ICARUS Prototype

DeliverableID	D4.2
ProjectAcronym	ICARUS
Grant:	894593
Call:	H2020-SESAR-2019-2
Topic:	Topic 31
Consortium coordinator:	E-GEOS SPA
Edition date:	November 2021
Edition:	00.00.06
Template Edition:	02.00.00

Founding Members

Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
D'Agostino Andrea/TPZ	GNSS responsible	01/03/2021
Piotr Dybiec/DroneRadar	Project Manager	1/10/2021
Sammarco Chiara/E-Geos	Technical Manager	28/10/2021
Łukasz Górny-Zając/DroneRadar	Chief Architect	29/10/2021
Adam Staszak/DroneRadar	Senior Developer	29/10/2021
Jan Mróz-Jaworski/DroneRadar	System Architect	29/10/2021
Sławomir Kubiak	Senior Analyst	29/10/2021
Paweł Korzec/DroneRadar	CEO	29/10/2021
Alberto Mennella/TOPV	Technical Coordinator	31/10/2021
Orsini Corrado/TPZ	Technical Manager	31/10/2021

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
All SC members		10/11/2021

Approved for submission to the SJU By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Cristina Terpessi/EGEOS	Project Coordinator and Deliverable Leader	12/11/2021
Alberto Mennella/TOPV	Technical Coordinator	12/11/2021
Corrado Orsini/TPZ	Technical Coordinator	12/11/2021
Manuel Onate/ EURSC	Communication and Dissemination Manager	12/11/2021
Marco Nota/ TPZ	Consortium Board member	12/11/2021
Wojciech Wozniak/ DRAD	Consortium Board member	12/11/2021
Filippo Tomasello/ EUSC-IT	Consortium Board member	12/11/2021
Mirko Reguzzoni/ Polimi	Consortium Board member	12/11/2021
Mattia Crespi/ DICEA	Consortium Board member	12/11/2021

Giancarlo Ferrara/ ECTL	Consortium Board member	12/11/2021

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

Document History

Edition	Date	Status	Author	Justification
00.00.01	1/07/2021	draft	Corrado Orsini	First draft
00.00.02	15/07/2021	draft	Andrea D'Agostino	GNSS chapter added
00.00.03	2/08/2021	draft	Corrado Orsini	VCS,GIS chapter added
00.00.04	30/10/2021	draft	Chiara Sammarco	VCS,GIS chapter update and overall review/contribution
00.00.05	31/10/2021	draft	Piotr Dybiec	Insertion of VALS chapter
00.00.05	31/10/2021	draft	Alberto Mennella	Insertion of Cockpit Simulator chapter
00.00.06	10/11/2021	draft	SC members	Reviewed version

Copyright Statement

© – 2020 – ICARUS beneficiaries. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions

ICARUS

INTEGRATED COMMON ALTITUDE REFERENCE SYSTEM FOR U-SPACE

This document is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No. 894593 of the European Union's Horizon 2020 research and innovation programme.

Abstract

This document aims at finalising and consolidating the design of ICARUS by describing the interfaces of the ICARUS services for each of the four ICARUS modules foreseen (Sections 2 to 5).

In the introduction, we give an overview of the overall architecture, and we clarify the terminology to facilitate the reader's understanding of the description. The ICARUS prototype will be the central player of the whole discussion. At a high level, this document will show how the prototype interacts with external entities, which can be of two types: *data providers* that act as data sources for the computation, and *service providers* that are intended as the distributors of the ICARUS services.

The last section ends the document with the ICD of the cockpit simulator, which is intended as a data provider for testing and validation purposes.

Table of Contents

List of Tables

List of Figures

1 Introduction[1]

1.1 General architecture and document overview

This document aims at finalising and consolidating the design of ICARUS by describing the interfaces of the ICARUS services for each of the four ICARUS modules foreseen. These modules compose the "ICARUS prototype", a set of dedicated web services conceived as separated interfaces to be integrated onto existing UTM/USSP platforms. For the ICARUS project, D-FLIGHT and PANSA UTM are the UTM/USSP platforms envisaged for this integration.

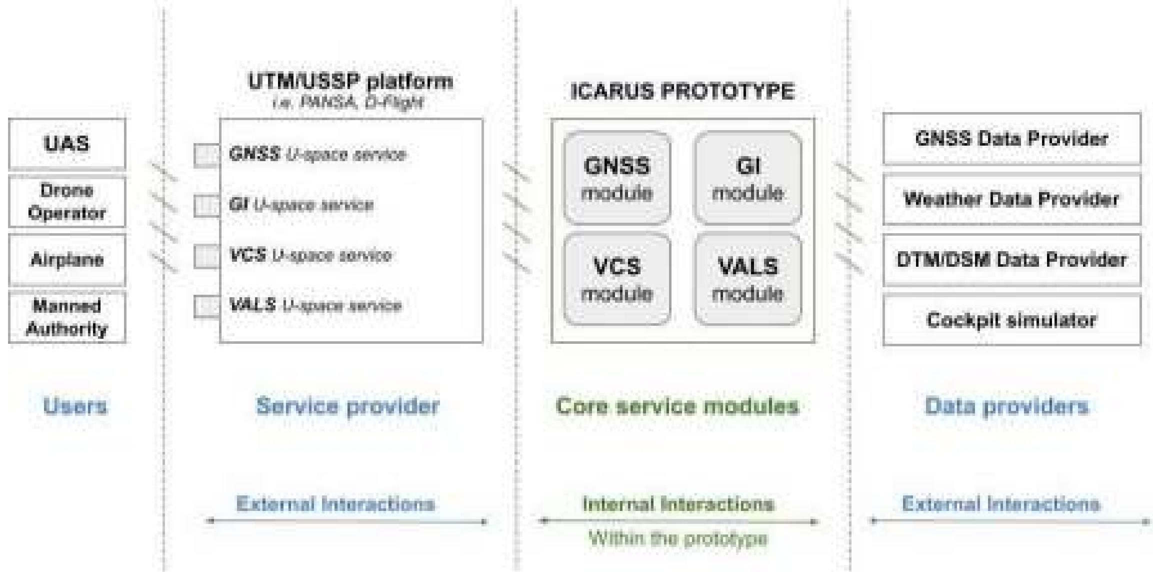

Figure 1-1: General architecture and type of interactions

Before giving detailed descriptions of the interfaces for each of the ICARUS modules, there follows an overview of the general architecture and the types of interaction (see Figure 2-1).

The ICARUS prototype is the principal player of the architecture described for this project. It is composed of the following modules:

- Global Navigation Satellite System (GNSS) module
- Geo-Information (GI) module
- Vertical Conversion Services (VCS) module
- Vertical Alert Services (VALS) module

[1] The opinions expressed herein reflect the author's view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

Founding Members
EUROPEAN UNION EUROCONTROL

Each of these modules provides one or more **services**: GNSS services, geo-information services (GIS), vertical conversion services (VCS), vertical alert services (VALS). The plan is to make them accessible to the final users as U-space services, in other words passing through a UTM/USSP platform.

The prototype's modules need to interact with external data providers for GNSS, weather, and DTM/DSM data. For validation and testing purposes, the cockpit simulator will also act as a data provider for the prototype.

Given the above, there might be two types of interaction:

- *internal* to the prototype (in and between the modules)
- and from the prototype to the *external* entities.

Therefore, throughout this document, the distinction is made between internal interfaces and external interfaces.

Section 1 concludes with a table of acronyms used in the present document. Sections 2, 3, 4, and 5 will provide the service interface descriptions for the GI, GNSS, VCS, and VALS modules. Section 6 ends the document with a description of the cockpit simulator interface.

1.2 Acronyms

Acronym	Meaning
API	Application Programming Interface
AGL	Above Ground Level
ASL (proposition)	Above Surface Level
ARAIM	Advanced RAIM
ATC	Air Traffic Control
ATM	Air Traffic Management
ATZ	Aerodrome Traffic Zone
BKG	Bundesamt für Kartographie und Geodäsie
BNC	BKG NTRIP Client
BVLOS	Beyond Visual Line of Sight
CARS	Common Altitude Reference System
CIS	Common Information Service
CORBA	Common Object Request Broker Architecture
CTR	Control zone

DAA	Detect And Avoid
DEM	Digital Elevation Model
DSM	Digital Surface Model
DTM	Digital Terrain Model
DOP	Dilution Of Precision
DSM	Digital Surface Model
DTM	Digital Terrain Model
EASA	European Union Aviation Safety Agency
EDAS	EGNOS Data Access Service
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
eTOD	Electronic Terrain and Obstacle Data
FLTA	Forward Looking Terrain Avoidance
GA	General Aviation
GAMZ	Geometric Altitude Mandatory Zone
GI	Geo Information
GNSS	Global Navigation Satellite System
GO	Ground Obstacle
GPS	Global Positioning System
HALB	Horizontal Alert Buffer
HPL	Horizontal Protection Level
ICAO	International Civil Aviation Organisation
ICD	Interface Control Description
ISM	Integrity Support Message
ISO	International Organisation for Standardisation
MCMF	Multi-Constellation Multi-Frequency

NTRIP	Networked Transport of RTCM via Internet Protocol
PL	Protection Level
QFE	Query Field Elevation
QNH	Query: Nautical Height
RAIM	Receiver Autonomous Integrity Monitoring
RIMS	Ranging Integrity Monitoring Stations
RGIS	Real Time GIS
RNP	Required Navigation Performance
RTCM	Radio Technical Commission for Maritime Services
SBAS	Satellite-Based Augmentation System
SORA	Specific Operations Risk Assessment
TCU	Telespazio Computing Unit
TSE	Total System Error
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
USSP	U-Space Service Providers (alias UTM service provider)
UTM	Unmanned aircraft system Traffic Management (alias U-space)
VCS	Vertical Conversion System
VALS	Vertical Alert Service
VLL	Very-Low-Level
VLOS	Visual Line Of Sight
VPL	Vertical Protection Level
VPN	Virtual Private Network

Table 1-1: Acronyms list

2 Geo-Information (GI) MODULE

This chapter is dedicated to the definition and description of the Interface Control Descriptions (ICDs) relating to the GI module.

2.1 Overview of the GI data scenario

The GI module provides a set of services to support all the other subsystems by providing geographical information, typically associated with three types of data:

- DSM data. A Digital Surface Model (DSM) is a discrete representation of the surface of the Earth visible from space, which includes vegetation, buildings, infrastructures, and generally all man-made objects.
- DTM data. A Digital Terrain Model (DTM) is a discrete representation of the surface of the bare ground, that is the surface of the Earth visible from space (DSM) filtered to remove vegetation, buildings, infrastructure, and generally all man-made objects.
- Obstacle data. An obstacle database is a digital representation of the obstacles that include the horizontal and vertical extent of man-made and significant natural features. In the context of electronic terrain and obstacle data (eTOD), obstacles are defined as: “All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that
    - are located on an area intended for the surface movement of aircraft; or
    - extend above a defined surface intended to protect aircraft in flight; or
    - stand outside those defined surfaces and that have been assessed as being a hazard to air navigation.”

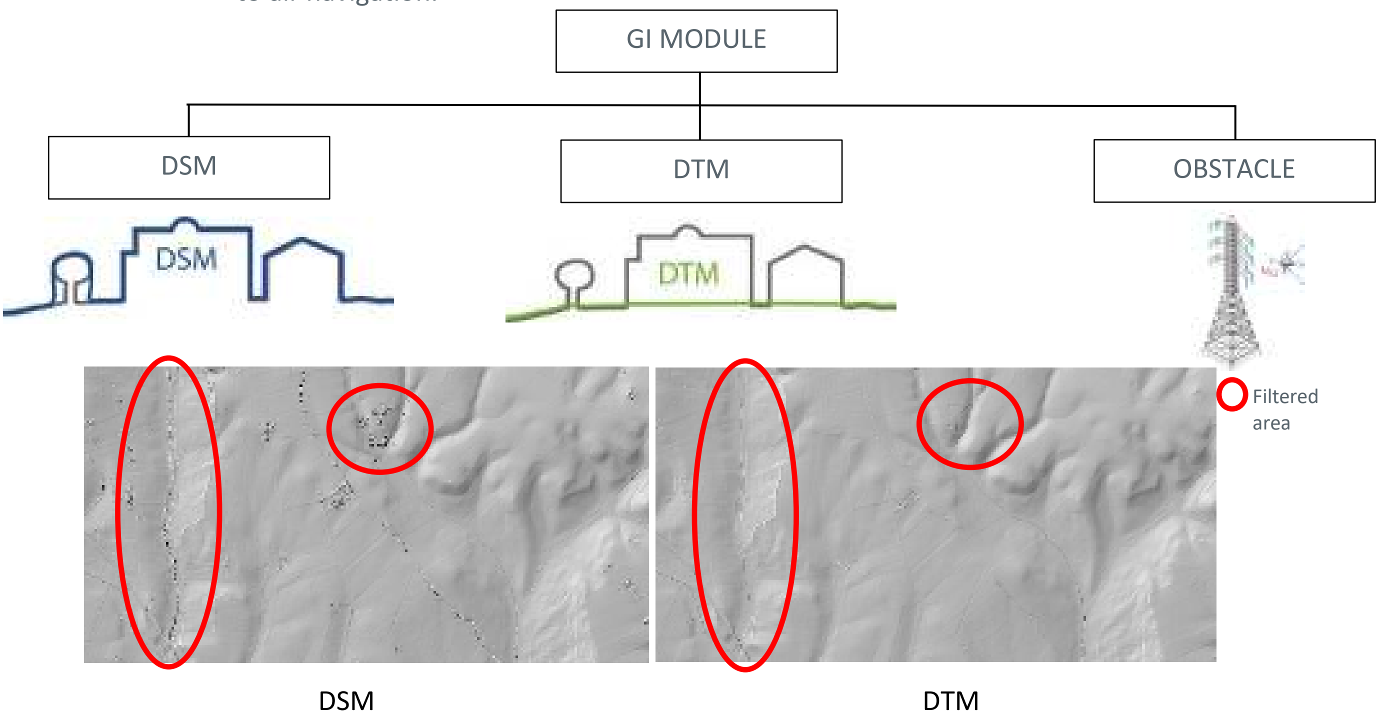

Figure 2-1: DTM/DSM overview

Founding Members
EUROPEAN UNION EUROCONTROL

The Geo-Information service receives input data from external data providers and allows the retrieval of DTM, DSM, and obstacle data. Data ingestion is triggered when mission planning is scheduled and data is physically transferred from external interfaces. Data are recovered both automatically and through physical support and inserted into local data storage. The data format is generally a raster type, such as GeoTiff or Image files. WGS84 is used as the datum and heights are orthometric. A quality check has to be performed to verify that the imported data comply in format type and reference frame with the specifications.

DEM data are very heterogeneous, so the terrain or surface model to be imported into the ICARUS system must provide the appropriate level of information required by the specific operation in terms of resolution and accuracy. The choice of the most suitable digital terrain/surface models is therefore related to the characteristics of the neighbourhood of the planned route, so there are two relevant use cases: urban areas or extra-urban areas.

In the first case, a detailed DSM city model is needed, with a 0.5-1.0 metre accuracy that can be higher in the case of historical centres. These requirements can be obtained from commercial and on-demand products generated from high-resolution/high accuracy photogrammetric aerial surveys.

In the case of transit over an extra-urban area, a DSM with an accuracy range of 5-10 metres is needed and can be obtained from satellite imagery products. This accuracy requirement is higher in the case of inspection of the area - in the range of 0.5-2.0 metres - and can be obtained from commercial and on-demand products generated from high resolution/high accuracy photogrammetric aerial surveys and high-resolution satellite images.

DSM/DTM

AREA	ACCURACY	GENERATED FROM	DATUM	COORDINATE SYSTEM	REPOSITORY
Urban Area	0.5 – 1 m	high resolution/high accuracy photogrammetric aerial surveys	WGS84	Geographic/ Cartographic	Commercial
Extra Urban Area	5 – 10 m	Satellite imagery	WGS84	Geographic/ Cartographic	Public (Free)
Inspection Area	0.5 – 2 m	high resolution/high accuracy photogrammetric aerial surveys and high resolution satellite images	WGS84	Geographic/ Cartographic	Commercial

Table 2-1: Recap of DTM/DSM features

The obstacle data must comprise the digital representation of the vertical and horizontal extent of the obstacles. Obstacles must not be included in terrain datasets, that is in the DSM, but obstacle data elements are features that must be represented in separate data sets by points, lines, or polygons. In an obstacle dataset, all defined obstacle feature types must be provided and each of them must be described according to the list of mandatory attributes.

2.2 Overview of the GI module interactions

Given the general introduction on the GI data in Section 2.1, we now provide an overview of the GI module interactions with the USSP service provider, with the GI data provider, and with the other internal ICARUS modules (see Figure 2-2).

This GI module is closely coupled to the GNSS one, which provides the more precise drone position needed to calculate heights with respect to the DTM and DSM, together with the undulation parameter. The undulation is related to the reference geoid for orthometric DTM/DSM heights, and is needed to switch from orthometric to ellipsoidal heights.

All these data are then forwarded to the vertical conversion service (VCS module) for the conversion from the geometric to the barometric reference system.

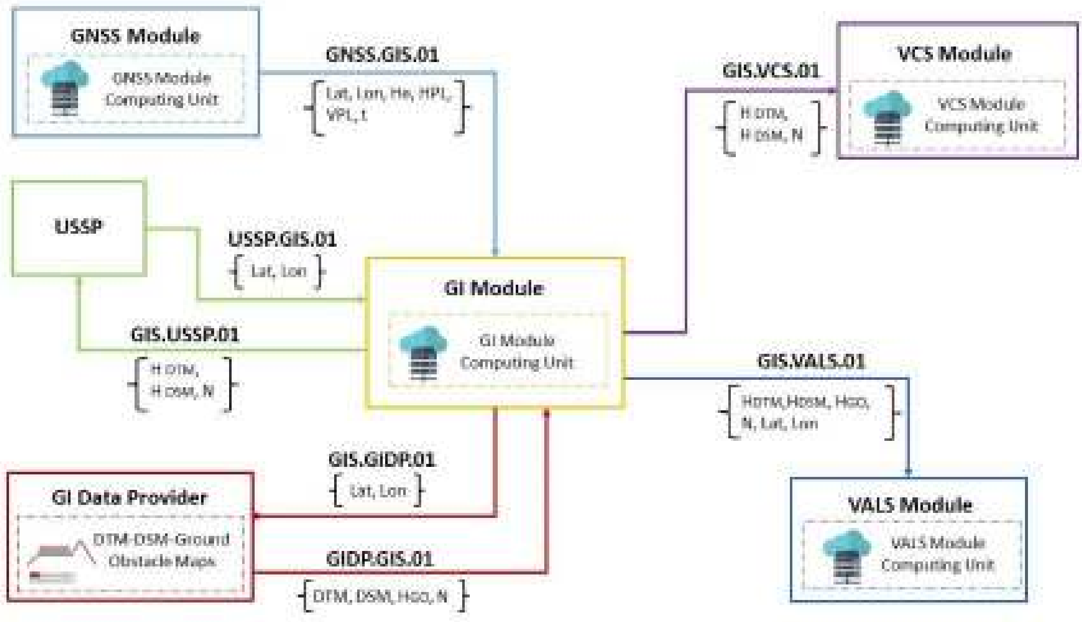

Figure 2-2: GI Module Interfaces (context diagram)

The list of the interfaces can be found in Table 2-2 (interfaces for incoming data) and Table 2-3 (interfaces for outgoing data).

Interface ID	Source	Destination	Internal / External[2]	Protocol	Data
USSP.GIS.01	USSP	GI Module Computing Unit	External	HTTP (S)	Latitude and longitude
GIDP.GIS.01	Geo Information Service Provider	GI Module Computing Unit	External	HTTP (S)	Latitude and longitude

[2] The distinction between "internal" and "external" indicates whether the source component belongs to ICARUS or not

Founding Members
EUROPEAN UNION EUROCONTROL

GNSS.GIS.01	GNSS Module	GI Module Computing Unit	Internal	MQTT	Unmanned aircraft traffic data: position, altitude, HPL, VPL, timestamp

Table 2-2: Interfaces for incoming data flows

Interface ID	Source	Destination	Internal / External[3]	Protocol	Data
GIS.USSP.01	GI Module Computing Unit	USSP	External	HTTP (S)	DTM Height, DSM Height, undulation
GIS.GIDP.01	GI Module Computing Unit	Geo Information Service Provider	External	HTTP (S)	DTM Height, DSM Height, Ground Obstacle Height, undulation
GIS.VALS.01	GI Module Computing Unit	VALS Module	Internal	HTTP (S)	DTM Height, DSM Height, Ground Obstacle Height, undulation
GIS.VCS.01	GI Module Computing Unit	VCS Module	Internal	HTTP (S)	DTM Height, DSM Height, undulation

Table 2-3: Interfaces for outgoing data flows

2.3 Interface description

2.3.1 USSP.GIS.01

This is an incoming external interface from the UTM/USSP platform to the GI Module. Through this interface, the USSP sends a query to the GI service. The answer is sent back through the GIS.USSP.01 interface.

The GI service is accessible using an HTTP POST request with target URI `/gi` and receives as input the following parameters in JSON format:

- `lat` is the latitude of the aircraft
- `lon` is the longitude of the aircraft

[3] The distinction between "internal" and "external" indicates whether the destination component belongs to ICARUS or not

When this interface is fed, the GI service starts its operations, which include the interaction with the GI Data Provider through the GIS. GIDP.01, and GIS.GIDP.01 interfaces.

The following is a sample request to the GI service:

```
{
    "lat": 52.39664053545001,
    "lon": 16.914957457864695
}
```

2.3.2 GIDP.GIS.01

This is an incoming external interface. Through this interface, the system is fed with DTM, DSM, ground obstacle data, and undulation parameter.

The data are obtained by means of an HTTP POST request sent through the GIS.GIDP.01 interface. Both DTM and DSM are orthometric heights provided in metres. The undulation parameter for the position requested is fundamental for switching from orthometric heights to ellipsoidal ones, and is also provided in metres.

2.3.3 GNSS.GIS.01

This is an incoming internal interface from the GNSS module to the GI modules. Through it, the GI module receives the "augmented" GNSS drone position. In other words, it receives a position made more precise thanks to advanced computations on unmanned raw data and enriched by some extra parameters which define its accuracy (position, altitude, Horizontal Protection Level, Vertical Protection Level, timestamp).

2.3.4 GIS.USSP.01

This is an outgoing external interface through which the GIS module sends both DTM and DSM heights, and the undulation parameter back to the USSP. They might then be used for mission planning purposes, or to forward them to drone operators.

The output received from this interface comes after a request to the GI service through the USSP.GIS.01 interface (see Section 2.2.1). The complete set of values, in JSON format, is:

- `coutry_code` is the two-letter code that identifies the state for input coordinates
- `h_dtm` is the height of the *Digital Terrain Model* for input coordinates
- `h_dsm` is the height of the *Digital Surface Model* for input coordinates
- `n` is the undulation value for input coordinates (this value refers to the geoid that is used to obtain the orthometric heights of DTM and DSM).

The following is a sample response from the GI service:

```
{
    "country_code": "PL",
    "h_dtm": 84.06,
    "h_dsm": 84.06,
    "n": 37.1836
}
```

2.3.5 GIS.GIDP.01

This is an outgoing external interface. Through this interface, the system asks for DTM, DSM, ground obstacle data, and the undulation parameter. The data are obtained through the GIDP.GIS.01 interface.

2.3.6 GIS.VALS.01

This is the outgoing internal interface through which the GIS module shares the DTM, DSM, ground obstacle data, and the N parameter with the VALS module. This data will then be used along with the Geodetic Altitude Mandatory Zone (GAMZ) map and the internal VALS module computations to provide an alert to drone operators in case of possible collisions with obstacles and terrain, or in case of manned aircraft or pilots crossing a GAMZ.

2.3.7 GIS.VCS.01

This is the outgoing internal interface. Through it, the GI module sends DTM and DSM heights and the undulation parameter to the VCS module. This information will then be used to compute both AGL and ASL heights.

3 GNSS Module

3.1 Overview of the GNSS Module interactions

The GNSS module provide the real-time information regarding the drone position and the integrity of the solution achieved to the other ICARUS subsystems. At the same time, the unit performs a check of the quality of the GNSS signal in the geographical area of interest, through the monitoring of the progress of the integrity parameters, providing a usability flag to the users.

Figure 3-1 gives an overview of the GNSS subsystem and its components. Details regarding the architecture, requirements and system composition can be found in other project deliverables ([1], [2]).

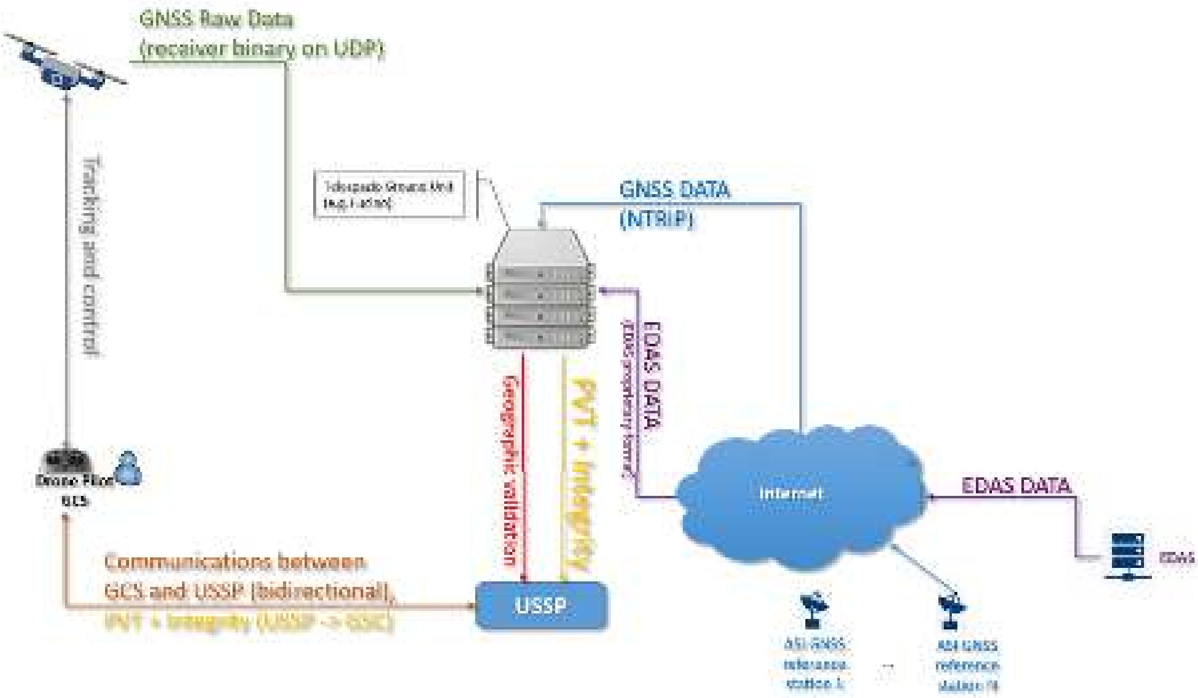

Figure 3-1: High-level diagram of GNSS subsystem

The context diagrams in Figure 3-2 and Figure 3-3 give a more detailed representation of the units of the subsystem and the data flows. The functionalities covered are described in Figure 3-4.

Founding Members
EUROPEAN UNION EUROCONTROL

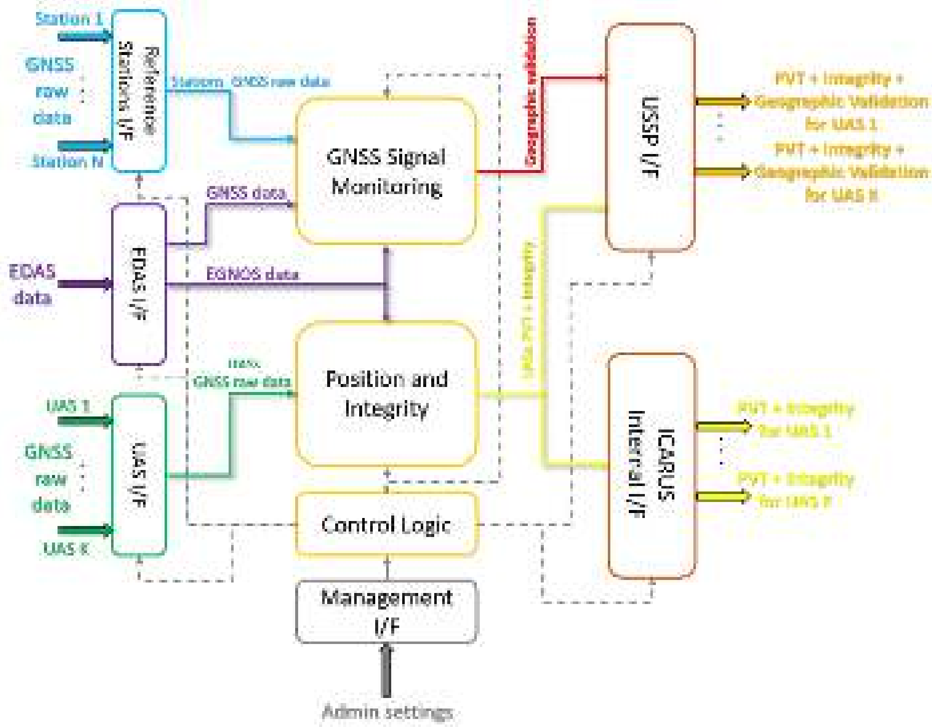

Figure 3-2: GNSS Module (context diagram) - direct access to GNSS raw data (IF UAS.TCU.01)

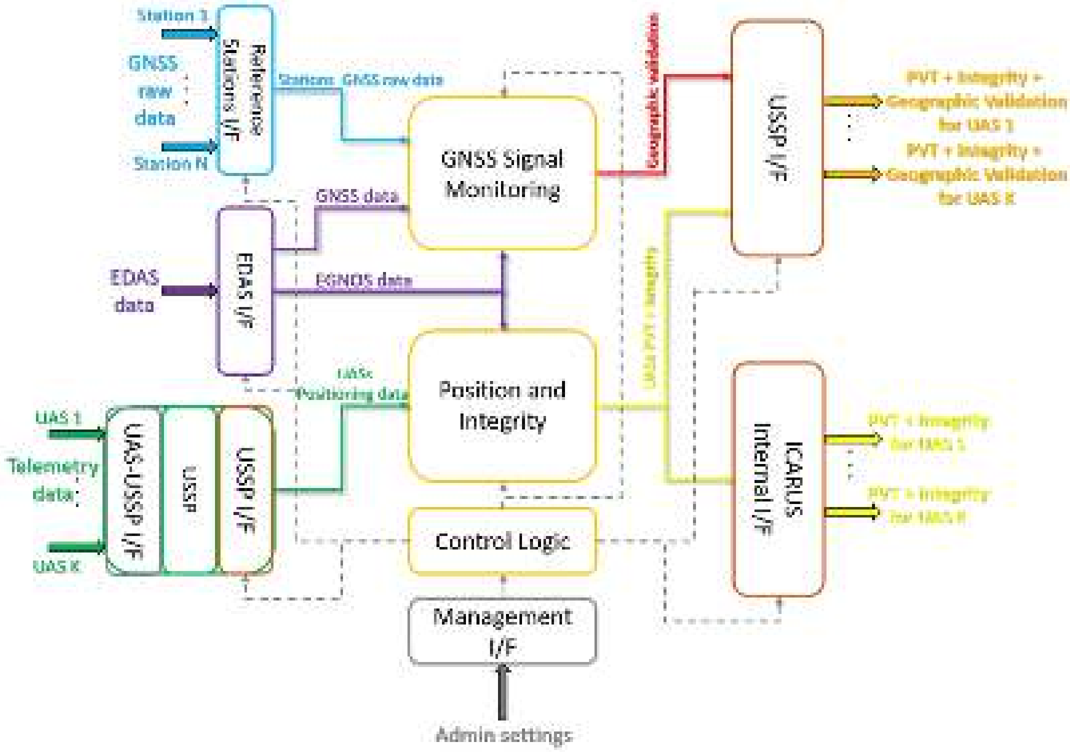

Figure 3-3: GNSS Module (context diagram) – no direct access to GNSS raw (IF USSP.TCU.01)

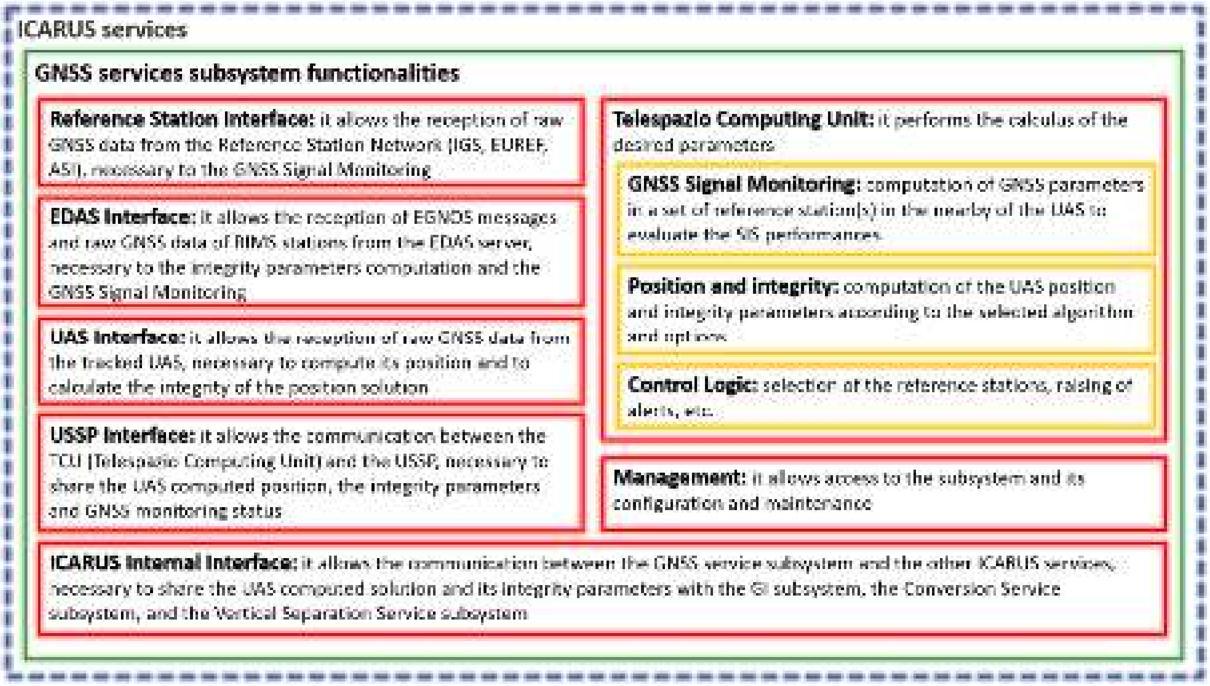

Figure 3-4: Functional architecture of the GNSS subsystem

Finally, the list of the interfaces is given in **Error! Reference source not found.** (interfaces for incoming data) and Table 3-2 (interfaces for outgoing data).

Interface ID	Source	Destination	Internal / External[4]	Protocol	Data
EDAS.TCU.01	EDAS	TCU[5]	External	EDAS proprietary	SBAS EGNOS messages, RIMS GNSS raw data
REF.TCU.01	IGS EUREF ASI trusted network	TCU	External	NTRIP	GNSS raw data
UAS.TCU.01	UAS	TCU	External	Receiver proprietary format	GNSS raw data

[4] The distinction between "internal" and "external" indicates whether the source component belongs to ICARUS or not

[5] TCU = Telespazio Computing Unit

Founding Members
EUROPEAN UNION EUROCONTROL

USSP.TCU.01	USSP	TCU	External	JSON on MQTT	Telemetry data
ADM.MAN.01	Administrator (authorised user)	Management unit	Internal	ssh access	Configuration files & settings

Table 3-1: Interfaces for incoming data flows

Interface ID	Source	Destination	Internal / External[6]	Protocol	Data
TCU.USSP.01	TCU	USSP	External	JSON on MQTT	Positioning, Integrity, Geographic Validation
TCU.GIS.01	TCU	Geo Information ICARUS subsystem	Internal	JSON on MQTT	Positioning, Integrity
TCU.VCS.01	TCU	Conversion Service ICARUS subsystem	Internal	JSON on MQTT	Positioning, Integrity
TCU.VALS.01	TCU	Vertical Alert ICARUS subsystem	Internal	JSON on MQTT	Positioning, Integrity

Table 3-2: Interfaces for outgoing data flows

3.2 Interface description

3.2.1 EDAS.TCU.01

This is the incoming interface between the EDAS server (data provider to the GNSS subsystem, external to ICARUS system) and the computing unit of the GNSS module. Through this interface the system is fed with:

- the EGNOS SBAS messages necessary for calculating the integrity parameters and the "geographic validation / signal monitoring";

[6] The distinction between "internal" and "external" indicates whether the destination component belongs to ICARUS or not

- the RIMS observation data, necessary to the "geographic validation / signal monitoring" function; and
- the broadcast navigation message, obtained by merging the different fluxes coming from the RIMS, useful for having a guaranteed, timely-provided navigation message for each function implemented by the computing unit.

This interface is composed of several stages:

1. Authentication to EDAS and reception of the flux of binary data, in a proprietary format, encapsulated within UDP, through COTS GSA software [3]
2. Multi-caster module, to allow the distribution of the data received to multiple processing instances through the TCP protocol
3. Data filtering and de-multiplexing, to extract three distinct fluxes:
   a. EGNOS SBAS messages, encapsulated within CORBA ([4]) messages
   b. GPS observation data from the single RIMS, encapsulated in RTCM
   c. GPS navigation data from merging several RIMS fluxes, encapsulated in CORBA
4. SBAS and navigation data message decoding, and their storage in software data structures that will be interrogated in real time by the processing modules of the TCU

3.2.2 REF.TCU.01

This is the interface between the reference stations used by the "GNSS Signal Monitoring" module that implements the GNSS monitoring, and geographic integrity validation functionalities. It consists of a set of NTRIP clients, that are connected (after authentication) to specific mount points of NTRIP casters belonging to the IGS, EUREF or ASI networks. Each mount point provides the GNSS raw data related to a specific station, encapsulated in the following RTCM messages (format specified in [5], [6]):

- RTCM 1004 and 1077: GPS raw data
- RTCM 1005 and 1006: antenna position
- RTCM 1097: Galileo raw data

3.2.3 UAS.TCU.01

This is the incoming interface between the UAS (to be more specific, its GNSS receiver module) and the computing unit of the GNSS module. The data flux consists of a binary data stream from the U-blox receiver ([7]), encapsulated in UDP packets and sent on a 4G/LTE data link by the UAS communication module. The TCU will act as the UDP server, the UAS as the UDP client. The connection will be established through VPN (the VPN server is hosted by Telespazio).

3.2.4 USSP.TCU.01

This is the incoming data interface used to receive telemetry (i.e. positioning data) from the USSP. It is implemented, activated and used only in the eventuality that the GNSS receiver module of the UAS is not capable of providing raw GNSS measurements to the TCU (see D3.1 "ICARUS Concept Definition" - §3.2.1 "Proposed solution: possible architecture", "case 2" [1], and D4.1 "Design and architecture of the ICARUS system & services" - §4.4.1 and §4.4.2 [2]). It is, therefore, an alternative interface to UAS.TCU.01; they do not coexist. To implement this interface, an MQTT Broker, such as Mosquitto, is foreseen for the collection and provision of the UAS's position data. The information is formatted in a JSON messages [8], published through the MQTT protocol over a secure websocket [9].

The MQTT topic mechanism is used to distinguish the different UASs whose the data are referred to. The main topic will be "icarus/ussp/positioning". The subtopics will be identified by the UAS identifiers. E.g., the data provided by the GNSS module referred to UAS "1234567890AB" will be published on the topic "icarus/ussp/positioning/1234567890AB".

The following tables give a description of the formatted data.

JSON section	Description
IDENTIFICATION	contains the UAS identification
STATEDATA	contains the position data of the UAS at a given time

Table 3-3: JSON sections

IDENTIFICATION SECTION	
Field	**Description**
UAId	Identification of the UA according ANSI/CTA-2063.
src	Type of data channel. Fixed to "3" (4G/LTE).
dev	Type of device source. TBD

Table 3-4: Identification section

STATEDATA SECTION	
Field	**Description**
time	Timestamp of position update; time of day in UTC. Format *dd/mm/yyyy HH:MM:SS.sss UTC*
lat	WGS-84 ellipsoid latitude in decimal format; unit of measure degrees.
lon	WGS-84 ellipsoid longitude in decimal format; unit of measure degrees.
height	WGS-84 ellipsoid height, in decimal format; unit of measure m.

Table 3-5: Statedata section

An example of a published JSON is:


```
{
        "identification":{
                "UAId":"1234567890AB",
                "src":3,
                "dev":
        },

        "statedata":{
                "time":"15/05/2020 17:22:26.711 UTC",
                "lat":42.123451,
                "lon":11.123451,
                "height":29
        }
}
```

3.2.5 ADM.MAN.01

This interface allows the authorised maintainer-operator to connect to the subsystem to carry out management operations. In the event of a connection from a different LAN from that used by the subsystems, it is necessary to set up a VPN connection between the two networks involved in advance. Regardless of everything, the connection to the modules in need of maintenance or configuration always takes place using the ssh protocol, where the connecting operator's workstation is the client and the modules accepting the connection act as servers.

3.2.6 TCU.USSP.01

This outgoing data interface is the only GNSS module interface through which the module provides data directly to an entity external to the ICARUS system. To implement this interface, an MQTT Broker, such as Mosquitto, is foreseen for the collection and sharing of the augmented (with integrity parameters) positioning solution with interested parties. The information is formatted in JSON messages [8], published through the MQTT protocol over secure web socket [9].

The MQTT topic mechanism is used to distinguish the different UASs whose the data are referred to. The main topic will be "icarus/satnav/positioning". The subtopics will be identified by the UAS identifiers. E.g., the data provided by the GNSS module referred to UAS "1234567890AB" will be published on the topic "icarus/satnav/positioning/1234567890AB".

The following tables give a description of the formatted data.

JSON section	Description
IDENTIFICATION	contains the UAS identification
STATEDATA	contains the position data of the UAS at a given time
AUGMENTATION	contains information about GNSS Augmentation system used (if any) to improve and validate positioning data

Table 3-6: JSON sections

IDENTIFICATION SECTION	
Field	**Description**
UAId	Identification of the UA according ANSI/CTA-2063.
src	Type of data channel. Fixed to "3" (4G/LTE).
dev	Type of device source. Fixed to "3" (Reserved to ICARUS GNSS Module).

Table 3-7: Identification section

STATEDATA SECTION	
Field	**Description**
time	Timestamp of position update; time of day in UTC. Format *dd/mm/yyyy HH:MM:SS.sss UTC*
lat	WGS-84 ellipsoid latitude in decimal format; unit of measure degrees.
lon	WGS-84 ellipsoid longitude in decimal format; unit of measure degrees.
height	WGS-84 ellipsoid height, in decimal format; unit of measure m.

Table 3-8: Statedata section

AUGMENTATION SECTION	
Field	**Description**

Founding Members
EUROPEAN UNION EUROCONTROL

POSAUGMode	GNSS Service Positioning Augmentation Mode. When greater than 0, positioning fields described in the "statedata" section are output by the augmentation system. 0: Service Unavailable 1: EGNOS with no integrity available 2: EGNOS 9: ARAIM 10: ARAIM in degraded mode (SF)
HPL	Estimated Horizontal Protection Level Integrity field, in decimal format. Unit of measure metres.
VPL	Estimated Vertical Protection Level Integrity field, in decimal format. Unit of measure metres.
GeoValidation	Geographic validation flag – ICARUS GNSS module specific. 0: geographic validation system unavailable [use at your own risk] 1: Normal condition, system working and performances as expected 2: Working without guarantees: locally performances within requirements, but NOT confirmed from geographic monitoring system 3: Local problem affecting the drone (e.g. multipath, interference): locally performances are bad, but geographic monitoring system reports nominal conditions 4: Not working, as expected

Table 3-9: Augmentation section

An example of a published JSON is:


```
{
	"identification":{
		"UAId":"1234567890AB",
		"src":3,
		"dev":3
	},

	"statedata":{
		"time":"15/05/2020 17:22:26.711 UTC",
		"lat":42.123451,
		"lon":11.123451,
		"height":29
	},

	"augmentation":{
		"POSAUGMode":9,
		"HPL":7.8,
		"VPL":12.5,
		"GeoValidation":1
	}
}
```


3.2.7 TCU.GIS.01, TCU.VCS.01, TCU.VALS.01

These are the interfaces through which the GNSS module shares the computed data with the other ICARUS modules that need the drone's augmented position information. They all present the same interface. As described above (§ 3.2.6), a MQTT Broker (e.g. Mosquitto), is foreseen for the collection and sharing of the augmented (with integrity parameters) positioning solution with the interested parties. The information is formatted in JSON messages, whose structure is the same described by Table 3-6, Table 3-7, Table 3-8, and Table 3-9. For the modules belonging to the same LAN (e.g. GI, CS), the publishing mechanism is MQTT over TCP with basic authentication. For the external modules (e.g. VA), the specifications of § 3.2.6 are applied.

The MQTT topic mechanism is used to distinguish the different UASs whose the data are referred to. The main topic will be "icarus/satnav/positioning". The subtopics will be identified by the UAS identifiers. E.g., the data provided by the GNSS module referred to UAS "1234567890AB" will be published on the topic "icarus/satnav/positioning/1234567890AB".

4 VCS Module

This chapter is dedicated to the definition and description of the ICDs relating to the VCS module.

4.1 Overview of the VCS Module interactions

The VCS module provides the Vertical Conversion Service (VCS), which converts the heights provided as input from a barometric to a geometric reference system, and vice versa.

As shown in Figure 4-1, it directly interacts with the U-Space Service Provider (USSP), with the other internal ICARUS modules, and with the Weather Data Provider that gets data from a set of distributed weather reference stations.

The VCS module can determine and share current aircraft altitude with respect to the Earth's surface (buildings and ground obstacles), terrain, mean sea level, ellipsoid and geoid model.

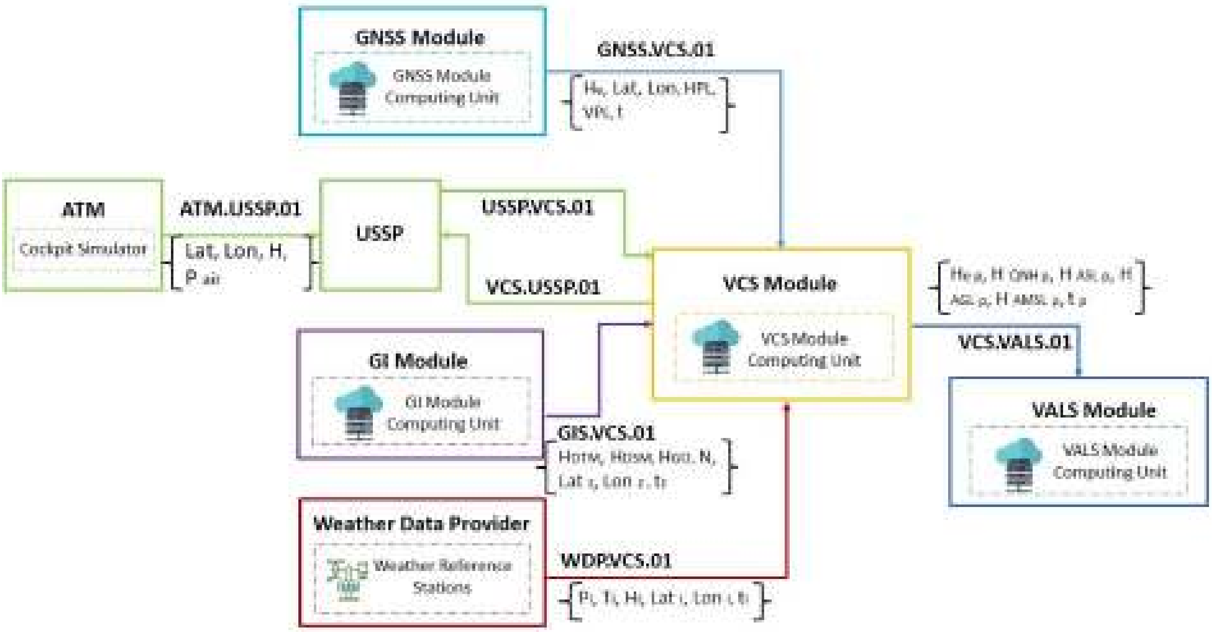

Figure 4-1: VCS Module Interfaces (context diagram)

Interface ID	Source	Destination	Internal/ External[7]	Protocol	Data
WDP.VCS.01	Weather Data Provider *(Regional Average QNH, Ground weather reference stations data)*	VCS Module Computing Unit	External	HTTP(S)	Pressure, Temperature, Orthometric Height, Timestamp of the ground weather reference stations
ATM.USSP.01	ATM Traffic Data *(from Cockpit simulator)*	USSP	External	HTTP(S)	Manned aircrafts traffic data: position, altitude, timestamp and regional average QNH
USSP.VCS.01	USSP	VCS Module Computing Unit	External	HTTP(S)	Manned and Unmanned aircrafts traffic data: position, altitude, timestamp and regional average QNH
GNSS.VCS.01	GNSS Module	VCS Module Computing Unit	Internal	MQTT	Unmanned aircrafts traffic data: position, altitude, HPL, VPL, timestamp
GIS.VCS.01	GI Module	VCS Module Computing Unit	Internal	HTTP(S)	DTM, DSM, undulation

Table 4-1: Interfaces for incoming data flows

Interface ID	Source	Destination	Internal / External	Protocol	Data
VCS.USSP.01	VCS Computing Unit	USSP	External	HTTP(S)	Height above terrain, surface, sea level, ellipsoid, geoid

[7] The distinction between "internal" and "external" indicates whether the source component belongs to ICARUS or not

Founding Members
EUROPEAN UNION EUROCONTROL

VCS.VALS.01	VCS Computing Unit	VALS Module	Internal	HTTP(S)	Height above terrain, surface, sea level, ellipsoid, geoid

Table 4-2: interfaces for outcoming data flows

4.2 Interface description

4.2.1 WDP.VCS.01

This is an incoming external interface that connects the Weather Data Provider to the computing unit of the VCS Module. Through this interface, the VCS service retrieves pressures, temperatures, positions, and orthometric height data of a distributed network of ground weather reference stations. This data will then be exploited to calculate the QNH pressure value for that point, given a certain set of coordinates where an aircraft is flying.

The Weather Data Providers are needed for accessing the regional average QNH pressure values. These are pressure values related to a certain region, which are computed and broadcast periodically by meteorology authorities. These values are used by airplanes at the airport, before landing, to calibrate their altimeter. Figure 4-2 gives an example of QNH region distribution for Poland.

These two QNH pressure values are fundamental for the conversion algorithm calculation.

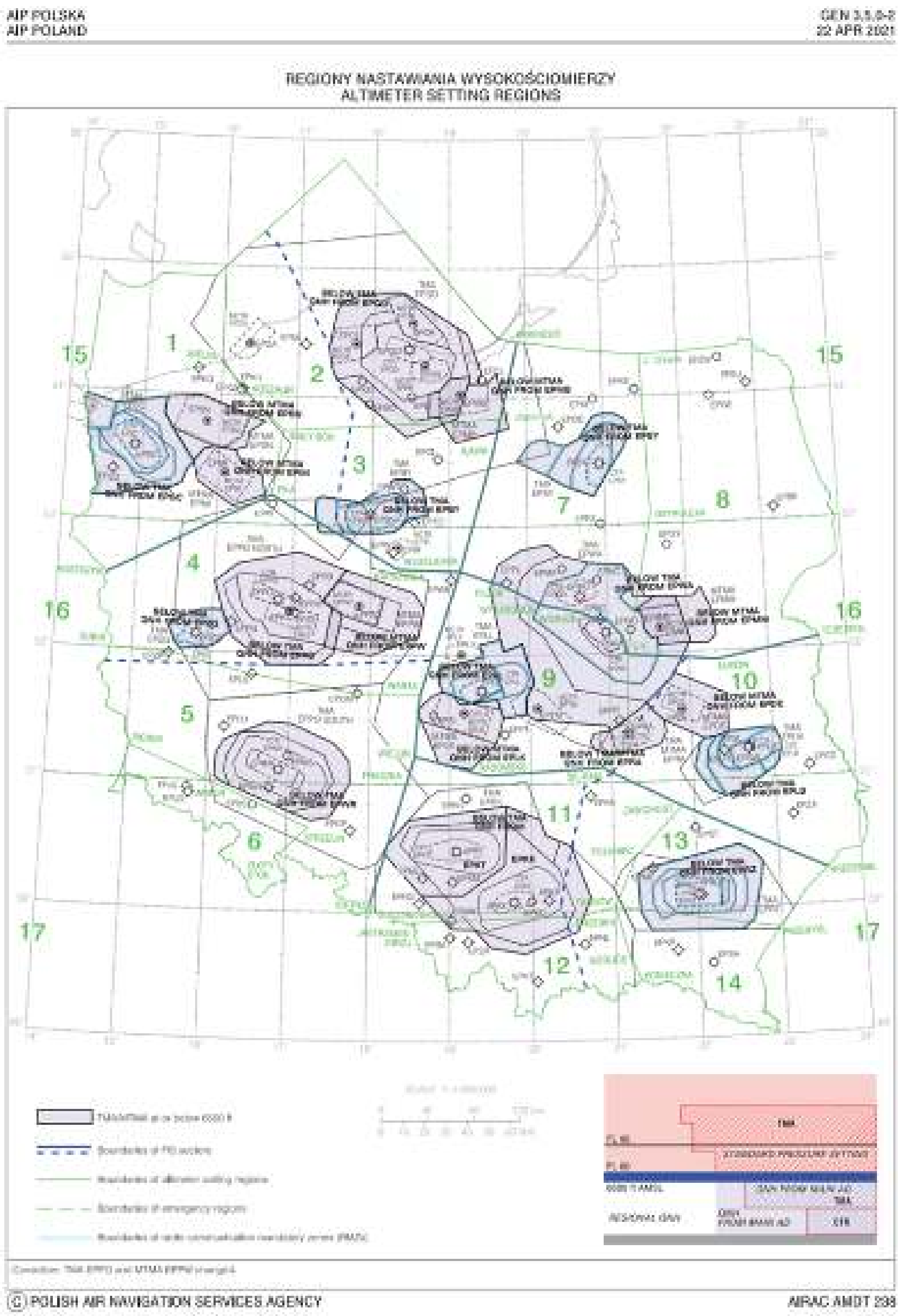

Figure 4-2: QNH region graphical description for Poland

Founding Members
EUROPEAN UNION EUROCONTROL

4.2.2 ATM.USSP.01

This is an incoming external interface. It connects the ATM service provider to the U-Space Service Provider. Through this interface, the ICARUS prototype receives simulated manned traffic data, together with regional average QNH. These values are necessary to compute the conversion from the barometric to the geometric reference system and vice versa.

4.2.3 USSP.VCS.01

This is an incoming external interface used to query the VCS service. The answer is sent back through the VCS.USSP.01 interface.

The service is accessible using an HTTP POST request with target URI `/conversion` and receives as input the following parameters:

- `vehicle_type` has to be equal to 0 if the request is coming from a drone, or equal to 1 for airplane requests.
- `h_obs_qne` the observed height over QNE in metres *(in case of an airplane request)*
- `h_ell` the ellipsoidal height in metres *(in case of a drone request)*
- `p_w` is the pressure in hectopascals (hPa) of the weather station nearest to the vehicle that is asking for conversion
- `h_w` is the orthomeric height (in metres) of the weather station nearest to the vehicle that is asking for conversion
- `p_qnh_airport` is the average QNH pressure in hectopascals (hPa) for the region in that the airport is located
- `h_dtm` the DTM height (in metres)
- `h_dsm` the DSM height (in metres)
- `n` is the *geoid undulation* in metres (height of the geoid relative to a given reference ellipsoid)

The following is a sample request for the drone case:

REQUEST

```
{
    "vehicle_type": 0,
    "h_ell": 199.6275431,
    "p_w": 1000,
    "h_w": 100,
    "p_qnh_airport": 1021,
    "h_dtm": 91,
    "h_dsm": 110,
    "n": 10
}
```

A sample request for the airplane case:

```
{
    "vehicle_type": 1,
    "h_obs_qne": 300,
    "p_w": 1000,
```

```
    "h_w": 100,
    "p_qnh_airport": 1021,
    "h_dtm": 91,
    "h_dsm": 110,
    "n": 10
}
```


4.2.4 GNSS.VCS.01

This is an incoming internal interface from the GNSS module to the VCS one. Through this interface, the VCS module receives advanced GNSS computations on unmanned aircraft traffic data. In particular, it receives a more accurate aircraft position. Indeed, the GNSS module, thanks to advanced computations, can refine drone positioning by providing accuracy parameters on both vertical and horizontal coordinates. The "augmented" data from the GNSS module will be position, altitude, horizontal protection level, vertical protection level, and timestamp.

4.2.5 GIS.VCS.01

This is an incoming internal interface from the GI module to the VCS one. Through this interface, the VCS module receives orthometric DTM and DSM heights, and the undulation parameter.

This information is used to calculate the barometric to geometric conversion or vice versa when a query from a vehicle or air traffic authority comes through the USSP provider (USSP.VCS.01).

4.2.6 VCS.USSP.01

This is the outgoing external interface through which the conversion output is provided from the VCS module to the USSP users.

The output is sent through this interface after a request to the VCS service through the USSP.VCS.01 interface (see Section 4.2.3). The output, which is sent in JSON format, is composed of five of the following heights:

- `h_ort` the orthometric height of the requesting vehicle in metres
- `h_obs_qnh` the orthometric height of the requesting vehicle with respect the QNH of the runway (in metres)
- `h_agl` the orthometric height of the aircraft with respect the DTM (in metres)
- `h_asl` the orthometric height of the aircraft with respect the DSM (in metres)
- `h_obs_qne` the orthometric height of P respect the QNE in metres *(only for drone requests)*
- `h_ell` the ellipsoidal height of P requesting vehicle in metres *(only for airplane requests)*

The following is a sample response for the drone case:


```
{
    "h_ort": 189.6275431,
    "h_obs_qnh": 125.58885128571274,
    "h_agl": 98.6275431,
    "h_asl": 79.6275431,
    "h_obs_qne": 300.03765657983604
}
```


The following is a sample response for the airplane case:

```
{
    "h_ort": 189.5897920936827,
    "h_obs_qnh": 125.55104551132536,
    "h_agl": 98.58979209368269,
    "h_asl": 79.58979209368269,
    "h_ell": 199.5897920936827
}
```


4.2.7 VCS.VALS.01

This is the outgoing internal interface through which the VCS module shares the conversion output (described in Section 4.2.6) with the VALS module, which will use it to provide the alerting service explained in Section 5.

5 VALS Service

5.1 VALS Overview

In traditional manned aviation, paragraph 6.15.7 of Part I (Commercial Air Transport by Aeroplanes) of Annex 6 (Aircraft Operation) to the Chicago Convention (ICAO) requires that a Ground Proximity Warning System (GPWS) shall automatically provide a timely and distinctive warning to the flight crew when the aeroplane is in potentially hazardous proximity to the earth's surface.

This GPWS only relies on on-board sensors to measure the height above terrain (e.g. radar-altimeter).

A new "Enhanced Ground Proximity Warning System" (EGPWS) system for manned aviation was introduced in 1997. The EGPWS, in addition to the airborne height sensors, is based on a worldwide digital terrain database and relies on satellite positioning technology.

Key features of the EGPWS are continuing reliance on on-board sensor (e.g. radar altimeter) to detect distance from terrain, satellite positioning and digital terrain information. The latter is loaded on the manned aircraft before take-off. Besides GNSS signals, no other external service supports EGPWS.

EASA and FAA, through European/Technical Standard Order (E/TSO) C151d, name this enhanced system Terrain Awareness Warning System (TAWS). So the terms EGPWS or TAWS are equivalent.

Conversely, VALS is a U-Space (alias UAS Traffic Management -UTM) service:

a) That requires no sensors on board in addition to the satellite navigation receiver; and
b) That relies on calculations on the ground, by a VALS UTM SP, to alert about the risk of collision with terrain or obstacles.

As such, VALS is suitable for small unmanned aircraft or also for light manned helicopters or manned aeroplanes flying at very low level. Not only because no sensors additional to the GNSS receiver are required on-board, but also because resources on board are neither required for storing large databases on board, nor for calculations of the alerts.

Furthermore, since the VALS UTM SP only transmits the alert, and not large amounts of digital terrain data, no large bandwidth is required for transmission.

Based on the above assumptions, ISO DIS 23629-12 defines VALS as:

"Safety-critical UTM service that alerts manned and unmanned aircraft about their current vertical distance from the surface or obstacles, based on the common geodetic reference system, when this distance becomes too small".

This definition implicitly implies that the alert is in fact calculated on the ground and then transmitted to the aircraft or Command Unit (CU) by the VALS SP.

In other words, VALS is a system that provides the pilot with alerts triggered by calculations on the ground. The alerts originate from a ground UTM system, when a potentially hazardous terrain situation

Founding Members
EUROPEAN UNION EUROCONTROL

is detected. Calculations are based on the drone position and vector transmitted to the UTM SP through the Network (Electronic) Identification Service (NIS) and digital terrain data available on the UTM system.

5.2 Principle of operation

The VALS (Vertical Alert Service) is a system that provides the UAS Pilot with information and alerts on detection of a potentially hazardous terrain situation and so that the UAS pilot may take effective action to prevent a crash event. The principal idea of the VALS service is shown in Figure 5-1. The main idea is to raise an alarm whenever the defined 3D safety-space buffer (FLTA, Forward Looking Terrain Avoidance) is breached by any type of obstacle on the UAS heading.

Figure 5-1: Example of VALS application operation

The VALS automatically provides a distinctive warning to pilots via a dedicated interface (VALS.USA.01), based on mathematical calculations of combined:

- 3D location
- FLTA buffer defined by its dimensions (Vertical Alert Buffer, VALB – Horizontal Alert Buffer, HALB – Width Alert Buffer, WALB)
- Known DSM

whenever it detects potentially hazardous proximity to the earth surface, including known obstacles.

The information may be conveyed to the pilot through the cockpit avionics of manned aircraft, through a portable Electronic Flight Bag (EFB) or on the remote pilot's Command Unit (CU). In fact, since very limited IT resources are required on-board, the service might be exploited also through a portable EFB.

Having received the information, the pilot may take effective action to prevent collision with terrain or with obstacles.

VALS may also be coupled with the airborne autopilot for automatic initiation of the escape manoeuvre.

In the initial (prototype) version, VALS will provide a Forward Looking Terrain Avoidance (FLTA*) function. The FLTA function looks ahead of the UAS along and below its lateral and vertical flight path and provides suitable alerts if a potential collision threat exists.

It is assumed that the VALS function will be available for all flight phases. In operational applications, there will be the possibility of turning it off in the case of landing and take-off operations during which the approach to the terrain/surface will be performed consciously.

TAWS equipment is classified as Class A or Class B according to the degree of sophistication of the system. In essence, Class A systems are required for all but the smallest commercial air transport aircraft, while Class B systems are required by larger General Aviation (GA) aircraft and recommended for smaller commercial or GA aircraft. Full details of regulatory requirements are given later in this article. (source Skybrary)

Similarly, VALS would provide functionality equivalent to Classes rate EGPWS/TAWS, so issuing alerts (examples):

- regardless of the aircraft speed
- only in the event of a calculated conflict in the space volume specified by VALS
- regardless of the phase of flight
- only to the pilot (not the UTM system)
- regardless of the size and maximum technical speed of the aircraft

In any case, the information provided by the VALS provider from the ground remains identical whichever the receiving device on-board the aircraft.

5.2.1 Requirement to connect to VALS

For the purpose of the ICARUS project, the use of the VALS system did not consider the potential risk it may pose in the event of a collision with terrain or an obstacle, in the context of verification of initial airworthiness for integration on-board. Such a verification should be carried out, when required, by the aircraft integrator, based on provisions issued by organisations dealing with GRC risk analysis (e.g. JARUS, EASA, FAA).

5.2.2 Response to a VALS Activation

The VALS safety alert indicates that the aircraft is in a dangerous situation and immediate action is required to avoid collision with terrain or obstacles. This means that the alert should be followed without hesitation as soon as received.

Appropriate VALS response procedures for a UAS pilot are determined after careful study of the performance capabilities of the aircraft model involved.

The maximum achievable performances (e.g. turn rate, rate of climb) must be clearly defined by the aircraft designer and published in the flight manual or equivalent document.

Founding Members
EUROPEAN UNION EUROCONTROL

In the case of a manoeuvre commanded by the pilot, s/he would be responsible for respecting the aircraft limitations. In the case of an automatic manoeuvre commanded by the autopilot, the aircraft designer is responsible for ensuring that the manoeuvre is feasible.

5.2.3 VALS Alert dissemination

For VALS, equivalent to a Class A EGPWS/TAWS, it is assumed that the alert will be communicated by the appropriate VALS system to the pilot, in the cockpit of the UAS CU. While the VALS alert will be generated at the level of UTM systems on the ground, manoeuvring the aircraft in response to the alert to avoid collision with terrain or obstacles, remains solely the responsibility of the pilot, either directly or through monitoring the action of the autopilot.

5.2.4 FLTA (Forward Looking Terrain Avoidance) buffer size

FLTA buffer size will be determined according to the following parameters:

1) Heading or bearing
2) performance parameters enabling the calculation of the horizontal distance to the potential impact (HALB)
3) performance parameters enabling calculation of the vertical distance to the potential impact (VALB)
4) Contingency volume (WALB)

Parameters 2), 3) and 4) will be calculated according to information received from the UAS (or its CU) through the NIS.

5.3 VALS Functional Architecture

The functional architecture of the VALS service is shown in Figure 5-2. It relies on data received from the UAS (telemetry and FLTA buffer definition) and the reference DSM terrain model obtained from the internal GI Service of the ICARUS CARS. The outgoing alert is raised whenever the alert conditions are met - any of the predefined FLTA buffers are breached by the terrain or obstacle. The alert carries the distance to the identified obstacle.

Error! Reference source not found.

Figure 5-2: VALS service architecture

The Table 5-1 contains the summary of mentioned incoming data interfaces. The Table 5-2 summarizes alert interface of the service.

Interface ID	Source	Destination	Internal / External[8]	Protocol	Data
UAS.VALS.01	UAS	VALS	External	RabbitMQ	Telemetry + HALB, VALB, WALB
GIS.VALS.01	GI Service	VALS	Internal	GeoTIFF	Digital surface model data

Table 5-1: Incoming VALS interfaces

Interface ID	Source	Destination	Internal / External	Protocol	Data
VALS.UAS.01	VALS	UAS	External	RabbitMQ	Alert containing the shortest distance to obstacle

Table 5-2: Outgoing VALS interface

5.3.1 UAS.VALS.01

This interface is used to feed the VALS service, which requires telemetry data of the given UAS as well as additional specific 3D parameters describing the expected FLTA buffer:

- VALB (Vertical Alert Buffer) – parameter describing the height of the VALS buffer
- HALB (Horizontal Alert Buffer) – parameter describing the length of the VALS buffer
- WALB (Width Alert Buffer) – parameter describing the width of the VALS buffer

5.3.2 GIS.VALS.01

This interface is used to feed the VALS service with the reference DSM model (to be provided by the GI service). A more precise DSM model will increase the effectiveness of the VALS. This is why the VALS algorithm should be considered to be highly scalable (vertically and horizontally). The expected format of DSM data exchanged is GeoTIFF.

5.3.3 VALS.UAS.01

This interface is used to provide the alert to the UAS. Most probably, the most appropriate method to distribute this information would be pub/sub type of interface (e.g., RabbitMQ).

[8] The distinction between “internal” and “external” indicates whether the destination component belongs to ICARUS or not

6 Cockpit simulator ICD and SW Interfaces

The external interfaces of the cockpit simulator are described in the following architecture (from D5.3). In this document, a specification of the ICD and SW interface with the D-flight USSP is provided.

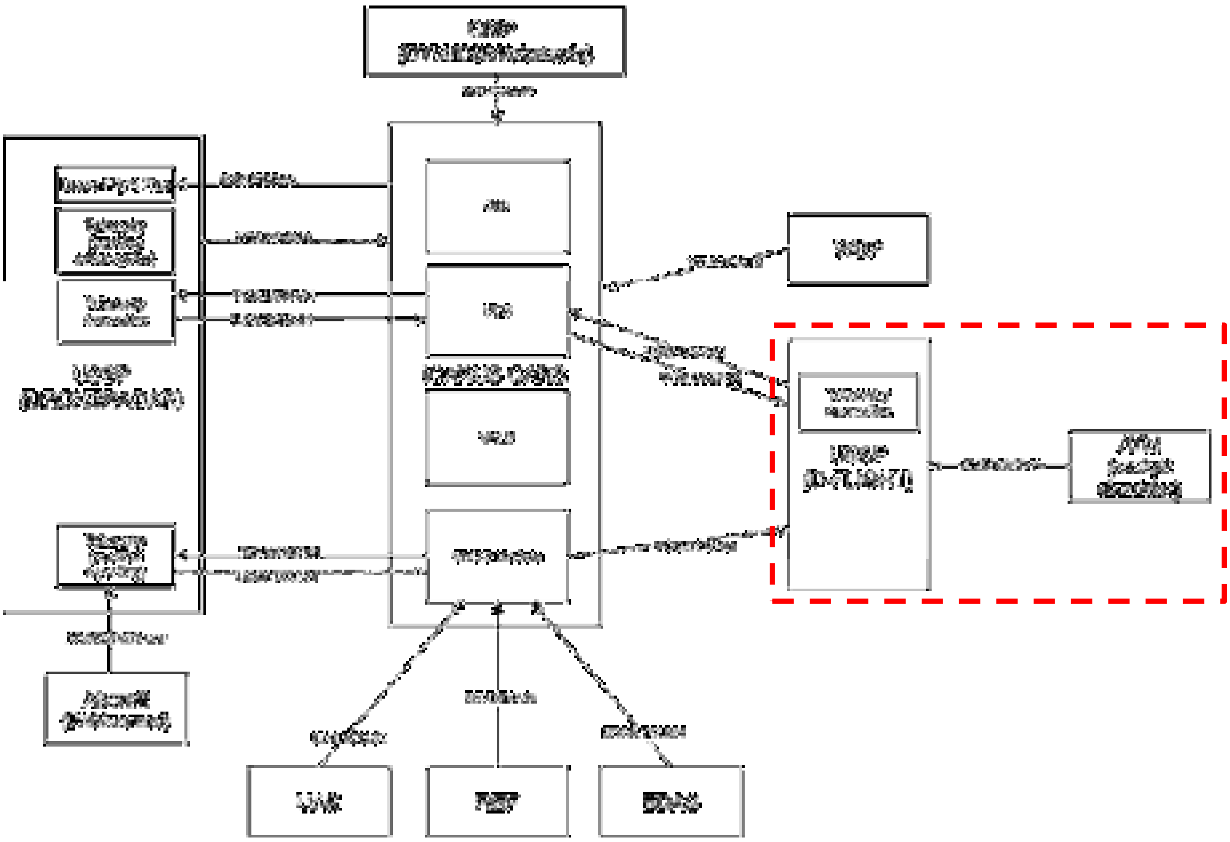

Figure 6-1: ICARUS testbed architecture and interface ATM.USSP.01 with Cockpit simulator

6.1 ATM.USSP.01 - USSP D-Flight

The cockpit simulator interface that communicates with D-Flight is a one-way interface that is developed specifically to interface the USSP, according to D-Flight public ICD **Error! Reference source not found.**. The interface developed to exchange position information of the simulated airplane with D-flight uses the JSON protocol.

The cockpit simulator has a native section with a graphical user interface as shown in Figure 4-2 for streaming different typologies of useful data including position, height, UTC time and any kind of simulation data.

These data are wrapped in a developed software interface capable of adapting the data generated with the D-Flight ICD using a JSON mechanism for communication.

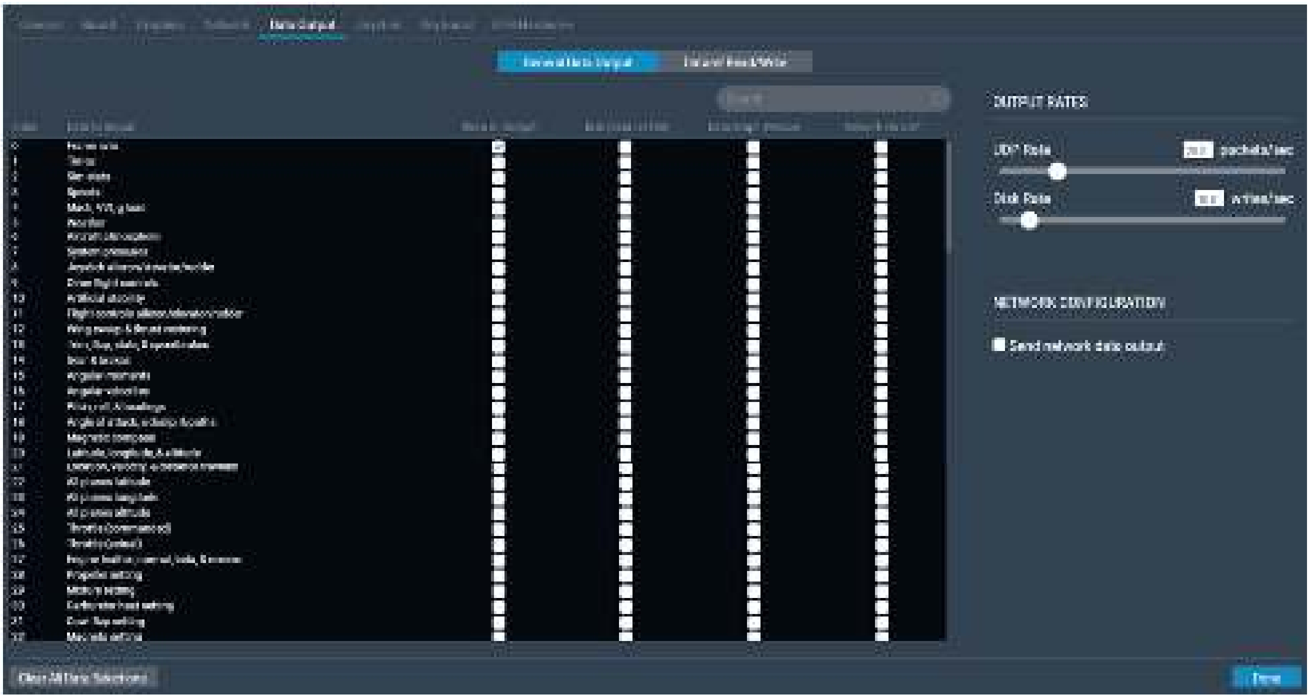

Figure 6-2: Data Output section from Cockpit Simulator

The tracking information of an airplane is sent in the same way as that of drones that use a physical UTM box located inside the drone. In this particular case, the data are generated by a developed software plugin inside the main computer of the cockpit simulator. Basic telemetry/position information is dispatched from the cockpit simulator, including the height and the ground speed. Additional information cannot be sent with the current version of the D-flight ICD, however an additional release of the ICD (v1.3) is expected at the beginning of 2022.

6.1.1 Tracking Message Specification

Tracking message specification (JSON) for interface ATM.USSP.01

The payload forwarded to the U-space platform has a JSON format composed of different basic sections:

1. IDENTIFICATION: the UA or aircraft identification and the operator identifications;
2. STATEDATA: the position data of the UA at a given time
3. STATUS: the health of the main devices and the accuracy of the position and speed values reported in the STATEDATA section
4. INTENT: the future intention of the UA as the next waypoint position and altitude
5. APPLICATION: data that is required only for certain purposes or applications, and specifically the take-off and the RPS position
6. GEFENCING: the time of last geo-fencing database update
7. AUGMENTATION: information about the GNSS augmentation system used by the aircraft or UAS (if any) to improve and validate positioning data
8. RAW DATA: raw satellite data information retrieved from GPS receiver

A single payload is composed of:

- IDENTIFICATION section
- One or more of the remaining basic sections, according to interface description

This composition makes it easy to specify different rates of transmission for each different section and permits the throughput required to be reduced.

Transmission rates

The frequency of transmission shall be (recommendation EUROCAE WG-105):

STATEDATA	At a 2 Hz rate as a minimum when airborne At a 1 Hz otherwise
STATUS	As soon as a change occurs At a 0.1 Hz rate as a minimum otherwise
INTENT	2 Hz rate as a minimum when the UA is flown manually 0.1 Hz rate as a minimum when the UA is flown in automatic mode
APPLICATION	At a 2 Hz rate as a minimum when airborne At a 0.1 Hz rate as a minimum otherwise
GEFENCING	As soon as a change occurs At a 0.1 Hz rate as a minimum otherwise
AUGMENTATION	At a 2 Hz rate as a minimum when airborne At a 1 Hz otherwise

Table 6-1: frequency of transmission

Identification section layout

Element	Description	Mandatory
UAId	Identification of the aircraft or UA according to ANSI/CTA-2063	**Y**
OpId	Operator identification	**N**
src	Type of data channel. This can be: 0=Bluetooth, 1=WIFI, 2=Lora, 3=4G/LTE, 4=Satellite	**Y**
dev	Type of device source. This can be: 0=U-Box on board, 1=U-Box at of GCS, 2=Virtual U-Box, 3=Reserved, 4=Drone operation area	**Y**

Table 6-2: Identification section layout

State data section layout

Element	Description	Mandatory
time	Timestamp of position update Time of day in UTC When transmitted as string, use at least 3 decimal digits,	**Y**
lat	WGS-84 latitude Latitude in decimal format. Unit of measure deg When transmitted as string, use at least 5 decimal digit	**Y**
lon	WGS-84 longitude Longitude in decimal format. Unit of measure deg When transmitted as string, use at least 5 decimal digits	**Y**
height	WGS-84 height Height in decimal format. Unit of measure m When transmitted as string, use at least 1 decimal digit	**Y**
altitudeMSL	Altitude above Mean Sea Level Altitude in decimal format. Unit of measure m When transmitted as string, use at least 1 decimal digit	**N**
speedNS	Ground speed North axis Speed in decimal format. Unit of measure m/s When transmitted as string, use at least 2 decimal digits	**N**
speedEW	Ground speed East axis Speed in decimal format. Unit of measure m/s When transmitted as string, use at least 2 decimal digits	**N**
VRate	Climb/descent rate Vertical Speed in decimal format. Unit of measure m/s When transmitted as string, use at least 2 decimal digits	**N**

Table 6-3: State Data section layout

Size of messages

Following the above specification, the JSON message can have an approximate size of 1.4-2.2kB (depending whether the advanced telemetry information is part of the message).

JSON/ZIP format

Compressed data, in zip or tgz formats, is supported when sending messages on specific interfaces. Compression rates have been seen to be around 55-66%, resulting in a message file size of around 600-750 Bytes.

7 Applicable and reference documents

[1] ICARUS D3.1, "ICARUS Concept Definition: State-Of-The-Art, Requirements, Gap Analysis".

[2] ICARUS D4.1, "Design and architecture of the ICARUS system & services".

[3] https://egnos-user-support.essp-sas.eu/new_egnos_ops/services/edas-service/downloads

[4] Common Object Request Broker Architecture (CORBA) standard, http://www.ois.com/Products/what-is-corba.html

[5] RTCM STANDARD 10410.1, "Networked Transport of RTCM via Internet Protocol", 28/06/2011.

[6] RTCM STANDARD 10403.2, "Differential GNSS (Global Navigation Satellite Systems) Services", 01/02/2013.

[7] ZED-F9P u-blox F9 high precision GNSS receiver - Interface Description, https://www.u-blox.com/sites/default/files/ZED-F9P_InterfaceDescription_%28UBX-18010854%29.pdf

[8] IETF, "The JavaScript Object Notation (JSON) Data Interchange Format", https://www.rfc-editor.org/rfc/rfc8259.html

[9] MQTT-V5.0-OS, "MQTT Oasis Standard", 07/03/2019.

Founding Members

EUROPEAN UNION EUROCONTROL