Implementing Multi-USSP Architecture in U-space: Operational Insights from Spain and Italy

Architectural and Operational Lessons Learnt from U-ELCOME project

Giovanni Riccardi
Industrial Research and Demonstration Activities
ENAV S.p.A
Rome, Italy
giovanni.riccardi.1@enav.it

Victor M. Gordo
Aerospace Systems Department
INECO
Madrid, Spain
vgordo@ineco.com

Rodrigo Benedit Pascual
Drone Business Development Department
ENAIRE
Madrid, Spain
rbenedit@enaire.es

***Abstract*— The increasing use of drones has led to the development of the U-space regulatory framework to ensure safe and efficient integration into airspace. In this context, the U-ELCOME project has demonstrated a multi-USSP architecture enabling several service providers to operate simultaneously in the same U-space airspace. Real-world validations in Spain and Italy included over 1,000 flights across diverse environments and use cases. The results confirm the feasibility of this model, showing strong performance in safety, interoperability, and human factors. These findings support the deployment of scalable U-space services in Europe.**

U-space; UAS; USSP; Multi-USSP; interoperability; CISP

I. INTRODUCTION

The concept of U-space refers to a set of services and procedures based on a high level of digitalization and automation of functions aiming to provide, in a regulated and coordinated manner in Europe, safe and efficient access to airspace for a large number of unmanned aircraft systems (UASs), while also facilitating their coexistence with manned aircraft in certain airspaces [1] [2].

These services are regulated by Implementing Regulation (EU) 2021/664 [3], which establishes rules and procedures for the safe operation of UASs in U-space airspace, and by two complementary implementing regulations (IR (EU) 2021/665 [4] and IR (EU) 2021/666 [5]), which incorporate requirements and obligations for Air Navigation Service Providers (ANSPs) and manned aviation in U-space airspace, as well as amendments to the Standard European Rules of the Air (SERA), respectively.

To implement such regulations, U-ELCOME project bridges the gap between research and implementation of U-space services. U-ELCOME project is a SESAR Digital Sky Demonstrator (DSD) project, co-founded by the European Climate, Infrastructure and Environment Executive Agency (CINEA) under the CEF Transport programme. The main objective of U-ELCOME project was to implement initial U-space services in controlled and uncontrolled airspace in Spain, Italy and France. For that, during the three years of the project, U-ELCOME partners have been conducting demonstration in real environments in those three countries.

In the context of U-ELCOME, this paper focuses on the multi-USSP (U-space Service Provider) architecture, where several USSPs operate concurrently in the same U-space airspace.

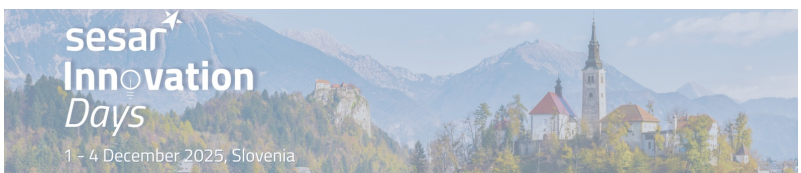
This paper is structured as follows: section I presents the topic and the U-ELCOME project, section II defines the multi-USSP architectures implemented by U-ELCOME demonstrations, section III shows the validation exercises conducted in Spain and Italy to test the multi-USSP architecture, section IV contains the results and outcomes from the validation exercises, and finally, section V summarizes the conclusions.

II. MULTI-USSP ARCHITECTURE

A. Architecture description

Among the possible types of U-space architectures [6] under Regulation (EU) 2021/664, U-ELCOME has adopted an architecture with a single CISP (Common Information Service Provider) and indirect communication between USSPs, which is carried out through a centralized platform. This U-space architecture model is also being used in other European Union countries, such as Belgium [7]. Centralized and Decentralized architectures present strengths and weaknesses; this paper shows that a Centralized Architecture can be deployed successfully in an operational environment, even with several USSP operating simultaneously.

As shown in Figure 1. , the U-space architecture used in U-ELCOME consists of a centralized platform with two distinct modules to which the different USSPs are connected. One of these modules is responsible for providing the USSPs with the



common information service (CISP module), while the other is responsible for ensuring the information exchange service between the USSPs (IXS module).

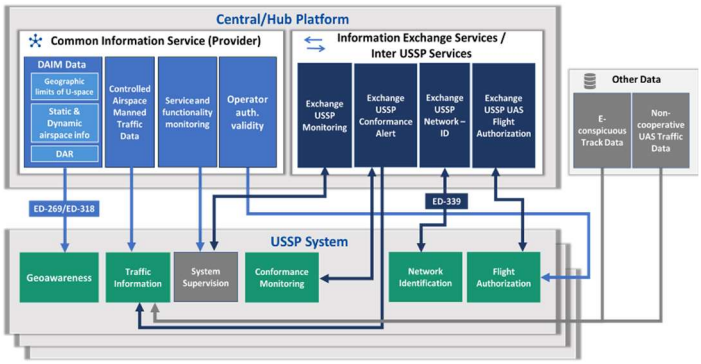


Figure 1. U-ELCOME U-space architecture

Independently of the model chosen for architecture, according to Article 7.5 of IR (EU) 2021/664, USSPs shall exchange information related to flight plans, network ID and conformance alerts, among others. In U-ELCOME, the USSP information exchange module used has four main functions, which allow USSPs to send and receive specific information from other USSPs:

- Network ID exchange service
- Flight plan exchange service
- Conformance alert exchange service
- USSP monitoring exchange service

As for the U-space services, all the U-ELCOME USSPs (ENAIRE USSP, DALIAH, DRONAS and D-Flight USSP) have provided the mandatory services listed in Article 3 of IR (EU) 2021/664: Network ID, Flight authorization, Geoawareness and Traffic information. In addition to these 4 services, all USSPs have also provided the optional service of Conformance monitoring, as it is considered a service that greatly benefits the operational safety of U-space operations.

The main advantage of this USSP communication model is that it allows USSPs to receive all the information they need to know from other USSPs operating in the same U-space by integrating only with the module of this centralized platform, which streamlines the U-space integration and deployment process.

In addition, this architecture offers another distinctive advantage: it provides authorities and other authorized users with a system that integrates all U-space operational information. This is essential for them to interact with the U-space in the event of an emergency or need. Moreover, this architecture also allows this information to be used to create an ATC/U-space interface, which is necessary for Dynamic Airspace Reconfiguration (DAR)-a procedure whereby a sector or the entire volume of U-space is temporarily deactivated, allowing manned aviation to operate in that airspace.

B. *Reference standards for U-ELCOME USSPs architecture development*

This section lists the main standards used during the development of the different U-space platforms within the project:

- EUROCAE ED-269 “Minimum Operational Performance Standard for UAS Geo-Fencing” [8], cited in IR(EU) 2021/664. This standard has been recently superseded by ED-269 Change 1 “Minimum Operational Performance Specification (MOPS) for Geofencing for UAS” [9].
- EUROCAE ED-318 “Technical Specification for Geographical Zones and U-space Data Provision and Exchange” [10].

  In order to prioritize operations and not delay the development of the project validations, given that ED-318 and ED-269 Change 1 were published in the final year of the project, we decided not to upgrade the platforms in line with these latest standards. However, the adaptation of the different platforms to the latest standards will be carried out once the project is completed. Therefore, the current platforms follow the ED-269 standard.
- ANSI-CTA-2063-A “Small Unmanned Aerial Systems Serial Numbers 2019” [11].
- ASTM F3411-22a "Standard Specification for Remote ID and Tracking" [12].
  This standard was partially applied to the Network ID exchange interface, with some field modifications to follow a Publish/Subscribe exchange pattern, using the well-established AMQP protocol. This approach was chosen over the Request/Reply exchange pattern, as it better suits the indirect communication between USSPs, allowing them to provide the data as soon as it becomes available.
- EUROCAE ED-339 “NID data exchange ICD for indirect exchange between USSP/USSP/Authorised users” [13]. Standard pending to be published by the end of 2025.
  For the interface Data Model, the ASTM standard has been followed with the minimum required modifications. These modifications/specifications are reflected in the new standard being developed by EUROCAE WG105 SG-3 for indirect information exchange between USSPs, which will be published under the name ED-339.

III. VALIDATION EXERCISES

During the 3 years of the project, the U-ELCOME consortium conducted over 1,000 validation flights across Spain, Italy and France. These validation flights addressed a range of use cases, including logistics, surveillance, and emergency response, and took place in various environments: urban, rural, and interurban areas.

In the following subsections, we present a selection of the most relevant use cases that illustrate the implementation and

Identify applicable sponsor/s here. *(sponsors)*

performance of the multi-USSP architecture developed within the project.

A. Demonstration 1: Spanish multi-USSPs exercise

In February 2025, U-ELCOME conducted the project's validation demonstration with the most simultaneous flights, with the aim of testing a multi-USSP environment in an urban area. This demonstration took place in Benidorm, Spain.

During the validation exercise, the three USSPs from the Spanish cluster of U-ELCOME (ENAIRE USSP, DALIAH and DRONAS) simultaneously provided U-space services to 13 UAS operators flying across different areas of the city.

The participating aircraft were very diverse: multirotor UASs, fixed-wing UASs, an air taxi and a manned aircraft. All aircraft were successfully integrated and displayed within the U-space platforms.

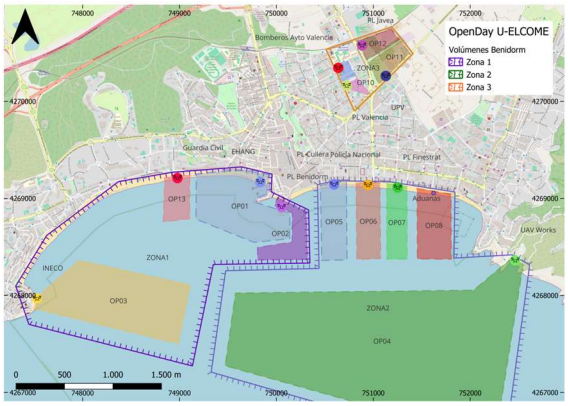


Figure 2. Distribution of flight plans for the use case 1 demonstration

In this exercise, the Spanish cluster also implemented the authorized users digital interface, enabling the authorities to interact directly with the U-space. This interface allowed the creation of emergency zones, which were used to revoke flight plans in the event of an emergency or other airspace requirements.

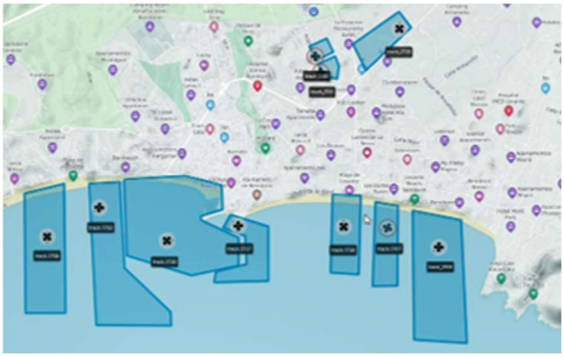


Figure 3. Screenshot of the ENAIRE centralized platform, showing simultaneous drone operations in a multi-USSP environment over the city of Benidorm, Spain.

This validation exercise demonstrated the wide range of business and operational possibilities that the U-space system developed in Spain allows. Specifically, it showed that:

- Enables a multi-USSP environment, fostering an open market for U-space service providers.
- Allows a high density of simultaneous UAS operations.
- Accommodates U-space operations with various types of unmanned aircraft, including both fixed-wing or rotary-wing.
- Integrates manned aircraft and provides interfaces for DAR and UAS emergency zones.

B. Demonstration 2: multi-USSP interoperabilty exercise with Spanish CISP

In June 2025, during the EXPODRÓNICA 2025 event in Toledo (Spain), U-ELCOME conducted a demonstration with the aim of validating the interoperability of the Spanish and Italian U-space systems.

To this end, during the validation flights, the three USSPs of the Spanish cluster (ENAIRE USSP, DRONAS, and DALIAH) operated simultaneously with the USSP from the Italian cluster (D-Flight). All four USSPs provided U-space services within the same airspace, coordinating and exchanging the necessary information in real time. During this exercise, the USSPs supported five UAS operators, demonstrating the feasibility of multi-USSP collaboration in a shared operational environment, as can be seen in the following image.

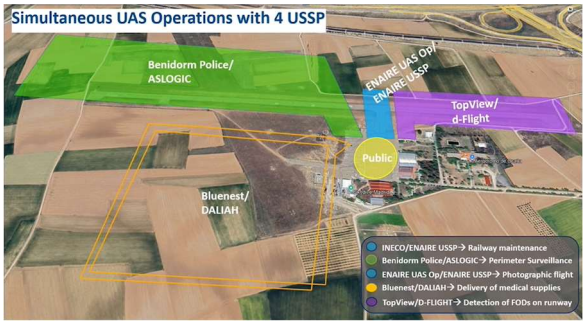


Figure 4. Distribution of flight plans for the use case 2 demonstration.

In order to achieve this objective, it was necessary to integrate the Italian USSP D-Flight with ENAIRE's centralized platform. This integration started several months before the final validation. The following factors contributed to the success of this process:

- On the one hand, the integration of Spanish CIS information into the D-Flight USSP platform was made possible by the adoption of the ED-269 standard by both platforms, which allowed the systems to easily transmit geographic information data.
- On the other hand, the integration into d-Flight of the information exchanged by the USSPs, as well as the possibility for D-Flight to send information to the other USSPs, was made possible by the adoption of this system of the ED-339 standard Data Model and protocols, making both U-space platforms highly compatible.

Once D-Flight was integrated with this centralized platform, it was able to simultaneously receive Spanish CIS information, as well as communicate and exchange information with the three Spanish USSPs, thereby significantly reducing integration times.

Figure 5. ENAIRE's centralized platform view, showing all the USSPs operating simultaneously in the same airspace, exchanging flight plans, positioning information, and alerts

C. *Demonstration 3: multi-USSP interoperabilty exercise with Italian CISP*

In May 2025, U-ELCOME conducted a demonstration in Castel Campagnano (Italy), which aimed at demonstrating the safe and efficient integration of drones into the airspace, with concrete applications in sectors such as infrastructure monitoring, environmental protection, and agriculture. The initiative was part of the Italian cluster of the project and featured two main demonstration activities.

The activity was focused on the coordination between different U-space airspaces, dividing the airspace over Castel Campagnano into two volumes managed respectively by 2 different USSPs: D-Flight (Italy) and DALIAH (Spain).

Figure 6. The two U-space volumes (light blue managed by ITG, dark blue managed by D-Flight). In white the U-plans of UAS operators

The two USSPs operated in synergy through D-Flight's CISP platform, ensuring interoperability between European systems. Within this framework, UAS operators carried out drone operations for aerial inspections of power lines, monitoring of the Volturno River, and surveys in vineyards.

Several actors and systems were involved in the demonstration activity:

- CISP: D-Flight d-CIS
- USSP1: D-Flight d-USS
- USSP2: ITG DALIAH
- UAS Operator 1: TopView
  - UAS: DJI M3TD, DJI Mavic 3E
- UAS Operator 2: Telespazio
  - UAS: DJI Mavic 3E
- HEMS Flight: General Aviation (GA) Helicopter
- DAR Manager
- Telespazio T-dromes
- Pollicino Drone Tracker
- Ground noise measurement equipment (CIRA)
- ADS-B/FLARM antenna

The following figure represents the operational architecture of the Italian U-space system used in this demonstration.

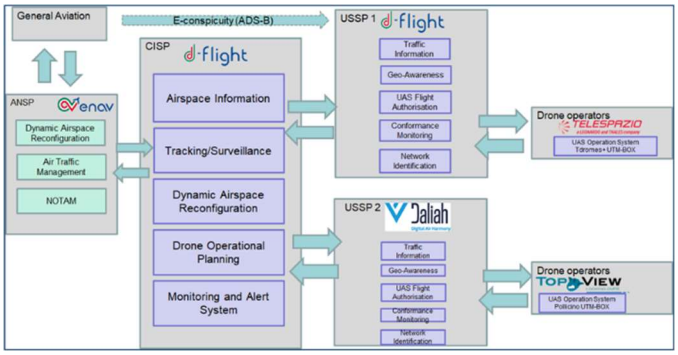


Figure 7. Multi-USSP architecture used in demonstration 3

In the upper left of the diagram, we find GA, which interacts with the system via e-conspicuity devices, i.e., electronic identification tools such as ADS-B. ENAV, the national Air Navigation Service Provider (ANSP), is responsible for air traffic management, publication of NOTAMs (Notices to Airmen), and dynamic airspace reconfiguration—activities that are crucial for ensuring the safe coexistence of drones and traditional aviation.

At the center of the diagram is D-Flight (D-CIS), that acts as certified Common Information Service Provider (CISP), and collects, processes, and distributes critical information — such as airspace structure, dynamic airspace restrictions, NOTAMs, traffic information — to both ANSPs and USSPs by ensuring all stakeholders have access to the same, timely data, the CISP enables shared situational awareness, coordinated decision-making, and safe integration of drones into airspace operations.

D-Flight is connected to two USSPs: D-Flight D-USS (USSP1) and DALIAH (USSP 2). Both provide UAS operators with five key services mentioned in section II.

Figure 8. Examples of Network ID and Conformance monitoring services

Specifically, Telespazio (connected to D-Flight USSP) used the T-dromes+ UTM-BOX operating system, while TopView (connected to DALIAH) used the Pollicino UTM-BOX. These platforms enable operators to plan, manage, and monitor missions safely and in compliance, within a highly interconnected digital ecosystem.

Figure 9. Pollicino UTM BOX used for Networkd remote ID with USSPs

1) Contingency management through DAR application

During nominal operations by UAS operators inside the two U-space volumes, a conspicuous ultralight aircraft requested permission to enter the U-space airspace, simulating an emergency. The GA aircraft pilot informed the DAR manager (DARM) of their intention to take-off and cross the U-space airspaces.

Subsequently, an emergency scenario was demonstrated: the DAR Manager initiated the corresponding procedure, which was executed by deactivating the affected U-space airspaces.

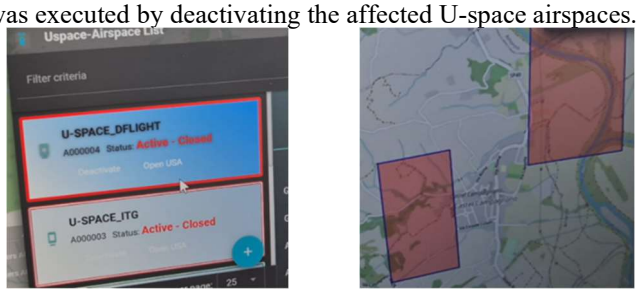


Figure 10. Application of DAR and closure of U-space airspaces

D-Flight USSP and DALIAH promptly informed all UAS operators about the contingency, notifying them the airspace closure. Following this warning, the UAS pilots interrupted their operations and returned the UAS to the starting point, successfully completing the landing phase.

Once the U-space deactivation was completed, the GA aircraft flew over the demo area, crossing the temporarily reserved airspace.

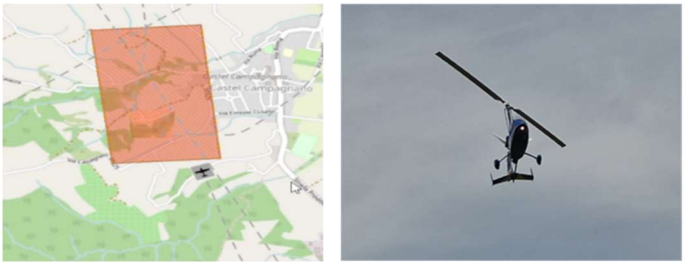


Figure 11. GA penetrates the U-space airspace

Once that operation was finished, DARM opened the U-space airspace again. The information was digitally propagated from CISP to USSPs, and from USSPs to UAS operators that resumed their own operations.

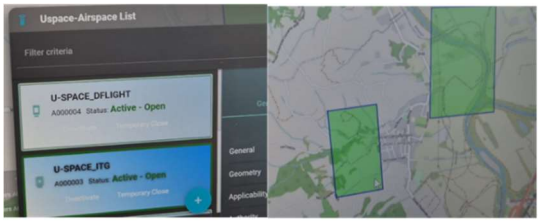


Figure 12. *Re-opening of U-space airspaces*

IV. VALIDATION RESULTS AND OUTCOMES

The validation activities collected data on various aspects of the execution, both quantitative (through USSPs' log analysis of parameters such as service response times and latencies) and qualitative (subjective), via questionnaires and oral feedback provided by pilots and operators (the areas investigated included ease of participation, interaction with tools, and understanding of processes).

As for the collection of quantitative data, all services provided by the USSP platform were equipped with automatic logging tools. These data, extracted in CSV format from databases, concerned API interactions both between U-space service providers (USSPs) and between the latter and UAS operators (for example, the notification of an operational plan sent by the USSP to the operator's ground control station).

A. KPIs description

As explained, U-space is a set of services and procedures aiming to provide safe and efficient access to airspace for a large number of unmanned aircraft systems (UASs), while also facilitating their coexistence with manned aircraft in certain airspaces. Therefore, the analysis of results has to evaluate if the U-space architectures deployed have been able to facilitate UAS operations in a U-space environment meeting these requirements. Accordingly, the evaluation of results has been focused in those Key Performance Areas (KPA) directly linked with the criteria and requirements related to U-space services provision.

Moreover, the IR (EU) 2021/664 establishes that U-space services may be provided concurrently by multiple USSPs in the same airspace, so another essential KPA is Interoperability.

Finally, the operation of U-space demands that Operators are able to understand the information received from U-space, achieving a high situational awareness with a limited workload, and interact easily with the HMI. Therefore, Human Performance has been also selected as a relevant KPA.

To sum up, the KPAs and Performance Indicators (PIs) selected, considering as a baseline relevant technical references in the field of U-space, are shown hereafter:

- **Capacity** (large number of UAS). To evaluate this KPA, the relevant considered have been:

- Maximum number of authorized U-plans [14][15]
- Maximum number of active U-plans [14]

- **Access & Equity** (*efficient access to airspace*). The relevant PIs evaluated have been:
  - Number of UAS operators per U-space airspace [14][15]
  - Authorization approval rate [14][15]
  - Negotiation percentage (authorized U-plans withdrawn, needing replan) [14][15]
- **Safety** (*safe access to airspace facilitating their coexistence with manned aircraft*). The relevant PIs evaluated have been:
  - Network Remote ID (NRID) reception ratio [15]
  - Percentage of flight time in alarm (non-conformance and geozone violation) [15]
  - Resolved alarms (non-conformance and geozone violation) [15]
- **Interoperability** (*provided concurrently by multiple USSPs*):
  - Number of USSPs operating simultaneously based on open protocols and formats [14]
  - USSP data exchange rate between U-space actors (Response time between USSP and UAS operators) [14][15]
- **Human Performance** (*high situational awareness with a limited workload*).
  - Situational Awareness [14][15][16]
  - Workload [14]
  - Adequacy of the human-machine interface in supporting the human in carrying out their tasks [14][17]

B. KPI Results

The following table summarizes the results obtained in the validation exercises developed in Spain and in Italy ([18],[19]). The results demonstrate that a multi-USSP environment can provide the required performances to operate in a U-space airspace which includes a large number of simultaneous operations, ensuring safety, interoperability and easy access to operators.

TABLE I. SUMMARY RESULTS

KPA	Results		
	Performance Indicator	***Spain***	***Italy***
Capacity	Maximum number of authorized U-plans	27	5
	Maximum number of active U-plans	12	5
Access & Equity	Maximum number of UAS operators per U-space airspace	13	2
	Authorisation approval rate	92.6%	100%
	Negotiation percentage (authorized U-plans withdrawn)	24.7%	0%
Safety	NRID reception ratio	93.6%	96.0%
	Percentage of flight time in non-conformane alarm	12.5%	3.4%
	Percentage of flight time in geozone violation alarm	5.4%	N.A
	Resolved non-conformace alarms	88.2%	100%
	Resolved geozone violation alarms	66.3%	N.A
Interoperability	USSP data exchange rate between U-space actors (Response time between USSP and UAS operators)	0.817 s	0.817 s
	Number of USSPs operating simultaneously	4	2
Human Performance	Situational Awareness	8.52/10	7/10
	Workload	3.35/10	3.8/10
	Adequacy of the human-machine interface	7.93/10	7.2/10

Capacity has been successfully demonstrated in the validation exercises, allowing a large number of simultaneous operations, both in the planning and execution phase, as can be seen in Figure 13. The results show that a centralized architecture can manage similar capacity levels than a decentralized one [15].

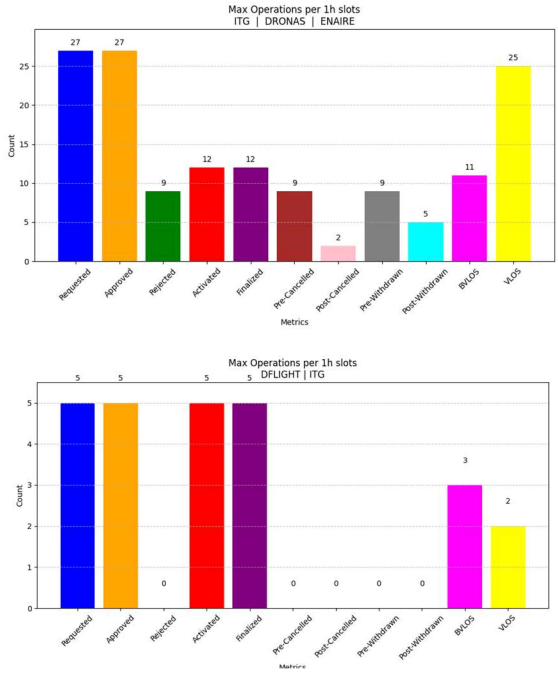


Figure 13. Maximum number of operations. Top graph Spain; bottom Italy

Access & Equity results are also promising, on the one hand considering the large number of UAS operators, but also due to the small percentage of U-plan requests rejected by U-space as seen in TABLE I. Again, the results obtained are similar to those reached with a decentralized architecture [15].

Safety results are also adequate, as the provision of Network Remote Identification, essential to gather the information required by the Traffic Information Service, has demonstrated a high level of reception ratio, as shown in Figure 14. Additionally, the alarms rates are also acceptable, considering that the demonstrations have forced the operators to generate non-conformance and geo-zone violation alerts to test the U-space services (e.g., Conformance Monitoring); as the Figure 15. shows, the duration of alarms is generally very low, not being a risk for U-space operations.

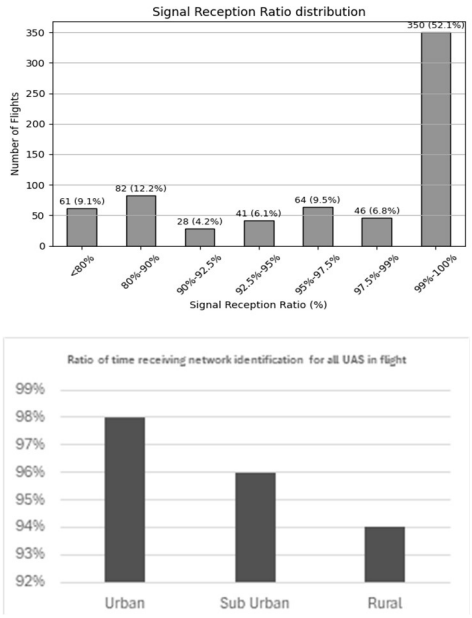


Figure 14. NRID reception ratio. Top graph Spain; bottom Italy

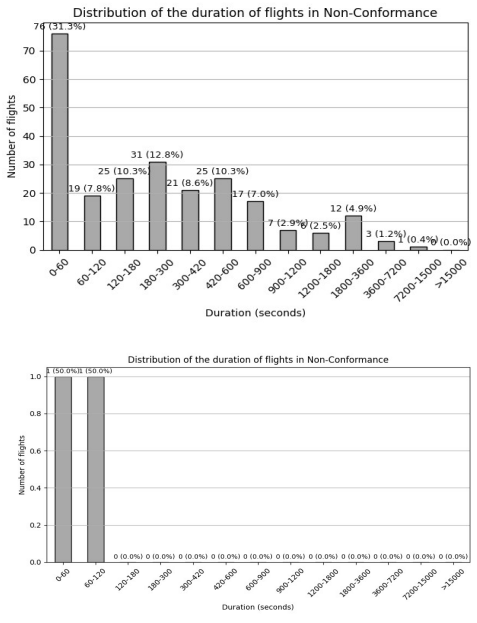


Figure 15. Non-conformance alarm rates. Top graph Spain; bottom Italy

With regard to Interoperability, Figure 16. shows the histograms of information exchange latency, showing that the mean value is approximately 0.8 seconds. These results demonstrates that the architecture chosen for the deployment, in which all the information exchanges among USSPs are developed via CISP, is able to provide the required data with a very small latency, being therefore suitable for multi-USSP operation.

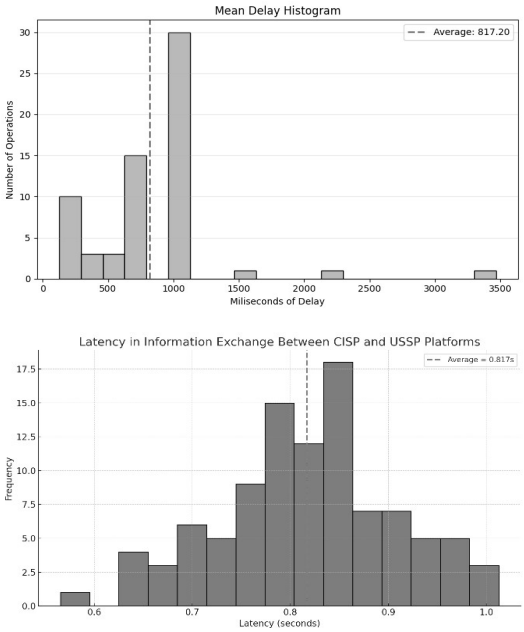


Figure 16. time for information exchange between platforms. Top graph Spain; bottom Italy

Finally, the Human Performance results show a very good situational awareness provided by U-space (Figure 17.) and an acceptable workload (Figure 18.). The HMI is also positively rated.

The questionnaires represented the main source of subjective data for Human Performance evaluation. In particular:

- The Post-Run Questionnaire (PRQ) included questions on specific events observed during the simulation, such as safety issues or platform malfunctions.
- The PSQ collected participants' comments on the operational concept, its limitations, and related recommendations.

In addition to the questionnaires, the validation team and assessment experts recorded observations during the sessions to document significant events or comments useful for integrating and contextualizing the data collected.

Finally, the debriefing sessions allowed participants to share opinions and experiences at the end of each day of activity. The results that emerged from these discussion moments supported the conclusions of the PRQ and PSQ.

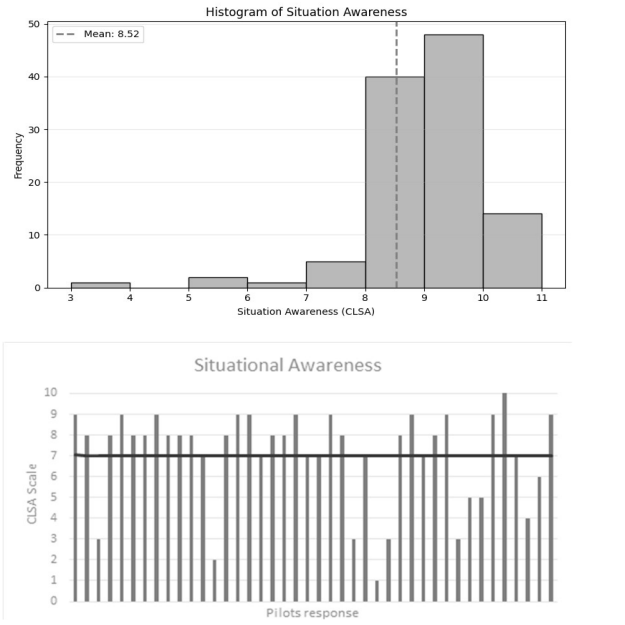


Figure 17. Situational Awareness. Top graph Spain; bottom Italy

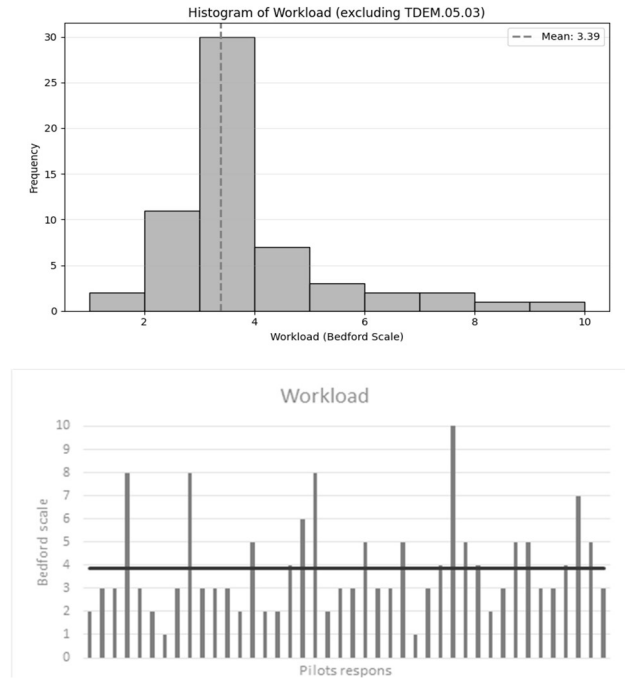


Figure 18. Workload. Top graph Spain; bottom Italy

V. Conclusions

The U-ELCOME project has successfully demonstrated the operational viability of a multi-USSP centralized architecture in U-space environments across Spain and Italy, showing that the performances provided are similar to those that can be reached with a decentralized one. By integrating several U-space Service Providers through a centralized platform, the project enabled simultaneous drone operations with high levels of safety, efficiency, and interoperability.

Validation exercises showed that the architecture supports a large number of concurrent UAS operations, with low latency in data exchange and effective management of Dynamic Airspace Reconfiguration (DAR) procedure.

The use of standardized protocols and data models, such as ED-269 and ED-339, facilitated cross-border interoperability between national systems. Human performance indicators also confirmed that operators maintained high situational awareness with manageable workload levels.

These results confirm that a multi-USSP centralized architecture can support scalable and safe U-space operations, paving the way for an open market of service providers and enhanced integration of unmanned and manned aviation.

VI. Future Challenges

While the U-ELCOME project has demonstrated the feasibility of multi-USSP operations in controlled environments, several challenges remain for large-scale and long-term deployment. Cybersecurity will be a critical concern as the number of connected systems, data exchanges, and external interfaces increases, requiring robust authentication, encryption, and resilience against malicious attacks. Scalability beyond the current experimental setup—particularly when involving more USSPs—will demand optimized coordination mechanisms, dynamic load balancing, and more advanced data-sharing strategies to maintain low latency and reliability. Furthermore, real-time contingency management remains an open issue: automated handling of unexpected events such as communication failures, GNSS degradation, or emergency landings will require improved decision-support tools and regulatory alignment across national authorities.

Addressing these challenges will be essential to ensure that future multi-USSP ecosystems can operate securely, efficiently, and seamlessly at continental scale

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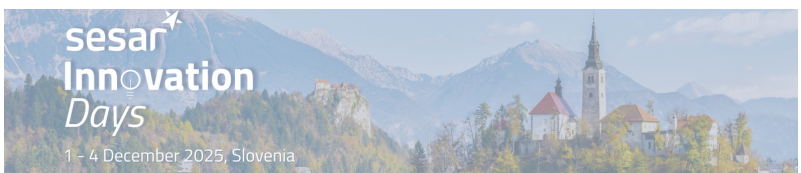
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