Simulation Trials Execution Plan

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00.01.07	11/11/2021	draft		Final version

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ICARUS

INTEGRATED COMMON ALTITUDE REFERENCE SYSTEM FOR U-SPACE

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Abstract

This document is deliverable D6.2 "Simulation Trials Execution Plan" of the ICARUS project.

Following on from D6.1, that described the design of the scenarios identified for the validation activities, this document provides the detailed execution plan of the ICARUS simulation trials. The execution plan is defined for each validation scenario regardless of whether its execution is to be performed with real flight activities, simulated trials, or "mixed" trials in a mixed scenario. A "mixed scenario trial" means the possibility of performing real flight activities (i.e. with a UAS) with U-space position reporting/tracking capabilities and simulated activities implemented by manned aircraft or VTOL taxi-drones, that take advantage of the presence of the cockpit simulator, tailored for the ICARUS project, that thus implements the same tracking capabilities. In this way the USSP (D-Flight or Pansa UTM) becomes the central aggregation element capable of querying the ICARUS prototype services (VALS, GIS or VCS) for the calculation and presentation of common altitude/height reference to both users in their preferred way; for example the barometric height of inbound UAS traffic with respect to local QNH or QFE from the perspective of a GA Pilot, or geometric altitude / height AGL for an airplane flying near to a UAS from the perspective of the UAS pilot.

In this document, the execution plan for the verification trials is given for both simulation and real flight activities, with a detailed operational plan. The operational plan used considers the typical information needed by an actual UAS operator to perform professional UAS flight activities.

An introductory paragraph on the verification and validation approach is provided to help the reader understand all of the information related to WP6.

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1 Introduction

The present document describes the execution plan for ICARUS trials intended for both simulation and real flight test activities. It provides operational details for the implementation of three validation scenarios defined in D6.1.

The approach applied for validation and verification of the cases is described to explain the methodology used and where to obtain information related the validation activities of WP6.

The validation scenarios described here cover the most relevant CAR problems addressed in the use cases, making use of the ICARUS micro-services (VALS, VCS, and RGIS) implemented in the form of prototype services in the ICARUS testbed architecture.

1.1 Applicable and reference material

The following documents may be considered as 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] H2020 SJU DACUS Project https://www.sesarju.eu/projects/dacus

[6] H2020 SJU BUBBLES project https://www.sesarju.eu/projects/bubbles

[7] DJI M300 drone https://dl.djicdn.com/downloads/matrice-300/20200507/M300_RTK_User_Manual_EN.pdf

[8] Pollicino© UTM box device https://topview.it/en/pollicino-drone-tracker

[9] Desk Aeronautico https://www.deskaeronautico.it

[10] ENAC UAS-IT Regulation https://www.enac.gov.it/sites/default/files/allegati/2021-Gen/Regolamento_UAS-IT080121.pdf

[11] Meteo services METEOAM http://www.meteoam.it

1.2 Acronyms and definitions

Acronyms	Signification
AGL	Above Ground Level
BVLOS	Beyond Visual Line of Sight

CARS	Common Altitude Reference System
CEP	Circular Error Probable
DOA	Drone Operation Area
DSM	Digital Surface Model
DTM	Digital Terrain Model
E2E	End to End
EFB	Electric Flight Bag
GA	General Aviation
GAMZ	Geometric Altitude Mandatory Zones
GCS	Ground Control Station
GNSS	Global Navigation Satellite System
KPI	Key Performance Indicator
MCMF	Multi Constellation Multi Frequency
MSL	Mean sea Level
MTOM	Max take off mass
NB-IOT	Narrow Band Internet Of Things
PPK	Post Processed Kinematic
PPL	Private Pilot License
QFE	Query Field Elevation
QNH	Query Nautical Height
RGIS	Real Time Geographical Information Service
RNP	Required Navigation Performance
RPAS	Remotely Piloted Aircraft Systems
RTK	Real Time Kinematics
UAS	Unmanned Aircraft System
USSP	UTM Service Provider

VALS	Vertical Alert Service
VCS	Vertical Conversion Service
VLL	Very-Low-Level
WP	Work Package

Table 1-1 – Acronyms list

1.3 ICARUS microservices

The ICARUS project proposes an innovative solution to address the challenge of the Common Altitude Reference System for drones in very low-level (VLL) airspaces with a GNSS altimetry-based approach and the definition of a geodetic-barometric transformation algorithm, implemented by a dedicated U-space service (U3 service).

ICARUS proposes the use of GNSS receivers with suitable requirements for a common UAS-UAS vertical reference, and the definition of a new U3 U-space service for altitude transformation for a common UAS-manned-aircraft reference, tightly coupled with the interface of existing U-space services (e.g. Tracking, and Flight planning services).

To better understand these aspects, three validation scenarios were defined representative of the situations of concurrent flight operations where the CAR service is needed. These scenarios are detailed herein with an execution plan regardless or whether a real, simulated or mixed approach is used.

Each execution plan is presented in the form of a "flight plan" that aims to describe the scenario, and the conditions and limitations for the players involved. An essential part of each scenario is the involvement of the ICARUS testbed that has been developed.

The micro-services implemented in ICARUS are:

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

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

1.4 Approach to verification and validation activities

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

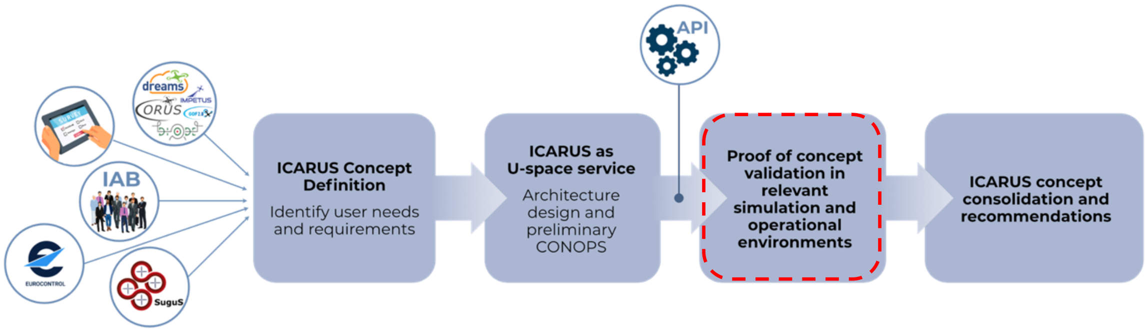

Figure 1-1: Methodology: focus on verification validation activities

For the verification activities, the services identified will be tested in this phase with a mixed approach involving both simulations in labs and verification activities in a real operational scenario, involving drones and manned aircraft flying at different heights. GA Flights (S1) and taxi-drone flights (S3) will be simulated (virtual flights); UAS flights and ultralight flights will be operated in a real scenario (S1, S2). The main objectives of the verification activities can be summarised as follows:

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

Subsequently, the validation of the ICARUS prototype services will start 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 developed and 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's premises in Italy, interfaced with the Italian USSP (D-flight) that is testing possible services to be provided to GA users at VLL. Some GA pilots will be invited to validate the service using the cockpit simulator and the EFB that displays ICARUS services.

Additionally, drone pilots will be invited to provide feedback on the new functionalities, provided by the ICARUS micro-services.

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

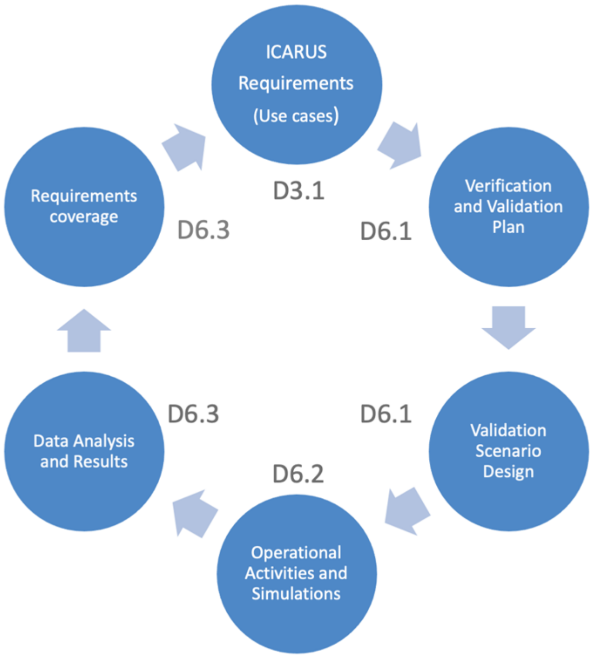

Figure 1-2: Organization of the information related verification and validation activities

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 D6.1 where the verification and validation plan is given, taking the project schedule into account, and test cases are identified and coded.
3. **Validation Scenario Design:** The validation scenario design is described in Section 3 of document D6.1. The design of different scenarios (both simulated and real) is 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 the present document. 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 will be described in D6.3 after the trials. 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 D6.1, 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).

The execution plan for each scenario identified is presented in the following sections.

2 S1: UAS-aircraft CAR

2.1 Introduction

This section describes the operational flight plan for the first scenario (S1), concerning concurrent UAS and manned aircraft operations. This scenario follows a mixed approach with a virtual GA flight and a real UAS flight.

2.2 Scope of the Mission

The mission is designed to provide UAS pilots and GA pilots with suitable tracking information about incoming traffic near their positions, during the flight, by exploiting the value-added services offered by ICARUS, with particular reference to the alerting service and altitude reference.

The mission described in this scenario contributes to validating the following ICARUS micro-services in the tactical phase:

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

In particular in this scenario, the VALS service will be used by the GA pilot for alerting them when in presence of other UAS traffic near the flight. The VCS service, in combination with VALS will provide the GA pilot with the altitude of the UAS expressed feet, under the same reference system as used by the aircraft (local QNH). On the other hand, the UAS pilot will receive the altitude of the aircraft under their reference system (WGS-84 or w.r.t. ground level at the home point)

2.3 Description of operations

This mission involves the presence of:

- **1 GA aircraft (C-172)** departing from an aeroclub in a valley in southern Italy (virtual flight).
- **1 drone (DJI M300 RTK)** involved in a filming operation, departing from a hill (real flight).

The GA C-172 aircraft (virtual flight) with two persons aboard (one flight Instructor and one trainee pilot) has a training flight mission of 30 minutes departing at 10:00 UTC from "Rains Club" airfield in the morning, flying over the surrounding valley for a training session. The C-172 flight is expected to land on the same airfield after the training session.

Figure 2-1: S1 - C-172 virtual flight in the Cockpit simulator

The aircraft is equipped with an ICARUS EFB device, placed in the cockpit of the airplane near the main panel, fixed with velcro tape.

Figure 2-2: S1 - C-172 during virtual flight with ICARUS EFB device

The DJI M300 RTK drone operated by TopView is involved in aerial filming for a nature and historical documentary. The drone HOME point is set on the top of a hill, about 10 kilometres from the airfield. The area of operations for the drone is circular around the home point, with a height limitation of 25 metres AGL, according to the local aeronautical cartography. The drone's horizontal distance from the pilot is 500 metres, respecting the conditions for a VLOS flight in the "open category" (A3). The flight is limited in height with a vertical limit for the area of 25 m AGL, to remain in the open category.

The drone involved in the flight operations is equipped with the Pollicino Pro© UTM Box, a high precision drone tracker with highly accurate DFMC GNSS receiver that also provides good accuracy on the vertical axis. This device implements the U-space tracking service with the local D-flight USSP.

Figure 2-3: S1 - M300 RTK with Pollicino Pro Tracker and D-flight cartography with UASs / aircrafts tracking information with altitude reference (translated by ICARUS prototype service)

2.4 Location

The areas where the operations take place are the following:

- For the **C-172 aircraft** "RAINS club" airfield (ident "LIWS" – Piana di Monteverna)
  - Lat: 41° 8'45.67"N
  - Lon: 14°20'20.36"E
  - Alt: 32 m AMSL
- For the **M300 RTK drone** "Home Point" – City of Caserta, approximate position:

- Lat: 41° 6'17.08"N
- Lon: 14°20'23.79"E
- Alt: 373 m AMSL

Figure 2-4: S1 - Positions of "RAINS club" for C-172 aircraft and "Home Point" for M300 RTK drone.

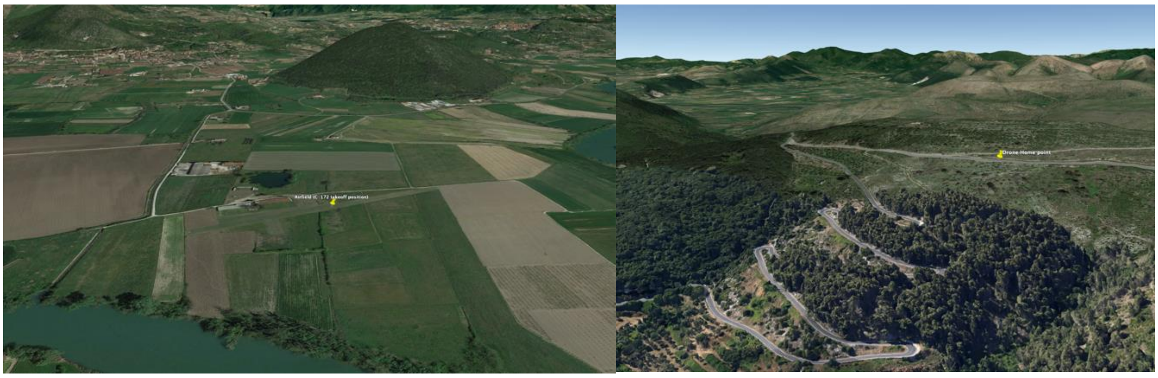

Figure 2-5: S1 - "Rains club" airfiled position – 31 m AMSL (left) – "Home Point" position – 373 m AMSL (right)

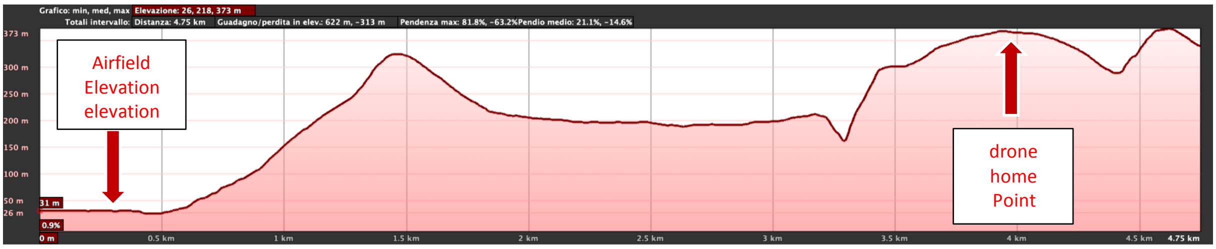

Figure 2-6: S1 - Difference in elevation between M300 drone and C-172 aircraft take off positions

2.5 Flight Plans

The flight plans for each aircraft are presented below.

2.5.1 C-172 GA aircraft

The flight plan of the C-172 aircraft is shown, together with the altimetric profile of the flight. The choice of the ascent and descent procedures will be left to the pilot and established shortly before take-off based on the weather conditions.

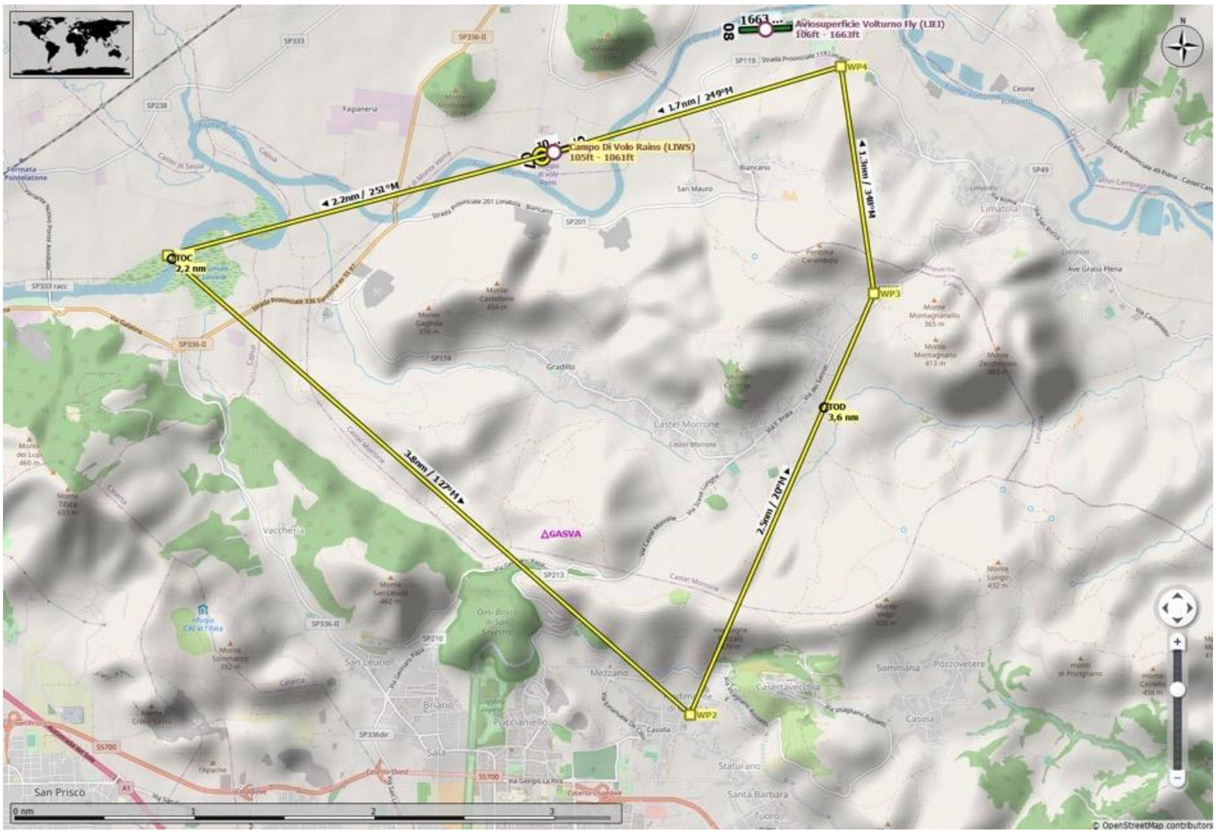

Figure 2-7: S1 - C-172 aircraft Flight plan related to the training mission from RAINS club airfield (LIWS)

The elevation profile of the terrain along the flight path from WP1 to WP4 and along the climbing and descent phases of the flight is shown below.

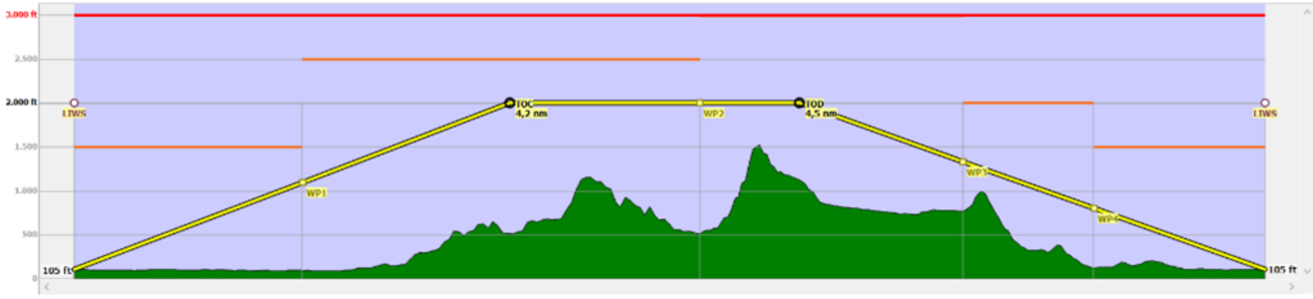

Figure 2-8: S1 - Elevation profile for C-172 aircraft Flight plan related to the training mission from RAINS club airfield (LIWS)

The flight plan provides a maximum cruise altitude of 2000 feet (QNH) for the duration of the flight. This altitude will be reached between waypoint 1 and waypoint 2 at a distance of about 4nm (TOC indicated in the elevation profile). Top of descent (TOD) is between waypoint 2 and waypoint 3 at about 4.5NM from the destination.

The preferred runway for the mission will be runway 24. In any case, the runway best suited to the wind conditions is used on the day of the flight activity.

Rains airfield does not publish METAR, the closest reference meteorological station used for the mission is the Grazzanise air base, which is situated 24 km away.

Below are the details of the waypoints foreseen by the flight plan.

Waypoint	Latitude	Longitude	Altitude (ft)	Course °M
WP1	41° 8' 11,47" N	14° 17' 29,18" E	1000	253
WP2	41° 5' 39,23" N	14° 21' 18,80" E	2000	129
WP3	41° 7' 58,91" N	14° 22' 39,58" E	1350	21
WP4	41° 9' 14,07" N	14° 22' 25,06" E	800	349

Table 2-1 - Details of the waypoints foreseen by the flight plan (S1)

2.5.2 M300 RTK drone

The flight plan for the M300 RTK drone is shown below, together with the flight limitations imposed in the local area. The flight is executed in the Open category (A3) in VLOS conditions at a maximum horizontal distance of 500 m and 25 m AGL vertically from the home point in the specified volume.

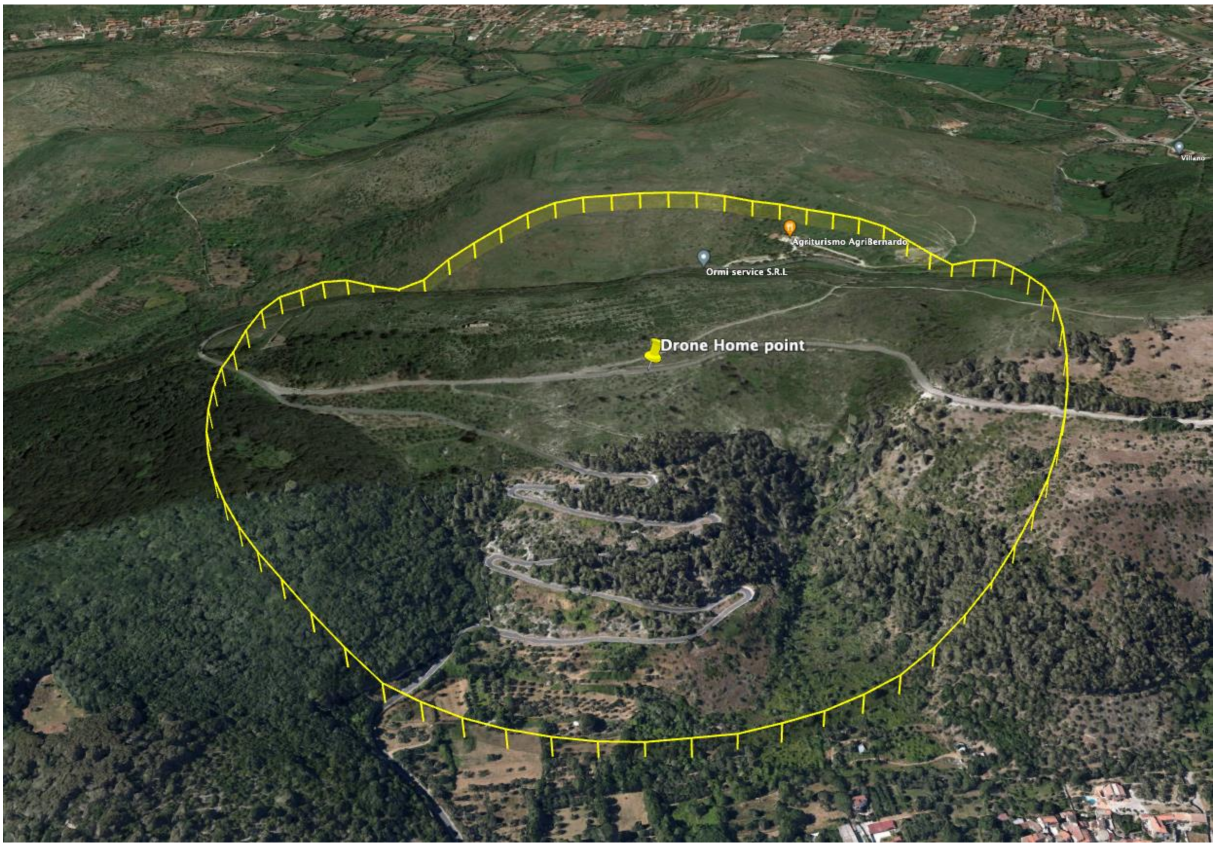

Figure 2-9: S1 - Volume for drone operations

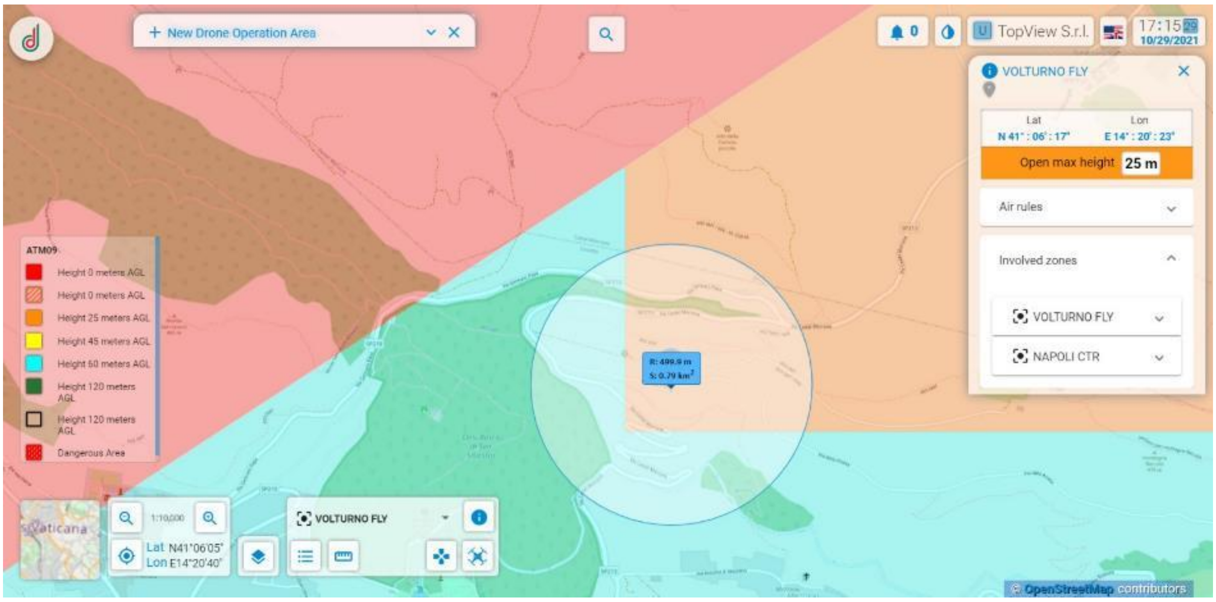

Figure 2-10: S1 - Drone Operation Area (DOA)

The drone operation area (DOA) is measured with the help of planning tool available on the D-flight platform. This instrument provides strategic deconfliction with other airspace users registered on the USSP portal. The DOA offers specialised UAS operators the ability to report their flight intent for specialised flight operations by activating the experimental drone operation plan (DOP) functionality on the D-flight platform. This functionality involves, among other things, the validation of the planning with respect to some geo-spatial and regulatory constraints.

The same planning, in full respect of privacy, will be available, via the D-Flight portal, for consultation by other airspace users who, for operational reasons, have the need to operate in areas adjacent to the corresponding space-time window.

For this specific operation , thanks to the installation of the Pollicino pro UAS tracker, the UAS operator will also be able to activate the tracking functionality through which it will be possible to show the position of the pilot / operator within the area affected by flight operations (DOA or DOP), in full respect of privacy. This information will be also used to feed the ICARUS VCS / VALS services and provide CAR tactical separation also to other U-space users.

2.5.3 Conflicts & Mitigation

The drone's flight plan is submitted to the D-flight USSP during the strategic phase. In this way all U-space users are aware of possible conflicts, with some mitigation strategies proposed by the U-space strategic deconfliction if necessary. In this case it is assumed that:

- ✓ The UAS operator submits the DOA two hours before the operation;
- ✓ The C-172 pilot does not access to the U-space services in the strategic phase, but has an EFB device (ICARUS EFB) for tactical CAR separation during the flight.

Figure 2-11: S1 – Drone Operation Area and C-172 aircraft flight Plan (Google Earth)

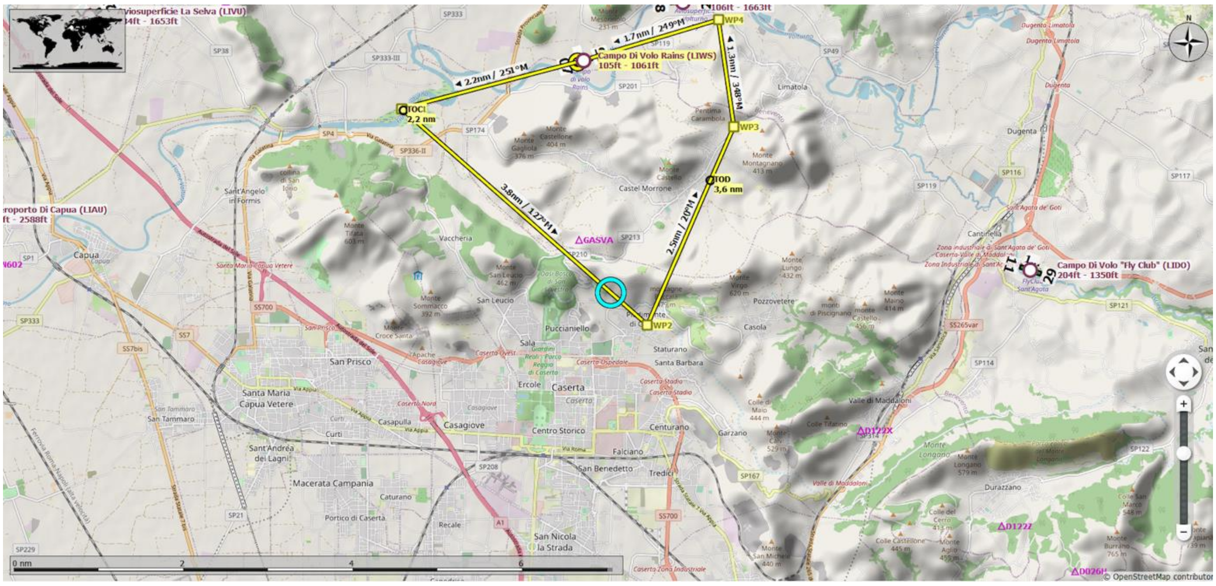

Figure 2-12: S1 – Yellow corridor: C-172 flight plan; Cyan area : Drone Operation Area

As shown in the figures above, there is an area of conflict where the drone and the aircraft will potentially be adjacent in the same area of operations at the same time. In this case, the ICARUS EFB device will promptly warn the GA pilot (through the VALS service), indicating the distance and bearing of the drone, including altitude expressed in the same reference as used by the GA pilot (VCS). The ICARUS EFB device is connected to the U-space.

2.6 Players involved

The players involved in S1 are:

- **1 Mission Coordinator:** in charge of the coordination of all players involved in the validation scenario with particular reference to:
    - USSP service availability and support for the UAS tracking service;
    - Schedule and time constraints for flight coordination (virtual GA aircraft flight + real UAS flight) supported by the WP6 Manager
    - Verification of all documentation for UAS operations, including UAS licences/attestation and insurance companies provided by UAS pilots;
- **1 General Aviation Pilot** (TopView Premises)**:** supported by a test engineer, will be in charge of the virtual GA flight in the cockpit simulator. For the purpose of the mission, an additional trainee pilot can join the mission. The GA pilot is external to the ICARUS consortium and will be invited for validation activities. After the virtual flights, they will be also invited to provide feedback on the ICARUS EFB device and the services offered.
- **1 Test Engineer** (TopView Premises)**:** will be in charge of cockpit simulator supervision during the virtual flight.
- **1 Drone Pilot** (Home point): will have responsibility for UAS flight activities
- **1 Drone Observer** (Home Point): will support the UAS pilot during the mission, with particular attention to the VALS and VCS services offered by ICARUS regarding the virtual GA flight.

- **1 USSP Engineer** (D-flight premises): One engineer appointed by D-flight will monitor the flight (Tracking service / DOA / DOP, VCS /VALS) during the validation activities.

2.7 Equipment involved

The following equipment is needed for the validation of S1:

- **Cockpit simulator:** described in D5.2, this is capable of simulating the flight controls, physical characteristics and the performance of a single-engined general aviation or ultralight category aircraft. It replicates the internal environment of a Cessna 172 Skyhawk and has the same dimensions. This cockpit configuration is highly realistic, making this simulator a valid and versatile platform for different purposes. In S1, the cockpit simulator is used by the GA Pilot in combination with the ICARUS EFB device.

  One external GA pilot will be invited for the validation activity. They will be asked to provide feedback on the simulation.

- **ICARUS EFB device** for the GA Pilot. As described in D5.2, the Electronic Flight Bag is a hardware tool installed in the cockpit simulator. It works as a visual indicator and, thanks to the presence of LEDs, it allows the operator to visualise information about possible drone presence in the same airspace as the aircraft, through the VALS micro-service. The information provided by the EFB is the following:
  - *Distance*: how close the nearest drone is;
  - *Direction*: the drone's direction relative to the cockpit simulator's nose;
  - *Altitude*: height difference (with altitude intervals of 100 ft for pilot's fast visualization) of the drone relative to the cockpit.

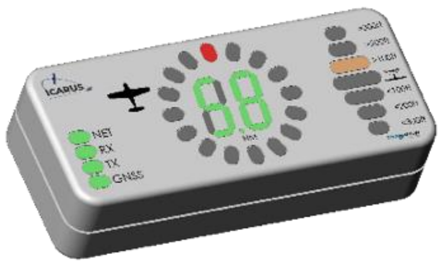

Figure 2-13: Electrical Flight Bag (physical device)

- **Operational Drone** with **GCS.** The drone for the proposed scenario is a *DJI M300*. The MATRICE 300 RTK is a powerful industrial drone platform with an advanced flight controller system, 6-directional sensing and positioning system and an FPV camera. It has a built-in RTK module, which provides more accurate heading data for positioning. It is equipped with a Pollicino Pro Tracker.

Figure 2-14: DJI M300 RTK drone

DJI M300 drone's specifications	
MTOM	9 kg
Dimensions	810x670x430 mm (without propellers-21")
Weight (batteries excluded)	3600 g
Operating frequency	2.400 - 2.4835 GHz; 5.725 - 5.850 GHz
Max Ascent Speed	6 m/s
Max Descent Speed (vertical)	5 m/s
Max Horizontal Speed	23 m/s
Max Service Ceiling Above Sea Level	5000 m (with 2110 Propellers, and takeoff weight ≤7 kg) / 7000 m (with 2195 High Altitude Low Noise Propellers, and takeoff weight ≤7 kg)
Max Forward Flight Time (Sea level)	45 minutes (Load weight 700 g)
Max Hover Time (Sea level)	43 minutes (Load weight 700 g)
Autonomy	up to 55 min
Wind resistance	15 m/s

Table 2-2: Drone specification

The *DJI Enterprise Smart Controller* features OcuSync Enterprise technology, capable of controlling aircraft that support this technology (C2 link).
The smart controller can reach a maximum transmission distance of 7 km in Europe in an unobstructed area with no electromagnetic interference at an altitude of about 400 feet (120 meters). A specific GCS tailored for the visualisation of ICARUS services can be installed (including the D-flight application) on the Smart Controller.

Figure 2-15: DJI M300's remote controller

DJI M300 remote controller's specifications	
OcuSync Enterprise Operation Frequency Range	2.400 - 2.4835 GHz; 5.725 - 5.850 GHz
Max Transmission Distance (Unobstructed, free of interference)	EU: 7 km
Working Time	Built-in battery: Approx 2.5 hours Built-in Battery+External Battery: Approx. 4.5 hours
Operating frequency	2.400 - 2.4835 GHz; 5.725 - 5.850 GHz
Power Supply Voltage/Current	5 V/1.5 A

Table 2-3: Remote controller specifications

- **Pollicino Pro© UTM Box** (Tracking service): This device has been tailored from the Pollicino© UAS tracker. This version has a more accurate GNSS receiver, based on the U-blox ZED-F9P chipset, that also guarantees outstanding performance for determining vertical position. This prototype device will be used in S1 for:
    - Implementing a tracking service for D-flight
    - Keeping raw GNSS data for post-processing activities

Figure 2-16: Pollicino Pro© prototype

- **Tablet with D-flight webapp:** The D-flight web application can either be installed on the pilot's remote controller or on a different tablet monitored by the observer.

Figure 2-17: D-flight webapp for tracking monitoring

- **Private local RTK/PPK GNSS station:** This equipment will be used in combination with the M300 RTK drone for the augmentation of positioning and navigation performance, and to collect data for post-processing activities

Figure 2-18: Private local RTK/PPK GNSS station

Finally, the ICARUS testbed (VCS, VALS service) and the D-flight USSP portal will obviously be used for S1 execution.

2.8 Schedule

The flight activities are planned for the week:

- **7 March-11 March 2022**

These activities will be scheduled from 10:00 to 12:00 a.m. in the morning.

A day will be defined in this week depending on weather condition and other limitations. A second day in the week could be used as spare if needed or if necessary for scenario repetition (more GA pilots involved).

2.9 Applicable Authorisations

For S1, the only applicable authorisations needed for the flight are those related to the UAS flight. According to the European EASA regulation 2019/947 and Italian regulation UAS-IT 04-01-2021, the registration of new drones has been handled by D-Flight (www.d-flight.it) since 1st March 2020. TopView, in charge of the UAS flight, has all the authorisation needed for this Open category UAS operation. In particular:

- UAS: registered with D-flight with QR code ITA-2496671
  - ENAC UAS operator no. ITEYj5NspP (declaration number generated by D-Flight).
  - Drone insurance: Lloyd's Insurance no. EG202109090929-LB (valid in EU, expiry date: 10th Sept. 2022)
  - Pilot in Command for the mission: Gianluca Luisi – APR (FI) L-VL/Mc CRO attestation no. I. APRA.000712 issued on 13/01/2017 (expiry date 31/01/2022, to be renewed before the execution of the mission)

Even though the operation is in the "Open" category, the UAS Operator TopView, the pilots and the drone are authorised for critical operations in standard scenarios IT-STS-01, IT-STS-02.

2.10 Airspace verification

The airspace has been verified at the planning stage using both D-flight for possible UAS conflicts in the strategic phase or any other restrictions and "Desk aeronautico" for NOTAM verification and any other kind of aeronautical information.

According to D-Flight cartography, the area appointed for UAS operations with HOME point centre in:

- Lat: 41° 6' 17.08"N
- Lon: 14°20' 23.79"E

falls into:

- The "VOLTURNO FLY" area where Open category operations are allowed with a maximum height of 25 m AGL. This is due to the presence of an airfield (Volturno Fly);
- Napoli CTR, where Open category operations are allowed below 60 m AGL.

There is no need to request a time slot or to remove limitations, although, the location is near the following No-Fly Zones:

- EST CAPUA AREA: Type: Ultralight (ULM) activity;
- GRAZZANISE CTR.

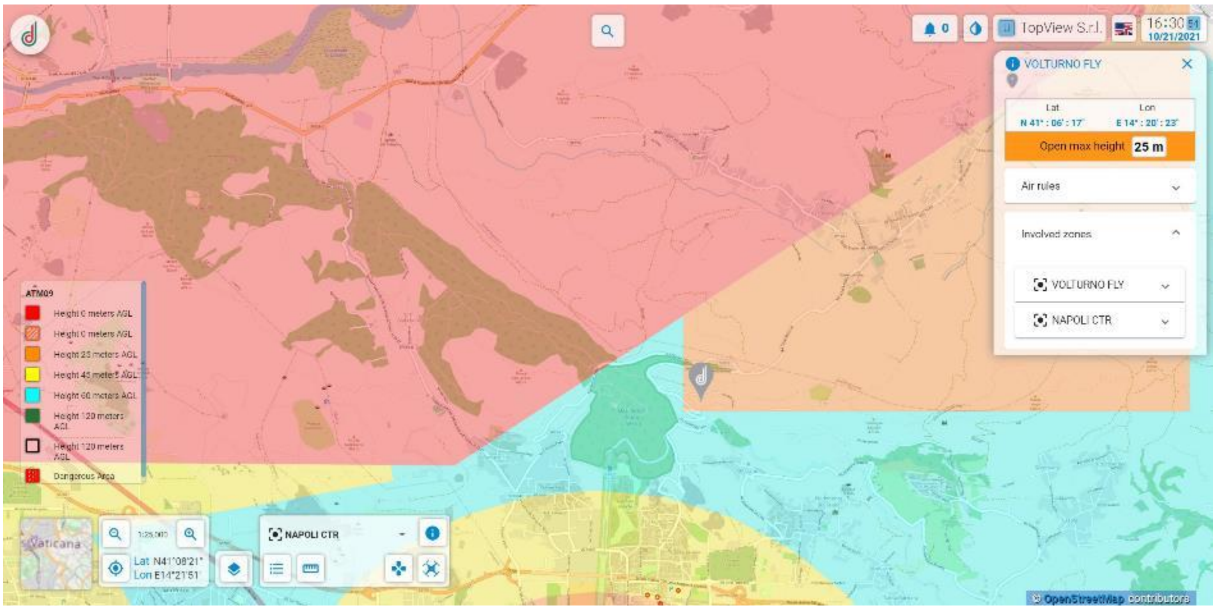

Figure 2-19: S1 - Airspace Verification (D-Flight cartography)

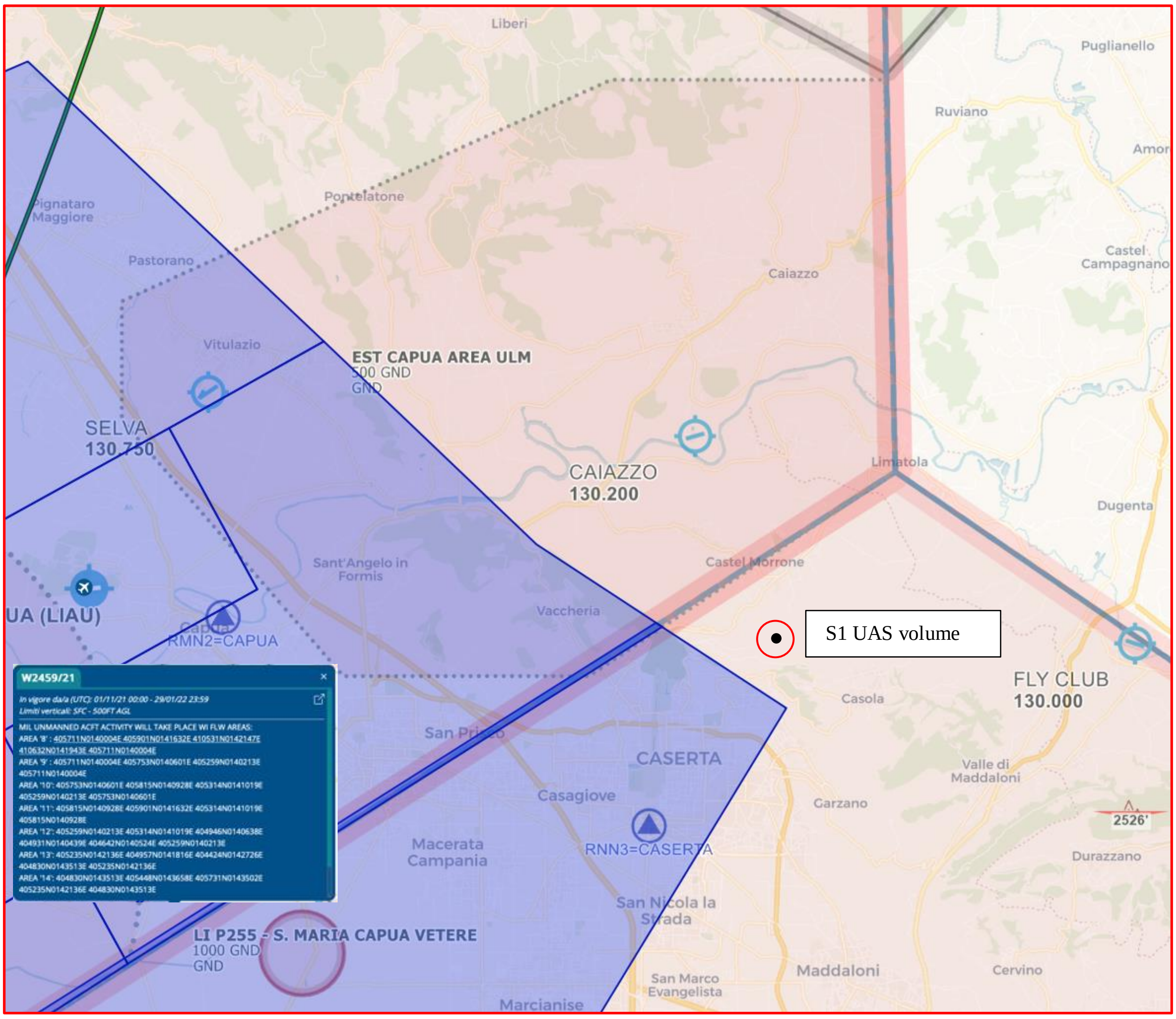

Figure 2-20: S1 - Airspace Verification (Desk Aeroautico)

According to the AIP dispatched on the "desk aeronautico" portal, "Military Unmanned will take place from ground up to 500 Feet AGL" in the area W2459/21.
However, this activity, although in a neighbouring area, does not affect our S1 UAS operations since it is temporarily planned up to 29/01/22 and is outside the UAS volume centred on the home point defined.

2.11 Weather conditions

It is assumed that missions will be executed with proper weather conditions according with the flight limitation of the M300 drone manual; one week before the operations, three days before and the day before the mission, the weather will be checked on the following sites: www.meteoAM.it, www.windy.com, www.D-Flight.it.
In the case of a bad weather forecast, the activity will be postponed and an alternative date proposed in the week defined for S1 validation.

3 S2: Ultralight aircraft-UAS CAR

3.1 Introduction

This section presents the operational flight plan for the second scenario (S2) that concerns concurrent UAS and ultralight aircraft operations. This scenario implements real operations with a real ultralight aircraft and a real UAS flight, flying in a segregated area.

3.2 Scope of the mission

The mission is designed to provide the UAS pilot with alerts about the incoming traffic nearby, during the flight, by using the value-added services offered by ICARUS, particularly the alerting service (VALS). Moreover, as a secondary objective, the mission aims to verify the radio coverage of the Pollicino Pro tracker, when used by an ultralight aircraft at 1,000 or 2,000 feet AGL.

The mission described in this scenario therefore contributes to validating the following ICARUS micro-service in the tactical phase:

- **Vertical Alert Service (VALS)** with particular attention to**:**
    - Radio coverage of tracking device for an ultralight flight flying up to 2,000 feet

In particular in this scenario, the VALS service will alert the UAS pilot when other ultralight traffic is near the UAS flight. The VCS service, in combination with VALS, will also provide the UAS pilot with the height of ultralight expressed in metres, under the same reference system as that used by the UAS (local home point). However, in this particular mission both aircraft take off and land not far from each other, therefore conversion by the VCS service is not a key element of the Scenario.

3.3 Description of operations

This mission involves:

- **1 Ultralight aircraft (Tecnam F7 "Picchio")** departing from an aeroclub in southern Italy (real flight)
- **1 drone (DJI M300 RTK)** involved in training operation, nearby the aeroclub (real flight).

The "Picchio" ultralight aircraft with one person aboard will undertake a leisure flight of about 30 minutes departing at 10:00 UTC from "Rains Club" airfield in the morning, flying over the surrounding valley and hills. The ultralight flight is expected to land on the same airfield.

The UAS aircraft has a training activity planned near the airfield in the "Fly Rise" approved UAS training centre. SInce the UAS flight is planned for training purposes in this case, a flight instructor pilot and a trainee pilot are involved in the operations.
The ultralight aircraft is fitted with a Pollicino Pro© UTM Box and with a Pollicino© Tracker used to implement the U-space drone tracking service. The two trackers will be installed with Velcro tape on the control panel of the aircraft. The pilot will not interact with any of these devices in any way so as not to interfere with his workload.

The ultralight pilot is aware of the possible presence of drones in the nearby area from the strategic phase since a permanent NOTAM warns GA and ultralight pilots about the possibility of UAS activity.

Figure 3-1: S2 – Ultralight "Tecnam F7 Picchio" and M300 RTK UAS

Figure 3-2: S2 – installation of Pollicino© Trackers in the Ultralight "Tecnam F7 Picchio" and new Pollicino Pro© prototype tracker to be installed.

As shown in the above figures, the ultralight aircraft is equipped with Pollicino© Tracker devices for reporting the ultralight position to U-space to feed ICARUS services. The presence of two trackers on the aircraft is justified for testing the difference in performance of the high-end GNSS chipset on-board under the same conditions. Moreover the opportunity of a real ultralight flight will be exploited in this scenario to also test radio coverage in remote areas as a stress test for this kind of equipment, using the ground-based 4.5G NB-IOT network for communication.

3.4 Location

The areas where the operations will take place are the following:

- For the **Tecnam Picchio F-7** "RAINS club" airfield (ident "LIWS" – Piana di Monteverna, runway 07)
  - Lat: 41° 8'45.67"N
  - Lon: 14°20'20.36"E
  - Alt: 31 m AMSL
- For the **M300 RTK drone** "Fly Rise" approved UAS training centre (approximate home point position):
  - Lat: 41° 8'45.67"N
  - Lon: 14°20'20.36"E
  - Alt: 31m AMSL

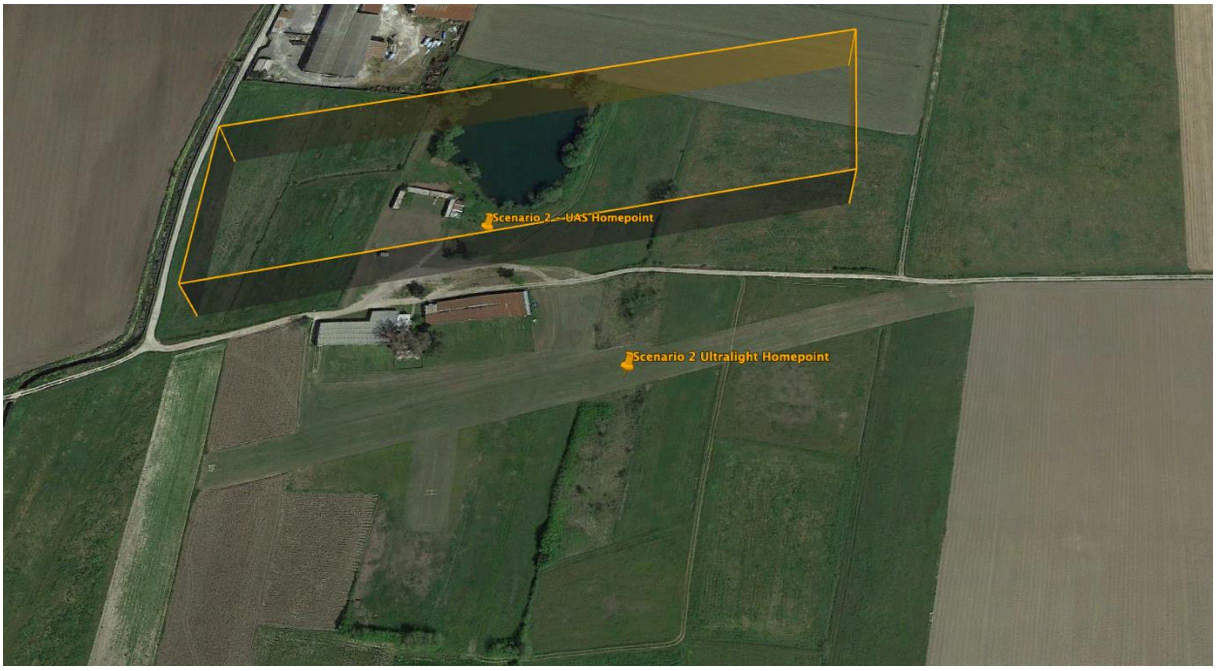

Figure 3-3: S2 - Positions of "RAINS club" for Tecnam Picchio F-7 aircraft and "Fly Rise" for M300 RTK drone.

3.5 Flight Plans

The flight plans for each aircraft is presented below.

3.5.1 Tecnam Picchio F-7 aircraft

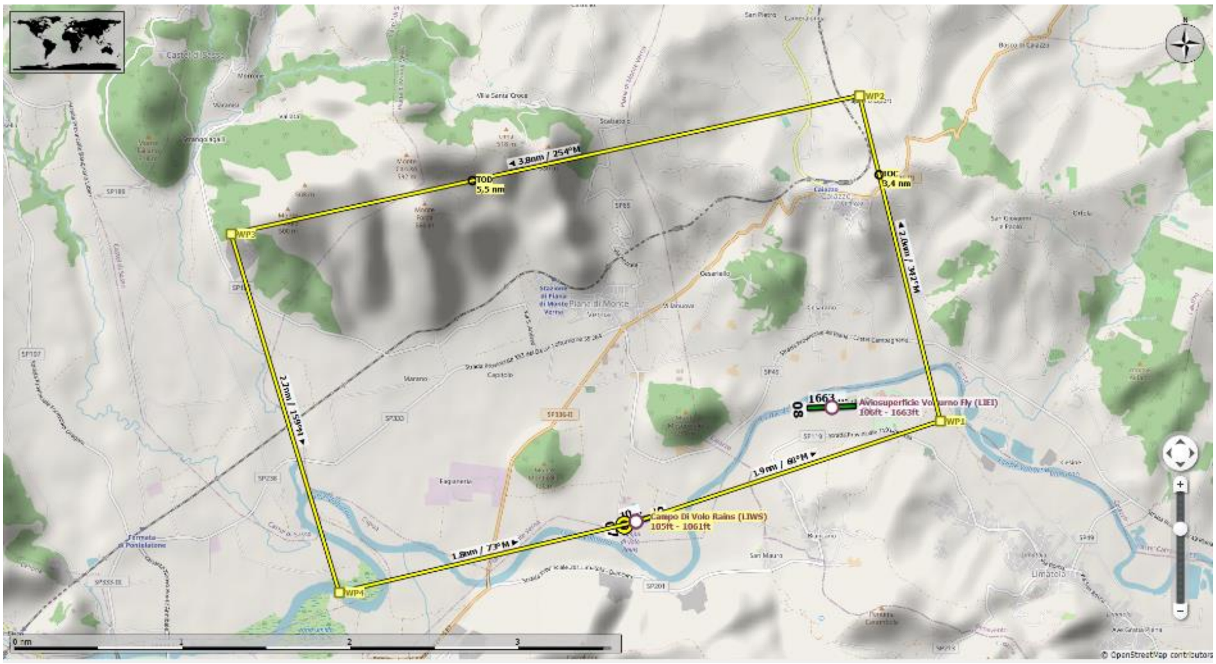

Figure 3-4: S2 - Tecnam Picchio F-7 aircraft Flight plan from "RAINS club" airfield (LIWS)

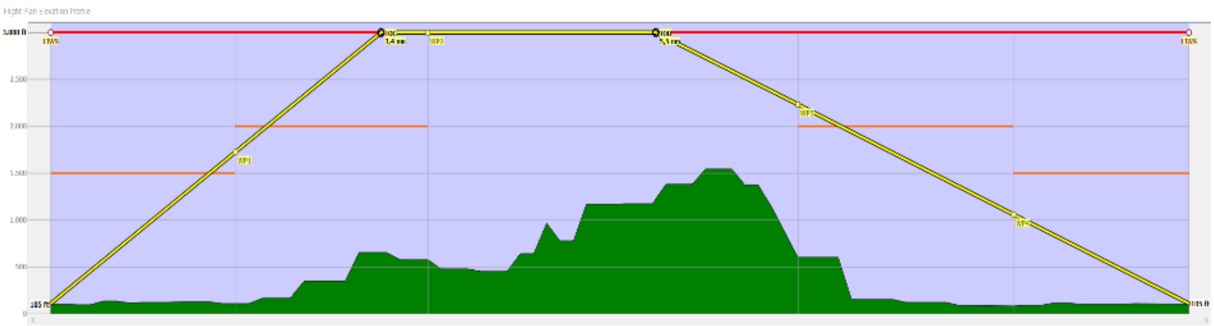

Figure 3-5: Figure 2 8: S2 - Elevation profile for Tecnam Picchio F-7 aircraft Flight plan from "RAINS club" airfield (LIWS)

Campo Di Volo Rains (LIWS) Runway 07 to Campo Di Volo Rains (LIWS)

11,8 nm, 0 h 07 m, 3.000 ft, 3,4 nm from departure to top of climb, 5,5 nm from start of descent to destination

Ident	Name	Procedure	Region	Airway or Procedure	Restriction ft/kts	Type	Freq. MHz/kHz/Cha.	Range nm	Course °M	Course °T	Distance nm	Remaining nm	Leg Time hh:mm	ETA hh:mm	Fuel Rem. lbs	Fuel Rem. gal	Wind °M/kts	Head- or Tailwind kts	Altitude ft	Remarks
LIWS	Campo Di Volo Rains	Departure									0,0	11,8		0:00	33	6			105	
WP1									68	72	1,9	9,9	0:01	0:01	33	5			1.722	
WP2									342	346	2,0	7,9	0:01	0:03	32	5			3.000	
WP3									254	258	3,8	4,0	0:02	0:05	31	5			2.228	
WP4									159	163	2,2	1,8	0:01	0:06	31	5			1.058	
LIWS	Campo Di Volo Rains	Destination							73	77	1,8	0,0	0:01	0:07	30	5			105	

Figure 3-6: S2 – Flight plan for ultralight TECNAM F7 Picchio from "RAINS club" airfield (LIWS)

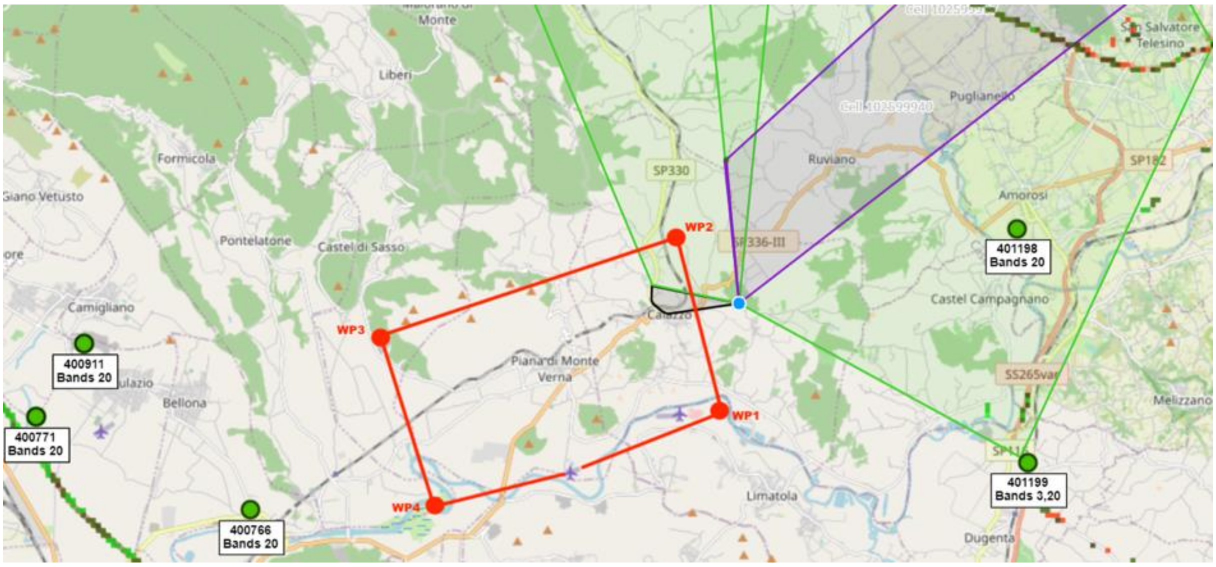

Figure 3-7: S2 – Coverage of 4G NB.IOT cells in the area of operations

The figure above shows the coverage offered by the 4G NB-IOT cells used for the UAS tracker installed on the ultralight airplane. As expected, the coverage is weak in the area of operations, especially over the mountain. Maximum coverage will be obtained in the WP1-WP2 segment and near the RAINS airfield (where it is needed for the VALS service). However this particular flight path has been selected to stress the limit of this technology for ultralight flights.

3.5.2 M300 RTK drone

The flight plan (DOA) for the M300 RTK drone is shown below. It takes the flight limitations imposed in the local area into consideration. The flight is executed in VLOS in the Open category (A3) within the segregated area used for UAS flight training activities. The operational UAS volume is shown, its maximum height is set at 25 m AGL.

The drone home point is more than 100m from the home point of the Tecnam F7 "Picchio" (as shown in paragraph 3.4) to ensure appropriate separation in the strategic phase.

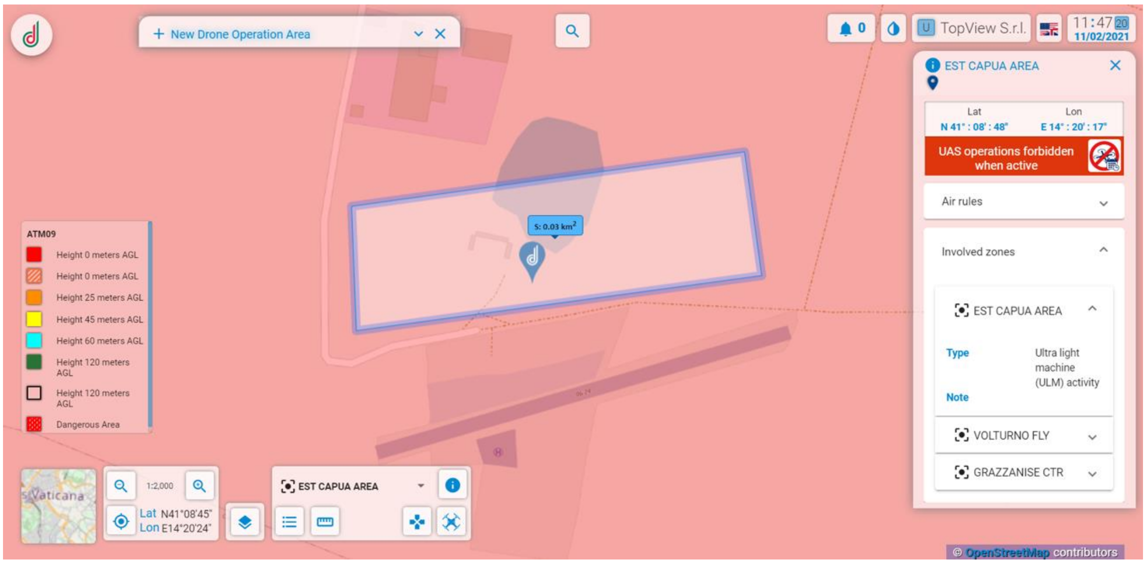

Figure 3-8: S2 – M300 UAS DOA

As was the case in scenario 1, the drone operation area (DOA) is measured with the help of a planning tool available on D-flight platform. The DOA offers specialised UAS operators the ability to report on their intentions for specialised flight operations through the experimental drone operation plan (DOP) functionality on the D-flight platform. This functionality involves, among other things, validating the planning with respect to some geo-spatial and regulatory constraints. In this case, a NOTAM is already active, since this area is used for UAS training activities.

The information generated by the UAS tracker installed on-board the ultralight aircraft will be used to feed the ICARUS VALS service that provides the UAS pilot with tactical CAR separation information if an ultralight flight is near (very likely considering the area).

3.5.3 Conflicts & Mitigation

No conflicts are expected in the tactical phase since all conflicts have been resolved in the strategic phase because there is a permanent NOTAM related to UAS flight activity that both manned and unmanned users are aware of.

Since no conflicts are expected, and strategic deconfliction provides an excellent mitigation strategy for risks, it was decided to test the ICARUS VALS service in a real scenario without affecting the actual level of safety of the operations.

3.6 Players involved

The players involved in S2 are:

- **1 Mission Coordinator:** in charge of the coordination of all players involved in the validation scenario with particular reference to:
    - USSP service availability and support for the UAS tracking service;

- Schedule and time constraints for flight coordination (ultralight flight and UAS flight) supported by the WP6 Manager
- Verification of all documentation for UAS operations, including:
    - UAS licences/attestation and insurance coverage (provided by the UAS pilots);
    - Ultralight licences/attestation and insurance coverage (provided by the ultralight pilot);

- **1 Ultralight Pilot** (RAIN aeroclub premises)**:** in charge of ultralight flight activities. Supported by a test engineer, they will be instructed on how to install and use the Pollicino tracker on the aircraft.
- **1 Test Engineer** (RAIN aeroclub premises)**:** will support the ultralight pilot and the UAS pilot supervision during the validation activity.
- **1 Drone Pilot** (Home point): responsible for UAS flight activities. For the purpose of this mission, a trainee UAS pilot, who would also act as a drone observer, may be also involved.
- **1 Drone Observer** (Home Point): will support the UAS pilot during the mission, paying particular attention to alerts generated by the ICARUS VALS service to signal the presence of activity of nearby ultralight flights.
- **1 USSP Engineer** (D-flight premises): One engineer appointed by D-flight will monitor the flight (Tracking service - VALS) during the validation activities.

3.7 Equipment involved

The following equipment is needed for the validation of S2.

- **"TECNAM F7 PICCHIO" ultralight airplane:** will used for the flight. The main body of the aircraft is composed of aluminium and steel; the wings are of composite materials (carbon and PVC sandwich). The aircraft's empty weight is less than 330 kg. For this reason, this type of aircraft is very easy to pilot during cruise and stall phases.

Figure S2 – TECNAM F7 Picchio aircraft used for testing

Tecnam Picchio F-7specifications	
Wingspan	9.29 m
Fusolage length	6.60 m
Fusolage height	2.55 m
Wing surface	12.7 m
MTOM	450 kg
Max speed	200 km/h
Rate of climb	8 m/s
Take-off distance	150 m
Landing distance	120 m

Figure 3-9: Tecnam Picchio F-7 specifications

- **Operational Drone** with GCS**.** The drone for the proposed scenario is the *DJI M300.* The configuration used will be the same as described in section 2.7.
- **Pollicino Pro© UTM Box** (tracking service for the ultralight flight): This device has been tailored based on the Pollicino© UAS tracker. This version includes a more accurate GNSS receiver, based on the U-blox ZED-F9P chipset that also guarantees outstanding performance in determining vertical position. This prototype device will be used in S2 for:
  - Implementing the ultralight tracking service to D-flight;
  - Keeping raw GNSS data for post-processing activities;
  - Feeding the ICARUS VALS service.
- **Tablet with D-flight webapp:** The D-flight web application will be used by the UAS pilot, either on the remote controller or on a different tablet monitored by the observer. This indicates the presence of the other ultralight traffic and displays alerts generated by ICARUS VALS service.
- **Private local RTK/PPK GNSS station:** This equipment will be used in combination with the M300 RTK drone for the augmentation of positioning and navigation performance as in S1 (see section 2.7)

Finally, the ICARUS testbed (VALS service, tracking) and the D-flight USSP portal, will of course be used for S2 execution.

3.8 Schedule

The flight activities are planned for the week of:

- **14 March-18 March 2022**

The activities will be scheduled from 10:00 to 12:00 in the morning.
One day in this week will be defined in accordance with weather condition and other limitations. A second day in the week could be used as spare day if needed, for repeating the scenario or in the case of bad weather conditions.

3.9 Applicable Authorisations

For S2, authorisations are needed for both the UAS flight and the ultralight flight.
According to EASA regulation 2019/947 and Italian regulation UAS-IT 04-01-2021, the registration of new drones has been handled by D-Flight (www.d-flight.it) since 1st March 2020. TopView, in charge of the UAS flight, has all the authorisation needed for this Open category UAS operation. The same authorisation apply as for S1. They are repeated here for convenience:

- UAS: registered on D-flight with QR code ITA-2496671
    - ENAC UAS operator no. ITEYj5NspP (declaration number generated by D-Flight).
    - Drone insurance: Lloyd's Insurance no. EG202109090929-LB (valid in EU, expiry date: 10th Sept 2022)
    - Pilot in Command for the mission: Gianluca Luisi – APR (FI) L-VL/Mc CRO attestation no. I. APRA.000712 issued on 13/01/2017 (expiry date 31/01/2022, to be renewed before the execution of the mission)

Even though the operation is in the Open category, the UAS Operator, TopView, the pilots, and the drone are authorised for critical operations in standard scenarios IT-STS-01, IT-STS-02.

For the ultralight manned aircraft, the applicable authorisation will be checked before the flights by the mission coordinator.

3.10 Airspace verification

The airspace has been verified at planning stage using both d-flight for possible UAS conflicts at strategic phase or any other restrictions and "Desk aeronautico" for NOTAM verification and any other kind of aeronautical information.

According to D-Flight cartography, the area defined for UAS operations with a HOME point centre at:

- Lat: 41° 8'48.41"N
- Lon: 14°20'17.28"E

falls into

- EST CAPUA AREA type: ultralight activity;
- "VOLTURNO FLY" area where Open category operations are allowed with a maximum height of 25 m AGL. This is due to the presence of an airfield (Volturno Fly);
- GRAZZANISE CTR.

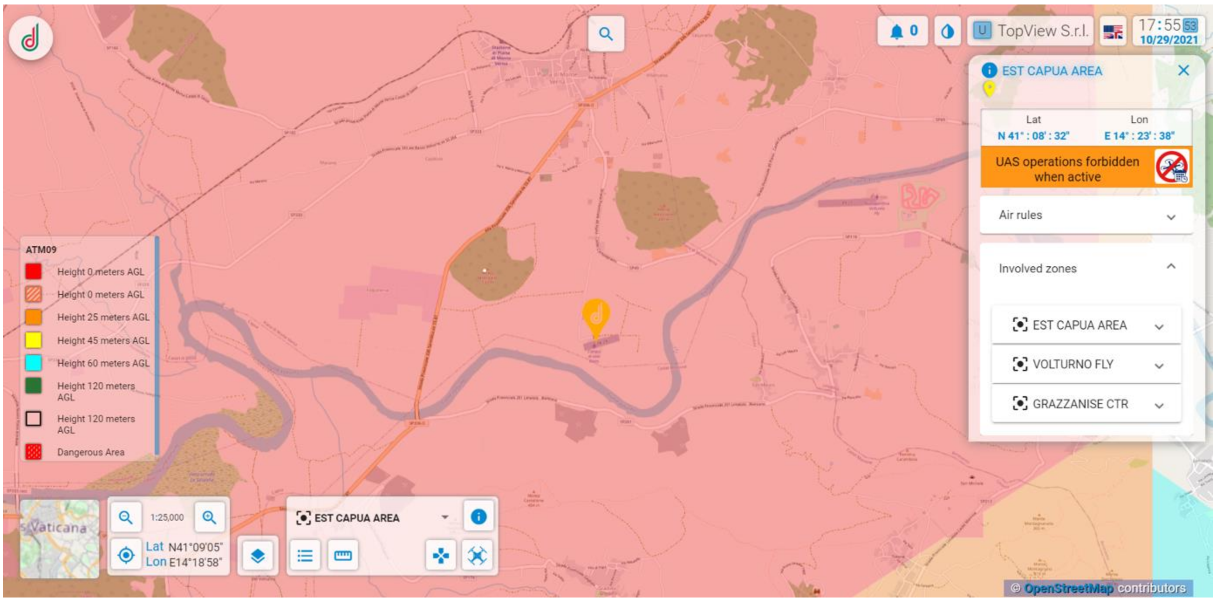

Figure 3-10: S2 - Airspace Verification (D-Flight cartography) for UAS operations

The area of operations involves the No-Fly Zones: if one of these is active, UAS operations are forbidden; therefore, UAS operations involved in this scenario will be executed after checking that both NFZs are inactive. Such limitations can be temporarily removed for the time slots requested, with the formal approval of the operations by the authorities.

Furthermore, other VFR air traffic are possible near the site because of the presence of different secondary sport airfields (one of which is the "Rains Club"). In this case the drone pilot will take control of the flight or will command the training pilot to execute the most appropriate manoeuvres to avoid collision and interference situations.

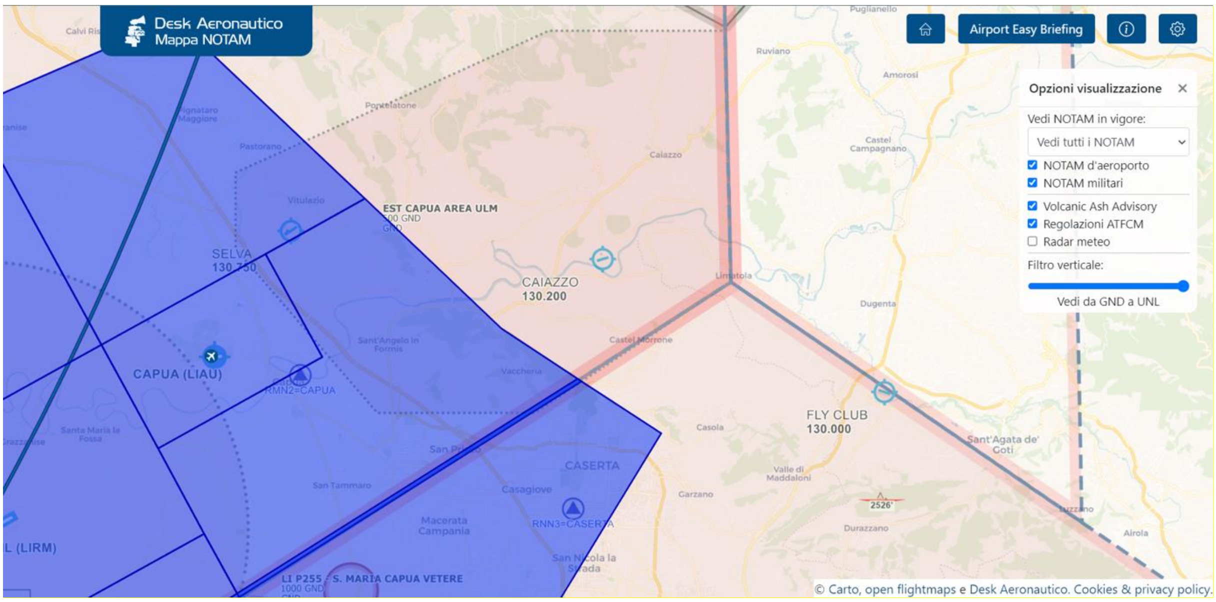

Figure 3-11 - S2 - Airspace Verification (Desk Aeronautico) - S2 - Airspace Verification (Desk Aeronautico)

As mentioned before, the UAS training activity is notified by a permanent NOTAM; it is therefore well clear of other aircraft. Other NOTAMs will be managed as described for S1.

3.11 Meteorological conditions

It is assumed that missions are executed under proper weather conditions according to the flight limitations given in the M300 drone manual and TECNAM F7 Picchio aircraft manual. One week before the operations, three days before and the day before the mission, the weather will be checked on the www.meteoAM.it, www.windy.com, www.D-Flight.it sites.
In case of bad weather forecast, the activity will be postponed and an alternative date proposed in the week defined for S2 validation.

4 S3: UAM operations

4.1 Introduction

This section contains the operational plan for scenario 3 (S3), which is focused on urban air mobility. It consists of a simulated flight carrying passengers from the airport to the city centre in a mixed urban and non-urban environment.

4.2 Scope of the Mission

The simulation aims to show how the remote pilot of a taxi-drone can safely manage the aircraft thanks to accurate ground obstacle information provided by an accurate DSM/DTM service and a system that alerts to both obstacles and other manned and unmanned air traffic. The mission also shows how an aircraft relates to the height and altitude datum when entering in a GAMZ.
So, this scenario aims to validate the following ICARUS micro-services:

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

in the strategic and tactical phase of the mission.

4.3 Description of operations

The mission involves an eVTOL taxi-drone, whose virtual flight will be executed in TopView's cockpit simulator.
The taxi-drone takes off from Torino Caselle Airport parking area, carrying one passenger to the centre of Turin, more than 13 km from the take-off point. The altimeter of the taxi-drone is set to the QFE of Caselle Airport.
It gradually ascends to 1,000ft AGL over a sparsely populated area, mostly flying over fields in the countryside. Once it has reached the bed of the river Stura, it follows this river for few kilometres until it gets closer to the urban area.
The taxi-drone now enters a Zu type airspace, with more relevant ground obstacles and ground risks, and with the possibility of encountering other UAS flights on delivery missions. S3 assumes that this area is a GAMZ, therefore the UAS in the area (in our GAMZ proposal) flies with a common altitude reference set to the WGS-84 datum and expressed in metres. It is assumed that the taxi-drone already has the certified avionics for reading the CAR under WGS-84.
Finally, the taxi-drone approaches its final destination - "Piazza della Repubblica" - and lands with the help of S&A sensors for VTOL, and knowledge of the elevation of the landing place under WGS-84.

Figure 4-1 - S3 - Taxi Drone concept - right view

Figure 4-2 - S3 - Taxi Drone concept - left view

According to EU Regulation, this operation is in the Certified category because it involves transporting passengers.
The taxi-drone pilot has to have information on both QFE and GNSS data: a part of the flight is executed in a Zu airspace (Urban Areas), so the drone will interact with a GAMZ area and with the vertiport operator for landing procedures.
Although the route has been designed to minimise interaction with ground obstacles for safety reasons, the taxi-drone (for the same safety reasons) must be aware of potential hazards through using the RGIS service.

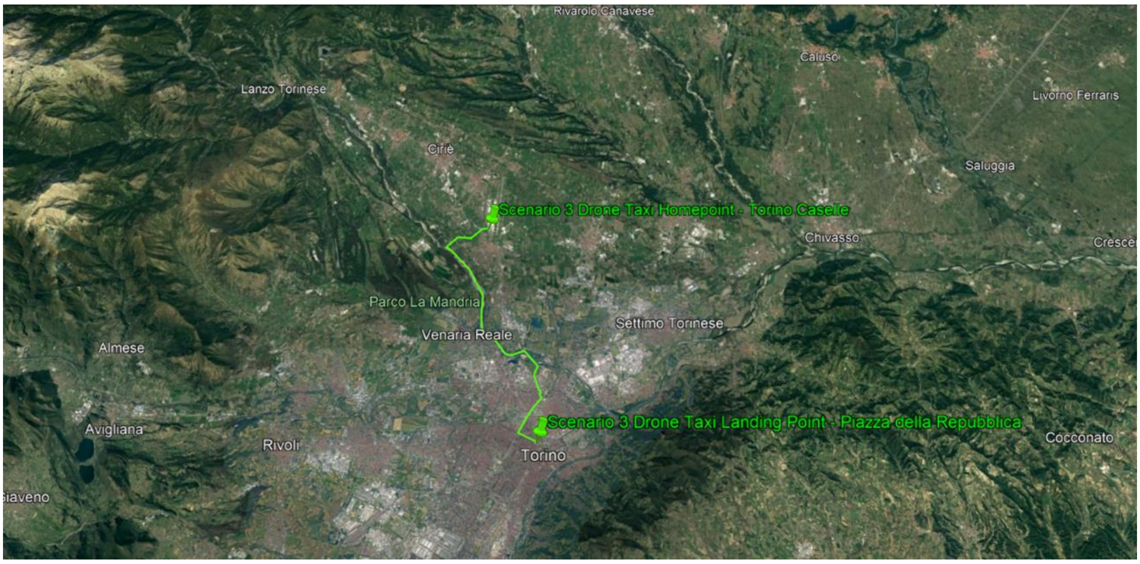

Figure 4-3 - S3, Taxi Drone flight path (Google Earth)

Figure 4-4 – S3, Detail of Taxi Drone and the assumed GAMZ (Google Earth)

4.4 Location

In the simulated flight, the flight operation take place at:

Taxi-drone home point (Torino Caselle Airport):

- 45°11'20.62"N
- 7°38'33.83"E
- Elevation: 294m AMSL.

Figure 4-5 - Scenario 3, Taxi-drone Home Point (Google Earth)

Taxi-drone landing point (Piazza della Repubblica, Torino):

- 45° 4'34.90"N;
- 7°41'1.75"E;
- Elevation: 236m AMSL.

Figure 4-6 - S3, Taxi Drone Landing Point

Figure 4-7 - S3 - Elevation Profile of the path projection to Ground Level

4.5 Flight Plan

The flight plan for the aircraft is shown below.

Figure 4-8 - S3 Taxi Drone Flight Plan

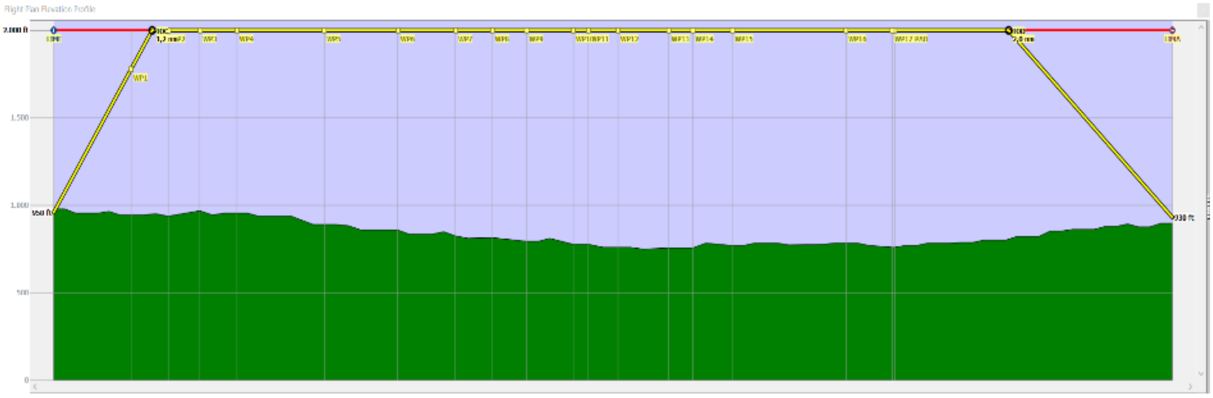

Figure 4-9 - Elevation profile for the taxi-drone aircraft flight plan from "Torino Caselle" to the landing point

The flight plan provides for a maximum cruise altitude of 2,000 feet (QNH) for the duration of the flight. This altitude will be reached between waypoint 1 (Home point) and waypoint 2 at a distance of about 0.67NM. Top of descent (TOD) is between waypoint 7 and waypoint 9 at about 1.8NM from the destination.

According to WP8, the UAS enters the GAMZ and starts sending its altitude in metres with respect to the WGS-84 datum.

The details of the waypoints foreseen by the flight plan are given belo.

Waypoint	Latitude	Longitude	Altitude (ft)
WP1	45°11'18.52"N	7°38'17.49"E	1,500
WP2	45°10'39.72"N	7°36'49.10"E	2,000
WP3	45° 9'4.47"N	7°38'30.64"E	2,000
WP4	45° 7'40.48"N	7°39'6.22"E	2,000
WP5	45° 7'21.25"N	7°40'21.06"E	2,000
WP6	45° 6'53.07"N	7°40'56.46"E	2,000
WP7	45° 5'54.33"N	7°41'8.96"E	2,000
WP8	45° 4'50.79"N	7°40'16.83"E	1,600
WP9	45° 4'36.36"N	7°41'1.04"E	1,300

Table 4-1 S3 - Details of the main waypoints foreseen in the flight plan

4.6 Players involved

The players involved in S3 are:

- **1 Mission Coordinator:** coordinates all the players involved in the scenario and all the activities in terms of:
    - Availability of USSP services
    - Schedule and time constraints of flight operations
    - Verification of UAS licences/attestation and insurance coverage

- **1 Remote Drone-Taxi Pilot** (TopView premises): is responsible for managing the UAS flight operations and to make the transport of the passenger safe, from take-off to landing at the vertiport.
- **1 USSP Engineer** (D-flight premises): a specific engineer appointed by d-flight will monitor tracking.
- **1 test engineer** (Telespazio premises): will be in charge of monitoring the RGIS/VALS services

4.7 Equipment involved

- **Cockpit simulator**: described in D5.2, this simulation environment will be tailored to the specific taxi-drone concept for S3.
- **Tablet with USSP web application** for remote taxi-drone pilot: the D-flight application will be used by the remote drone pilot for monitoring ICARUS VALS /RGIS services when other traffic or unexpected ground obstacles are present.
- **The ICARUS testbed** (VALS, RGIS service, tracking) and D-flight USSP portal will be involved.

4.8 Schedule

The flight activities are planned for the week of:

- 7 March-11 March 2022.

The activities will be scheduled during one day of the week, with no particular time constraints or limitation.

One day in this week will be defined as a function of the other simulation scenario (S1). A second day in the week could be used as spare day if needed for repeating the scenario.

Since the S3 is entirely simulated, weather conditions are not relevant for operation scheduling and execution.

4.9 Applicable Authorisations

For this simulation it can be assumed that the UAS and the operator comply with all (current and future) requirements, regulations and authorisations.

4.10 Airspace verification

The flight path crosses several types of airspace. Airspace is verified through D-flight web app cartography. According to this source, the home point coordinates are:

- 45°11'20.62"N
- 7°38'33.83"E

This means that it falls within the civil ILS airport of Torino Caselle (TORINO/CASELLE and TORINO/CASELLE 18/36):

- Torino/Caselle, civil ILS airport;
- "Torino Caselle" ATZ;
- "Torino" CTR.

UAS Operations in the Open category are prohibited, therefore, but Certified category operations are possible, under the circular ATM-09.

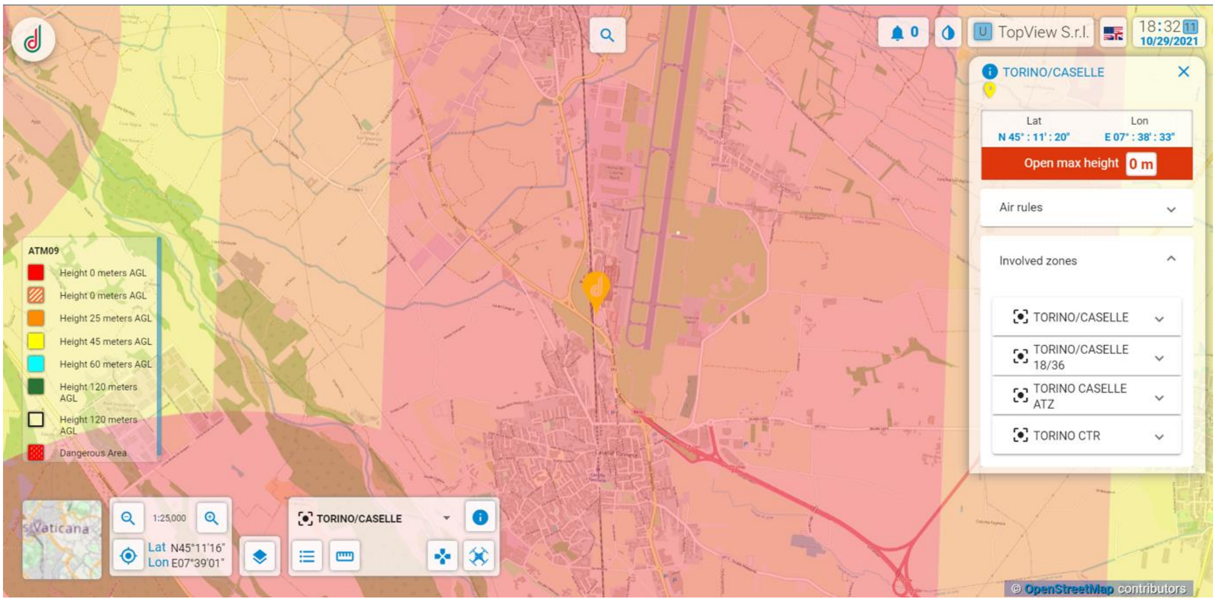

Figure 4-10: S3, Area of operations – taxi-drone take-off area

The landing point is in Piazza della Repubblica:

- 45° 4'34.90"N;
- 7°41'1.75"E;

This falls within:

- LI R34 – Torino Città restricted areas;
- Torino/Aeritalia 10R/28L (civil non-ILS airport);
- Torino/Caselle (civil ILS airport);
- Torino/Caselle 18/36 (civil ILS airport);
- Zebra (Helipad);
- Torino CTR.

The area contains several geographic zones which, when active, do not allow UAS operation. It is possible to obtain authorisations from ENAC according to ENAC ATM circulars.

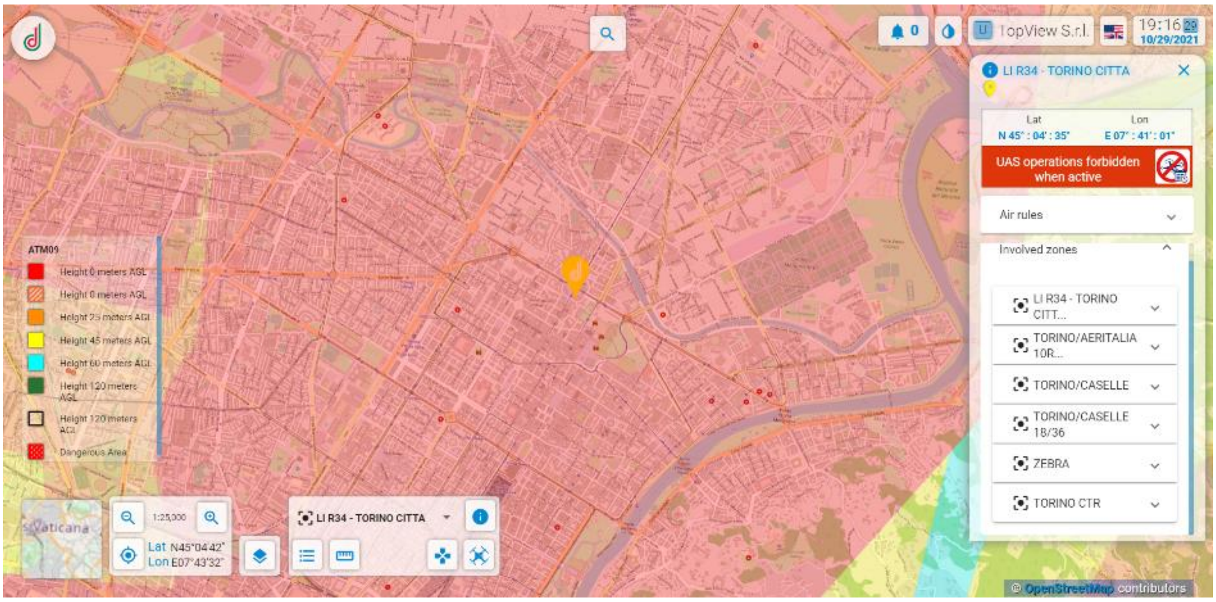

Figure 4-11: S3, Area of Operations – GAMZ and Landing area

Furthermore, it is likely that other air traffic will be encountered along the route due to the presence of different airports, both ILS and non-ILS.
The remote taxi-drone pilot in the simulation is trained to perform contingency manoeuvres in case of interfering traffic.
NOTAMs are monitored on the www.deskaeronautico.it portal, as shown in the following figure:

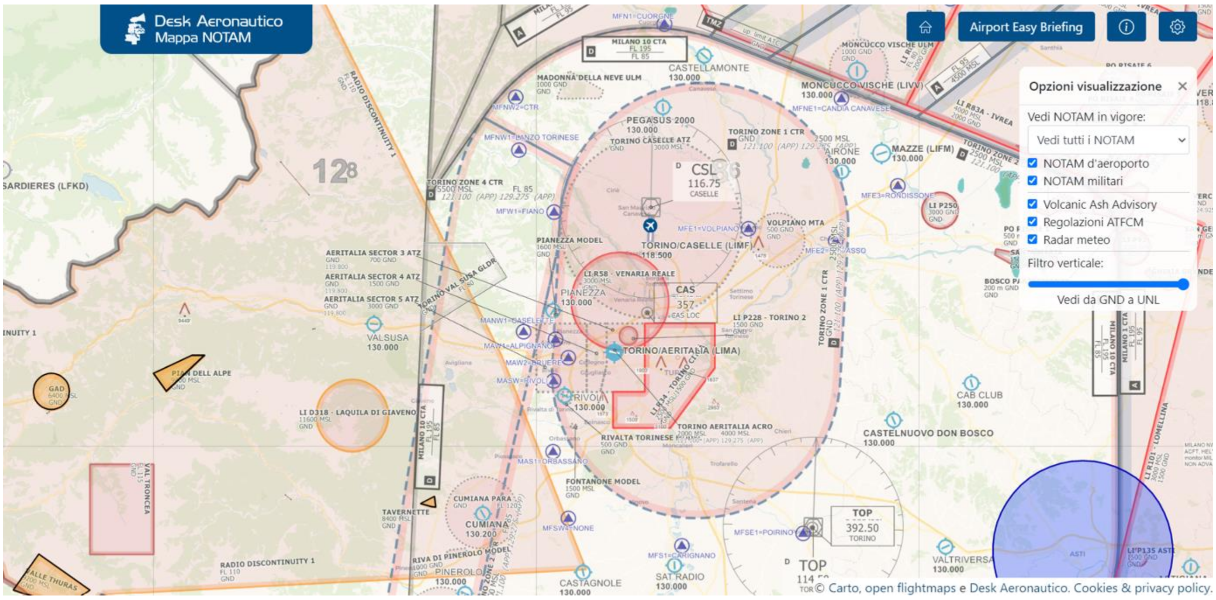

Figure 4-12 – S3, NOTAM map on "Desk Aeronautico" in the TORINO/CASELLE area

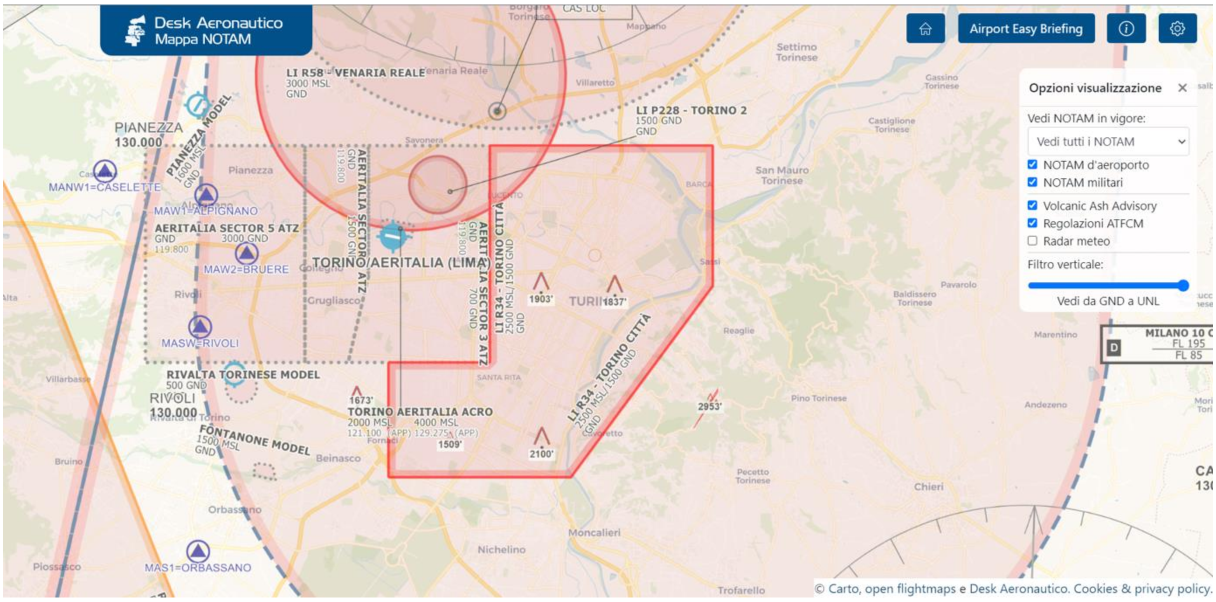

Figure 4-13 – S3, NOTAM map on "Desk Aeronautico" in the Torino city centre

Several NOTAMs related to Torino Caselle Airport are in place, but at the time of writing none of them are valid up to the scheduled dates of the virtual flight. To provide more realism to the simulation, further checks of active NOTAMs will be made.