EXPLORATORY RESEARCH

Validation Scenario Design

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ICARUS

INTEGRATED **C**OMMON **A**LTITUDE **R**EFERENCE SYSTEM FOR **U**-**S**PACE

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Abstract

This document is deliverable D6.1 "Validation Scenario Design" of ICARUS project. Together with D6.2 "Simulation and real trials execution", this is the first document of WP6 that reports on the planning for the project's verification and validation activities. In particular this document provides information about the design of scenarios envisaged for validation activities and the test-bed, including equipment, drones, components, and USSP interfaces that will be used. It also covers the verification of the requirements defined during the requirements analysis in Document D3.1 "ICARUS concept definition".

Information related to verification and validation activities is given briefly in the introduction section of each WP6 document to give the reader a better understanding of each document.

The main objectives of D6.1 can be summarised as follows:

- Identification of a suitable scenario for testing ICARUS services representative of the use cases identified in D3.1;
- Design of the scenarios for validation activities to be performed with drones and manned flights in Italy and Poland (both simulated and real);
- Identification of verification activities related to the assessment of the accuracy of the ICARUS concept.

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1 Introduction

The ICARUS project proposes an innovative solution to address the challenge of the Common Altitude Reference System for drones in very low-level (VLL) airspace through the use of a GNSS altimetry-based approach, and the definition of a **geodetic-barometric transformation algorithm**, implemented through a dedicated U-space service (U3 service).
The first part of the project was dedicated to the definition of the concept and of the feasibility of the altitude translation services proposed by ICARUS, considering different elements that make up the final end-to-end (E2E) error. To better understand the problems, five use cases were defined as representative of flight operations where the CAR service is needed. With the help of such use cases, a detailed analysis of the requirements was conducted, and a set of requirements and the related environment type were identified to drive the design of the architecture of the CAR service. The prototype service will be validated in simulated and operational environments.

The present document (D6.1) describes the design of the validation scenarios and provides the details of the validation scenarios for the use cases identified in D3.1. The validation scenarios described here cover the most relevant CAR problems addressed in the use cases, making use of the services implemented in the ICARUS test-bed architecture. The micro services identified, developed and implemented in ICARUS are:

- **VCS (Vertical Conversion Service):** provides automatic translation between barometric height and GNSS altitude (i.e. conversion from a barometric reference system to a geodetic one or vice-versa);
- **VALS (Vertical Alert Service):** Alerts drones and manned aviation over the common geodetic reference system about the current vertical distance to the ground (or other drone traffic), when such a distance becomes too small.
- **RGIS (Real Time Geographical Information Service)**: provides accurate cartography and 3D DTM / DSM of ground obstacles during the execution of a flight, to provide real-time information on the vertical distance to the ground, including above taller obstacles.

These micro-services will be validated through the scenarios presented in this document.

The document is structured as follows:

- Section 1: Introduction and approach to verification and validation activities
- Section 2: Verification Strategy
- Section 3: Test Cases design and definition
- Section 4: Design of validation scenarios and schedule

The approach used for verification and validation activities is presented in Chapter 1; however the operational details for the plan of each simulated (or real flight) exercise are presented in D6.2, which is intended as an operational document for supporting the both operational and simulation trials.

Finally, the outcome of the verification and validation campaign will be collected and analysed in D6.3 with the support of GA and UAS operator communities.

1.1 Applicable Reference material

The following documents are considered applicable reference material:

[1] Grant Agreement-894593-ICARUS
[2] ICARUS Consortium Agreement
[3] SESAR 2020 Exploratory Research Call H2020-SESAR-2019-2 (ER4), available at http://ec.europa.eu/research
[4] Project Handbook of SESAR 2020 Exploratory Research Call H2020-SESAR-2019-2 (ER4) (Programme Execution Guidance), edition 03.00.00, 14th March 2019
[5] D3.1 – ICARUS concept definition: state of the art, requirements, gap analysis
[6] D4.1 – Design and Architecture of the ICARUS system & service
[7] D5.1 – UTM Platform architecture
[8] D5.2 – Cockpit Simulator Architecture
[9] D5.4 – External I/F test
[10] D-Flight USSP ICD - https://www.d-flight.it/new_portal/2021/06/24/nasce-il-manifesto-per-lo-spazio-aereo-dei-droni-d-flight-in-campo-per-il-decollo-del-settore/
[11] ICARUS_Requirements_v1.3

1.2 Acronyms

Acronyms	Signification
AMSL	Above Mean Sea Level
ATC	Air Traffic Control
BVLOS	Beyond Visual Line of Sight
CARS	Common Altitude Reference System
DSM	Digital Surface Model
DTM	Digital Terrain Model
E2E	End to End
EFB	Electronic Flight Bag
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
GA	General Aviation
GAMZ	Geometric Altitude Mandatory Zone

GBAS	Ground Based Augmentation System
GCS	Ground Control Station
GNSS	Global Navigation Satellite System
HPL	Horizontal Protection Level
ISA	International Standard Atmosphere
MCMF	Multi Constellation Multi Frequency
MFMC	Multi Frequency Multi Constellation
QFE	Query Field Elevation
QNH	Query Nautical Height
RGIS	Real Time Geographical Information Service
RNP	Required Navigation Performance
RPAS	Remotely Piloted Aircraft System
RMS	Root Mean Square
SBAS	Satellite Based Augmentation System
SFMC	Single Frequency Multi Constellation
SiS	Signal in Space
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
USSP	U-Space Service Provider
UTM	Unmanned Traffic Management
VALS	Vertical Alert Service
VCS	Vertical Conversion Service
VLL	Very-Low-Level
VPL	Vertical Protection Level

Table 1-1 – Acronyms' list

1.3 Approach to verification and validation activities

The micro-services developed in ICARUS (VALS, VCS, RGIS) have been defined according to the following methodology:

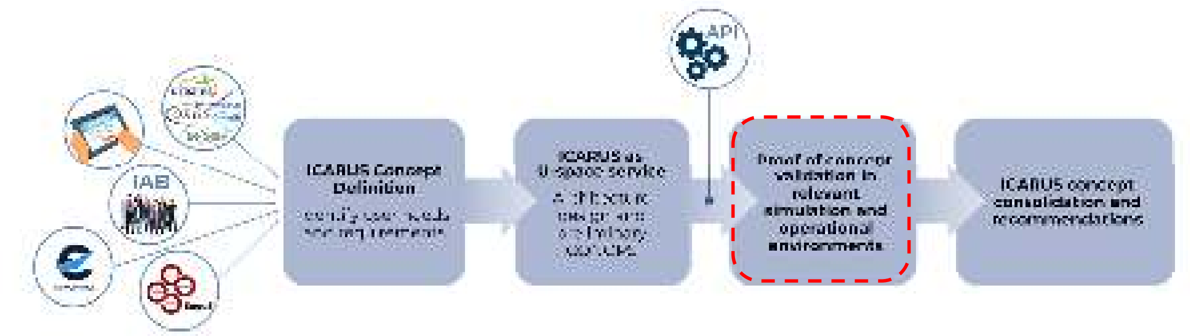

Figure 1-1 – Methodology: focus on verification and validation activities

For the verification activities, these services (or part of them) will be tested in this phase with a mixed approach involving both simulations in labs and verification activities in real operational scenarios, involving drones and manned aircraft flying at different heights. GA flights and taxi-drone flights will be simulated; UAS flights and ultralight flights will be operated in a real scenario. The main objectives of the verification activities can be summarised as follows:

- to stress the differences in the different altitude measurement systems with different height / altitude settings
- to recognise the importance of the concept underpinning the micro-services proposed in terms of E2E accuracy and other KPIs;
- to provide a limited number of test cases that enable the full coverage of the requirements defined in D3.1
- to provide flight logs, data and external references (benchmarks) for data analysis and interpretation of the results;

Subsequently, the validation of ICARUS prototype services can begin with particular reference to the final E2E performance achieved. The validation will be supported by two actual USSPs:

- D-Flight (Italy https://www.d-flight.it/new_portal/) with the support of Telespazio and TopView;
- Pansa UTM (Poland https://www.pansa.pl/en/pansautm/) with the support of DroneRadar;

As a final step, the validation activities will involve both UAS pilots and GA / ultralight pilots to test and provide feedback on the ICARUS micro-services that will be queried during the validation activities.
For this activity, the simulation exercises will be supported by the use of a C-172 cockpit simulator available at Topview premises in Italy, interfaced with the Italian USSP, D-flight, that is testing possible services to be provided to GA users in VLL. Some GA pilots will be invited to validate the service using the cockpit simulator and the electronic flight bag (EFB) that displays output from the ICARUS service. Drone pilots will also be invited to provide feedback on the new functionalities using a simulated ground control station (GCS) that offers a visualisation of the information provided by the ICARUS micro-services.

The verification and validation methodology can be organised as shown in *Figure 1-2*. This diagram illustrates the process followed for verification and validation activities (WP6).

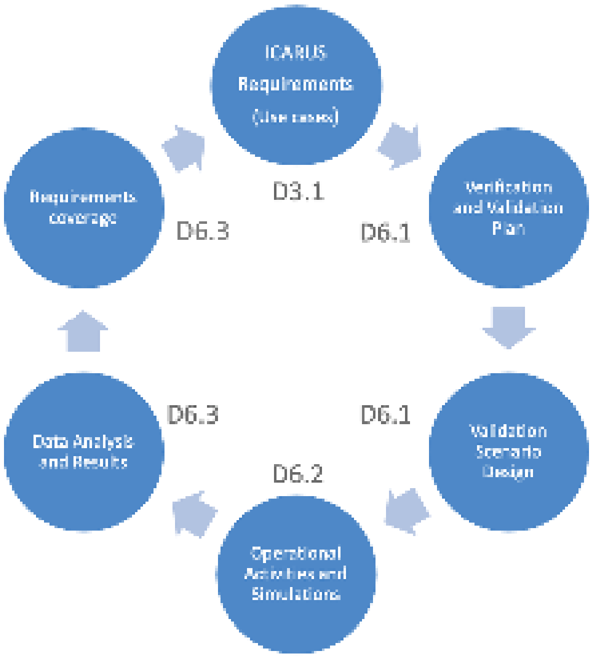

Figure 1-2 – Organisation of information-related verification and validation activities

1. **ICARUS requirements (Use Cases):** Relevant use cases for ICARUS were defined in Section 6 of D3.1. This set of five use cases was defined to support the definition of the requirements used to drive the design of the ICARUS micro-service architecture and the flight trials (simulated and real) for the assessment of the performance and the validation of the concept. The requirements will be used as the input to the other activities.
2. **Verification and Validation Plan:** This is described in Section 2 of the present document, taking the project schedule into account. In this section the test cases, the test procedures, and the naming convention will be identified and coded.
3. **Validation Scenario Design:** The validation scenario design is the heart of this document and is described in Section 3. In this section the design of different scenarios (both simulated and real) will be described, with particular reference to the ICARUS micro-services that will be queried and the target users that will be engaged in the validation (e.g. GA pilots, drone pilots, USSP operators).
4. **Operational Activities and Simulations:** These activities are described in D6.2. This provides operational details about the validation campaigns and exercises that will be conducted, considering the particular areas where trials will take place. In this document the operational plan for execution of real flights and the **simulation trials** will be described.
5. **Data Analysis and Results:** This information is described in D6.3. In this document, all the data collected during the flights (simulated and real) will be described and analysed for final results and recommendations. The test results, from the test cases and test procedures defined in Section 2 of the present document, will be presented in D6.3.
6. **Requirements coverage:** The final step is a final check of the coverage of the requirements defined in D3.1. A traceability matrix will be used to support this stage (D6.3).

2 Verification strategy

The ICARUS project addresses the problem of the Common Altitude Reference System, responding to SJU ER4-2019, topic 31 - Area 2. Although not strictly compulsory in research and innovation actions (RIAs), the consortium decided to follow a verification and validation strategy common to many System Engineering methodologies, as shown in *Figure 2-1*.

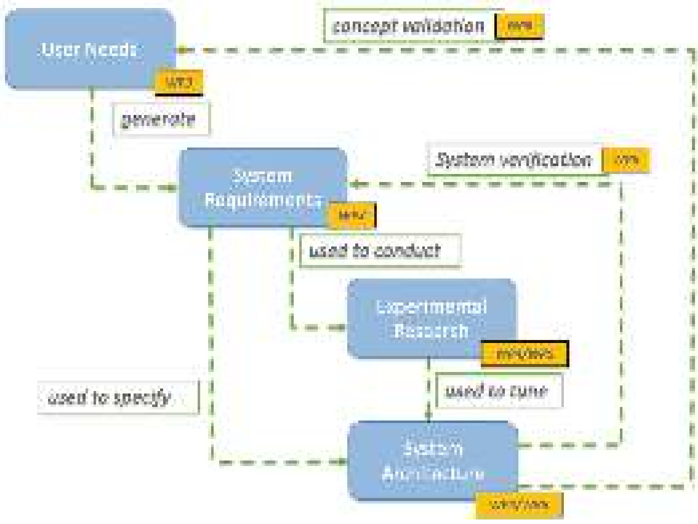

Figure 2-1 – verification and validation strategy

Through this approach, **user needs** are identified to identify the actual demand from UAS pilots, GA pilots, USSPs operators and ATC controllers, who require a reliable, simple, and effective reference system for altitudes and heights. User needs in this case were not coded as was done with the requirements, since the only perceived user need derives directly from the ICARUS topic.

System requirements were generated according to this single user need with the goal of translating this high-level need into a specified architecture that implements the requested innovative functionalities. The set of system requirements is given in the form of an excel file attached to D3.1.

Experimental research was conducted as different topics analysed during the design stage, but this needed verification before freezing the final ICARUS architecture.

Finally, the **system architecture** was designed and implemented (WP5) by exploiting the specification of system requirements and also taking into account the results from dedicated experimental research that contribute to tuning the architecture, in particular for the GNSS solution adopted for determining the vertical position of a UAS and for the barometric measurements needed to feed the core ICARUS algorithm for barometric/geodetic translation.

System verification is performed by confirming (through examination and evaluation) that the ICARUS architecture built matches with the identified system requirements (D3.1). This process will allow a correct answer to the question: “*Are we building it correctly?*”.

Finally, the concept will be validated by confirming that the solution built (ICARUS architecture and flight operations) meets the user needs for its intended use. This process will allow a correct answer to the question: “*Are we building the right thing*?”

2.1 User Needs

The single user need identified derives directly from the SESAR topic area and can be stated in the following form:

- *Study and definition of Common Altitude Reference System for Manned and Unmanned aircraft at VLL*

For a better understanding of all the problems related to the study, the following five use cases were identified (D3.1), with a storyboard and a description of the main key parameters to stress the Common Altitude Reference problems.

Figure 2-2 – Use cases identified as expression of user needs

The subsequent (system) requirements were derived from the use cases presented.

2.2 System Requirements

The system Requirements are specified in the D3.1 (ref. ICARUS req. V1.2 12-dic 2020 -excel file).

2.3 Experimental Research

Experimental research has been focused on specific topics (RNP capabilities, DTM/DSM errors, barometric/geodetic conversion model as addressed in D3.1, D4.1, D5.1).

2.4 System architecture

ICARUS system architecture is described in D5.1. The present document provides methodologies to verify the architecture implemented for providing ICARUS prototype services.

2.5 Verification

The verification activity, through experimental exercise is the starting point to better verifying critical items (i.e. conversion algorithm, UAS GNSS receiver configuration, etc.). In some cases results are available from literature on the state of the art; other cases require dedicated test activities.

The following section gives details of the methodology used to implement the verification process starting from the set of system requirements.

2.5.1 *Requirements classification*

The requirements defined for ICARUS (v1.2 17-12-2020) are classified as follows:

- ✓ ***General requirements***
- ✓ ***Functional***

This kind of system requirement identifies the functionalities to be implemented in the ICARUS micro-service architecture

- ✓ ***Operational***

This kind of system requirement identifies the processes to be put in place to guarantee the operational use of the ICARUS micro-services by the players involved.

- ✓ ***Performance***

This kind of system requirement identifies the performance to be attained by ICARUS micro-service or by subparts of it.

2.5.2 *Methods*

The following verification methods have been taken into account:

- ✓ ***Test (T)***

Compliance with requirements is validated by executing an item under controlled conditions, configurations, and inputs to observe the response. Results are quantified and analysed in dedicated test reports

- ✓ ***Analysis (A)***

Compliance with requirements is determined by interpreting results using established principles as statistics, qualitative design analysis, modelling and computer simulation.

- ✓ ***Review of Design (RoD)***

Compliance with requirements is validated by using existing records or evidence such as validated design documents, approved design reports, technical descriptions, engineering drawings

- ✓ ***Inspection (I)***

Compliance with requirements is determined by visual determination of physical characteristics which include construction features, hardware conformance to documents, drawings, or workmanship requirements, physical conditions, an software source code conformance with coding standards

2.5.3 *Strategy*

The verification process is composed of the following steps:

- ✓ System requirement generation from identified user needs;
- ✓ System design test to determine if the identified system requirements are fulfilled. The test activity is implemented by selecting an appropriate verification method, taking into account the verification method expressed during the requirements definition stage. For each identified requirement, a relevant verification method is selected. As a general assumption, the method “Test” will first be considered in combination with “analysis” in cases where the test method is not implementable. The following possibilities are considered:
    - o Verification by A/RoD/I: in this case, a short description is provided to justify how the requirement is fulfilled. The justification is included in the verification control matrix (D6.3)

- Verification by T: in this case the following activities will be performed:
  - Test case specifications: Test cases are defined and linked to relevant requirements to verify final fulfilment (D6.1);
  - Test procedure specifications: Test cases are detailed in test procedures that explain step by step how to execute the relevant test case (executed before the tests and reported on in D6.3);
  - Test execution: test execution includes final analysis and output data collection (D6.3);
  - Test report preparation: Finally, a test report is prepared (D6.3);

The tests will be executed in E-GEOS, TPZ, DRAD, TOPV premises once the ICARUS micro-service platform is finally integrated. In fact, the ICARUS micro-service architecture is distributed and is hosted across the consortium partners' servers.

2.5.4 Process and Naming convention

✓ ***Requirements***

ICARUS requirements are built according to the following identification format:

- ICARUS-<DOC>-<NNNN> where:
- <DOC>: 3 digit string identifying the deliverable (document) of the project that has generated it
- <NNNN>: Incrementing number e.g. ICARUS-D31-0010

Additional information on requirements can be found in the D3.1 document

ReqID	ReqTitle	ReqText	Environmental type	Tracebility	Type	Verification Method
ICARUS-D31-0010	CARS options	According to the following options for a Common Altitude Reference System for Manned aircraft and drones at VLL: - Option 1: barometric measurements for all operations at VLL, no U-space services; - Option 2: GNSS measurements for all operations at VLL, no U-space services; - Option 3: Mixed approach; each airspace users will use its approved altimetry system, U-space services will be used for translation; ICARUS will follow up with option 3 (mixed approach)	<Rural>; <Suburban>; <Urban>; <Maritime>; <Forestry>; <Aerodrome>	EC/EASA CARS Study	General	RoD

Figure 2-3 – Example of ICARUS requirement

✓ ***Test Cases***

ICARUS test cases are built according to the following identification format:

✓ TEST_<*Type*>.<*Item*>.<NN> where:

- <*Type*> indicates the typology used. Possible values are:
  - "SIM", in case of test activity Simulated in a controlled environment such as laboratories
  - "OPS", in case of test activity that requires flight operations
- <*Item*> indicates the activity. Possible values are:
  - "GNSS", in case of test activity involving GNSS Receivers
  - "BARO", in case of test activity involving barometric measurements
  - "DTM", in case of test activity acquisition of terrain models.
- <NN> is an incrementing number (e.g. TEST_SIM.DTM.10),

Moreover, test cases contain the following sections:

- Test case ID, according to the naming convention

- Test objective, indicating the aim of the test
- Test description, giving a short explanation
- Required data, indicating if data included are mandatory
- Required equipment, indicating which kind of tools/ general equipment are needed for the test
- Pass/Fail criteria, indicating the condition to be evaluated
- Parent requirement, indicating the system requirements intended to be fulfilled in the case of successful execution
- Remark, free text if needed for further explanation

2.5.5 External Interfaces

The interfaces of the distributed ICARUS architecture are specified in D5.4, where a report of external interface verification is provided.

2.5.6 Verification Matrix

The verification matrix (D6.3) will be built according to the following format:

ReqID	ReqTitle	ReqText	Type	Verification	D,A,I Justification	Stauts of Compliance	Close-out Status
Requirement Identification	Requirement Title	Requirement Text	Functional or Performance	A, I, RoD or T	Comment to be fulfilled only in the case of a requirement verified by A,I or RoD	<C>, <NC> or <PC> depending on the verification outcome	<open> or <closed>

Table 2-2 – Verification Matrix

In the verification matrix the following abbreviation are used.
For verification:

- ✓ A = Analysis
- ✓ I = inspection
- ✓ RoD = Review of design
- ✓ T = Test

For assessing the status of compliance:

- ✓ C= Compliant
- ✓ NC = non-compliant
- ✓ PC = Partially compliant

2.5.7 Test Report

For each executed test, a dedicated report is provided in D6.3 as a general text reporting interesting outcomes (including pictures and graphics when possible) of the specific test executed.

3 Test Cases

The test cases described hereafter are related to the verification of the ICARUS concept and in particular to:

- ✓ The altitude conversion algorithm with respect to E2E accuracy;
- ✓ The verification of the altitude conversion algorithm in relevant environment;
- ✓ UAS-UAS altitude reference with a DFMC GNSS receiver and augmentation service;
- ✓ Manned aircraft – ground obstacle altitude reference;

The test cases presented here do not include verification of the software interface ICD, which is included in the D5.4 document.
The successful verification of the test cases presented here AND the verification of the software interfaces (D5.4) unlock the final validation activity.

3.1 TEST_OPS.GNSS.10 – UAS-UAS altitude reference (urban)

3.1.1 Objective

The objective of this test is to verify the performance of different GNSS receivers (from low -cost SFMC to high-end MFMC GNSS receivers) for the UAS-UAS common altitude reference in an urban environment.

3.1.2 Description

For the present test, a multicopter UAS will be used. The drone will be equipped with a custom payload composed of three GNSS receivers ranging from low performance to high performance. The payload is composed of one unique triple-frequency antenna, working in the E1, E5, E6 bands feeding 2 or 3 GNSS receivers coupled with a GNSS signal splitter. In particular the receivers that will be used are:

- ✓ Septentrio GNSS Development Board Mosaic X5 (Triple band with Galileo E5 AltBoc enabled);
- ✓ U-Blox F9P GNSS receiver dual-frequency constellation receiver
- ✓ Pollicino low-cost GNSS receiver, single-frequency multi-constellation GNSS Receiver

This payload will allow raw GNSS data (and NMEA data) to be stored on-board and used for post processing analysis. The main goal is to gather meaningful GNSS Rx data to assess the vertical accuracy achievable with each GNSS receiver with respect to a reference trajectory
The drone will perform different flights (tentatively five) of about 30 minutes with the same configuration but at different time slots:

- ✓ **Ground control station** with mission planning software for a simple 3-waypoint automatic loop mission at a given height of 25 m AGL in a suburban environment.
- ✓ **Private RTK GNSS station:** to augment the UAS position and navigation performance during the flight for determining the reference trajectory.

Figure 3-1 – Drone and Test equipment for Test Case: TEST_OPS.GNSS.10

Figure 3-2 – Trajectory in an urban environment for TEST_OPS.GNSS.10

3.1.3 Required data

The data required for analysis (D6.3) is described below:

- ✓ raw GNSS data from a Septentrio X5 GNSS receiver (about 30 minutes x 5 flight sessions);
- ✓ raw GNSS data from a U-Blox F9P GNSS receiver (about 30 minutes x 5 flight sessions);
- ✓ NMEA data from a Pollicino GNSS receiver (about 30 minutes x 5 flight sessions);
- ✓ raw GNSS data from the permanent private RTK GNSS station;
- ✓ Drone trajectory data (augmented positions from an RTK GNSS station) used as reference trajectory

3.1.4 Required Equipment

The following equipment is needed for this test:

- ✓ Payload composed of 3 GNSS receivers;
- ✓ DJI M300 RTK drone
- ✓ Ground control station with software for automatic mission planning;
- ✓ Private RTK GNSS station (geodetic grade);
- ✓ Spare batteries and recharging station for batteries.

3.1.1 Output

The expected output for this test is:

- ✓ To verify the performance of different GNSS receivers in dynamic flight conditions in urban / suburban environment where **some multipath is expected**. In particular the following figures will be assessed during the analysis (D6.3):
  - Accuracy (mu, sigma) of the vertical axis and horizontal plane w.r.t. the reference drone trajectory for:
    - Septentrio X5 GNSS Receiver;
    - UBlox F9P GNSS Receiver;
    - Pollicino GNSS Receiver;
  - Precision (mu, sigma) of the vertical axis w.r.t. the mean vertical height for:
    - Septentrio X5 GNSS Receiver;
    - UBlox F9P GNSS Receiver;
    - Pollicino GNSS Receiver;
  - Integrity figures (mu, sigma for VPL) for:
    - Septentrio X5 GNSS Receiver;
    - UBlox F9P GNSS Receiver;
    - Pollicino GNSS Receiver;
  - Integrity figures (mu, sigma for HPL) for:
    - Septentrio X5 GNSS Receiver;
    - UBlox F9P GNSS Receiver;
    - Pollicino GNSS Receiver;

The figures previously explained refer to the entire flight time for accuracy and for each flight session for precision.
All figures will be updated in post processing, including the integrity.

3.1.2 Pass / Fail Criteria

The test is passed if any of the GNSS devices ensures an accuracy of at least:

- ✓ 9 metres for the vertical accuracy (req. ICARUS-D31-0310)
- ✓ 1.5 metres for the vertical accuracy in static tests (req. ICARUS-D31-0240)
- ✓ 1.0 metres for the horizontal accuracy in static tests (req. ICARUS-D31-0240)

and for integrity:

- ✓ 27 metres for the VPL level when flying at 15 m/s (req. ICARUS-D31-0320)

- ✓ 46 metres for the HPL level when flying at 15 m/s (req. ICARUS-D31-0330)

3.2 TEST_OPS.GNSS.20 – UAS-UAS Altitude reference (open sky)

3.2.1 *Objective*

The objective of this test is to verify the performance of different GNSS receivers (from low-cost SFMC to high-end MFMC GNSS receivers) for the UAS-UAS common altitude reference in an open sky environment (country side - X,Y Volumes)

3.2.2 *Description*

See description of TEST_OPS.GNSS.10

Figure 3-3 – 4 waypoint Trajectory in open-sky conditions. TEST_OPS.GNSS.20

3.2.3 *Required data*

See required data for test TEST_OPS.GNSS.10

3.2.4 *Required Equipment*

See required equipment for test TEST_OPS.GNSS.10

3.2.5 *Output*

The expected output for this test is:

- ✓ To verify the performance of different GNSS receivers in dynamic flight conditions in open sky conditions where **multipath is not expected**. In particular the following figures will be assessed during the analysis (D6.3):
  - Accuracy (mu, sigma) of the vertical axis and horizontal plane w.r.t. the reference drone trajectory for:
    - Septentrio X5 GNSS Receiver;
    - UBlox F9P GNSS Receiver;
    - Pollicino GNSS Receiver;
  - Precision (mu, sigma) of the vertical axis w.r.t. the mean vertical height for:
    - Septentrio X5 GNSS Receiver;
    - UBlox F9P GNSS Receiver;
    - Pollicino GNSS Receiver;
  - Integrity figures (mu, sigma for VPL) for:
    - Septentrio X5 GNSS Receiver;
    - UBlox F9P GNSS Receiver;
    - Pollicino GNSS Receiver;
  - Integrity figures (mu, sigma for HPL) for:
    - Septentrio X5 GNSS Receiver;
    - UBlox F9P GNSS Receiver;
    - Pollicino GNSS Receiver;

The figures previously explained refer to the entire flight time for accuracy and for each flight session for precision.
All figures will be updated in post processing, including the integrity.

3.2.6 Pass / Fail Criteria

The test is passed if any of the GNSS devices ensures an accuracy of at least:

- ✓ 9 metres for the vertical accuracy (req. ICARUS-D31-0310)
- ✓ 1.5 metres for the vertical accuracy in static tests
- ✓ 1.0 metres for the horizontal accuracy in static tests

and for integrity:
- ✓ 27 metres for the VPL level when flying at 15 m/s (req. ICARUS-D31-0320)
- ✓ 46 metres for the HPL level when flying at 15 m/s (req. ICARUS-D31-0330)

Although, the same requirements apply for this test, better figures are expected in an open sky environment since requirements were not written for open sky as they were for the urban environment (ICARUS-D31-0240)

3.3 TEST_OPS.GNSS.30 – UAS-UAS Altitude reference (continuity)

3.3.1 Objective

The objective of this test is to verify the performance of continuity figures with different GNSS receivers (from low-cost SFMC to high-end MFMC GNSS receivers) for UAS-UAS common altitude reference in both open sky and urban environments.

3.3.2 Description

This test gathers data from the previous experiments (TEST_OPS.GNSS.10 and TEST_OPS.GNSS.20) covering over about 300 minutes of flight (10 flights x 30 minutes), corresponding roughly to 18,000 position samples at 1 Hz or 180,000 position samples acquired at 10 Hz.
Each position sample has a UTC time (epoch) stamp that must be verified for continuity in the absence of a GNSS signal (req. ICARUS-D31-0220).

3.3.3 Required data

All data acquired by the GNSS receivers during tests:

- ✓ TEST_OPS.GNSS.10
- ✓ TEST_OPS.GNSS.20

3.3.4 Required Equipment

See required equipment for test TEST_OPS.GNSS.10

3.3.5 Output

The output expected is the number of epochs or navigation position solutions without a valid navigation solution with respect to the total data acquired (i.e. 180.000 epochs).
This output is expected to be very closed to zero according to req. ICARUS-D31-0220. This requirement will be not strictly demonstrated (Verification per Analysis only), however the data acquired in the previous tests is useful to support the verification of the test per analysis, in combination with Literature review.

3.3.6 Pass / Fail Criteria

The test is passed if 1 sample or fewer is corrupted or invalid for every 100,000 results.

3.4 TEST_OPS.GNSS.40 – UAS-UAS Altitude ref. (Availability)

3.4.1 Objective

The objective of this test is to verify the availability performance of the GNSS signal in a non-urban environment, considering the data acquired from different GNSS receivers (from low-cost SFMC to high-end MFMC GNSS receivers).

3.4.2 Description

This test gathers data from the previous experiments (TEST_OPS.GNSS.10 and TEST_OPS.GNSS.20) covering about 300 minutes of flight (10 flights x 30 minutes), corresponding roughly to 18,000 position samples at 1 Hz (RF signal used for continuity).
Each position sample has a UTC time (epoch) stamp that must be verified for Signal in Space (SiS) availability in dynamic conditions in the absence of a GNSS signal (req. ICARUS-D31-0230).

3.4.3 Required data

All data acquired by the GNSS receivers during tests:
- ✓ TEST_OPS.GNSS.10
- ✓ TEST_OPS.GNSS.20

This data acquired in dynamic conditions is needed to verify the availability of GNSS signal (SiS) during turns or UAS manoeuvres considered in the tests (automatic plan).

3.4.4 Required Equipment

See required equipment for test TEST_OPS.GNSS.10

3.4.5 Output

The output expected is the number of navigation position samples without a valid navigation solution with respect to the total data acquired (i.e. 18,000 samples).
This output is expected to be very close to zero according to requirement ICARUS-D31-0230. This requirement will be not strictly demonstrated (verification by analysis only), however the data acquired in the previous tests is useful to support the verification of the test by analysis, in combination with a literature review.

3.4.6 Pass / Fail Criteria

The test is passed if 1 sample or fewer is corrupted or not valid at GNSS receiver RF front end for every 1,000 results (raw data only).

3.5 TEST_OPS.DTM.10 – UAS-Ground Obstacle common reference

3.5.1 Objective

The objective of this test is to verify the **accuracy figures of the DTM/DSM** models used for vertically geo-referencing ground obstacles with respect to the same common altitude reference used by UAS (WGS-84 for BVLOS operations).

3.5.2 Description

For this test no flight operations are needed. The payload used for tests nos. TEST_OPS.GNSS.10 and TEST_OPS.GNSS.20 will be reused for this test. The payload will be put on the top of a building with access to the rooftop, or as an alternative it will be placed on the top of a hill with the GNSS receiver antenna in open sky.
This test requires a knowledge of the height of the structure / hill, through an independent and more accurate measurement system. A trusted geodetic reference point can be used as an excellent support for the positioning of the antenna payload during the test.

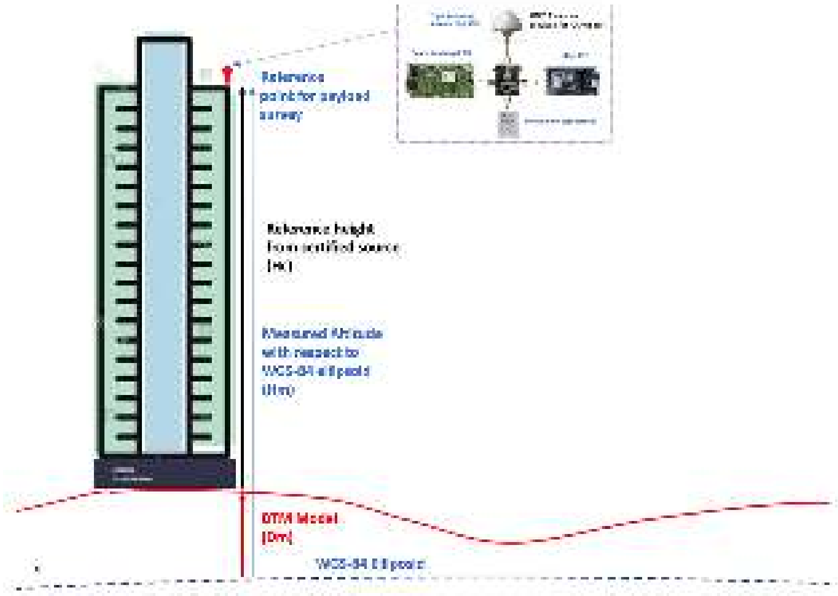

Figure 3-4 – DTM Accuracy estimation.

1. Report the height of the building obtained from public land registry or from other certified sources (i.e. project) at the trusted geodetic reference point (Hc)
2. Place the GNSS payload at the trusted geodetic reference point in a static position for 30 minutes and record GNSS data (Hm).
3. Consider the DTM/DSM model used in the ICARUS prototype service (Dm)
4. Assess the E2E Error considering error = Hm-Dm-Hc

The E2E error can be filtered of the GNSS error (previously estimated in TEST_OPS.GNSS.10) to assess the DTM accuracy.

This test is useful for ICARUS RGIS service accuracy figures when expressing ground obstacles in the same reference system as used by the UAS (WGS-84) during BVLOS operations.

3.5.3 Required data

The required data for analysis (D6.3) is described below:

- ✓ Raw GNSS data from a Septentrio X5 GNSS receiver (about 30 minutes x 5 flight sessions);
- ✓ Raw GNSS data from a U-Blox F9P GNSS receiver (about 30 minutes x 5 flight sessions);
- ✓ NMEA data from a “Pollicino” GNSS receiver (about 30 minutes x 5 flight sessions);

3.5.4 Required Equipment

The following equipment is needed for this test:

- ✓ Payload composed of 3 GNSS receivers;

3.5.5 Output

The expected output for this test is:

- ✓ To verify the accuracy of DTM model for the determination of the ground obstacles vertical height expressed in the same altitude reference system of UASs when flying in BVLOS conditions (WGS-84)
- ✓ In particular the following figures will be assessed during the analysis (D6.3):
  - Estimation or RMS Error of the Height of the Ground obstacle compared with the real height w.r.t. the different GNSS receivers of the payload used for the measurement:
    - Septentrio X5 GNSS receiver vertical component accuracy;
    - UBlox F9P GNSS receiver vertical component accuracy
    - Pollicino GNSS receiver vertical component accuracy

3.5.6 Pass / Fail Criteria

The test is passed if the DTM accuracy, calculated as E2E Error = Hm-Dm-Hc, is in the following ranges (req. ICARUS-D31-0380):

- ✓ for urban areas, in the range of [0.50-1.00] m;
- ✓ for rural areas in the range [5.00 – 10.00] m;
- ✓ for suburban areas [0.50 – 2.00] m, in the case of inspection operations;
- ✓ for suburban areas [5.00 – 10.00] m, in the case of transit;

The vertical accuracy of the GNSS receiver is assessed through TEST_OPS.GNSS.10

3.6 TEST_OPS.BARO.10 – Static conversion

3.6.1 Objective

The objective of this test is to assess the accuracy of the core **barometric – geometric conversion algorithm**; the main component of the ICARUS VCS service. This test does not consider the delivery of the service through the defined software interfaces (D5.1, D5.4), but only aims to evaluate conversion accuracy.

3.6.2 Description

This test will use the GNSS payload implemented for test TEST_OPS.GNSS.10 that will be placed at incremental distances from the given meteorological station positions. For this test, public aeronautical METAR data will be used, as well as pressure data from a private network of weather stations.

METAR data is a certified source of aeronautical meteorological data. However the resolution might not be enough for the calculations. For this reason a private network of weather stations with a resultion of 0.1 HPa is considered.

This test does not consider any flight operations and will address the following steps:

1. The GNSS payload will be placed near to a meteorological station (i.e. 100 metres) at a given identified position, taken from the private weather station network. Data from the weather station will be logged with a time stamp and made available for post processing activities.

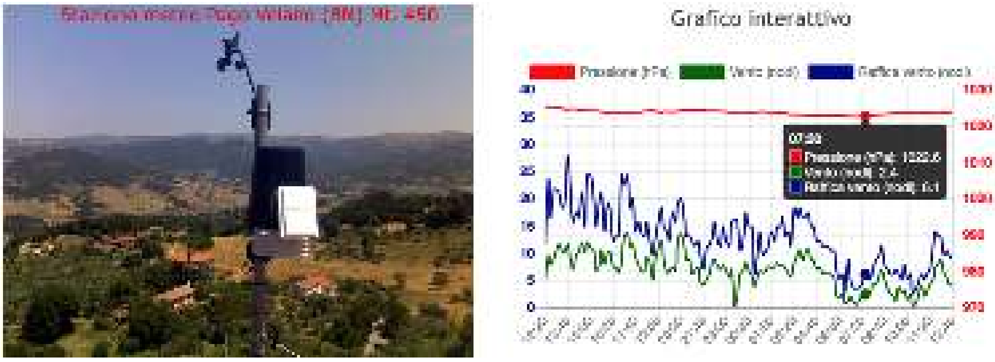

Figure 3-5 – 4 Example of weather station (Pago Veiano – Benevento, Italy) connected to the Campanialive weather station network - http://www.campanialive.it/dati-meteo.asp?stazione=pagoveiano .

2. In the same way, pressure data from 2 neighbouring weather stations will be read and stored with their epochs.
3. The GNSS payload will be moved 1 Km, 5 km, 10km, 20 km, 50 km away from the stations. The positions calculated by the payload will be stored with their epoch with the altitude information. The measurement made 20 km and 50 km away should differ by hundreds of metres in height (i.e. 300 m) to better assess the algorithm's performance.
4. For each position of the GNSS payload, a table will be constructed with the positions measured by the payload and the **position calculated** by the algorithm considering one or more weather station data interpolations. METAR data will be used for reference only.

3.6.3 Required data

The following data is needed for the test:

- ✓ Raw GNSS data/NMEA data acquired by the payload (position, epoch)
- ✓ Pressure data acquired by 3 weather stations near (up to 50 km) the GNSS payload (pressure of each station, epoch), provided by a trusted weather station (http://www.campanialive.it/dati-meteo.asp?stazione=pagoveiano)

3.6.4 Required Equipment

The following equipment is needed for the test:

- ✓ GNSS payload or private GNSS reference station

3.6.5 Output

The output of the test case is:

- ✓ Altitude measured (WGS-84) versus altitude calculated from pressure data;

3.6.6 Pass / Fail Criteria

The test is passed if the vertical conversion service does not introduce an error greater than 10 metres per 1 hPa.

3.7 Requirements vs Test Case Traceability

The following table reports for each requirement, the corresponding previously defined test case.

ReqID	ReqTitle	ReqText	D,A,I Justification
ICARUS-D31-0060	UAS-UAS Common vertical Reference at VLL	Each UAS shall be able to guarnatee the Required Navigation Performance (Accuracy, Integrity, Continuity, Availability, Monitoring,…) for the common altitude reference and for a given airspace volume, route or procedure by means of airborne equipment and /or U-space services	The Total System Error assessed in D3.1 with simulatad data will be updated in D6.3 document using real flight data deriving from tests: TEST_OPS.GNSS.10 TEST_OPS.GNSS.20 TEST_OPS.GNSS.30 TEST_OPS.GNSS.40
ICARUS-D31-0070	UAS-Ground Obstacles vertical Reference at VLL	Ground Obstacles represented in a given DSM shall be reported and referenced by U-space Geospatial Information Service in the same datum used by UAS for Common Altitude Reference System (WGS-84) Remark Gedetic->Geometric transformations of Buldings and obstacles might be needed to ensure the same reference for all airspace users at VLL	TEST_OPS.DTM.10 D6-.1 - Validation Scenario 3
ICARUS-D31-0080	UAS-Manned Aircraft vertical Reference at VLL	UAS and Manned aircraft must use WGS-84 datum in Zu and Y volumes for vertical common reference.	the WGS-84 datum is used as common datum in Zu and Y volumes by direct measurement from EFB. (D6.1, D6.2)
ICARUS-D31-0090	AGL Height information in BVLOS	AGL Height (Above Ground Level) information shall be always visible on UAS pilot's Ground Control Station during BVLOS operations in tactical phase Remark during planning, at least each waypoint shall report its AGL height	TEST_OPS.DTM.10 D6.1 - Validation Scenario 1
ICARUS-D31-0100	Altitude information in BVLOS	Geometric Altitude (above WGS-84 ellipsoid) information shall be always visible on pilot's Ground Control Station during BVLOS operations for Common Altitude Reference with other UAS	TEST_OPS.DTM.10 D6.1 - Validation Scenario 1 D6.1 - Validation Scenario 2
ICARUS-D31-0130	Geometric-Barometric conversion service to UAS users	The translation service shall be able to provide to UAS pilots the altitude of airplanes (using their given QNH datum) expressed in meters with respect to the WGS-84 datum	the ICARUS VCS service implemets such functionality (D5.1, D5.3)

ICARUS-D31-0140	Geometric-Barometric conversion service to GA users	The translation service shall be able to provide to GA pilots the height of UAS (using their given WGS-84 datum) expressed in feet with respect to the current QNH datum in use	TEST_OPS.BARO.10 the ICARUS VCS service implemets such functionality, the EFB defined in D5.2 will display to pilots such infrmation (D5.1, D5.3, D5.2)
ICARUS-D31-0150	Geometric-Barometric conversion service update	The Geometric-barometric coversion service must calculate the dynamic offset among WGS-84 and local QNH datum at least every 30'	TEST_OPS.BARO.10
ICARUS-D31-0160	Geometric-Barometric conversion information	Pilots must be always informed everytime an altitude-height calculation by the geometric-barometric service is performed. The communication shall be made by means of effective communication on target devices (different colors, sounds,…)	TEST_OPS.BARO.10 The EFB equipment defined in D5.2 will display to pilots such infrmation with diffrent colours. UAS pilots have diffrent colours as well on their GCS (D5.2, D6.3)
ICARUS-D31-0170	Geometric-Barometric conversion service alert	The Geometric-barometric altitude service must warn users in case of malfunctioning in less than 6 seconds	the VCS service interface specified in D5.4 document adresses possible service outage. TEST_OPS.BARO.10
ICARUS-D31-0180	GAMZ	Geometric Altitude Mandatory Zones (GAMZ) shall be accessed only by drones or manned aircrafts using WGS-84 datum as common reference for Altitude <u>Remark</u> Geometric to barometric service can be queried by drone pilots, manned aircraft pilots or drones for datum translation in strategic and tactical phases	the ICARUS VCS service or EFB for direct measuement complies with GAMZ definition. D6.2 - Scenario 3
ICARUS-D31-0190	Geo-Awareness service & GAMZ	Geo-Awareness service shall present suitable logical interfaces through U-space for the following funcionalities: - GAMZ temporarly (or periodic) removal; - to force RTH for all drones involved in operations (i.e. presence of HEMS operations); - to warn all GAMZ airispace users about changes	ICARUS microservice external I/Fs for such functionality are defined in D5.4.
ICARUS-D31-0200	tracking service for CAR	The UAS shall provide position information (including integrity) with respect to WGS-84 datum for CAR at VLL. The altitude information must be expressed in meters	D6.2 - Scenario 1
ICARUS-D31-0210	Navigation for Tracking	The UAS shall provide estimated levels of accuracy and integrity for the navigation information. This information shall be provided within the position reporting packet payload	TEST_OPS.DTM.10 D6.1 - Validation Scenario 1

ICARUS-D31-0220	Continuity requirement for Tracking	The tracking service shall deliver information with a continuity (Max tolerable probability of interruption of service per flight/hour) equal to 1E-05.	TEST_OPS.GNSS.30
ICARUS-D31-0230	GNSS signal availability	The availability of GNSS signal in Rural, Maritime and Forestry environment shall be better than 99.9%	TEST_OPS.GNSS.40
ICARUS-D31-0240	GNSS Receiver Accuracy	The GNSS receiver accuracy in Urban Environment shall be at least: - 1 m horizontal (1σ) - 1,5 m vertical (1σ)	TEST_OPS.GNSS.10
ICARUS-D31-0250	GNSS Integrity	GNSS signal integrity shall be monitored by UAS during BVLOS operations through: - Onboard: GNSS Receiver autonomous techniques (RAIM / ARAIM); - Onboard: Navigation Data fusion using other sensors (barometer, Vision system, D&A) - U-space service (Navigation Infrastructure Monitoring)	The GNSS Integrity is monitoired through the GNSS microservice offered by ICARUS architecture (option 3). This service augments the GNSS position of drone, providing also VPL and HPL providing to UAS the recalculated position (D5.1, D5.3)
ICARUS-D31-0260	GNSS Receivers for altitude measurement	DFDC (Dual Frequency Dual Constellations) GNSS Receiver / EGNOS enabled shall be used as minimum configuration to enable a reliable altitude measurment in Urban environment	TEST_OPS.GNSS.10
ICARUS-D31-0280	ICARUS prototype service	ICARUS prototype service shall be available for verification and valdiation activities to USSPs involved in the project in the form of a microservice that can be queried through a specific Application Program Interface (API)	D5.4 external I/F document USSPs are involved in validation activities D6.2 - Scenario 1 D6.2 - Scenario 2 D6.2 - Scenario 3
ICARUS-D31-0300	Geometric-Barometric conversion service interface	The Geometric-Barometric altitude conversion service shall be interafaced with Navigation (GNSS) performance monitoring stations (U-space service) and with barometric stations or service providers (ANSP or U-space service).	the ICARUS VCS service implements this interface (D5.1, D5.3)
ICARUS-D31-0310	Total System Error (Accuracy)	During BVLOS operations, for a straight trajectory (Waypoint 2 Waypoint), according to PBN ICAO definition, it shall possible for UAS to reach a navigation accuracy performance with TSE of about: - 10 meters for the horizontal accuracy for copters; - 3 to 9 meters for the vertical accuracy for copters; - 14 meters for the horizontal accuracy for planes; - 3 to 9 meters for the vertical accuracy for planes;	TEST_OPS.GNSS.10 D6.2 - Scenario 2

ICARUS-D31-0320	Stay Well Clear (vertical)	Two UASs flying in BVLOS conditions in the same airspace volume, in automatic flight mode and with same WGS-84 altitude reference datum, shall possibly be considered "well clear" from each other, if a minimum vertical distance of +-27 m (6 sigma) is respected; <u>Remark</u> According with simulations perfomed with Ground speed limitation to 15 m/s for copters and 25 m/s for planes	D6.3 valdiation reprot document from data acquired in TEST_OPS.GNSS.10
ICARUS-D31-0330	Stay Well Clear (horizontal)	Two UASs flying in BVLOS conditions in the same airspace volume, in automatic flight mode and with same WGS-84 altitude reference datum, shall possibly be considered "well clear" from each other, if a minimum vertical distance of +-46 m (6 sigma) is respected <u>Remark</u> According with simulations perfomed with Ground speed limitation to 15 m/s for copters and 25 m/s for planes	D6.3 valdiation reprot document from data acquired in TEST_OPS.GNSS.10
ICARUS-D31-0340	Path Definition Error (vertical)	Path Definition Error (according to ICAO PBN manual) with respect to the vertical axis, shall be negleted only if the home point vertical position is updated before flight, through a proper mitigation strategy implemented by GNSS Receiver position update.	D6.3 valdiation reprot document from data acquired in TEST_OPS.GNSS.10
ICARUS-D31-0350	Path Definition Error (horizontal)	Path Definition Error (according to ICAO PBN manual) with respect to the horizontal plane, must be considered in case of very precise operations with UAS <u>Remark</u> PDE cannot be higher thatn the error intriduced by the digital carthography used by UAS operators for mission planning	D6.3 valdiation reprot document from data acquired in TEST_OPS.GNSS.10
ICARUS-D31-0360	Surface Model	The Terrain or surface model must provide the adequate level of information required by the specific operation, in terms of elements to be represented, resolution and accuracy. <u>Remark</u> Urban area may require high level of detail for the presence of ground obstacles, while extra-urban or rural areas can opt for less detailed model.	D6.3 validation report document from data acquired in D6.2 - Scenario 3

ICARUS-D31-0370	Geo Awareness	U-space shall be able to provide to VLL airspace users the geospatial information related to vertical in tactical and strategic phases	D6.3 validation report document from data acquired in D6.2 - Scenario 3
ICARUS-D31-0380	Detailed Surface Model Position Accuracy	Detailed Surface Model accuracy must be: - for urban areas, in the range of [0,50-1,00] m; - for rural areas in the range [5,00 – 10,00] m; - for suburban areas [0,50 – 2,00] m, in case of inspection operations; - for suburban areas [5,00 – 10,00] m, in case of transit;	TEST_OPS.DTM.10

Table 3-3 – Requirements vs Test Cases

3.8 Test Cases vs Requirement Traceability

The following table gives the requirements covered for each test case. Only requirements with the "Test" methodology for verification are given. The full traceability matrix with requirements coverage will be presented in D6.3.

Test Case ID	Test Case Title	Req ID	Status
TEST_OPS.GNSS.10	UAS-UAS altitude reference (urban)	ICARUS-D31-0060 ICARUS-D31-0240 ICARUS-D31-0260 ICARUS-D31-0310 ICARUS-D31-0320 ICARUS-D31-0330 ICARUS-D31-0340 ICARUS-D31-0350	open
TEST_OPS.GNSS.20	UAS-UAS altitude reference (open sky)	ICARUS-D31-0060	open
TEST_OPS.GNSS.30	UAS-UAS altitude reference (continuity)	ICARUS-D31-0060 ICARUS-D31-0220	open
TEST_OPS.GNSS.40	UAS-UAS altitude reference (availability)	ICARUS-D31-0060 ICARUS-D31-0230	open
TEST_OPS.DTM.10	UAS-Ground Obstacle common reference	ICARUS-D31-0070 ICARUS-D31-0090 ICARUS-D31-0100 ICARUS-D31-0210 ICARUS-D31-0380	open
TEST_OPS.BARO.10	static GNSS/BARO conversion	ICARUS-D31-0140 ICARUS-D31-0150 ICARUS-D31-0160 ICARUS-D31-0170	open

Table 3-4 –Test Cases vs Requirements

4 Validation Scenarios

The validation campaign will be conducted after the verification activities are finalised, using the test cases detailed in the previous chapter.
As with the verification activities, the validation stage foresees four representative scenarios aimed at the final validation of the concept and the delivery of the service.
For the final validation of the ICARUS concept, it is foreseen to involve stakeholders for some scenarios. The stakeholders identified to provide feedback on ICARUS micro-services are:

- **General aviation pilots**: a limited number of GA pilots will be invited to fly (only in simulated mode) in the cockpit simulator equipped with the EFB displaying the ICARUS micro-services;
- **UAS pilots**: TOPV, as an authorised UAS operator, will be in charge of some UAS flights with the possibility of displaying the information generated by the ICARUS micro services directly on the ground control station. Additional qualified local UAS operators may be engaged to provide extra feedback to the service. The UAS operations will be conducted in the Open category in accordance with EU regulation 2019/947.
- **USSP operators**: The validation activities foresee the engagement of two USSPs. Representatives of D-Flight and Pansa UTM will be invited to provide feedback on the validation activities directly on their dashboard, on which ICARUS micro-service results will be displayed.
- **Ultralight pilots:** A small Italian aerodrome with leisure ultralight aircraft has been contacted to validate one CAR validation scenario. For safety reasons in this case, no concurrent ultra-light / UAS flight will take place; however, virtual UAS flights will be added in the proposed scenario.

4.1 Design of Validation Scenarios

The design of the representative scenarios is shown in the following diagram:

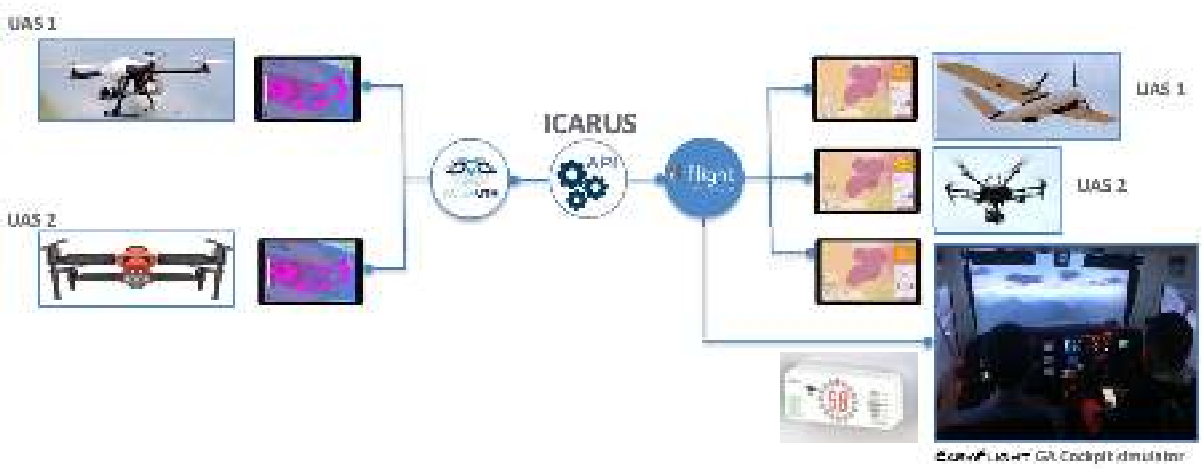

Figure 4-1 – Generic architecture of validation scenarios

In Figure 4.1, ICARUS services (here represented in the form of APIs) are queried by UAS or GA "clients" through the USSPs. The general schema provided is applicable for both virtual and real flights.

- ✓ **UAS pilots** will be able to visualise, through their ground control station or the web application directly provided by the USSP, CAR information dispatched by ICARUS VCS, VALS and RGIS micro-services, in the strategic and tactical phases.
- ✓ **GA pilots**, flying the cockpit simulator, will be able to access CAR information through EFB devices and in particular:
  - a tablet running the USSP web application and/or
  - a simple add-on device presenting the essentials of the VALS and RGIS service information

For the Italian USSP, D-flight, the tracking service (NRI) needed to feed the ICARUS micro-services in the tactical phase, is already available for UAS and manned aircraft (e.g. GA, ultralights flying at VLL) in experimental mode, in accordance with the public ICD issued in June 2021 [10].

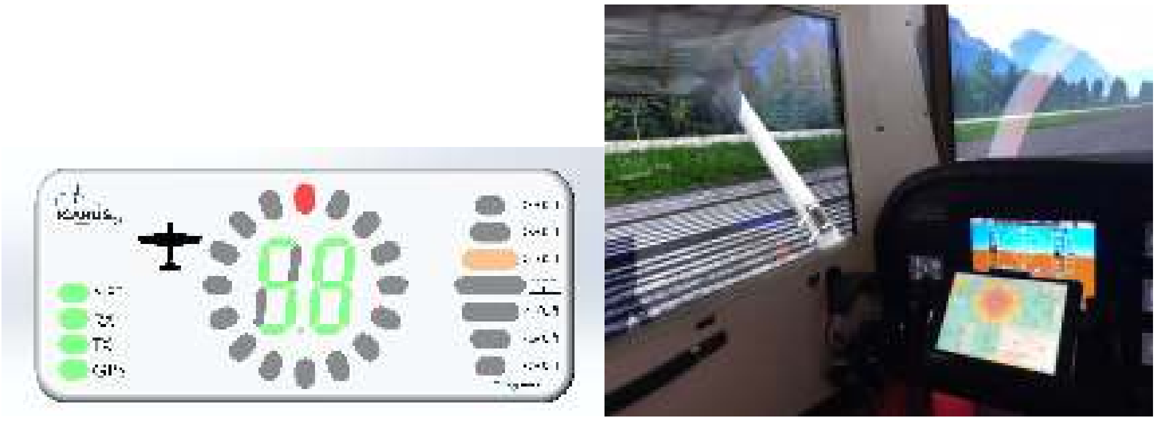

Figure 4-2 – EFB proposed for the validation activity – Physical device (left) – Tablet with USSP D-flight web Application

Each scenario proposed will use the real interface of the ICARUS prototype service developed in the distributed architecture. For each scenario, a particular configuration is proposed with the aim of testing a specific service.

4.2 Scenario 1: UAS-Manned aircraft CAR service

4.2.1 Objective

This scenario aims to validate the following ICARUS micro-services:

- ✓ Vertical Alert Service (VALS)
- ✓ Vertical Conversion Service (VCS)

in a dynamic scenario (tactical phase).

4.2.2 Description

This validation scenario involves the presence of:

- ✓ **1 small manned leisure aircraft (C-172)** departing from an aeroclub in a valley in southern Italy (***<u>simulated flight</u>***). Approximate take off area:

- **Lat:** 41° 8'45.67"N,
- **Lon:** 14°20'20.36"E
- **Elevation:** 31 m AMSL

✓ **1 small drone** involved in a filming operation, departing from a hill. Approximate home point position:

- **Lat:** 41° 6'17.08"N
- **Lon:** 14°20'23.79"E
- **Home point Elevation:** 370 m AMSL

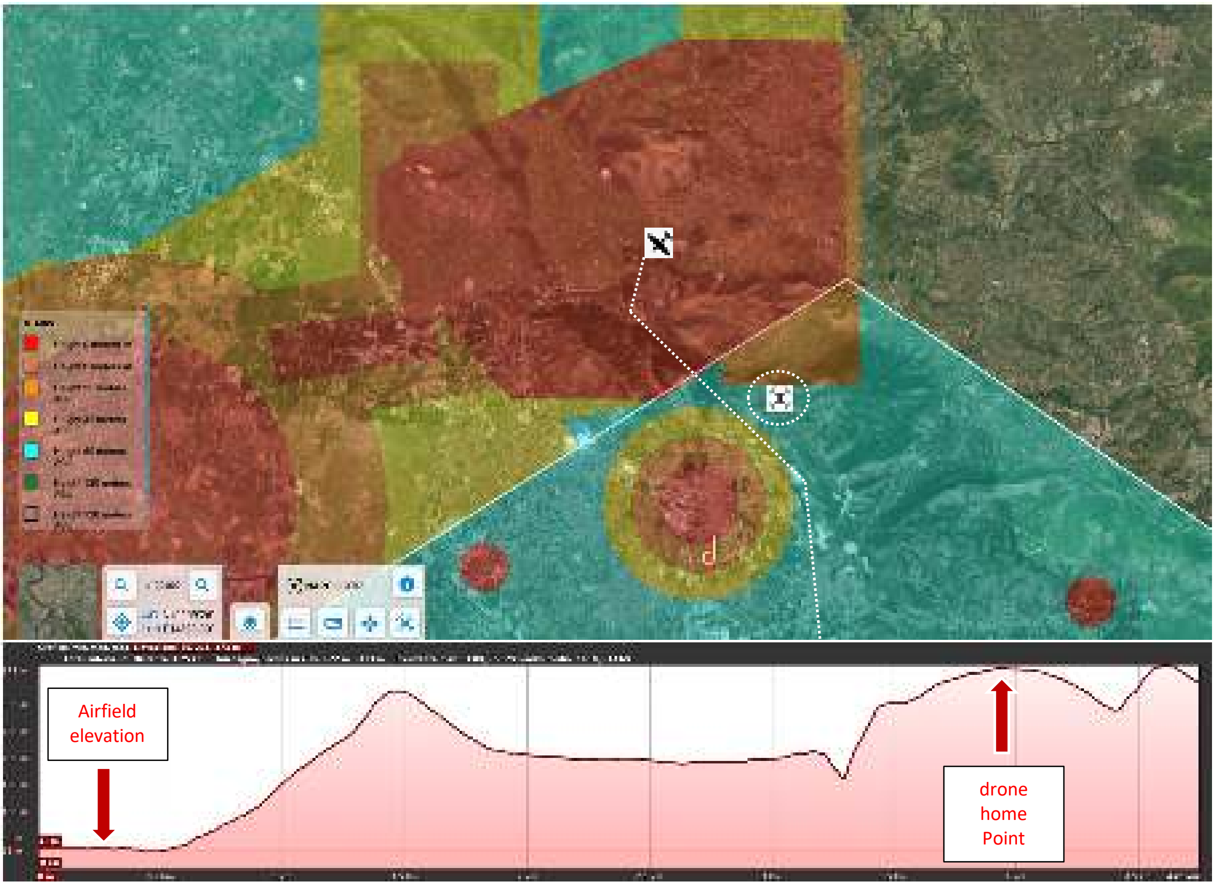

Figure 4-3 – Airplane and drone positions on D-flight cartography and approximate terrain profile (google Earth)

Additional information is given in the operational plan (D6.2).

4.2.3 Players involved

The players involved in this use case are:

✓ General Aviation Pilot
✓ Drone Pilot
✓ Drone Observer
✓ USSP operator

4.2.4 Equipment involved

- ✓ Cockpit simulator
- ✓ EFB for GA Pilot (VALS for GA pilot)
- ✓ Operational drone with GCS
- ✓ UTM Box (Tracking service) and MFMC GNSS DevBoard for drone (post-processing of raw GNSS data)
- ✓ Tablet with USSP web application for drone pilot
- ✓ GNSS RTK/PPK local private station for GNSS data post-processing and enhanced drone navigation performance.
- ✓ ICARUS testbed with VCS, GNSS augmentation, VALS micro-services

4.2.5 Testbed Architecture

The following picture shows the testbed architecture for Scenario 1.

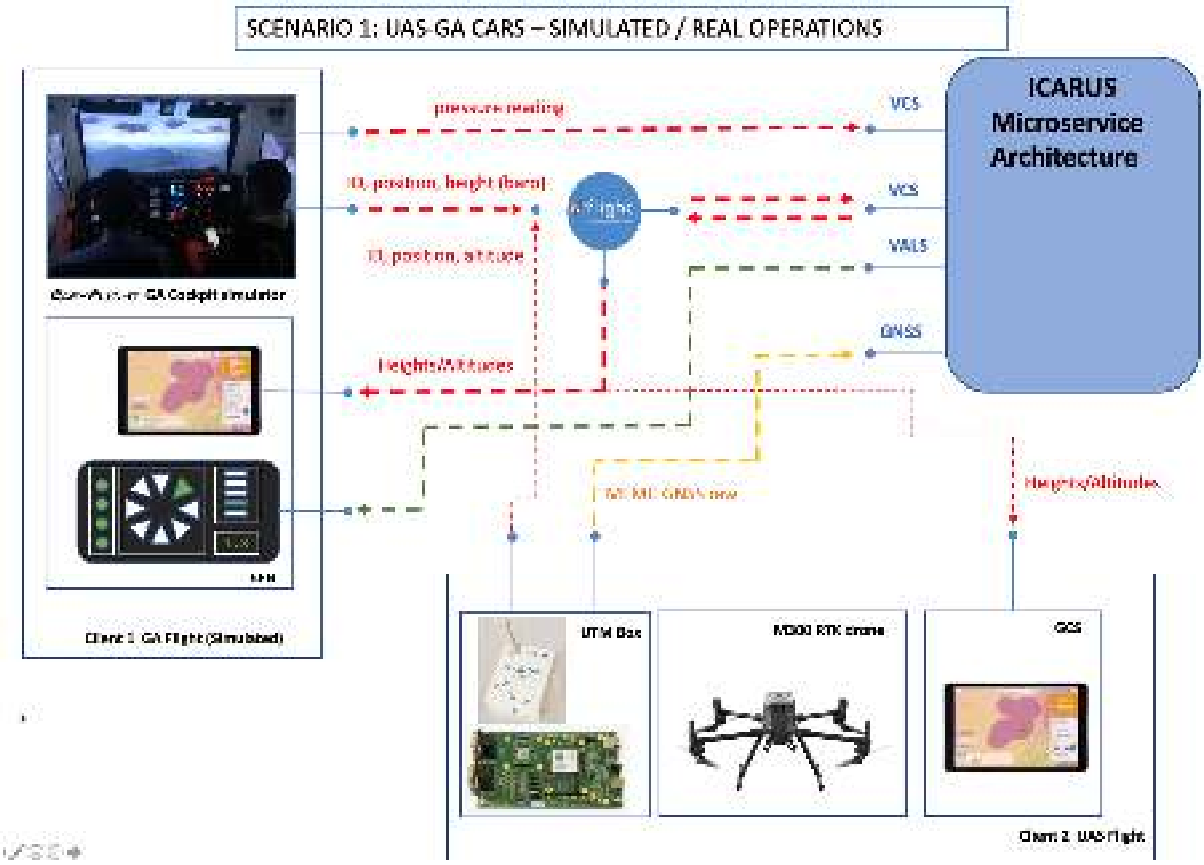

Figure 4-4 – Testbed architecture for scenario 1

4.2.6 Operational plan

The operational plan (flight plan and trial execution), including detailed temporal and spatial constraints is detailed in D6.2.

For the drone flight, the operational plan will include:

- ✓ UAS operator name, national code, EASA Code
- ✓ Drone insurance details
- ✓ Pilot-in-command name, applicable attestation/license and expiry date
- ✓ UAS name, D-Flight registration, MTOM
- ✓ Operation category /sub category

4.2.7 Expected output

The following outputs are expected for data elaboration and analysis (D6.3):

- ✓ Cockpit simulator logs
- ✓ VALS triggers and indications
- ✓ VCS micro-service logs
- ✓ Cockpit simulator logs
- ✓ MFMC GNSS receiver logs
- ✓ Height/altitude visualisation on GCS (or tablet-based D-Flight web application)
- ✓ Players' feedback

4.3 Scenario 2 UAS-Manned Aircraft CAR performance

4.3.1 Objective

This scenario aims to validate the following ICARUS micro-service:

- ✓ Vertical Conversion Service (VCS) performance with low-cost UTM Box and high-end UTM Box (DFMC GNSS Receivers)
- ✓ Vertical Alert Service VALS (VALS)

In the tactical phase.

4.3.2 Description

This validation scenario involves the presence of:

- ✓ **1 small ultralight leisure aircraft (Tecnam P-92)** departing from an aeroclub in southern Italy (***simulated flight***). Approximate take off area:
  - **Lat:** 41° 8'45.67"N,
  - **Lon:** 14°20'20.36"E
  - **Elevation:** 31 m AMSL
- ✓ **1 small drone** involved in a training operation near the aeroclub. Approximate home point position:
  - **Lat:** 41° 8'48.98"N
  - **Lon:** 14°20'15.80"E
  - **Home point Elevation:** 31 m AMSL

Figure 4-5 – Airplane and drone positions on D-flight cartography

Additional information is given in the operational plan (D6.2)

4.3.3 Players involved

The players involved in this use case are:

- ✓ Ultralight pilot
- ✓ Drone pilot
- ✓ Drone observer
- ✓ USSP operator

4.3.4 Equipment involved

- ✓ 1 P92 Tecnam ultralight airplane
- ✓ Low-cost UTM Box (Tracking service) for ultralight (position report only, no interaction with pilot)
- ✓ Operational drone with GCS
- ✓ GNSS RTK/PPK local private station for GNSS data post-processing and enhanced drone navigation performance.
- ✓ High-end UTM Box (Tracking service) and MFMC GNSS DevBoard for drone (post-processing of raw GNSS data)
- ✓ Tablet with USSP web application for drone pilot (VALS for drone pilot)
- ✓ ICARUS testbed with VCS, GNSS Augmentation, VALS micro services

4.3.5 Testbed Architecture

The following diagram shows the testbed architecture for Scenario 2.

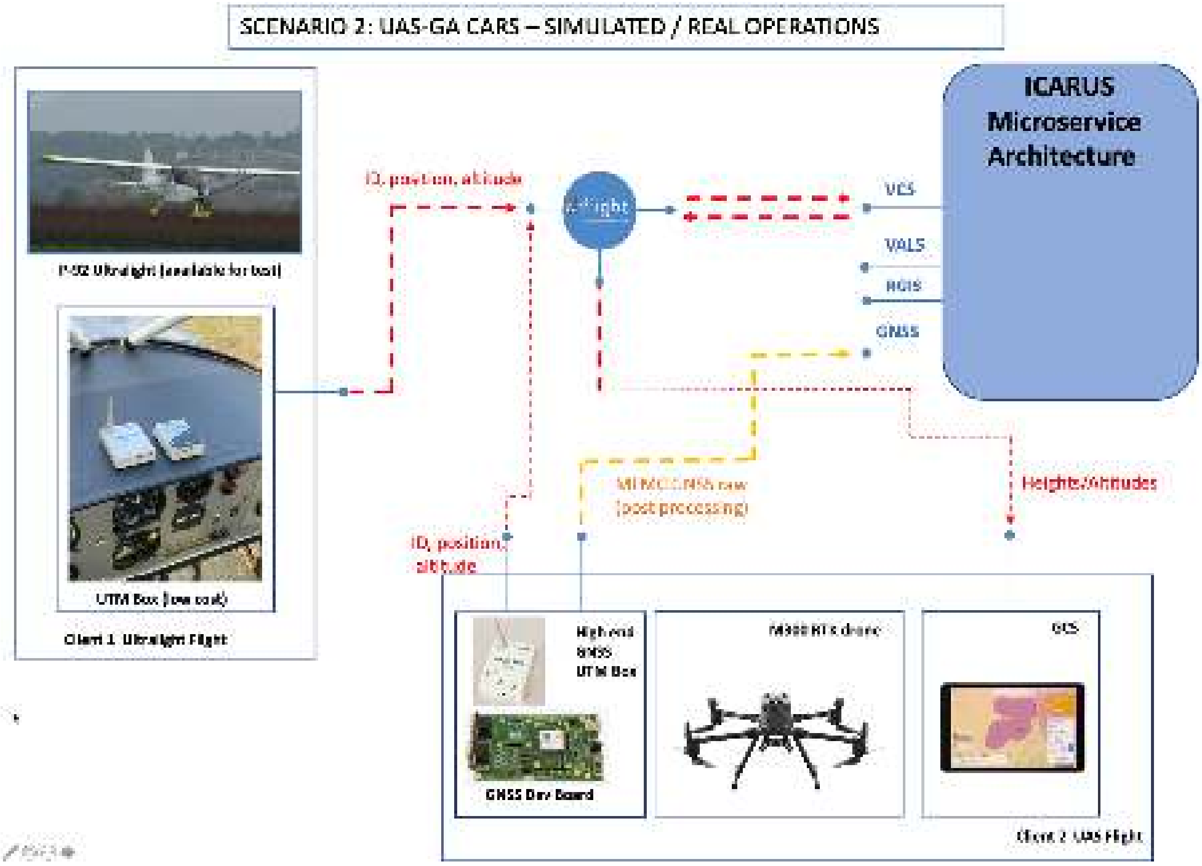

Figure 4-6 – Testbed architecture for scenario 2

4.3.6 Operational plan

The operational plan (flight plan and trial execution), including detailed temporal and spatial constraints as well as active NOTAM for the flight activity is detailed in D6.2.

4.3.7 Expected output

The following outputs are expected for data elaboration and analysis (D6.3):

- ✓ VALS triggers and indications
- ✓ VCS micro service logs
- ✓ UTM Box logs (airplane)
- ✓ High-end UTM Box logs (drone)
- ✓ MFMC GNSS receiver logs (drone)
- ✓ Height/altitude visualisation on GCS (or a tablet-based D-Flight web application)
- ✓ Players' feedback

4.4 Scenario 3 UAM operations

4.4.1 Objective

This scenario aims to validate the following ICARUS micro-services in a future scenario of Urban Air Mobility:

- ✓ Real-time Geographical Information (RGIS)
- ✓ Vertical Alert Service (VALS)

in both the strategic and tactical phases of flight.

4.4.2 Description

This scenario aims to simulate an example of passenger transfer for a future Urban Air Mobility scenario in northern Italy (Torino Caselle Airport) considering different aspect such as:

- ✓ QFE setting / GNSS setting procedures (entering geometric altitude mandatory zones - GAMZ)
- ✓ Vertical Alert Service for ground obstacle awareness

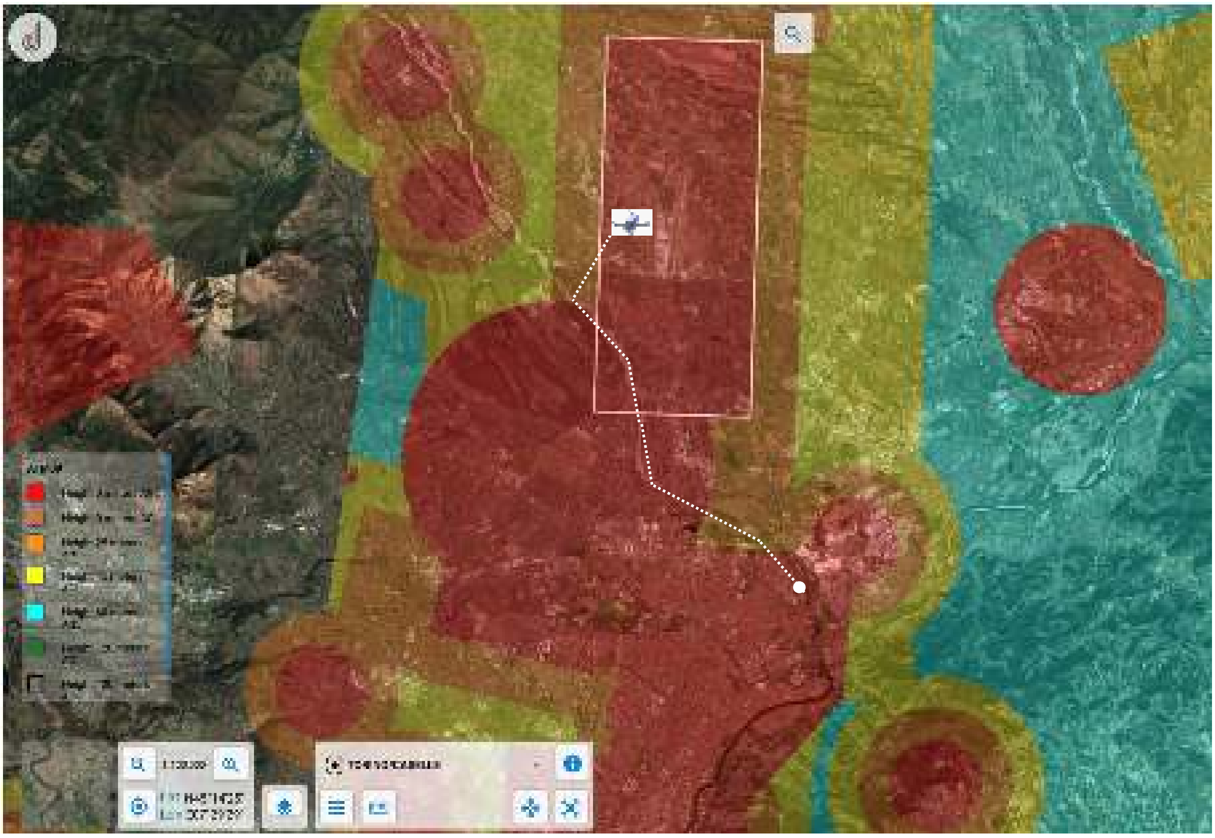

Figure 4-7 – Taxi drone Passenger transfer from Torino Caselle Airport

The detailed plan will be described in D6.2 document.

4.4.3 Players involved

The players involved in this use case are:

- ✓ Taxi-drone pilot (virtual)
- ✓ Taxi-drone passenger (virtual)
- ✓ USSP operator (virtual)
- ✓ ATC controller (virtual)

4.4.4 Equipment involved

- ✓ Cockpit simulator (configured for a taxi-drone)
- ✓ Tablet with USSP web application for remote taxi-drone pilot
- ✓ ICARUS testbed with RGIS, VALS micro-services

4.4.5 Operational plan

The operational plan (flight plan and trial execution), including detailed temporal and spatial constraints for virtual flight activity is detailed in D6.2.

4.4.1 Expected results

The following outputs are expected for data elaboration and analysis (D6.3):

- ✓ VALS triggers and logs of warnings of ground obstacles during flight
- ✓ RGIS in strategic phase (elevation mission profile)
- ✓ RGIS in tactical phase (vertical distance from ground obstacles)
- ✓ Players' feedback

4.5 Schedule

The verification and validation activities of task T6.2 are proposed to be extended without any impact on other tasks foreseen in the overall schedule.
In particular, for the verification activities, the period **November 2021-January 2022** is proposed for:

- ✓ Implementing the test cases described in section 3 and collecting the results
- ✓ Reporting on the results in the D6.3 document.

For the validation activities, the period **February 2021-April 2022** is proposed for:

- ✓ Executing the validation scenarios described in section 4
- ✓ Inviting stakeholders to give feedback on the ICARUS services offered during the simulated scenarios
- ✓ Writing the final validation report (D6.3 document)