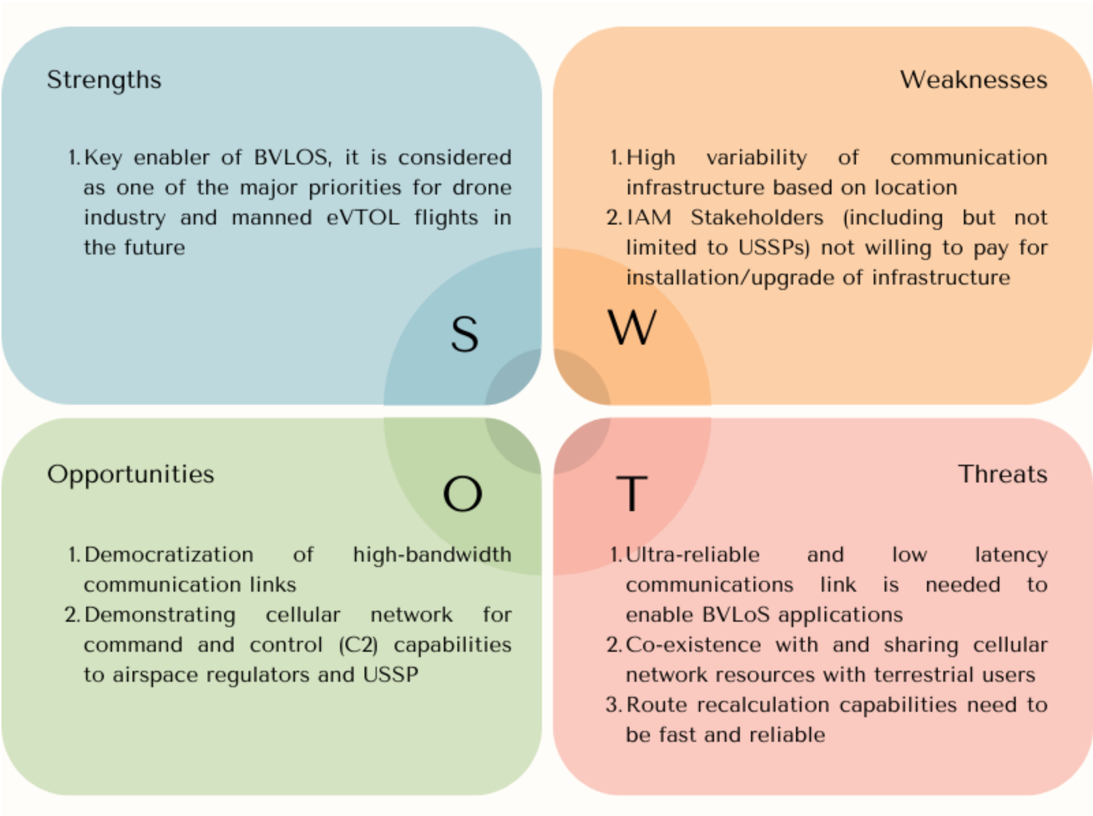
Many companies see the outcome of projects such as GOF2.0 as the opportunity to compete by integrating further with USSPs and developing a joint offer to companies willing to use drones. This was the case between Threod Systems and Frequentis, where industries willing to conduct infrastructure inspections could be approached with a solution including the drone, the analytics, and the means to fly in legacy airspace.

Beyond drones only, some companies introduced themselves as technology providers. This was the case of Unmanned Life, assembling various drones and payload options into unmanned systems. There GOF2.0 proved the ability of such companies to integrate with UTM systems. A key strategic move for those companies is to slowly switch from hardware to software provider, meaning that licensing a modular drone integration software would be more interesting than just selling a drone machine. There the flexibility of the UTM is seen as a critical enabler. Based on the drone option chosen, U-space services will need to dynamically adapt to the different vehicle classes but are not foreseen to be individualized due to diverse configuration options.

Command and Control Communication Service Provider (C2CSP)

A major opportunity of flying drones near urban areas is to leverage the existing communication infrastructure. C2CSPs aim to exactly do that and put as many communications means as possible at the service of drone flights to facilitate links to USSPs, Operators and Remote Pilots (if applicable). To do so, a key service must be the ability to access a reliable and available communications network such as cellular, satellite, or switch between them.

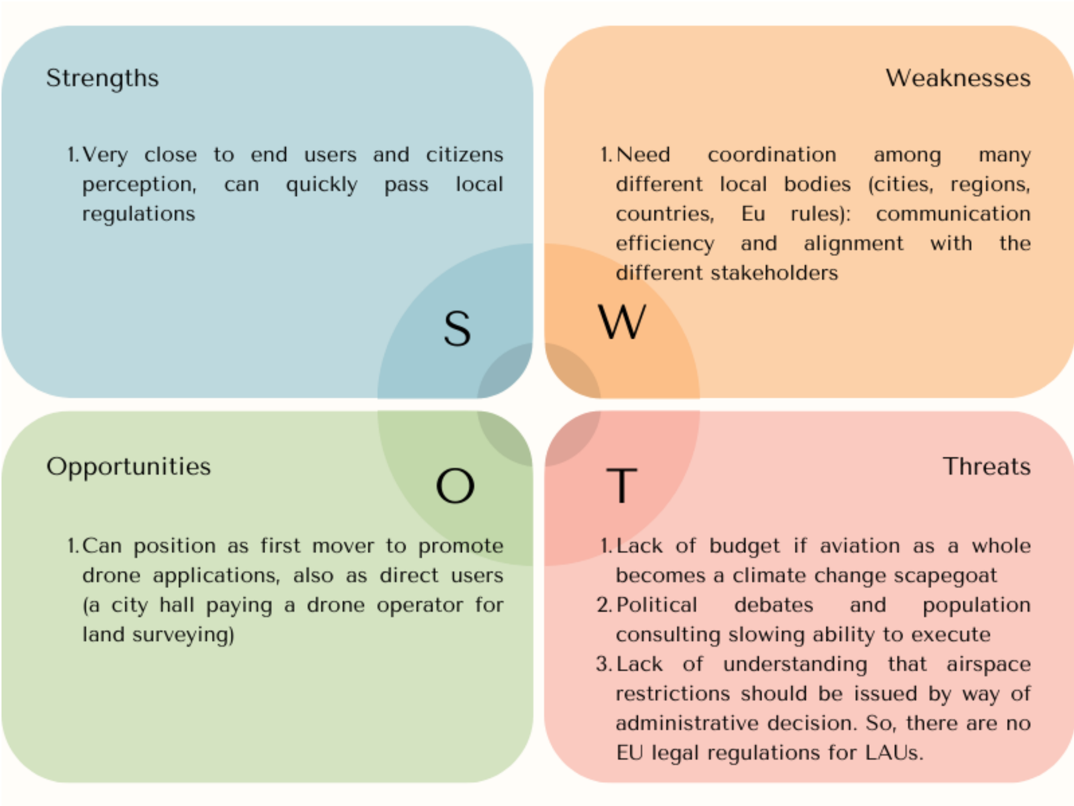
Furthermore, having access to cellular network data can help assess the number of people on ground through their cell phones. This could enable C2CSP providers to also become Supplemental Data Providers and develop a dynamic SORA service considering a proper assessment of ground risk. C2CSPs expect ANSPs to be the first customers of their services for safety critical applications, and eventually later USSPs. The interface to USSPs such as the one between Dimetor and Frequentis was a key achievement of GOF2.0.



Local Administration Units (LAUs)

During GOF2.0 trials, cities and governments were not direct consortium members but facilitators of every instant, assisting in the demos. This highlighted the key stakeholders that they are, having intimate knowledge of their environment. This role was further highlighted in the creation of drone geozones where cities could help define where it is possible to fly at a local level.

Drones could at the same time be suppliers of service and customers of city governments. Suppliers through applications such as city mapping, connectivity relays, infrastructure inspections, and customers indirectly through USSPs purchasing services about flight authorization, geozones, etc.



5.2. Barriers and Enablers for IAM

Disconnect between U-space and Drone regulation

Currently, there is a hopefully temporary regulatory disconnect in the Europe IAM market. While the U-space airspace regulation expects U-space airspaces to be established in cities and other locations of large IAM service demand in airspaces segregated from manned air traffic, the drone regulation expects early IAM traffic to be segregated from cities and locations of elevated ground risk. This creates a chicken and egg -problem, where there is no need for U-space until IAM safety cases can be approved in cities, but investments in IAM use cases, especially with smaller drones, are lacking due to the difficulties to prove the use cases commercially in their intended environments.

Even though IAM airworthiness and safety cases can be proven in sandboxes outside cities, the value of IAM services cannot be proven without live validation integrated to end-customer operations and systems. Given that the costs of regulatory compliance for IAM in cities are higher than in sparsely populated areas, the IAM industry and by implication the emergence of paying users of U-space airspace, are at a lull until risk capital has enabled sufficiently airworthy IAM vehicles to emerge on the European market.

Recalling that the advent of unmanned aviation was sparked by low entry barriers and easy access to affordable technology, the current need for significant risk capital to create a new IAM vehicle has created a barrier for innovation in IAM. This can be seen positively, as the industry needs a higher degree of professionalism. However, the current lack of means of compliance and guidance material for IAM vehicle airworthiness have often led to an underestimation of airworthiness costs, effectively slowing the go to market plans of some operators.

Lack of interoperability between U-space stakeholders inside and across Member States

Aviation is international by nature. Also, the IAM market should be shaped to be international from the start. While the drone regulation has prescribed U-space services such as e-registration and Remote Identification on a European level, the U-space airspace regulation has not required pan-European standards to be used. There are good reasons for this, mostly due to a lack of standards for interoperability for several of the new U-space services. Going forward, the GOF2.0 consortium strongly suggests, that a requirement for pan-European interoperability of U-space services is lifted onto the regulatory and standardisation working tables to ensure that UAS operators can take their operations from one Member State to another without revising their Operating Procedures.

GOF2.0 successfully demonstrated a set of U-space Information Exchange Services, detailed below, that allow all U-space stakeholders to align on a common view of the Data Models, stakeholders, interactions, and Data Formats of the different U-space services. GOF2.0 supports the use of SWIM Yellow Profile Technical Infrastructure for protocol-level coordination.

Standardisation of interfaces between service providers and UAS Operators could also be established, allowing free movement of UAS Operators, increasing safety (redundancy) in case of service provider outages, and ultimately supporting free movement of UAS operators.

Communities have their word to say

Ultimately, public communities will play a major role in the development of the IAM market. A few cities in Europe have already chosen a few years back to be at the forefront and to welcome drone technology and the entrepreneurs are also willing to experiment. Use cases such as building surveying, medical deliveries, police use give visibility to the sector and make good press. However, the limited number of flights prevents large potential disturbances to the population and exposure to risk.

As for future deployments of drones in larger scales, opinions differ. Some believe that a drone network seen as an infrastructure benefiting society could be subsidized through government investments. After all, if a societal problem is answered, the taxpayer could be put to contribution. That would be the case if we think about a necessary air bridge connecting communities or if drones equipped with defibrillators improve the efficiency of a health system. But in another fashion, if drones start to be majorly used to save time for food deliveries, then the public support might erode for what could be perceived as a luxury and not an essential need. And such delivery use cases, notably pioneered by e-commerce champions, are often the ones that carry the vision of a soon to be congested U-space. This forecast of a large number of flights is the one justifying today the development of UTM services.

So, will our airspace become congested with delivery drones one day? In case that comes, the cities that were interviewed expressed a clear opinion: they do not want to ban any type of technology but they can regulate it. Parallels were drawn between drones and e-scooter deployments. So here is what might happen with drones: every company will be welcome, but citizens will ultimately decide through their representatives about landing authorizations, number of stations...etc. In the interest of the IAM industry, it is then clear that perceived benefits of new air mobility must be felt by communities so that the regulation falls in place effectively.

And if drone examples were mostly described here, passenger eVTOLs will follow an equal treatment when they are certified. Up to any operator or manufacturer to deploy within cities step by step to find the best product market fit and fly the missions that communities desire.

Technology Enablers

The development of the IAM industry also remains tied to the development of technology onboard the aircraft. As many of those aircraft are planned to be powered by batteries, lots are expected from research on new types of cells. While power density provides performance in the hover phases and failure cases, energy density directly correlates with the range of the aircraft.

Beyond batteries, high power density electric motors, custom electronic components such as high integrity flight control computers will be key to boosting the performance of those new flying machines. One needs to acknowledge that many concepts have architectures fundamentally different from helicopters and conventional airplanes. Again here, public stakeholders can contribute so that this technology is tested in realistic field conditions. Armies opening their test sites, private companies experimenting new drone routes will all reinforce the acceptance and understanding of this new IAM technology.

5.3. GOF2.0 - An Enabler in IAM Ecosystem

Information Exchange Services

The advent of the (EU) 2021/664, 665 and 666 U-space airspace regulation has highlighted significant gaps in the standardisation on how the different stakeholders in the U-space ecosystem should be interconnected, as summarised in Recital (16) to 2021/664:

"This Regulation should establish requirements for common interoperable open communication protocols between authorities, service providers and UAS operators, as well as data quality, latency and protection requirements for the information exchanged, necessary for safe and interoperable operations in the U-space airspace."

The regulation establishes these requirements explicitly for information exchanges (IEX) between CISP, USSP and ATSP, largely ignoring the critical role of UAS operator systems and SDSP's.

GOF2.0 has successfully implemented and demonstrated a complete set of Information Exchange (IEX) services to address these gaps. The deliverables on different service specifications can be found on the GOF2.0 project website at this link. The maturity level of these IEX services is listed below.

Mature according to E-OCVM V3:

- GOF2-IEX1 Traffic telemetry exchange service
- GOF2-IEX5 Operational message exchange service
- GOF2-IEX7 Network coverage and population density exchange service

Partially mature according to E-OCVM V3:

- GOF2-IEX2 Operation plan exchange service

- GOF2-IEX3 Geozones exchange service
- GOF2-IEX4 Registration exchange service
- GOF2-IEX8 Weather exchange service

Not demonstrated and not assessed for E-OCVM V3:

- GOF2-IEX6 Conformance monitoring exchange service
- GOF2-IEX9 Drone flight exchange service

Several of these IEX's have already been adopted by PJ34 AURA as a baseline.

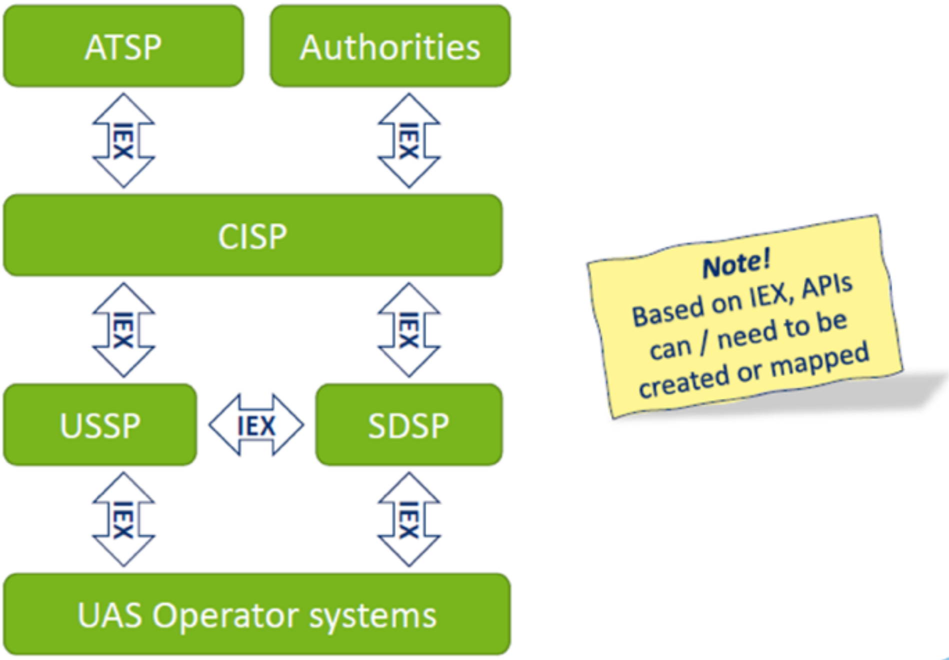


Figure 3: GOF2.0 demonstrated how IEX enable open & interoperable connections among U-space stakeholders

The available standards for Network Remote ID ASTM F3411 and for Operation Plan ASTM F3548 are not fully satisfactory, and the respective IEX's provide a European-led path forward. There are also several gaps in interoperability standards in the U-space airspace regulation and it is recommended to develop standards for:

- Alerts (operational messages)
- Conformance monitoring
- Weather data exchange
- Position data exchange, beyond Network Remote ID, unless ASTERIX is adopted in U-space, which GOF2.0 does not advocate as sole protocol

Outside the U-space regulation, there is also a clear need for standardisation, such as:

- No standard for network coverage or population density data

Standardisation is needed for safety related interfaces between UAS operator and USSP to facilitate the envisioned harmonized ecosystem on European level.

Multistakeholder approval as part of the operation plan processing

The possibility of multi-stage mission management understood as an acceptance, rejection and modification of the process related to the flight authorisation, by many parties responsible for different areas, will be a very powerful tool. Flights in a low airspace will be performed in areas of compounded interests of many users, with different business and environmental needs and goals.

It is necessary to understand why a multi-stage flight approval involving various organizational units is needed at all. Example of a UAS pilot requesting a flight within a City Park located in a remote part of a CTR controlled area. Let's assume that a UAS flight, due to its nature, will require the consent of the Air Traffic Services, and at the same time permission from Park Manager. For the flight to be performed, a strategic (pre-tactic) consent from both parties (ATS and Park manager) will be required. Both these consents are independent of each other, as they protect different interests. The one issued by the ATS protects the interest of manned aviation, and the one issued by the park manager protects the interest of leisure citizens. Only the issuance of both the approvals (the process can be parallel or serial) will enable the flight – give permission to fly.

The above example is one of many. The MSA (Multi Stake Holder Approval) function, in the opinion of the consortium members, will become a tool used on a daily basis in many configurations. The implementation of the MSA itself will not only be a technological challenge. Our observations show that it requires support at the level of administrative law which in turn, differs in detail in different countries of the European Union. Hence, the process of implementing multi-stage acceptance of flights will require following standardizations and regulations:

- Presence of Geozones as described in Article 15 of the (EU) 2019/947 regulation
- Definition of the areas of jurisdiction (vertical and horizontal) integrated with the Geozones
- An attempt to standardize whether the Geozone airspace border should end and start exactly at the plot border (boundary), or it may have a buffer zone. If buffer zones are preferred, then 'how wide should they be?' will be the question to be answered.
- Training for all those admitted for acceptance
- Specifying the means of communication between all stakeholders involved in the flight management process (e.g., the park will issue consent only on days with nice weather, and on rainy and cloudy days, consent will not be required)
- Specifying how long the applicant (UAS Pilot or Operator) should wait for a decision
- Specifying how long logs are to be stored in the system
- Allowing the possibility of managing MSA flights for the configuration of many USSPs in a given area (in accordance with (EU) 2021/664)

Drone Flight Object

In GOF2.0, the Drone Flight Object tracks the state of a drone flight separately from operation plan states – it combines information from the strategic planning of an operation plan and the actual current position and state of the drone.The Drone Flight exchange service transfers information about an ongoing drone flight and associated data. The central part of the data model for this service is the Drone Flight structure, which includes a summary of the drone flight state information, together with a reference to the related Operation Plan and optionally a reference to tracking information.

A typical U-space flight goes through several stages, starting strategic-tactically pre-flight, from Strategic Planning in the proposed state, over to Pre-Tactical Planning, to Tactical Planning in authorized state. Then, tactical-operationally it enters the actual in-flight stages (Activated on Operation Plan side) from Departure, over to In-Flight (Active on Drone Flight State), and finally Arrival (Closed on Operation Plan, Finished on Drone Flight). Further post-flight stages may evaluate the results from the data produced during the prior stages. Following figure shows the combination between Operation Plan state and Drone Flight state. For more details see GOF2.0 D2.4. Annex I Service Specification Drone Flight at this link.

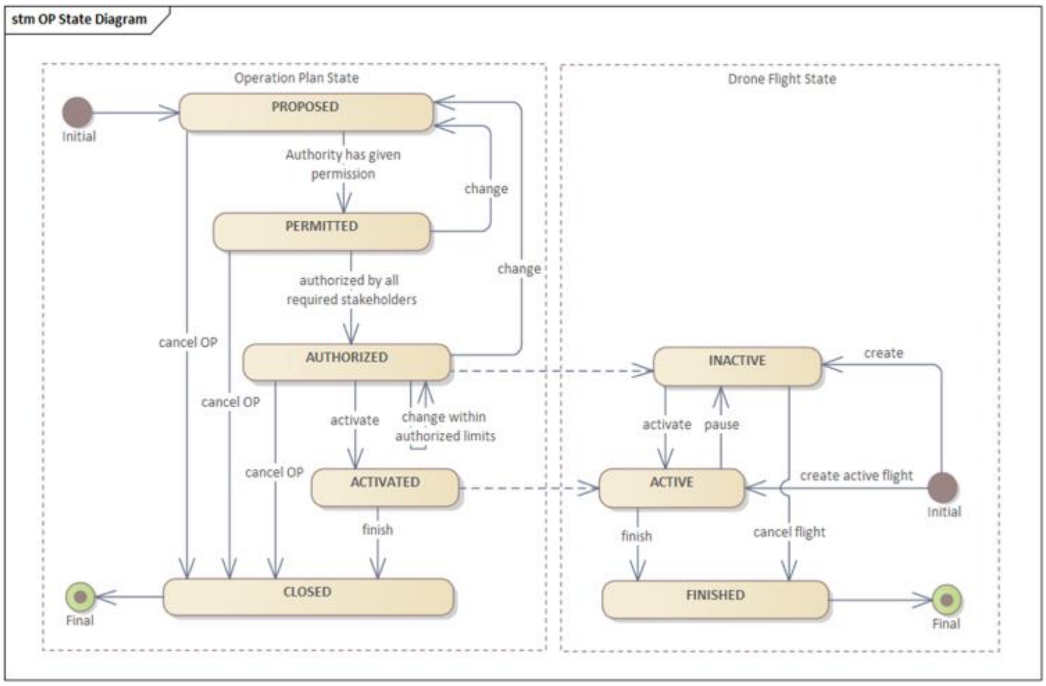


Figure 4: Operation Plan State and Drone Flight State

The Drone Flight Exchange service primarily is relevant during the actual operational in-flight stages of a U-space flight during which the flying device and/or the corresponding ground stations produce the position data which we convey via the Traffic/Telemetry service.

The Drone Flight Exchange service may be seen as a means of correlation between the position reporting (provided by the Traffic/Telemetry service) on one side and the operation planning (provided by the Operation Plan Information Exchange service) on the other side. The following figure shows Drone Flight Service Data Model, for more details see GOF2.0 D2.4. Annex I Service Specification Drone Flight at this link.

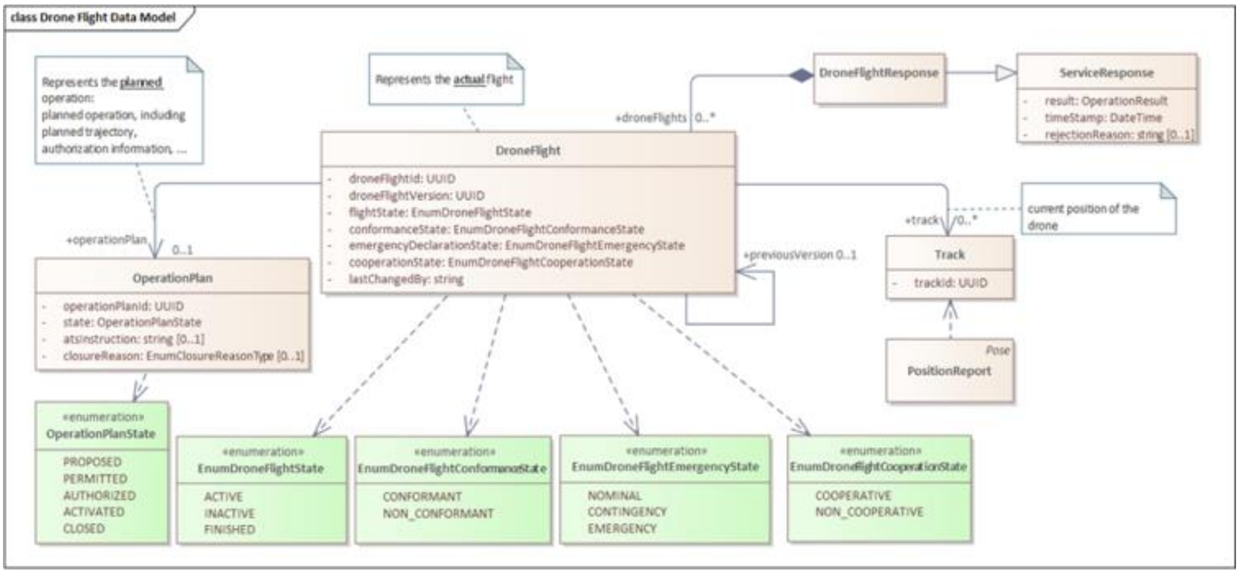


Figure 5: Drone Flight Service Data Model

The Operation Plan State enumeration type specifies the possible states of an operation plan.

Property	Description	Note
PROPOSED	Initial state of the operation plan. This operation is not yet APPROVED. It may be awaiting information from the operator, it may be in conflict with another APPROVED or ACTIVATED operation and undergoing a negotiation process, or for some other reason it is not yet able to be declared APPROVED.	
PERMITTED	Authority has given permission to proceed (Certification Processes, SORA, ...)	
AUTHORIZED	This operation has been deemed approved by the supporting USS. This implies that the operation meets the requirements for operating in the airspace based on the type of operation submitted.	Authorization of an OP may include the approval by multiple stakeholders. ATM may be one such stakeholder. In some cases, an OP may be AUTHORIZED without the approval of ATM (in cases where no ATM airspace is involved.
ACTIVATED	Operation plan has been activated. Drone is cleared to take off.	
CLOSED	This operation is closed. It is not airborne and will not become airborne again.	If the UAS and the crew will fly again, it would need to be as a new operation. A USS may announce the

		closure of any operation but is not required to announce unless the operation was ROGUE or NONCONFORMING.

Enum Drone Flight State enumeration type specifies the possible life cycle states of a drone flight.

Property	Description	Note
ACTIVE	The drone has potentially taken off and is performing its mission according to the operation plan.	This is the initial state of a drone flight, as the drone flight is created with its activation.
INACTIVE	The drone flight was activated but is currently pausing or has not taken off yet.	
FINISHED	The drone flight is completed.	

The Enum Drone Flight Conformance State enumeration type specifies the possible conformance states of a drone flight.

The conformance state indicates whether the drone flight conforms to an approved Operation Plan.

Property	Description	Note
CONFORMANT	The drone flight conforms to the referred Operation Plan. This means, the drone plan is currently in line with the planned 4D-constraints described by the Operation Plan.	Note that a drone flight is still CONFORMANT, even if it is in contingency mode, as long as it follows the contingency plan provided within the Operation Plan.
NON_CONFORMANT	The drone flight is currently not conformant to the referred Operation Plan, or there is no Operation Plan known for the drone flight. The Non-Conformance may be a violation of spatial or temporal constraints specified in the Operation Plans Operation Volume or Trajectory or Contingency Plan. Overdue is an example of Non-Conformant state.	

The Enum Drone Flight Emergency State enumeration type specifies the possible kinds of contingency/emergency states that can be declared by the drone operator.

Property	Description	Note
NOMINAL	The drone flight is in nominal conditions.	
CONTINGENCY	The drone flight is in contingency conditions.	
EMERGENCY	The drone flight is in emergency conditions.	

The Enum Drone Flight Cooperation State enumeration type specifies whether the drone flight is co-operative or not.

Property	Description	Note
CO_OPERATIVE	The drone flight is behaving co-operatively.	If only a flight declaration is possible (without telemetry transmission), the CO_OPERATIVE flight may be a flight reported (submitted) to the system.
NON_COOPERATIVE	The drone flight is not behaving co-operatively.	A NON_COOPERATIVE NON_CONFORMING drone flight is considered rogue!

Details on the Drone Flight interface can be found in Annex I of GOF2.0 D2.4 Updated Service Specification at this link.

Therefore, standardization of a Drone Flight concept and data exchange is recommended and will require the following aspects:

- Definition of Drone Flight Service to enable information flow between stakeholders based on
- Definition of Service Interfaces
- Definition of Data Model

Definition of Service Dynamic behavior including sequence of events and state machine.

Operational Messages

The Operational Message Exchange service transfers operational messages, such as instructions by air traffic control or a UTM service provider (e. g. "Land now!"), and the corresponding acknowledgements via the Operational Message and Acknowledge Message data structures, respectively. Such message exchange may take place between an operator and the U-space service provider (USSP), or between the involved USPs and/or air traffic services (ATS) units.

Each Operational Message shall be acknowledged by a corresponding Acknowledge Message. Reference to the related Operation Plans should be provided. Likewise, the corresponding Drone Registrations and Position Info may be provided as required.

Figure 6 below shows the Data Model of the Operational Message Service, more details can be found in GOF2.0 D2.4 Annex E Service Specification Operational Message at this link.

An operator subscribes to the **Operational Message Exchange Subscription Interface** of the USSP for each one of the Operation Plans.

A USSP or ATSU subscribes to the **Operational Message Exchange Subscription Interface** for its **areaOfInterest** of the other USSPs or ATSUs operating that area.

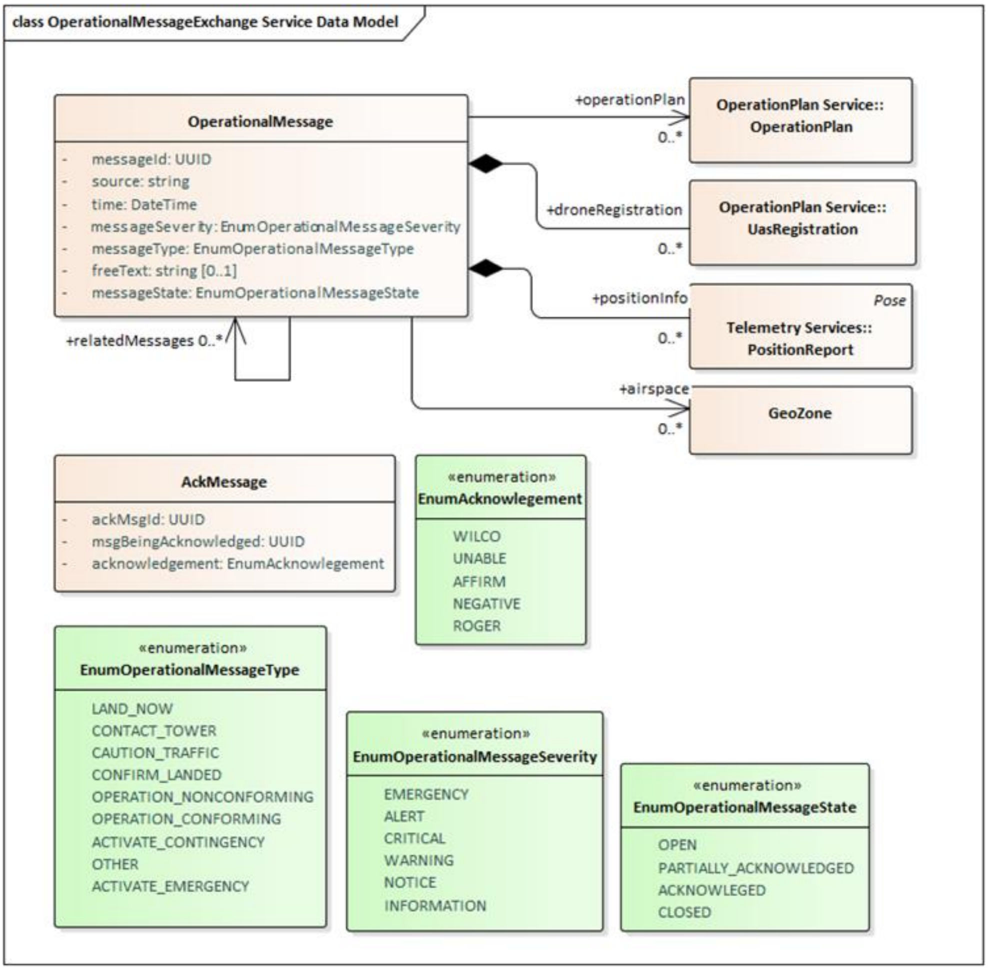


Figure 6: Operational Message Service Data Model

The **Enum Operational Message Severity** enumeration type specifies the Operational Message severities.

Property	Description
EMERGENCY	There is an *immediate* impact to the safety of other air operations, the safety of people, or the safety of structures on the ground. Actions to mitigate required by other operations.

ALERT	There may be an impact to the safety of other air operations, the safety of people, or the safety of structures on the ground. Actions to mitigate required by other operations.
CRITICAL	Without mitigations by the affected operation, the situation may rise to an emergency in the near future.
WARNING	There is a contained issue in this Operational Message that may result in the loss of aircraft. No immediate or likely effect to other operations, people on the ground, or structures.
NOTICE	The information conveyed in this Operational Message is provided for situational awareness. Planning by operators and USSs may be affected.
INFORMATION	The information conveyed in this Operational Message is provided for situational awareness.

The **Enum Operational Message Type** enumeration type specifies the Operational Message types.

Property	Description	Note
LAND_NOW	Instruct the receiver to land the drone immediately.	
CONTACT_TOWER	Instruct the receiver to contact the ATC tower.	
CAUTION_TRAFFIC	Informs the receiver about nearby traffic.	
CONFIRM_LANDED	Informs the receiver that the drone was landed.	
OPERATION_CONFORMING	Informs the receiver about a conforming operation.	
OPERATION_NONCONFORMING	Informs the receiver about a non-conforming operation.	
ACTIVATE_CONTINGENCY	Informs the receiver that the state of Contingency has been entered	
ACTIVATE_EMERGENCY	Informs the receiver that the state of Emergency has been entered	
OTHER	Any other message as described in the freeText field.	This option should not be used, as it cannot be processed automatically

Please note the concept of operational message was already adopted by SESAR PJ34. More details on the interface can be found in Annex E of D2.4. Updated Service Specification at this link.

Therefore, standardization of an Operational Message concept and data exchange is recommended and will require the following aspects:

- Definition of Drone Flight Service to enable information flow between stakeholders based on
- Definition of Service Interfaces
- Definition of Data Model
- Definition of Service Dynamic behaviour including sequence of events and state machine

Conformance Monitoring

Conformance Monitoring is one of the safety critical functions. GOF2.0 validations showed that there are many situations that are not entirely unambiguous, i.e., those in which, knowing all the conditions, it is difficult to determine whether a "non-conformant" situation has occurred. Example where telemetry signal from UAS disappears in the system. Does it mean that UAS has gone down or divert away? Not necessarily. The disappearance of the UAS from the monitoring systems can only mean that we have lost contact with it, and the mission is likely to continue automatically.

Therefore, standardization of the Conformance Monitoring systems will require standardisation of the following aspects:

- Unambiguous definition of the conditions when a flight should be considered non-compliant
- Conformance monitoring must be a 4D system, i.e., it must consider time. For example, taking off too early or not landing on time (overdue) should be treated the same as a 3D deviation from the planned flight plan.
- Conformance monitoring should be a real-time service. Due to the rapidly growing number of missions and Geozones, the demand for computing power will also grow very quickly. Consequently, the method of determining the maximum capacity of the system, i.e., the number of flights, flight plans, Geozones and the complexity of the terrain in which the system will ensure efficient operation within the expected reaction time, should be defined.
- Conformance monitoring system should be able to log all events and alarms.
- The method of exchanging information between the Conformance monitoring system and other systems (CISP/USSP/FIMS, etc...) should be standardized in such a way that all users receive unambiguous information in an expected time.
- Conformance Monitoring could be considered as independent service providing oversight on drone missions ensuring fair and equitable use of airspace, e.g., if USSP and UAS operator roles are assumed by the same entity.

Network Connectivity Data

Connectivity is a critical requirement for safe and successful deployment of drones into an integrated airspace at scale. To satisfy the legal airspace obligation to have a "pilot in command", sufficient and reliable connectivity is a must have requirement for flying beyond visual line of sight (BVLOS).

Therefore, even for the flight planning and flight clearing it is important to know where sufficient connectivity for a reliable ground-to-air and air-to-ground communication exists.

Furthermore, for a holistic risk assessment, information about the number of people on the ground, or "population density", is required as well for the planned flight path. To ensure that flight planning and flight clearing can include such additional, supplemental data, interfaces to the most appropriate data sources, which are mobile network operators, are required.

The objective in GOF2.0 thus was to define a service specification that allows the seamless data exchange between the common information service and the respective mobile network operators. This is highly innovative, as it didn't exist before. Another objective was to validate the capabilities operationally in the field, adjust and enhance, and then recommend the respective service definitions to the standardization bodies for global harmonization and certification.

As part of the GOF 2.0 project, FREQUENTIS and Dimetor developed a service specification that describes the general architecture comprising stakeholders, services, interfaces and data models for automated data exchange between mobile network operators (MNOs) and the UTM ecosystem. This service specification served as the basis for the NetworkCoverage Service Definition by ACJA. ACJA, the Aerial Connectivity Joint Activity – founded by GSMA, the global representative of the mobile network operators and GUTMA, the Global UTM Association representing key aviation stakeholders such as drone operators, UTM providers, ANSPs and CAAs.

ACJA's public mission statement says:

"*The main aim of the ACJA is to promote the exchange between the aviation and cellular communities, and to synchronise contributions between the existing Standard Development Organisations (SDOs) of each community, in order to avoid incompatibilities between them.*"

Therefore, ACJA has used the Connectivity Service Specification as the basis for the ACJA Network Coverage Service Definition 1.0 available at this link, which is now further recommended to the associated standardization bodies as the globally accepted standard for exchanging network connectivity data.

The service specification has been implemented by Dimetor, FREQUENTIS and other GOF 2.0 partners for field implementation and validation. During the GOF 2.0 field implementations in 2022 in Latvia, Poland and Austria, further key enhancements have been achieved in the network data service definition. Working closely with ACJA again, the findings in GOF 2.0 again formed the basis for the evolution of the interface specification, now being called "Network Data Service Definition 2.0" – which is currently under the approval process of ACJA, i.e., GSMA and GUTMA board, respectively.

The Network Data Service 2.0 has already been introduced to "CAMARA – The Telco Global API Alliance", which has been established as a global interface specification and standardization platform. CAMARA is an open-source standardization project within Linux Foundation defining, further developing and testing the interfaces. By doing so it makes APIs available to everybody in the industry, driving safety standards on a global level. This in return will allow UTM systems, SORA processes, aviation standardization bodies and others to benefit from globally harmonized data exchange that is standardized across the industry, so that it can be certified and standardized for the aviation applications.

Population Density Data

Predicting population density is a wildly subjective task. An attempt to systematize this issue was originally undertaken by the JARUS organization and defined by many aspects in JARUS Annex F. These, in turn, were used to define the requirements specified and required by the official SORA process. Overall, GOF2.0 saw two big, fundamental issues that need to be further standardized:

- A way to measure population density

The problem with population density begins from the simple fact that the same number of people can be counted in a given area in many ways. Let's imagine that we have 100 people on the desert. This means that in a given area we have a population density of 100 people per 1 square km. But if we move the measurement area slightly beyond these people, it may turn out that the population density is zero. On the other hand, if we compact the measurement grid, e.g., to squares with dimensions of 100 by 100 meters, then we will actually have information about where people are, but then their statistical density will increase from 100 people/sq. km to 10000 people/sq. km.

- The authorisation of the data source

At present, data from censuses are most often used. It should be emphasized that in many countries this method has become dominant due to the possibility of accrediting the source as official. Data from the statistical census, although considered official in many countries, introduces a significant error, and unnecessarily overestimates or underestimates the iGRC coefficient. The census refers to the places where people live. However, as is well known, people move, work and travel. Additionally, census data does not consider hourly, weekly and monthly fluctuations.

Regardless of which data source we use, data source accreditation is required, which should consist of elements of calibration (specific to the behaviour in a given area and the characteristics of the area itself) as well as determining where static and where dynamic data will be required.

Therefore, other population density prediction systems are needed. During the GOF2.0 project, the following two solutions were considered, in which the consortium members demonstrated sufficient knowledge, experience and competence to perform the tests:

- analysis of data from mobile operators
- analysis of data collected based on EO (ESA HOPE project)

Both methods appear to be more accurate than census data and provide the ability to analyse hourly, weekly, monthly, and even yearly people fluctuations. However, their disadvantage is the fact that they do not have accreditation to be recognized by state authorities. Consequently, standardization of data prediction and calibration methods should be considered in such a way that their results are recognized by state authorities.

Weather Data

GOF2.0 has been one of the first large demonstration projects to integrate a specific micro-weather service into the emerging U-space ecosystem. In June 2022, as part of the Malmi airport trial in Finland, VAISALA demonstrated a Doppler-Lidar based micro-weather data service by making the near real-time wind and turbulence awareness available for consortium members. Information was shared through the API interface, which enabled smooth data integration e.g., into AVIAMAPS user interface.

In the U-space system weather information is categorized as a non-essential service as part of the U-space Service Providers (USSP) services. Despite the non-essentiality, weather can often prevent flight operations or otherwise cause delays. Different U-space operations have different kinds of weather limits which will also make it difficult to set any specific one-size fits all weather criteria.

During the last years EASA (in Europe) and ASTM (in U.S.) working groups have been active developing initial weather-related guidance and regulations for U-Space & UTM. VAISALA has also provided contributions into those. It is good to note that the EASA guidance is fairly general (setting basic expectations) and ASTM is aiming more detailed outcome.

Standard aviation weather reports are typically a good representation for the conditions on the ground, but not particularly good fit for the very low-level airspace. This should be emphasized in the weather standards and that different U-space operations have different kinds of weather requirements and operational limits which will also make it difficult to set any specific one-size fits all weather criteria.

Suggested updates to EUROCAE ED-269

The ED-269 standard is a very good start for Geozone definition and management. The standard itself solves many problems that turned out to be unsolvable in the AIXM standard. Still, ED-269 standard requires further development especially around ConditionExpressionTypes.

Hence, further standardisation requires more guidance on how to realize conditional language ideally on European level:

- Examples of parse flows
- Dictionary of Chart types
- Definition of UAS and Operator/Pilots registry exchange
- Support for more complex condition logic
- Expressed preference between Access list and Deny list

Offloading ATC Controllers

During the GOF2.0 tests, ATC personnel were involved in several trials. Feedback was received from them that ATC personnel were overloaded by different dataflows and information on display. Automated workflows and ATC should be notified only when intervention is required. For this, supervisor role for strategic and tactical approvals should be considered.

The proper use of the human potential of Air Traffic Controllers is in integrated UAS flight management. However, this requires adaptation of the entire system to the specific needs of drone flights, considering, among others:

- The human factor, including the limitations of perception and the minimum possible time to recognise the situation

- Limitations resulting from the training process for all participants of U-space flights, especially UAS Pilots and GA Pilots
- Awareness of the number of flying aircraft, many times exceeding the number of manned aircraft managed by ATC in the jurisdiction of the responsibility
- The need to adapt operating procedures at the controller's workplace
- User interface integration problem rises as today's air traffic control systems are galvanically separated from the internet for security reasons. On the other hand, U-space systems are inherently connected to the Internet, which may pose a potential risk of multidimensional hacking attacks (spoofing, DoS, DDoS, MITM, attack for data integrity, malware attack, password attack, phishing attack, SQL injection attack and many others). Consequently, the ATM and U-space systems will be separated from each other for a long time, which means that the controller must operate at least two critical systems (monitors) at once.
- Understanding, by analogy to manned aviation, specifics of UAS flights in a given area.
- Definition of emergency procedures, e.g., what to do in the event of the need to issue the Land NOW command, if the UAS has completed half of the planned route in the CTR and it is not possible to land due to the congested city area. Should UAS turn back, continue the mission, or change the horizontal trajectory to leave the CTR as quickly as possible? Each of these functions has its consequences, but the most important thing is a multilateral (Pilot, Controller, System, procedures) situational awareness and understanding intentions.
- Due to the simple fact that the main communication system is the public internet, it should be assumed at any time that it may fail.
- Since most of the GCS systems use generally available operating systems on which, apart from the flight management software, any software can be installed, the possibility of their negative impact on the entire system should be considered.

In conclusion, the relief of the controller's workload will require standardization of the following aspects in the near- and long-term future:

- Separation of strategic and tactical UAS traffic management. Consequently, this means that the strategic role of planning processes related to Operational Flight Plans should be undertaken by AMC1, 2, 3 (ASM) units.
- Creation of an understandable interface managing the airspace capacity in the tactical (take-off clearance) area of the jurisdiction, divided into smaller areas (approach zone, IFR circling approach procedure, etc.).
- Defining the procedures which UAS Pilots and which automatic and autonomous systems can expect automatic approval. In other words, in the registration system, it should be possible to add a feature describing a trusted (frequently flying pilots) along with the geographical area assigned to them.

- Division of the role of the tactical user, into the one working at the operational position from the one who manages the capacity of the space and its sub-sectors (e.g., TWR Supervisor).
- Standardization of procedures between civil and military ANSPs at the strategic and tactical level. In this case, it is about systems of routine daily activities and ad-hoc activities in case of specific situations.
- The ability to disable and enable automatic or semi-automatic procedures at any time in the entire area of responsibility or its sub-areas.
- In situations where it will be required, extending the MSA (Multi Stakeholder Approval) functionality with tactical communication with LAUs (Local Administration Units) and public order organizations (112, fire brigade, etc.). Unification of the continuous risk management, on every U-space stakeholder (ATC, AMC, LAU, UAS Pilot, UAS Operator, LAU) as well as keeping up to date the unified education process is necessary.
- Definition of the MEL and MMEL systems known from manned aviation in such a way that each party knows about the limitations resulting from them.
- Understanding the problem of determining and interpreting the height/altitude along with the unification of its presentation. In other words, ATS should continue to use altitude values determined by barometric sensors, and Pilots and UAS operators should continue to use GNSS based systems.

In conclusion, the issue of standardization and regulation of aspects related to the work of the Air Traffic Controllers is a multidimensional and interdisciplinary issue. In the above recommendations, we have included those that we noticed as evident during the GOF2.0 project. The basis for these recommendations is the many years of experience gained while working on the operational PansaUTM system and the possibility of cooperation with ATS from many ANSP under the GOF2.0 project: EANS, Fintraffic, Naviair, LFV, PANSA and LGS.

5.4. Regulatory framework

U-space regulation (EU) 2021/664

UAS Operator system integration to USSPs

It is important to recognize the importance of drone system and ground control system manufacturers as key stakeholders to ensure, that the USSP services can be directly integrated into the UAS GCS (Ground Control Station). In GOF2.0, the UAS operators who had integrated U-space services Operation Plan, Alerts and Traffic Information into their Ground/Fleet management systems experienced much better situational awareness and dramatically improved workflow effectiveness compared to operators, who relied on HMI from the USSPs.

Using a separate user interface to interact with U-space services is not scalable for more advanced flight missions but may be adequate for simple VLOS operation plans. Integration between USSP and UAS fleet management systems is operationally a safer and more efficient way to ensure data quality and pilot attention – of course provided that the necessary integrations are fully operational. GOF2.0 recommends adding integration between USSP and UAS into the scope of regulation to ensure ease of migration for UAS operators from one Member State to another without a need to change software (similar to how roaming works for mobile phones).

Ensure information exchange services are governed on a European level and discourage any attempts to create unique, national implementations

The integration approach based on interfaces and common information models has not prescribed a specific architecture, i.e., enforcing a fully centralized or fully federated system. Based on the nature of shared information, it's origin and geographical applicability, different partners within GOF2.0 provided the "single source of truth" (which could be realized common information service), supported by means for service discovery.

To consume provided services, partners could use subscription-based interfaces only (especially in CIS – CIS, CIS – USSP settings), some might gear towards request/response (command based) interfaces. Focused interfaces allow to reuse the service specification between any stakeholders, i.e., operation plan and telemetry could be used to share information between CIS / USSP as well as between USSP / UAS Operator. Standardisation of interfaces between service providers and UAS Operators could be established, allowing free movement of UAS Operators, increasing safety (redundancy) in case of service provider outages, and ultimately supporting free movement of UAS operators.

Drone regulation (EU) 2021/947

Clarify the role of ATS to provide segregation from manned air traffic resulting in ARC-a in controlled airspace

Annex C to AMC1 to Article 11 of the AMC/GM to (EU) 2019/947 edition September 2022, section C.6.3 Lowering the initial ARC by common structures and rules, states:

"*Outside the scope of the SORA, a UAS operator may appeal to the competent authority to lower the ARC by strategic mitigation by using common structures. The determination of acceptability falls under the normal airspace rules, regulations, and safety requirements for ATM/ANS providers.*"

GOF2.0 experience shows that this approach is not uniformly and commonly understood by NAA's and ATSP's throughout Europe. It is clear, that ATS regulation gives an ATSP the ability to provide atypical airspace, by dynamically activating sectors of controlled airspace for BVLOS drone traffic. An ATSP will typically create an own safety case, and subject to being satisfied, that separation distances to an active drone sector can be maintained by manned traffic, the ATSP can provide a more dynamic segregation of airspace sectors compared to temporary danger or restriction area activation mechanisms. Indeed, D or R areas in CTR are not easily acceptable by an ATSP, so having another segregation means fully under ATC control is positive.

So, the project consortium recommends to EASA to provide clear Guidance Material to support ATS providers and CAA to accept this mechanism enabled by SORA, thereby increasing the speed of adoption for UAM in CTR and the ability to perform advanced trials in CTR without U-space airspace establishment requirements.

Consider the total level of safety for single demonstration flights compared to commercial flights

Currently, the process to apply for Operational Authorisation does not distinguish between a single flight day or continuous operations, even if the risk between the missions is vastly different. Based on feedback from operators in GOF2.0 we recommend EASA to designate 3rd party entities to manage the Design Verification consultation and compliance process on behalf of EASA to ensure that UAS operators and manufacturers can receive service on DVR in their home country, in their home language. For instance, authority can be delegated to CAAs to accept declarations of airworthiness up including SAIL III for a limited number of flights. For commercial flights it should be possible to have more than one aircraft flying in TRA (or similar airspace structure). EASA with national authorities should prepare tool to easily check operational vicinity on ground with standardized population density. There should be standardized forms of checklists and operational manuals for operators.

Accepting that a forced UAS landing is seldom catastrophic, even in cities

The current interpretation of the drone regulation in Europe emphasises the segregation of UAS from society. For example, the means of compliance for enhanced containment using flight termination systems instructs an applicant to apply worst-case instead of average-case to calculations. As a forced landing of a UAS is seldom catastrophic "hitting someone with fatal consequences", it should be acceptable for UAS err outside ground risk buffers part of the time. It should not be an objective to segregate this new mode of urban transportation from the urban environment, even at lower levels of robustness. What we are observing that the safety systems are not as much developed as other systems in UAVs. Some of the safety systems are parachutes, airbags, kill switches, cages, etc.

GOF2.0 suggests that EASA revises its view of forced landings and out-of-control events, and adopt the ICAO framework, where ground risk is a combination of out-of-control, of hitting people or critical infra structure and finally, having a killing effect. Current interpretations seem to emphasize only the first of the three factors in the equation. We think that EASA should encourage companies by creating a special fund for overall safety of UAVs operations. New, better and safe solutions should be developed to minimise the risk of fatal incidents in case of critical malfunction of UAV over people. Also, there should be recommendations on UAV design to create more redundant systems which affect safety.

Furthermore, Open and Specific categories do not currently form a continuum of increasing risk. A flight with a 1.9 kg drone was demonstrated by GOF2.0 to be acceptable on very short notice on airside in an aerodrome with only ATSP safety assessment and without CAA involvement, whereas a 2.1 kg drone would take months to be allowed to operate in the same environment. The step between Open and Specific is currently (way) too large, especially when it comes to time and money involved. The regulation also needs to be supplemented to assess the safety of the lift of lighter-than-air gases (e.g. balloon-type UAVs), the risk of which is significantly lower than that of UAVs of the same MTOW that use only engines to remain airborne.

National approvals and EASA approvals and Design Verification Process

GOF2.0 conducted 16 trials within total 17 trial runs with well over 50 live flights ranging from small multi-copters to long endurance, medium altitude surveillance drones, air taxi and manned aircraft. In total nine (9) different operators of real and simulated drones from the consortium participated in four (4) countries: Finland, Estonia, Poland and Austria.

5 of 36 flight missions were rejected by the NAA: Two related to flying under national transit rules (accepted by NAA, contested by EASA), one specific category flight at an aerodrome, one open subcategory A3 not allowed in an aerodrome, one valid OA of a UAS operator was rejected by the NAA in another Member State during Article 13 cross border coordination.

The transition from national drone regulations to EASA regulations has partly paralysed the permit procedures in several member states. Safety cases that have been acceptable under previous national regulations in 2021 were rejected in 2022. The reasons were not in the regulation itself, but in the lack of experience by CAAs to apply them towards a positive outcome. The reason was also the lack of proper regulation and form updates from EASA to national CAAs. The two main stumbling stones were:

- Not accepting ATS -provided segregation as ARC-a/b outside SORA
- Not accepting declarations of Enhanced Containment

The procedures required to achieve compliance in 2022 cost thousands of euros and lasted several months. At the time of the processes nearing completion, the GOF2.0 consortium had to change location for trials enabling Open category flying to be able to mitigate the risk of possible rejection of applications for Operational Authorisation or Cross-border coordination in the specific category.

The drone regulation (EU) 2021/664 would benefit from an update, that

- Clarifies the role of ATS to provide segregation from manned air traffic resulting in ARC-a in controlled airspace, considering normal SERA separation minima.
- Provide Guidance Material to support ATS providers and CAA to accept this mechanism.
- Considers the total level of safety for single demonstration flights compared to daily flights. Currently, the process to apply for Operational Authorisation does not distinguish between a single flight day or continuous operations, even if the risk between the missions is vastly different.
- Delegate authority to CAAs to accept declarations of airworthiness up including SAIL III for a limited number of flights.
- EASA to designate 3rd party entities to manage the Design Verification process on behalf of EASA to ensure that UAS operators and manufacturers can receive service and DVR in their home country by qualified entities.
- Consider accepting forced landings and out-of-control events as being acceptable and allowed. Open and Specific categories are not a continuum of increasing risk. A flight with a 1.9 kg drone is acceptable on very short notice inside an aerodrome without CAA involvement, whereas a 2.1 kg drone may take months to be allowed to operate the same mission. The step between Open and Specific is (way) too large, especially when it comes to time and money involved.
- Operational authorisations between member states under Article 13 should be prepared in less complex and time-consuming way. There also should be created standardized forms and instructions what to do and NAAs should be better informed about how to do it.
- Regulation should be revised because of multiple interpretations of the same sentence, for example: what does it mean “utility” area in Open A3 category?
- EASA should create some kind of newsletter with its latest updates on regulations because operators are sometimes working on old rules without being aware of new ones that have been established.

6 Conclusions

With regulators not willing to compromise on high safety standards in aviation and with rising concerns on security and privacy, it remains a long-term ambition to massively democratize drone utilization. Technical challenges remain on U-space deconfliction strategies, and GOF2.0 was a key step in implementing strategic deconfliction schemes to real life situations. The Commercial off the Shelf (COTS) systems from different stakeholders in the project have been successfully integrated and subjected to acid test situations by means of implementing complex scenarios in live demonstrations. The drone operators and the passenger eVTOL operators were able to successfully integrate with the USSPs within the GOF2.0 project and they feel better prepared to meet the flight operations and flight safety requirements of the integrated airspace.

The proceedings from the GOF2.0 project are being leveraged further by the project partners, such as, Frequentis, DroneRadar, Aviamaps, Unmanned Life, Dimetor, Vaisala and Airbus to develop their respective subsystems into mature products for commercial UTM applications. Vaisala which tested Wind LIDARs for weather prediction within GOF2.0 plans to leverage the learnings also in their existing industries e.g., renewable energy applications. Likewise, Robots Experts intends to utilize the findings and outcomes of GOF2.0 to provide professional consulting services to ATM, UTM and IAM stakeholders.

In terms of business models, interviews realized in the frame of this deliverable highlighted the key role of taxpayer contributions to fund the development of U-space. Before scale enables monetization, drone companies mostly expect services to remain free of charge in order to lighten their cost base and develop their activities. ANSPs are often seen as the entities injecting the first euro into the system, feeding developments at USSP, CISP, SDSP level and enabling drone operators to access hitherto restricted airspace.

One of the most successful achievements of GOF2.0 is the multi-stakeholder integration that was performed at the GOF2.0 trials. The consortium plans to further advance the technologies developed within GOF2.0 through mutually funded projects and aims to push the technical boundaries of both flight operations and flight safety. By fostering collaboration, companies can also develop joint offers and attractive U-space packages for ANSPs or governments. Through collaboration amongst different GOF2.0 partners, the concept of Very Large Demonstrations (VLDs) is also being exported to other geo-political regions, such as Australia. The industry connections and the technologies developed within the project are being directly leveraged for grants and public funded projects in other regions to further implement and test the UTM Systems.

Out of the GOF2.0 system architecture, it became clearer that many companies were keen on filling several boxes, thus integrating vertically. This was the case for Frequentis, being CISP and USSP. At an international level, such collaboration will be key to winning large tenders, especially if large companies push this vertical integration concept even further. For instance, in the US, Wing and Amazon claim to deliver new services by becoming drone manufacturers, operators and USSPs at the same time. Such large companies can afford to “be right too early” and the European industry with fewer digital champions should remain alert to this competitive threat.

7 Glossary of Terms

Term	Definition	Source of the definition
AIR-REPORT	A report from an aircraft in flight prepared in conformity with requirements for position, and operational and/or meteorological reporting.	ICAO Annex
eVTOL	Helicopters or novel aircraft, that uses electrical propulsion to take-off, hover, and land vertically.	UAM Glossary
Advanced Air Mobility	An air transportation system that moves people and cargo between places previously not served or underserved by aviation – local, regional, intraregional, urban – leveraging new technologies and possibilities, where some of these are still under development.	UAM Glossary
Aeronautical Information Management	Dynamic, integrated management of aeronautical information services through the provision and exchange of quality-assured digital aeronautical data, in collaboration with all parties.	UAM Glossary
Air Taxi	Aircraft carrying passengers along typically short routes, which are not serviced by conventional civil aviation operators. Commonly used to describe commercial services.	UAM Glossary
Air Traffic Control	A service provided by ground-based air traffic controllers who direct aircraft on the ground and through controlled airspace and can provide traffic information services to aircraft in uncontrolled airspace.	Wikipedia
Air Traffic Management	An umbrella term describing the necessary toolkit of airborne and ground-based functions (air traffic services, airspace management and air traffic flow management) required to ensure the safe, secure, and efficient movement of aircraft during all phases of operation.	Wikipedia
Autonomous Aerial Vehicle (AAV)	Aircraft designed to operate autonomously, predominantly without a person involved in the mission control. It is close, by definition, to the Unmanned Aerial Vehicles (UAVs), although not all UAVs are AAVs, since some UAVs require a remote operator or pilot.	UAM Glossary

Beyond Radio Line of Sight	Subgroup or specification of BLOS where there is no direct link between ground station and the aircraft, and another form of relay is used – for example, Satcom, mobile technology, etc.	UAM Glossary
Beyond Visual Line of Sight	Sometimes also called BLOS, it describes BVLOS operations, where the flying of a drone is without a pilot always maintaining visual line of sight to the aircraft.	UAM Glossary
Concept of Operations (in Urban Air Mobility)	A definition of operations, operational environments and applicable legislative and/or regulative framework documents, in the context of Urban Air Mobility operations.	UAM Glossary
Drone	Aircraft (Unmanned Aircraft – UA) or vehicle (e.g., underwater drones) designed to operate in fully autonomously (pre-programmed route and behaviour, without a human in control), automated (pre-programmed route and possible to take control at any time by Remote Pilot) or piloted remotely (Remote Pilot controls the drone on the ground). Also called Unmanned Aerial Vehicle (UAV) or Unmanned Aircraft (UA) when referring to drone aircraft.	UAM Glossary
European Aviation Safety Agency	Agency of the European Union responsible for designing the civil aviation safety framework. EASA's mission is to promote the highest common standards of safety and environmental protection in civil aviation. The Agency develops common safety and environmental rules at the European level.	UAM Glossary
Emergency Medical Services	These are emergency or Urgent services providing sufficient pre-hospital treatment or even replacing it with on-site qualified medical care in case of challenges for the patient transportation.	UAM Glossary
Electric Vertical Take-Off and Landing aircraft	Helicopters or novel aircraft, that uses electrical propulsion to take-off, hover, and land vertically.	UAM Glossary
Geofencing	A virtual geographic boundary defining a volume of airspace, which the autopilot of an aircraft will not cross in normal operating conditions.	UAM Glossary
Geographic Information System (GIS)	Computer-based software that allows the user to store and edit spatial and non-spatial data, analyse spatial information output, and visually share the	UAM Glossary

	results of these operations by presenting them as maps.	
GOF2.0 System of Systems	An interconnected combination of USSP, CIS, ATM and GCS systems, that share information in real time, and is able to manage both manned and unmanned air traffic.	GOF2.0 consortium
Helicopter Emergency Medical Services flight (HEMS)	Out-of-hospital emergency medical services provided by air, with a helicopter. A flight by a helicopter operating under a HEMS approval, the purpose of which is to facilitate emergency medical assistance, where immediate and rapid transportation is essential.	UAM Glossary
Metropolitan area	Populated region with a high-density core (city) and lower density peripheral region (suburbs, rural areas).	UAM Glossary
Public-Private Partnership (PPP)	Cooperative arrangement and/or undertaking between two or more public and private stakeholder organisations, aiming long term collaboration to serve both public and private interests.	UAM Glossary
Regional Air Mobility	Mode of IAM using existing small airports to transport people in small aircraft over distances of up to 300 kilometres.	UAM Glossary
Remotely Piloted Aircraft (RPA)	An unmanned aircraft which is piloted from a remote pilot station and is expected to be integrated into the air traffic management system equally as manned aircraft and, where real-time piloting control is provided by a licensed remote pilot.	UAM Glossary
Remotely Piloted Aircraft System (RPAS)	Originating from ICAO, consists of the Remotely Piloted Aircraft (RPA) and all the necessary components for its operation, including its hardware, software, control links and the associated remote pilot station(s).	UAM Glossary
Joint European ATM Research Join Undertaking (SESAR 3 JU)	As the technological pillar of Europe's ambitious Single European Sky (SES) initiative, SESAR is the mechanism which coordinates and concentrates all EU research and development (R&D) activities in ATM, pooling together a wealth of experts to develop the new generation of ATM.	UAM Glossary
Smart City	Urban area applying various digital technologies and methods, as well as Artificial Intelligence, for	UAM Glossary

	data collection, processing, analysis, and decision-making support, with the final aim of improved well-being of its citizens.	
Strategic deconfliction	A service that, before take-off, ensures that different aircraft will not collide. Each new operation/flight plan is before take-off compared to other known operation/flight plans and a deconfliction in time or route is proposed.	UAM Glossary
Sustainable Urban Mobility Plan (SUMP)	Strategic and long-term policy plan designed to improve quality of life in cities by satisfying mobility needs of their inhabitants, businesses, and their environment through the implementation of sustainable mobility and transport solutions.	UAM Glossary
Tactical Deconfliction	A service that, during the flight of at least one of the vehicles, ensures that different aircraft will not collide. Each flight path is segmented into four dimensional volumes that are reserved for a vehicle. In-flight "tactical" deconfliction consists in making sure that those volumes do not intersect with those of other aircraft.	Wikipedia
Temporary Restriction Area (TRA)	A notice of temporary restrictions on a specific volume of airspace linked to the presence of government VIPs, special events, natural disasters, and other occurrences.	UAM Glossary
Transportation planning	Process of defining and managing various issues related to the establishment and development of transportation systems of cities, countries, and regions.	UAM Glossary
Urban Air Mobility (UAM)	Extension of transportation systems at metropolitan areas, or between those for distances that are not covered by regular aviation, in the third dimension – air.	UAM Glossary
Urban Air Mobility Ecosystem	The entire range of stakeholders such as city, regional, aviation and environmental authorities as well as drone and air taxi operators relevant for the successful planning, integration, and operation of UAM in a particular location or region.	UAM Glossary
Urban Air Mobility integration	Managed framework for the organisational, infrastructural, regulatory, and economic integration of the Urban Air Mobility operations without degrading safety, security, or overly disrupting existing airspace operations.	UAM Glossary

Urban Air Mobility operator	Commercial stakeholder responsible for the practical operation of drones and Air Taxis, who shall hold valid licenses and certifications from EASA.	UAM Glossary
Route planning	Static or dynamic four-dimensional route planning for aircraft in a complex urban environment, considering multiple factors from the domains of air and ground risk, including the built environment, citizens, other existing transport & mobility modes as well as environmental factors.	UAM Glossary
Unmanned Aircraft (UA)	Also called drone or UAV, is an aircraft without a pilot on board.	UAM Glossary
Passenger-carrying Unmanned Aircraft	An Unmanned Aircraft with passengers onboard.	UAM Glossary
Unmanned Aircraft System (UAS)	UA plus the necessary operation infrastructure and control units on ground and in air, such as data transmission infrastructure and other operation support systems or elements.	UAM Glossary
Unmanned Aircraft System geographical zone	A portion of airspace that facilitates, restricts, or excludes drone operations to address risks pertaining to safety, privacy, protection of personal data, security, or the environment, arising from UAS operations.	UAM Glossary
Urban development	The development or improvement of an organised inhabited spatial unit or area by building and introduction of new supportive functional and infrastructural processes and units.	UAM Glossary
Urban planning	Technical and political process focused on the spatial, construction, infrastructural and functional design, and development process management in organised inhabited spatial units and/or areas.	UAM Glossary
U-space	A set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient, and secure access to airspace for large numbers of air vehicles. Not synonymous to "U-space airspace".	UAM Glossary
U-space airspace	A volume of airspace, in which the EU U-space regulation (EU) 2021/664 applies. Not synonymous to 'U-space'.	UAM Glossary
U-space service Provides (USSP)	Private or public entity supporting the safe and efficient operation of drones and safe access to	UAM Glossary

	airspace. These organisations must be certified to provide U-space services in one or more European member states.	
Unmanned aircraft System Traffic Management (UTM)	A digital air traffic management ecosystem that ensures the flight safety of unmanned aircraft. UTM is separate from, but complementary, to the ATM system.	UAM Glossary
Vertiport	Landing site designed specifically to support Vertical Take-Off and Landing operations, including taxiing, parking, and servicing of the aircraft as well a cargo and passenger handling facility.	UAM Glossary
Very Low-Level (VLL) Airspace	The airspace below 500 feet (~150 meters) above the ground level.	UAM Glossary
Vertical Take-Off and Landing UA (VTOL UA)	UA able to take off, hover and land vertically.	UAM Glossary
Urban Airspace Zoning	A dynamic 4D spatial planning process of the low-level urban airspace, with special flight conditions imposed in different parts of the airspace. Flight conditions may also vary during specific times of the day and week. Examples of flight conditions are preferred or no-fly zones or approach and departure routes from landing sites.	UAM Glossary

List of Acronyms

Acronym	Definition
3D	Three-Dimensional
3G	Third Generation of Wireless Mobile Communications Technology
4D	Four-Dimensional
4G	Fourth Generation of Wireless Mobile Communications Technology
5G	Fifth Generation of Wireless Mobile Communications Technology
ACJA	Aerial Connectivity Joint Activity
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-L	Automatic Dependent Surveillance - Light
AGL	Above Ground Level
AIM	Aeronautical Information Management
AIXM	Aeronautical Information Exchange Model
AMC	Air Traffic Services Messaging Management Centre

AMC/GM	Acceptable Means of Compliance/Guidance Material
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
API	Application Programming Interface
ARC	Air Risk Class
ARR	Arrival
ASM	Airspace Management
ASTM	American Society for Testing and Materials
ASTERIX	All Purpose Structural Eurocontrol Surveillance Information Exchange
ATC	Air Traffic Controller
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
ATS	Air Traffic Service
ATSP	Air Traffic Service Provider
ATSU	Air Traffic Services Unit
B2B	Business to Business
B2C	Business to Consumer
BVLOS	Beyond Visual Line Of Sight
C2	Command and Control
C2CSP	Command and Control Service Provider
CAA	Civil Aviation Authority
CARS	Common Altitude Reference System
CIS	Common Information Service
CISP	Common Information Service Provider
CNS	Communication, Navigation and Surveillance
CONOPS	Concept of Operations
COTS	Commercial off-the-shelf
CR	Change Request
CTR	Controlled Area
DDoS	Distributed Denial-of-Service
DEMOP	Demonstration Plan
DEMOR	Demonstration Report
DEP	Departure

DJI	Da-Jiang Innovations
DoS	Denial-of-Service
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVR	Design Verification Report
E-ATMS	European Air Traffic Management System
E-OCVM (V3)	European Operational Concept Validation Methodology (Version 3)
EANS	Estonian Air Navigation Services
EASA	European Union Aviation Safety Agency
EATMA	European ATM Architecture
ED	EUROCAE-Document
EO	Earth Observation
ESA	European Space Agency
EU	European Union
EUROCAE	European Organization for Civil Aviation Equipment
EUROCONTROL	European Organization for the Safety of Air Navigation
EVTOL	Electrical Take-Off and Landing
FAA	Federal Aviation Administration
FIMS	Flight Information Management System
FIR	Flight Information Region
GA	General Aviation
GCS	Ground Control Station
GNSS	Global Navigation Satellite System
GOF	Gulf of Finland, also part of the name of this VLD (GOF2.0)
GSMA	GSM Association
GUTMA	Global UTM Association
HEMS	Helicopter Emergency Medical Services
HMI	Human Machine Interface
HPAR	Human Performance Assessment Report
IAM	Innovative Air Mobility
ICAO	International Civil Aviation Organisation
ICT	Information and Communications Technology
ID	Identification

IEX	Information Exchanges
IFR	Instrument Flight Rules
INTEROP	Interoperability Requirements
IP	Internet Protocol
IT	Information Technology
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
JSON	JavaScript Object Notation
KPA	Key Performance Area
KPI	Key Performance Indicator
LAU	Local Administrative Unit
LFV	Luftfartsverket (Air Navigation Service Provider in Sweden)
LGS	Latvijas Gaisa Satiksme (Air Navigation Service Provider in Latvia)
LIDAR	Light Detection and Ranging
LTE	Long Term Evolution
MEL	Minimum Equipment List
MITM	Man-in-the-Middle
MMEL	Master Minimum Equipment List
MNO	Mobile Network Operator
MSA	Multi-Stakeholder Approval
MTOW	Maximum Take-Off Weight
NAA	National Aviation Authority
NOTAM	Notice to Airmen or Notice to Air Missions
OA	Operations Authorisation
OBJ	Objective
OGN	Open Glider Network
OI	Operational Improvement
OP	Operation Plan
OPAR	Operational Performance Assessment Report
OSED	Operational Service and Environment Definition
PANSA	Polish Air Navigation Services Agency
PAR	Performance Assessment Report
PIRM	Programme Information Reference Model
QoS	Quality of Service

ReST	Representational State Transfer
RID	Remote Identification
SAC	Safety Criteria
SAIL	Specific Assurance and Integrity Level
SAR	Safety Assessment Report
SC	Success Criteria
SD	Service Description
SDO	Standard Development Organization
SDSP	Supplementary Data Service Provider
SecAR	Security Assessment Report
SESAR	Single European Sky ATM Research Programme
SIM	Subscriber Identity Module
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SOA	Service-oriented architecture
SORA	Specific Operations Risk Assessment
SPR	Safety and Performance Requirements
SQL	Structured Query Language
SSR	Secondary Surveillance Radar
SWIM	System Wide Information Model
SWOT	Strengths, Weaknesses, Opportunities and Threats (SWOT)
TI	Technical Infrastructure
TMA	Terminal Control Area
TRA	Temporary Reserved Area
TS	Technical Specification
TWR	Air Traffic Control Tower
UAM	Urban Air Mobility
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UML	Unified Modeling Language
URL	Uniform Resource Locator
US	United States
USS	UAS Service Supplier
USSP	U-space Service Provider

USP	UTM Service Provider
UTM	Unmanned Traffic Management
VFR	Visual Flight Rules
VLD	Very Large Demonstration
VLL	Very Low Level (airspace)
VLOS	Visual Line of Sight
VTOL	Vertical Take-Off and Landing
XML	Extensible Markup Language

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GOF2.0 consortium

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