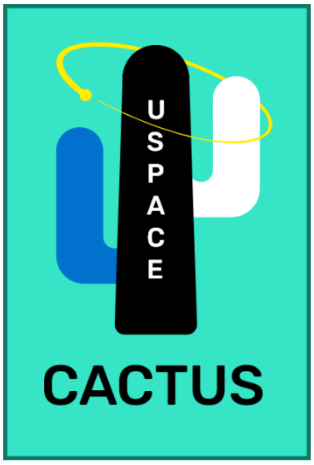
Development of an Unmanned Aerospace Test Site
U-space Sandbox

Project CACTUS



Solution Architecture and Technical Design

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1. Introduction

ANRA Technologies, Inc. (ANRA), in partnership with the Tartu Science Park Foundation (TSP) are pleased to submit this document in support of the Development of an Unmanned Aerospace Test Site (U-space Sandbox). The project is called CACTUS, an acronym for "Competent Authority Coordinating Testing in U-space Sandbox." This document satisfies Deliverable 3.1 (Solution Architecture) and Deliverable 3.2 (Technical Design).

2. Background

To fully realize the market potential for U-space and in order to enable the U-space implementation from set-up and commissioning to regular control, CACTUS offers a valuable means in order to demonstrate that the European U-space concept works in practice. Our approach provides all of the foundational infrastructure to enable the interaction of the various U-space services, exchange data with stakeholders in the ecosystem throughout automation software and data interfaces to enable integration between the Competent and local Authorities, ANSPs, USSPs, CISP, Supplemental Data Service Providers (surveillance, weather, etc.) and UAS operators. Please reference Figure 1 for the high-level CACTUS architecture.

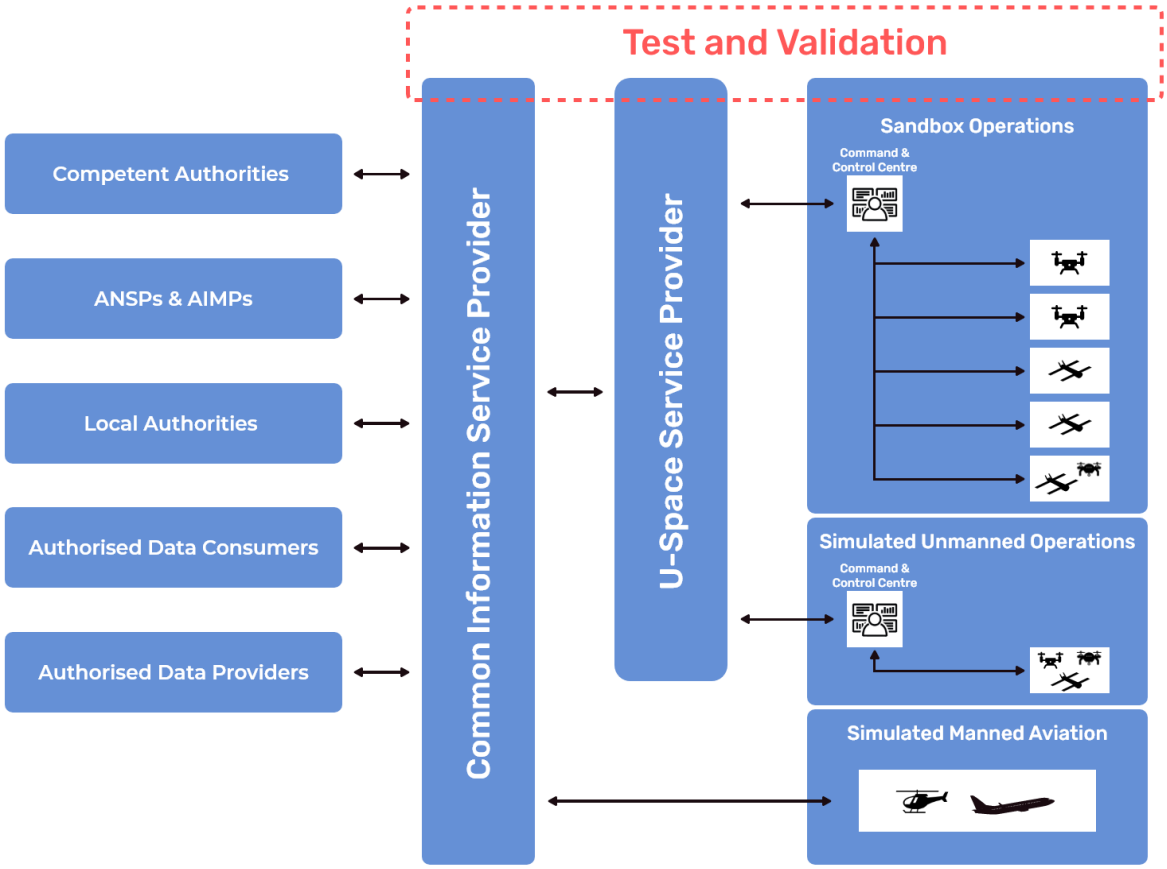

Figure 1: CACTUS Conceptual View

3. Architecture Overview

Figure 2 is the proposed architecture and the associated services that will be in scope and deployed as part of the CACTUS Phase 2 deployment.

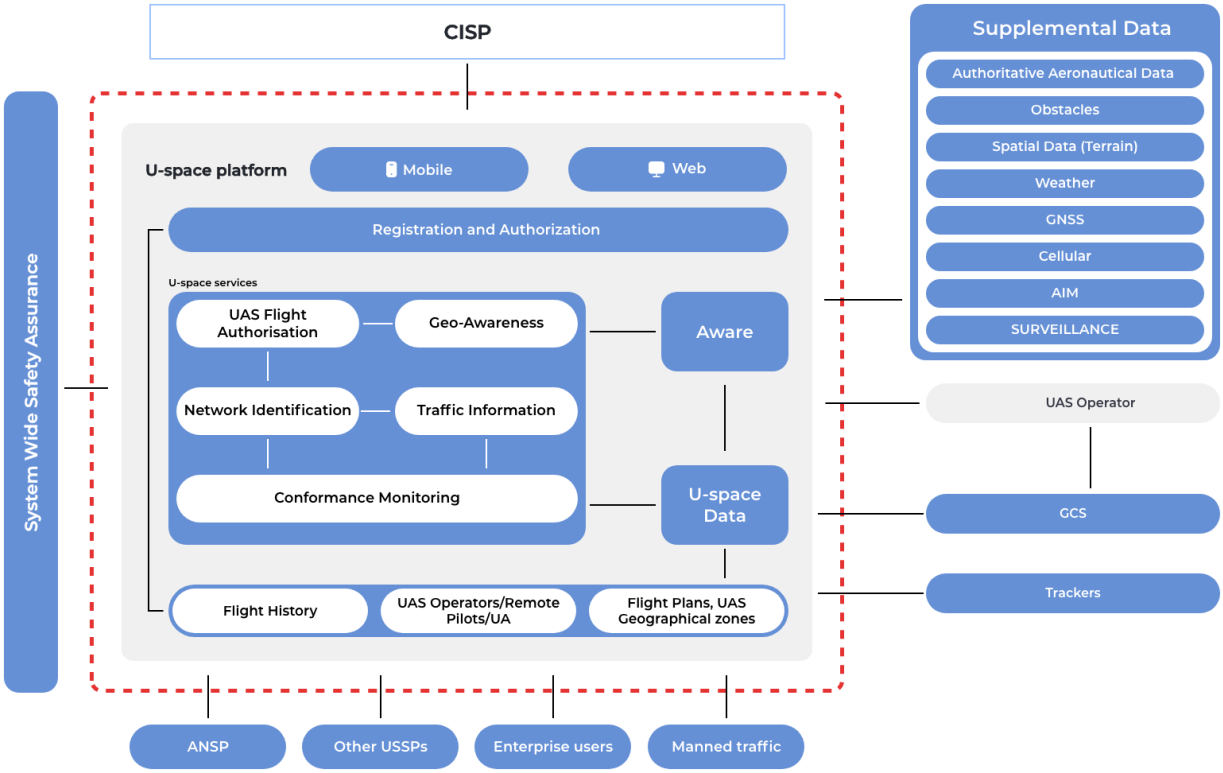

Figure 2: U-Space Logical View

The functional blocks and their workflows represented in Figure 2 are explained in the sections below.

4. Workflow Requirements

U-space is a set of new services relying on a high level of digitization and automation of functions and services designed to provide safe, efficient, and secure access to airspace for large numbers of unmanned aircraft, operating automatically and beyond visual line of sight. U-space services to include the Common Information Service for the CACTUS are described below.

4.1 U-space Services

UAS Flight Authorisation Service

- **Description:** The UAS Flight Authorisation Service facilitates the process for UAS (Unmanned Aircraft Systems) operators to request and obtain necessary permissions or authorizations for

their planned flights. It ensures that UAS operators comply with relevant regulations and airspace restrictions before conducting their operations.

- **Functional Requirements:** The UAS Flight Authorisation Service requires seamless integration with UAS operators' flight planning tools or applications. It should connect with airspace management systems to verify the requested flight's feasibility and safety. The service must consider various factors, such as airspace classifications, active airspace restrictions, and potential conflicts with other flights.

Geo Awareness Service

- **Description:** The Geo Awareness Service provides UAS operators with real-time information about their operational environment. It includes dynamic geofencing, which alerts UAS operators about no-fly zones, temporary flight restrictions, or any other geographical constraints that may affect their flight.

- **Functional Requirements:** The Geo Awareness Service relies on accurate geospatial data and real-time updates to inform UAS operators about any changes in the airspace status or environmental conditions that might impact their flight plans. It requires integration with airspace management databases and a responsive communication system to relay critical information to UAS operators promptly.

Network Identification Service

- **Description:** The Network Identification Service aims to establish a reliable and standardized method for remotely identifying UAS during their operations. It allows authorities and other airspace users to identify drones and link them to their respective operators, enhancing accountability and security in the U-space airspace environment.

- **Functional Requirements:** The Network Identification Service involves equipping UAS with identification technologies that can broadcast their identity or connect to a network-based identification system. The service must comply with privacy and security standards to protect the UAS operators' information while still providing the necessary identification data to relevant authorities.

Traffic Information Service

- **Description:** The Traffic Information Service provides UAS operators with real-time information about nearby air traffic, including both manned and unmanned aircraft. It helps UAS operators make informed decisions to avoid potential collisions and maintain safe distances from other airborne vehicles.

- **Functional Requirements:** The Traffic Information Service relies on data from various sources, such as ADS-B (Automatic Dependent Surveillance-Broadcast) or transponder-equipped aircraft, as well as other cooperative UAS. It requires accurate and up-to-date data exchange to deliver timely traffic information to UAS operators. Additionally, it may involve conflict resolution advice to help UAS operators take appropriate actions to avoid hazardous situations.

Conformance Monitoring Service

- **Description:** The Conformance Monitoring Service focuses on verifying and ensuring that UAS operators adhere to the required regulations, standards, and safety procedures during their flights. It monitors the performance and behavior of UAS operations to detect any deviations or non-compliance with established rules.

- **Functional Requirements:** The Conformance Monitoring Service utilizes data from UAS operations, such as flight telemetry and other relevant information, to assess whether operators are complying with established guidelines. It may involve analyzing factors like flight paths, altitude, speed, and adherence to airspace restrictions.

Please note that being an optional U-space service, the Conformance Monitoring Service might not be universally available or implemented in all U-space airspaces. The adoption and specific details of this service may vary across different regions and authorities.The adoption and implementation of an optional U-space service will be based on the U-space airspace risk assessment outcome.

Figure 3 provides a detailed view on the U-space services and their interfaces.

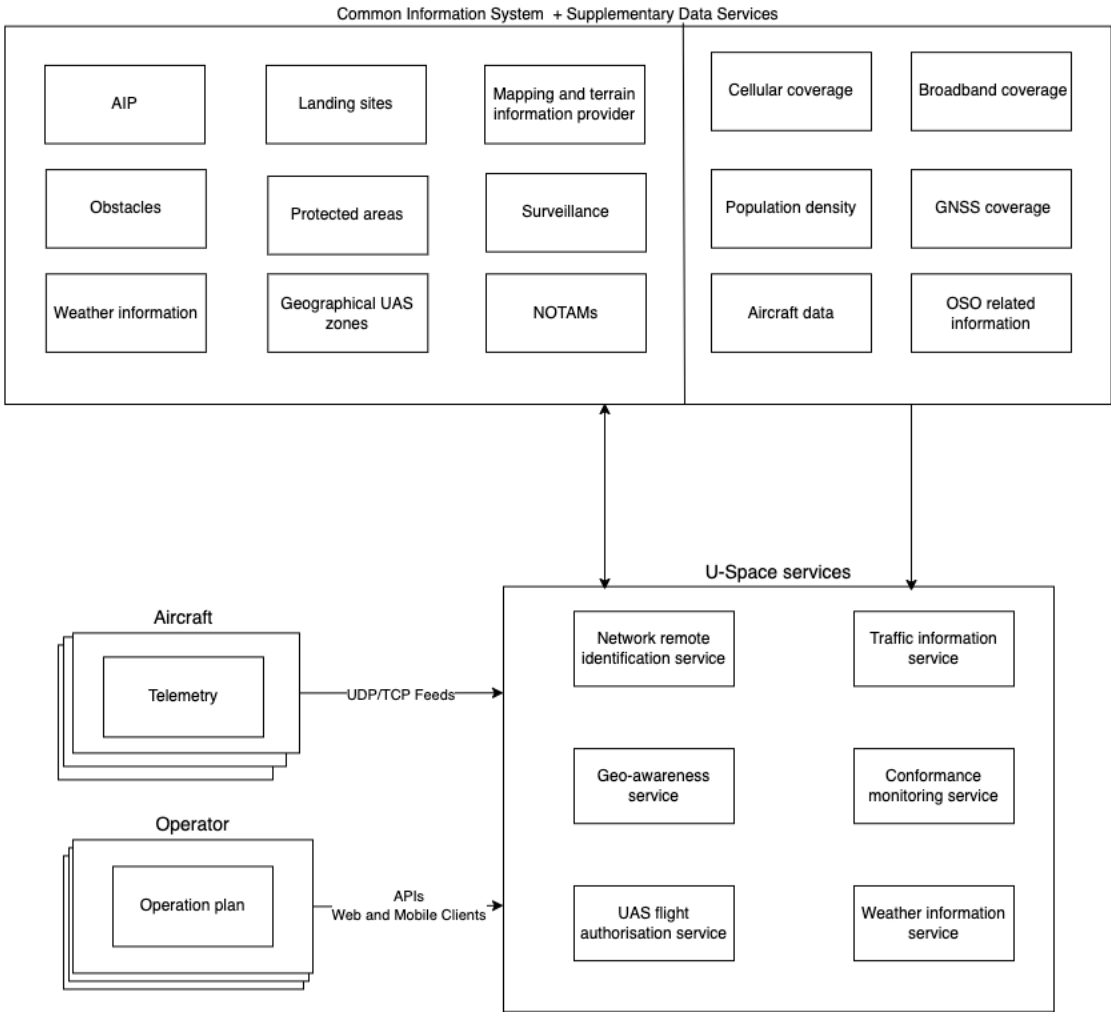

Figure 3: U-space Services and Interfaces

4.2 Common Information Service (CIS)

The Common Information Service serves as a central information sharing platform in the U-space framework. It enables the seamless exchange of real-time data and information related to UAS operations and airspace management. The CIS acts as a crucial communication hub, ensuring that all relevant parties have access to the necessary information to support safe and efficient drone operations.

Core Features of the CIS

- **Data Sharing:** The CIS allows for the secure and standardized exchange of various types of data, including flight plans, UAS identification, traffic information, airspace restrictions, weather updates, and other critical information relevant to U-space operations.

- **Interoperability:** The CIS is designed to be interoperable with different U-space service providers and authorities, ensuring that information can flow seamlessly across the U-space ecosystem. It

adheres to standardized data formats and communication protocols to facilitate smooth integration between various systems.

- **Real-Time Updates:** The CIS provides real-time updates, ensuring that all stakeholders receive timely and accurate information. This enables UAS operators to make informed decisions based on the most up-to-date data, enhancing the safety and efficiency of their flights.

- **Secure Data Exchange:** As the CIS handles sensitive information related to UAS operations and airspace management, it incorporates robust security measures to protect data privacy and prevent unauthorized access.

- **Centralized Repository:** The CIS acts as a centralized repository for essential U-space data, making it accessible to authorized users and service providers. This centralization streamlines the information flow, reducing redundancy and enhancing overall efficiency.

Potential CIS Providers in European Member States

The provision of the Common Information Service can vary between European member states due to differences in their U-space implementation strategies and UAS traffic volumes. Potential CIS providers could include:

- **National Aviation Authorities:** In some countries, the national aviation authorities may take on the role of operating and managing the CIS, ensuring compliance with U-space regulations and standards.

- **U-space Service Providers**: Dedicated U-space service providers may offer the CIS as part of their suite of U-space services, catering to the needs of UAS operators and other stakeholders within the country or region.

- **Collaborative Initiatives:** In certain cases, multiple stakeholders, such as aviation authorities, air navigation service providers, and private companies, may collaborate to establish and operate a shared CIS to pool resources and expertise.

- **Government Agencies:** In some member states, government agencies responsible for aviation and airspace management may take on the responsibility of providing the CIS as part of their broader U-space implementation efforts.

4.3 Interfaces with Supplemental Data Services

The U-space platform needs to be able to consume and act on based on the data provided by a variety of supplemental data sources. The supplemental data service serves as a data warehouse for any available machine-readable datasets. Should data sources allow, datasets can be automatically updated based on

scheduled processes. Once a dataset is incorporated into the supplemental data service, it is exposed to any authorized human-driven or automated workflows.

Supplemental data services, such as weather information, C2 (Command and Control) coverage, aeronautical information, terrain data, and obstacle data, play a crucial role in enhancing the safety and efficiency of U-space operations. Integrating these data services into a USSP (U-space Service Provider) can significantly add value to the overall U-space solution.

Potential SDPSs and Their Benefits

- **Weather Information:** Weather information can be integrated into the USSP through APIs (Application Programming Interfaces) provided by dedicated weather data providers or national meteorological agencies. The USSP can query and retrieve real-time weather data to assess the feasibility and safety of UAS flights.

  Weather information allows UAS operators and the USSP to make informed decisions about flight planning and potential hazards. Access to real-time weather updates enables drone operators to avoid adverse weather conditions, increasing flight safety and reducing the risk of accidents.

- **C2 (Command and Control) Coverage:** C2 coverage data can be integrated into the USSP through direct communication with the C2 service providers or by leveraging existing communication infrastructure and networks used for UAS operations.

  Ensuring reliable C2 coverage is critical for maintaining control and communication with UAS during their flights. By integrating C2 coverage data, the USSP can validate whether a UAS has sufficient communication link coverage within the intended operating area, ensuring stable and safe drone operations.

- **Aeronautical Information:** Aeronautical information, such as airspace classifications, NOTAMs (Notices to Airmen), and temporary flight restrictions, can be integrated into the USSP through standardized aeronautical data feeds provided by air navigation service providers or national aviation authorities.

  Access to aeronautical information enables the USSP to verify that UAS flight plans comply with relevant airspace restrictions and regulations. It ensures that UAS operators are aware of any airspace constraints or temporary restrictions that may affect their planned flights, promoting safe and legal drone operations.

- **Terrain and Obstacle Data:** Terrain and obstacle data can be integrated into the USSP using APIs or geospatial data feeds provided by relevant authorities or organizations responsible for maintaining such data.

Incorporating terrain and obstacle data allows the USSP to conduct real-time risk assessments and collision avoidance analysis for UAS flights. UAS operators can receive alerts if their planned flight paths intersect with hazardous terrain or obstacles, helping prevent potential accidents.

- **Traffic Information:** Traffic information can be integrated into the USSP through APIs and data exchange with air traffic management systems, ADS-B (Automatic Dependent Surveillance-Broadcast) networks, or other cooperative surveillance systems.

  Real-time traffic information enables the USSP and UAS operators to be aware of nearby manned aircraft and other cooperative UAS. This enhances situational awareness and supports the USSP in providing conflict resolution advice to UAS operators, reducing the risk of mid-air collisions.

By integrating these supplemental data services into the USSP, U-space operations can benefit from enhanced safety, efficiency, and situational awareness. UAS operators can make better-informed decisions, and the USSP can provide more comprehensive and valuable services to ensure the safe integration of UAS into the airspace.

4.4 Interface with UAS Operators

In a U-space system, the USSP serves as a central entity that connects various UAS operators and facilitates the exchange of information to support safe and efficient drone operations. The USSP typically provides Application Programming Interfaces (APIs) that enable drone operators to interact with the U-space system, submit flight plans, and share live telemetry data from their drones. Here's how the connection process works:

USSP API Integration

- **UAS Operators:** UAS operators, either individual operators or companies, use the APIs provided by the USSP to connect their UAS operations to the U-space system. These APIs are well-defined interfaces that allow UAS operators to access specific U-space services, such as flight authorization, geo-awareness, and traffic information.

- **Integration Process:** UAS operators integrate the USSP-provided APIs into their ground control systems (GCS) or flight planning applications. This integration enables them to establish communication and data exchange with the U-space system.

Submitting Flight Plans

- **Pre-Flight Planning:** Before a UAS flight, the operator uses their GCS or dedicated UAS operation application to create a flight plan, which includes information such as the intended flight path, altitude, and duration.
- **API Communication:** Using the USSP's Flight Authorisation Service API, the UAS operator submits the flight plan to the U-space system. The USSP then validates the flight plan against airspace restrictions, weather conditions, and other relevant data to assess its safety and feasibility.
- **Authorization Response:** The USSP's system responds to the UAS operator, either granting or denying the flight authorization based on the evaluation of the submitted plan. If authorized, the UAS operator receives a confirmation to proceed with the flight.

Sharing Live Telemetry Data

- **Real-Time Telemetry:** During the UAS flight, the drone continuously generates telemetry data, including its current position, altitude, speed, and other relevant flight parameters.
- **Telemetry APIs**: The USSP provides APIs for live telemetry data sharing. The UAS operator configures their drone and GCS to use these APIs to send the real-time telemetry data to the U-space system.
- **Data Exchange:** The USSP processes and disseminates the live telemetry data to relevant parties, such as other airspace users, air traffic controllers, and traffic information services, to ensure situational awareness and collision avoidance.

Communication Options

- **Ground Control System (GCS):** The GCS acts as an intermediary between the drone and the USSP, facilitating data exchange and communication during the flight. The GCS may receive and process telemetry data from the drone, convert it into a compatible format, and then transmit it to the USSP using the provided APIs.
- **Cellular Network or Direct Communication:** Depending on the USSP's infrastructure and capabilities, the drone might directly connect to the USSP over a cellular network or other communication channels. In such cases, the drone's onboard system communicates directly with the USSP's APIs, eliminating the need for a GCS as an intermediary.

Overall, the integration of USSP-provided APIs into UAS operations enables seamless communication between UAS operators and the U-space system, ensuring that the necessary information is exchanged to support safe and efficient UAS operations within the U-space airspace.

5. Automated Testing Framework

Automated testing is common in aviation being used primarily to verify specification requirements through standardisation of test scripts, traceability tools, emulators and simulators. Software tools used to automate verification processes typically are designed to verify functional requirements, code coverage analysis, resource usage and checking compliance with standards. Such tools are used in the aviation industry for developing safety-critical software together with compliance information and evidence.

As part of the certification process, UTM businesses have to provide compliance evidence to show that the use of UTM software will not result in a hazard or that the failure of UTM service will not cause an accident. Following aviation industry standards on software assurance will require organisations to demonstrate the adoption and use of a structured approach and best practices laid out in technical standards such as ED-153 Guidance for Software Assurance or DO-278A or ED-109A Software integrity assurance for CNS-ATM systems. The core argument of these documents is discipline and traceability throughout the lifecycle of the software and thorough testing at key stages.

The UTM industry can benefit hugely from incorporating automated testing into the verification and validation workflows to demonstrate conformance to technical standards, compliance to regulations, test for robustness and resilience.

In April 2022, the InterUSS Platform (https://interussplatform.org/) introduced an open-source automated testing framework for the UAS flight authorisation service, enabling any interested USSP to run the onboarding process by themselves. The Federal Office of Civil Aviation (FOCA), actively contributes to the development of the testing framework by submitting code, conducting reviews and contributing to the development to ensure compatibility with the U-Space Regulation. The framework can be understood as a digital flight director (called test driver) submitting operational intents and other data as mandated by the regulation to the participating USSP. To allow the test driver to submit flights, participants are required to implement a dedicated standard interface that is also specified. They can then translate the flight plans into their proprietary data models internally within their systems. Each participant is required to maintain a system identical to the one running in their production environment. This environment is used for interoperability testing. It allows new participants to test their infrastructure against the one of existing participants without having an impact on live operations.

The open source automated test suite developed on the InterUSS Platform enables the USSPs to continuously test their ability to meet the requirements set in the standards as means of compliance that shape the framework for the implementation of a U-spaceservices.

Using the framework, the authority can test whether USSPs are meeting the data exchange requirements set forth in the U-Space regulatory package. Access to the qualification environments will be granted by the authority through an authorization service. No human coordination will be required to check out the new participant. The Competent Authority will receive a report which contains all the information

required to assess the ability of the participant to join the production environment. This report includes the test configuration, test target versions, test driver version, request traces, and the list of issues the test driver encountered while submitting requests or inconsistencies in the system during the test sequence.

This approach has already been developed for:

- Network remote identification service based on the ASTM F3411-19 Standard.
- The UAS flight Authorisation service is based on the ASTM F3548-21 Standard.

Figure 4 provides an example of the UAS flight Authorization Automated Testing.

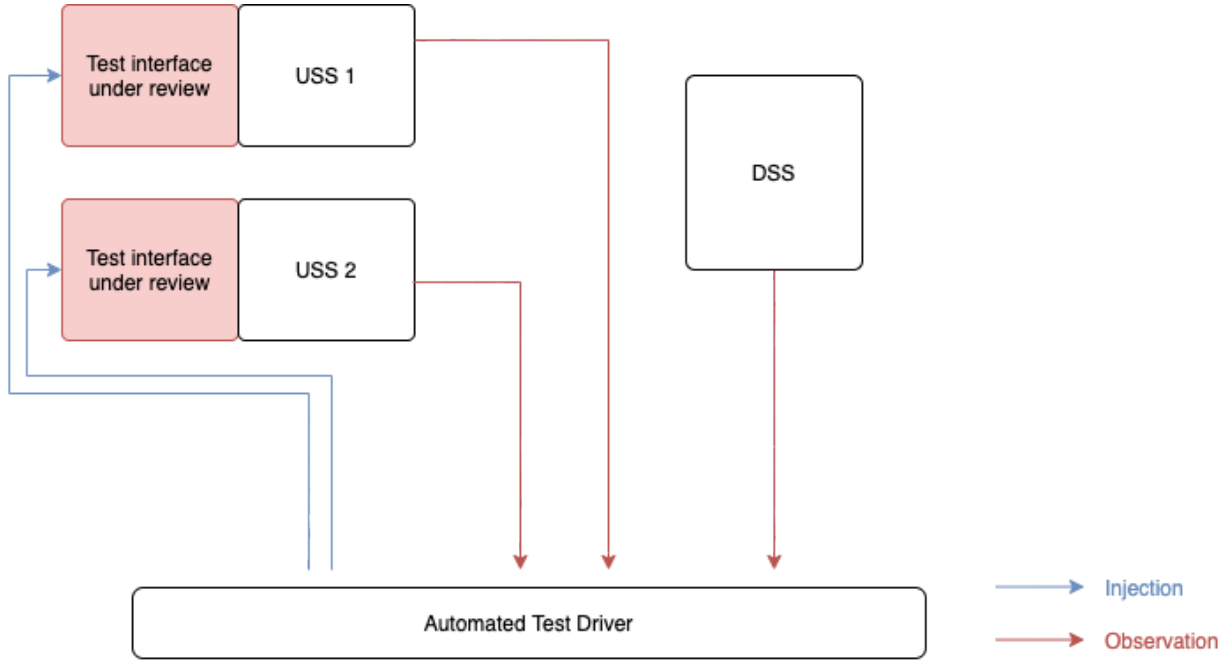

Figure 4: Example UAS Flight Authorization Automated Testing