"5G for Drone-based Vertical Applications"

D2.1 – Initial definition of the trial controller architecture, mechanisms, and APIs

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Executive Summary

5G!Drones deliverable D2.1 reports an initial version of the trial controller architecture, its mechanisms and APIs. It aims to support different objectives of WP2 among which: the design and implementation of the 5G!Drones software layer for executing UAV trials, and the design of a high-level scenario descriptor language for running and analysing the UAV trials.

Deliverable D2.1 further expands the high-level architectural design proposed in T1.4 and reported in the deliverable D1.3. While the latter has introduced a high-level overview of the 5G!Drones architecture, this deliverable focuses more on the trial controller and further details its components. Moreover, the present deliverable also emphasizes further the definition of the reference points. These reference points are derived based on the proposed trial controller architecture and contribute towards the definition of the different APIs of the trial controller. Furthermore, initial supporting mechanisms and algorithms that can be considered to ensure safe & secure preparation and deployment of the trials (e.g., UAV traffic modelling, flight planning, security) are discussed and analysed in this deliverable.

The deliverable will serve as the basis for the next release of the trial controller architecture, mechanisms and APIs (D2.4). Therefore, this deliverable emphasizes several aspects and potential updates to be considered in D2.4. This deliverable will also serve as a basis for WP4 to integrate the different components, test them and perform validation of the overall system.

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List of Abbreviations

5G	5th Generation of Cellular Network
5GNR	5G New Radio
ABAC	Attribute Based Access Control
AMF	Access and Mobility Management Function
API	Application Programming Interface

AppD	Application Descriptor
ARC	Airworthiness Review Certificate
ATM	Air Traffic Management
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CN	Core Network
CRL	certificate revocation list
dFPL	Drone Flight Plan
Dx.y	Deliverable No y of Work Package x
EASA	European Union Aviation Safety Agency
eMBB	Enhanced Mobile Broadband
EPC	Evolved Packet Core
FBS	Functional Breakdown Structure
GCS	Ground Control Station
GRC	Governance, Risk Management and Compliance Management
GUI	Graphical User Interface
ICONIX	A practical method of object oriented analysis and design based on use cases
IoT	Internet of Things
IRP	Integration Reference Point
KPI	Key Performance Indicator
LCM	Lifecycle Manager
MEC	Multi-access Edge Computing
mMTC	Massive Machine-Type Communications
NFV	Network Function Virtualization
NFV	NFV Infrastructure
NFVO	NFV Orchestrator
NSD	Network Service Descriptor
NST	Network Slice Template
NWDAF	Network Data Analytics Function
OCSP	Online Certificate Status Protocol
RAN	Radio Access Network

SMF	Session Management Function
SORA	Specific Operations Risk Assessment
TSD	Trial Service Descriptor
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UDM	Unified Data Management
UE	User Equipment
UML	Unified Modelling Language
UPF	User Plane Function
uRLLC	Ultra-reliable low latency communication
USSP	U-Space Service Provider
UTM	UAS Traffic Management
VLOS	Visual Line of Sight
VNF	Virtual Network Function
VNFD	VNF Descriptor
WF	Work Force
WPx	Work Package x

1. INTRODUCTION

1.1. Objective of the document

This document aims to present an initial definition of the trial controller architecture to launch UAV use cases over 5G trial facilities. A number of 5G!Drones use case scenarios has been elaborated and reported in D1.1 [1]. These scenarios are intended to be launched on the top of the trial facilities. It is the role of the trial controller to support the UAV verticals in describing their trials (by providing the means to follow the security and safety processes for planning the drone flights in VLOS and BVLOS conditions) and enable their execution on the top of the selected 5G facilities. In particular:

- If required, submit planned experiment to the authorities and ask for authorisation;
- Translate the high-level trial scenario description to a set of network components required to run on the top of the 5G facilities, verify their availability and configuration;
- Give the experimenter means to download the mission to the drone, supervise it during the flight, safely terminate the flight;
- Collect and store all logs and collected inputs. Give the means to analyse them after the mission is completed.

In these regards, the objectives of the present deliverable are the following:

- Design and implementation of the software layer that will enable the execution and control of trials on top of the selected 5G facilities;
- Development of tools and APIs to generate automatic tests for the use cases;
- Provision of high-level scenario description languages and APIs, as well as mechanisms to translate scenarios to deployments using the APIs provided by facilities and the 5G!Drones enablers;
- Design and implementation of management and monitoring interfaces to verticals and facility owners.

1.2. Structure of the document

The present deliverable follows the following structure:

Introductory section emphasizes with the objective, the structure and target audience of the deliverable.

Section 2 introduces the 5G!Drones trial architecture reference design. It initially provides general concepts and principles considered in the design of the trial controller architecture, including 5G infrastructure managers/orchestrators, UAV operator, U-Space, IoT devices and user equipment. This leads to the introduction of the overall architecture and the organization of the partners into work forces handling the different components of the architecture. These components are thereafter detailed and described.

Section 3 handles the definition of the reference points based on the trial controller architecture. Different reference points are derived from the interconnection between the different components of the trial controller. Furthermore, this section also deals with the reference points derived from the connection between the trial controller with the 5G facilities, with U-space, and with the UAV operators.

Section 4 emphasizes with different supporting mechanisms and algorithms that can be considered for the trial controller. It covers different scopes in relation with trial definition, validation and enforcement.

Finally, **Section 5** concludes the deliverable and emphasizes with potential updates to be considered in the deliverable D2.4, which represents the second release of the definition of the trial controller architecture, mechanisms, and APIs.

1.3. Target audience

The present deliverable mainly targets the following audience:

- **The Project Consortium and Stakeholders**. This includes the contributing beneficiaries of the design and implementation of the trial controller architecture within WP2 and WP4. The initial definition of the trial controller architecture proposed in this document will serve as a basis for the upcoming deliverables of WP2. Furthermore, the document will also support the integration and validation work to be carried out in WP4;
- **The Research Community, Industry, funding EC Organization and 5G-PPP** to report on the definition of the trial controller architecture considered for the project, as well as the underlying research and innovations within the scope of the trial controller;
- **The broadest possible technical and non-technical audience (General public)** to obtain a better understanding of the scope, objectives and general architecture of the 5G!Drones project.

2. 5G!DRONES TRIAL ARCHITECTURE REFERENCE DESIGN

2.1. General concepts and design principles

This section emphasizes on general concepts and design principles of 5G!Drones trial architecture. It presents 5G infrastructure managers/orchestrators, U-Space, UAV operator, IoT devices and user equipment.

2.1.1. 5G infrastructure managers/orchestrators

The 5G!Drones project trials are expected to be carried out in four 5G facilities. These include two ICT-17 facilities and two non-ICT-17 facilities. The ICT-17 facilities are the ones of 5GEVE and 5GENESIS projects (in France and Athens respectively), while the non ICT-17 facilities include Aalto University's X-Network and the University of Oulu's 5GTN.

To support the trial architecture, each 5G facility is expected to have interfaces to the trial controller. The interfaces will allow the 5G facility managers and orchestrators to dynamically create the required 5G network services and slices based on the use case requirements. Hence, while the trial controller manages the overall operation of a 5G drone trial across UAVs, U-space and the 5G facility, the facility managers and orchestrators will manage the 5G service deployment within the facility.

The 5G facilities manager and orchestrator can be responsible for the deployment of following network services, crucial for the overall operation of the trial architecture:

- End to end network slicing across the RAN, CN and TN;
- Edge computing or MEC deployment;
- VNF instantiation across the facility, etc.

The deliverable D1.2 [2] under each facility section highlights the current status of different facilities interfaces, while Deliverable D1.5 [3] further describes the managers and orchestrators in each facility required for the use case scenarios that will be trialled.

In summary, the aim of each facility manager and orchestrators is to enable an easy, automatic and dynamic creation of network services, while ensuring lifecycle management, autoscaling and auto-healing of virtual resources. Hence, whenever a request is made in the trial controller for the implementation of the trial of a use case scenario, the enforcement of the use case in the 5G facility will be carried by the facility managers and orchestrators enabled through the provided interfaces.

The available resources to be orchestrated in the facility will be available in the 5G repository of the trial controller, as described in section 2.4.1.3.

2.1.2. U-space

Based on requirements derived from use cases described in D1.1, U-space was identified as significant entity in the overall architecture design in D1.3 [4] as shown in Figure 1, (refer to Chapter 4 in D1.3). To enhance legibility, a summary of U-space and related D1.3 content is also provided.

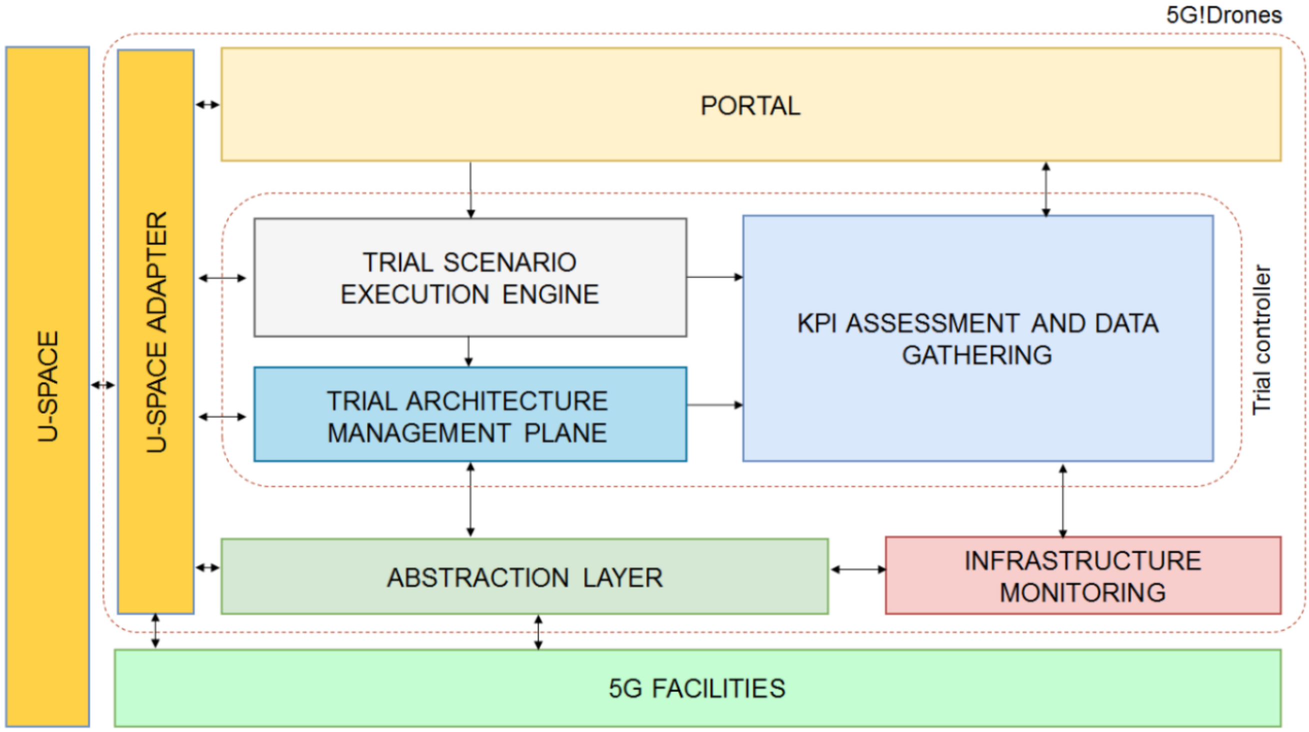

Figure 1: High Level overview of the 5G!Drones architecture (D1.3 Figure 25)

An introduction on U-space concepts and European research targeted on establishing U-space was given in D1.3. Two projects especially relevant for 5G!Drones were described:

- CORUS [5] – providing a first low-level concept of operations for U-space;
- GOF USPACE [6] – providing a framework for actors in and connected to U-space.

Interoperability, already a key enabler in U-space, was identified as important topic in 5G!Drones as well.

Based on ICAO (10039) SWIM [7] principles, Information exchange services were described, ensuring data exchange between both ecosystems. They connect business services on 5G (in the project scope especially at the test Facilities) and on U-space side.

An established and proven way to design and document respective services was defined.

Please note, regulatory work regarding U-space is ongoing during the project execution period of 5G!Drones. Several drafts and finally an opinion [8] of an initial U-space regulation have already been published by EASA (European Union Aviation Safety Agency).

At the time D1.3 was delivered, the opinion was still in draft state. In the meanwhile, it has been delivered by EASA, therefore an update on the U-space ecosystem is necessary and provided in this document.

An overview on the actors and main dataflows is given in Figure 2.

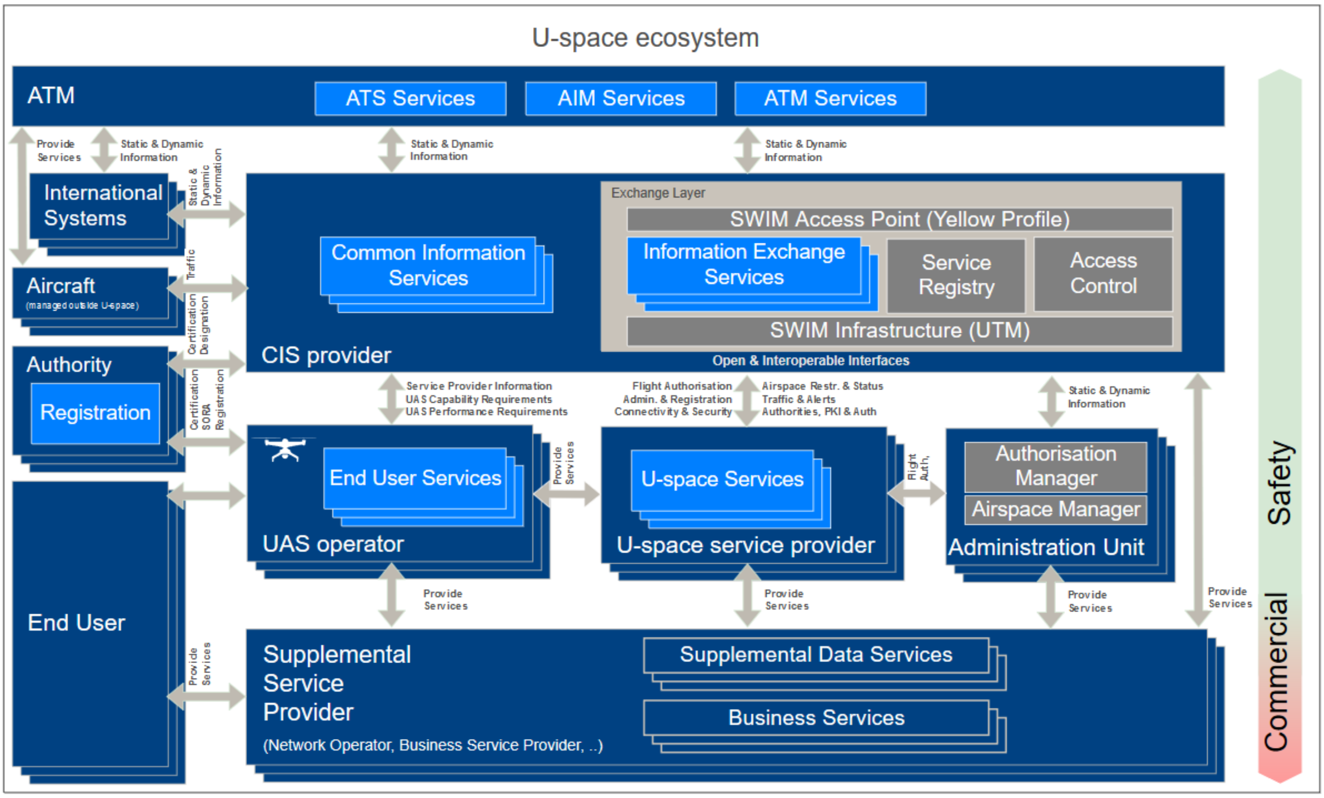

Figure 2: EASA Opinion No 01/2020 - High-level regulatory framework for the U-space

Main key actors described are the following:

- UAS Operators – focussed on flying UAV;
- U-space service providers (USSPs)– focused on providing safety relevant services to UAS Operators;
- Common Information Service (CIS) providers – focused on establishing a “single source of truth”, providing fair access for USSPs, integrating relevant services & components (e.g., Air Traffic Management - ATM).

Please note the overview does not only contain stakeholders mentioned in Opinion No 01/2020 but also includes additional actors. Those new entities were added to:

- Complement the U-space centred view of Opinion 01/2020 with selected ATM elements,

- Complement actors already mentioned in the CORUS ConOps, which are essential in the 5G!Drones project, namely “End User” & “Supplemental Service Provider”.

In this framework, for 5G!Drones, a 5G Test Facility is conceived as equivalent to a Supplemental Service Provider.

Partners from the UAS/UTM vertical will provide UAS operations, CIS services, USSP services and simulate other required components where necessary/applicable. Relevant interfaces to those services & components will be bundled in the U-space adapter as interface between U-space and the telecom domain.

In 5G!Drones, a component called U-space adapter was introduced to focus all relevant U-space actors and the respective interfaces in one component. Though significant aspects of USSPs and UAS operators are included, the primary role of the U-space adapter will be to act as CIS provider. The U-space adapter and its interfaces are described in more detail in section 2.7.

2.1.3. UAV operator

The UAV operator is the partner in a given trial enabling the flight of a drone. UAV operators in 5G!Drones trials will enable three types of flights:

- Fully manual; in which a human operator is responsible for sending C2 commands to a UAV;
- Semi-autonomous; in which a UAS operator uses a basic ground control station (GCS) to upload a fixed list of waypoints to UAVs which then visit those waypoints in turn;
- Fully autonomous; in which a UAS operator uses a more sophisticated GCS which enables UAVs to make higher-level, in-flight decisions based on run-time analysis of sensor data.

As such, the services provided by UAV operators differ based on the use case at hand and the type of flight being executed. The UAV service enablers for this project were identified and described in detail in Section 6.2: *UAV Service Enablers* of D1.3 [4]. A brief summary of the primary service categories provided by UAV operators is included below for legibility:

- UAV services: Hardware & software solutions for interfacing the UAV’s flight controller and its embedded equipment with 5G (to e.g., stream telemetry, stream sensor data, send C2 commands, etc);
- Edge services: UAV management software and application-specific functions (e.g., real-time data processing) requiring low-latency/high-bandwidth;
- Cloud services: Centralised UAV management software or application-specific functions requiring more processing power;
- Operator services: Configuration and management of related UAV management software on-site (e.g., interfaces to UAV management software running on edge devices).

UAV operators are expected to communicate with the Trial Controller via the interfaces described in Section 2.5.2. These interfaces allow the Trial Controller to initiate, configure, and monitor transitions in the state of operation of the UAV operator as part of the execution of a 5G!Drones trial.

During operation, UAV operators are responsible for ingesting telemetry and other sensor data in order to provide filtered subsets of that data to various modules of the Trial Controller as illustrated in Figure 3: UAV Operator Data Outputs (e.g., Dashboard, KPI Monitoring, U-Space Adapter).

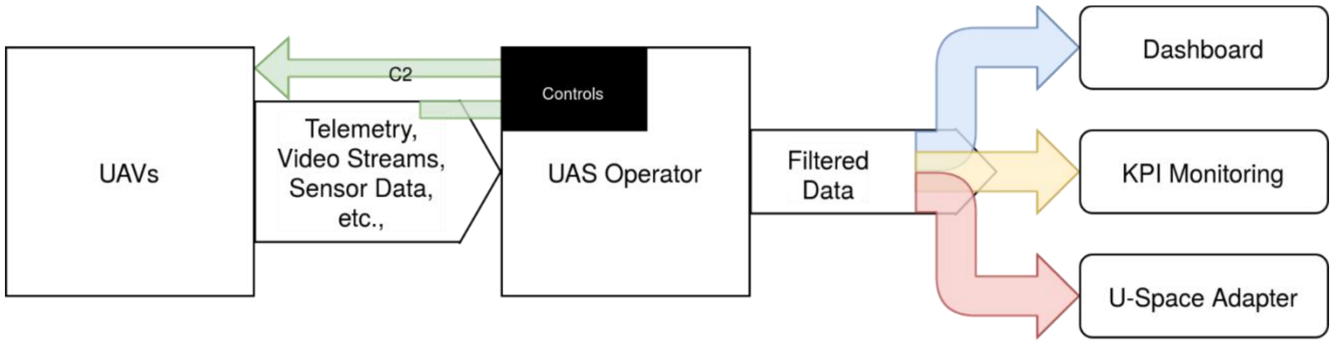

Figure 3: UAV Operator Data Outputs

In summary, the UAV operator is responsible for executing the behaviour of UAVs as specified by the use-case narrative, while the Trial Controller provides coordination for the various supplementary services required in a drone flight (i.e., UTM authorization, 5G resource allocation, and MEC resource allocation).

2.1.4. IoT devices, user equipment and environments for vertical and end users

The project will use IoT devices in the following scenarios: UC 1 / Scenario 3 ("UAV Logistics"), UC 2 / Scenario 1 ("Monitoring a wildfire"), UC 2 / Scenario 3 ("Police, incl. Counter-UAS") and UC 3 / Scenario 2 ("UAV-based IoT data collection").

Trials´ facilities use both NB-IoT and LTE CatM1 / 2 compliant IoT devices. IoT devices have two way communication capabilities, i.e. IoT management system can send commands to IoT devices (such as a task to take a photo) as well as receive data that the device collects. Data related to the IoT sensor is stored and analysed during experiments.

An important element of the 5G!Drones project experiments is User equipment, mainly 5G smartphones and 5G dongles. 5G UE-s communicate with 5G network and MEC using all 5G beneficiaries. 5G UE is gateway for end users, verticals and operators to send commands and receive information over the 5G network.

5G MEC runs applications used by both verticals (service providers) and end users who send commands for applications or use applications data. Verticals primarily use applications that work with the 5G MEC to provide lower latency and better performance. Applications in the project are:

- UAV command and control (C2)
- Control of IoT devices
- Drone logistics network system
- Mission Critical Systems
- Video analysing
- 3D Mapping
- Network coverage QoS mapping

Verticals and end users use 5G smartphones or tablets or PCs with 5G dongle to receive information and send commands to applications running in the 5G MEC.

The configuration, deployment, management and monitoring of these applications are performed through the technical solutions provided in the Trial Enforcement block.

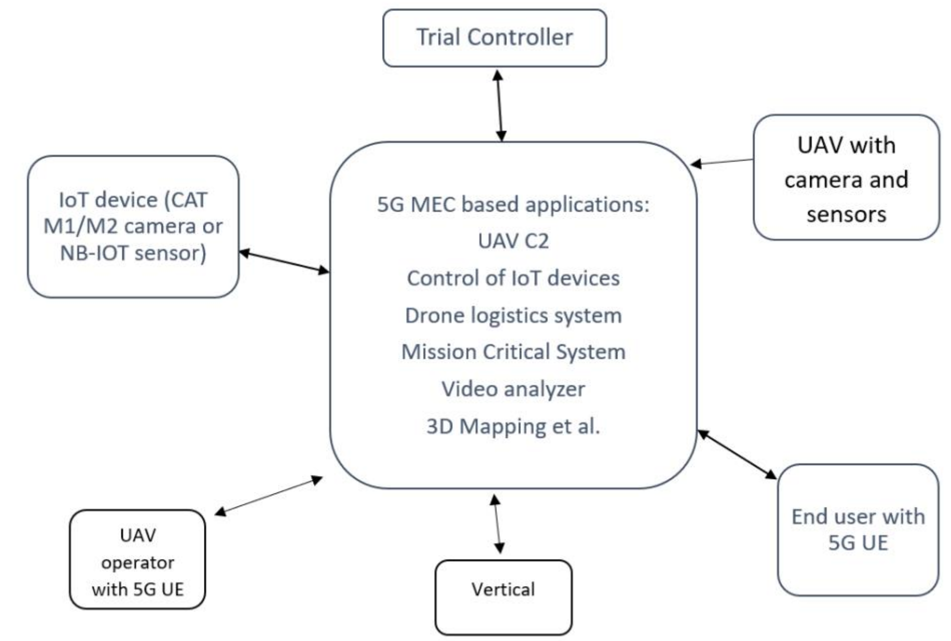

Figure 4: IoT devices, user equipment and 5G MEC based applications for verticals and end users

2.2. Overall architecture and work forces

This subsection introduces the overall architecture of the trial controller. It also emphasizes with the domain model and a generic process of the trial controller, as well as the organization of the work.

2.2.1. Overall architecture

The proposed architecture of the trial controller is depicted in Figure 5. The trial controller interacts with the experimenter to describe the scenario to evaluate, along with the technical description of the network slices and the target KPIs to evaluate. The trial controller coordinates with trial sites in order to run the different experiments on the top of these facilities. Furthermore, in order to validate the trial and ensure safe access to the airspace by the drones, the trial controller also interacts with the U-space through a dedicated interface. As shown in Figure 5, the trial controller is broken up to into five functional blocks, which are the web portal, the trial execution engine, the trial enforcement, the KPI monitoring, and the U-space adapter.

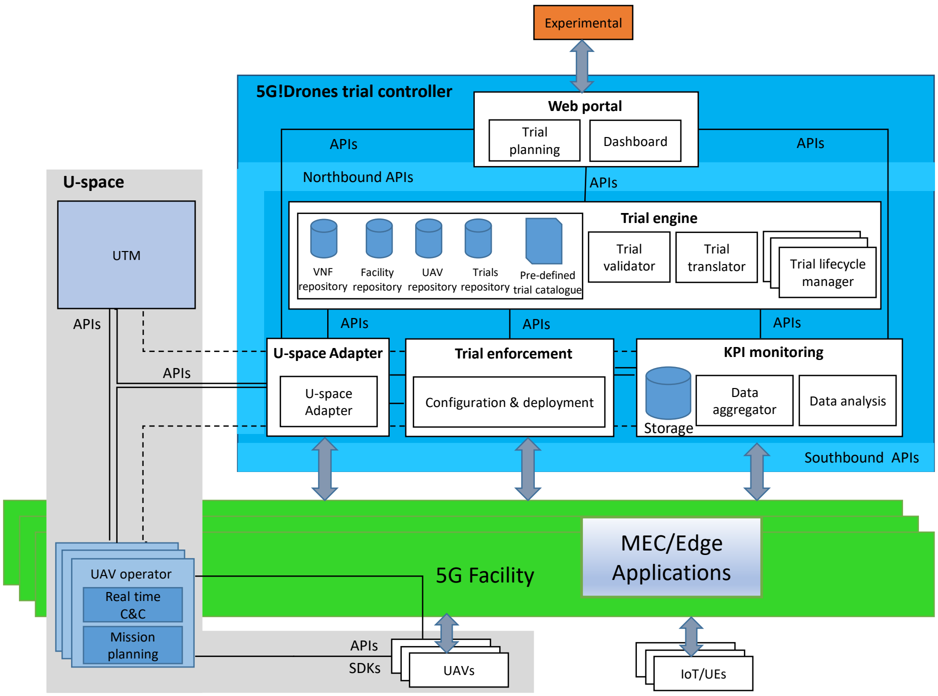

Figure 5: 5G!Drones trial controller architecture

An experimenter will use the **web portal** for accessing the functionalities of the system. The web portal is composed of two sub-modules, allowing respectively the planning of the trials and the browsing/modification of the running trials (dashboard).

The **trial execution engine** is responsible for translating the description of the scenario to a full UAV and network service components to run over the 5G facilities. The execution engine module is also responsible for managing the lifecycle of the trial. It is composed of three sub-modules which are the trial validator, the trial translator and the lifecycle manager. The **trial enforcement** reflects the module that will be run the trials, as per the requests of the trial execution engine. This includes request for deployment as well as request for run time configuration and update. The **KPI monitoring** is responsible for collecting data on the running trials and performing analytics. Based on the collected data, different statistics and analysis can be executed and exposed to the experimenter.

The **U-space adapter** is responsible for interfacing between the U-space and the different modules of the trial controller. This includes the web portal (for providing the experimenter with assisting information such as none flying zones), the trial execution engine (for the validation of the trials), and the KPI monitoring (in order to provide information from the U-space such as telemetry data).

2.2.2. Trial controller domain model

For the clarity and robustness of the analysis and design, approach based on ICONIX Process is applied. Following the rules of this process, in this chapter domain modelling is performed. It allows to define the problem space in unambiguous terms. Domain modeling is the task of building a project glossary, or a dictionary of terms used in the 5G!Drones project. The domain model for the project defines the scope and forms the foundation on which system design driven by use cases is performed. For notation purposes it is based on UML 2.0, but mostly limited to aggregation and generalization relationships. It is the first approach to organize design classes and objects around key abstractions of

the project. It is not the final class diagram neither the complete data model. It embraces all key terms in one, common diagram but without any deep implementation details yet. They are provided, along detailed descriptions of particular components of the solution, in following chapters.

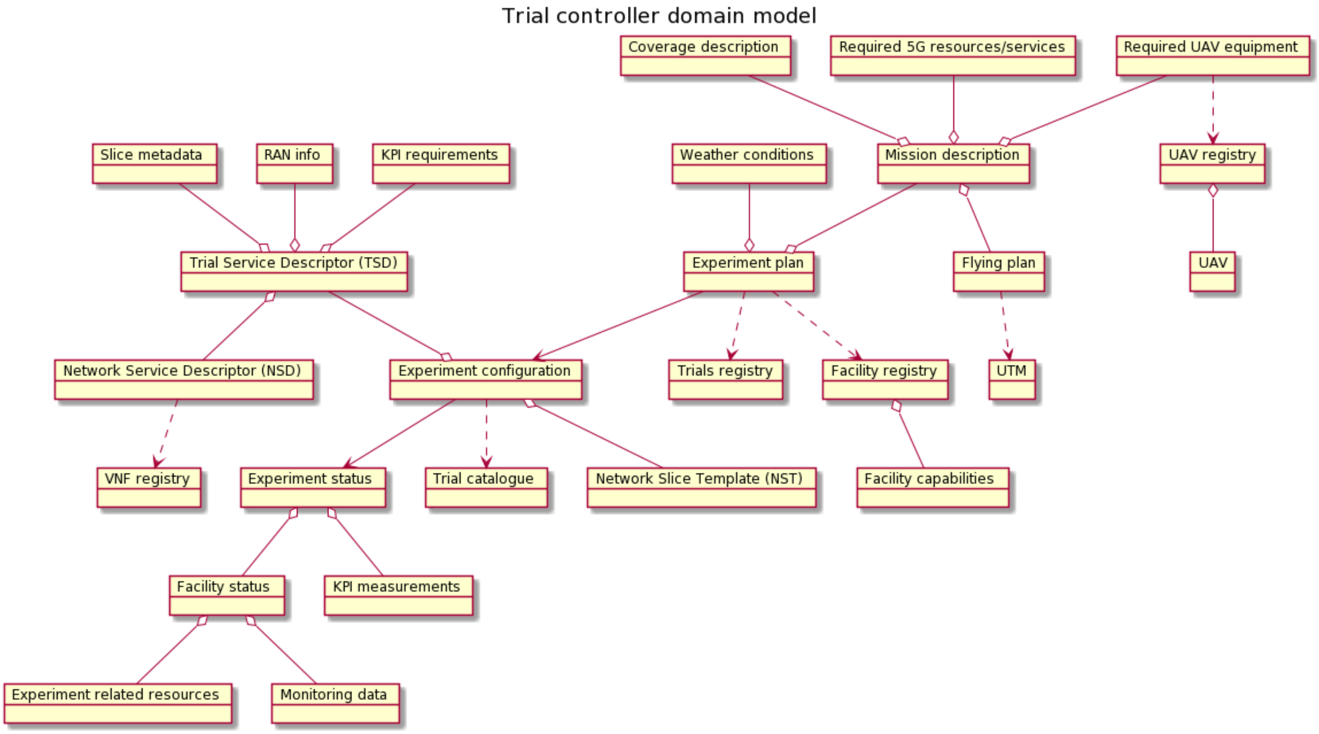

Figure 6: Trial controller domain model

Diagram presented on Figure 6 contains all the key abstractions of the trial controller solution. The main abstractions presented are:

- Experiment plan
- Experiment configuration
- Experiment status

Above classes reflect the information scope that the trial controller main user (Experimenter) has while using the system through 3 main phases:

- Trial planning phase
- Trial implementation on 5G premises phase
- Trial execution – monitoring and results presentation

Trial planning phase requires, that all the necessary information describing the trial from the implementation perspective are gathered. This is represented by Mission description and Weather conditions objects, which are mostly provided by the Experimenter. On the diagram they are depicted in further details like Coverage description, required 5G resources/services, Required UAV equipment, Flying plan. Some of the information necessary to complete the Experiment plan relies/depends on information provided/gathered from other entities: UAV repository, UTM, Facility repository and Trials repository.

Trial implementation on 5G premises is used for configuration of telecom network serving the mission. From the information scope perspective, it embraces such types of information as: Trial Service Descriptor (TSD), RAN info, slice metadata, KPI requirements, Network Slice Template (NST), Network Service Descriptor (NSD). Preparation of this configuration requires also interaction with VNF repository and Trial catalogue.

After successful provisioning of 5G facilities with appropriate configuration depicted in above step, mission is ready for execution. During this stage, trial controller is used mainly for 2 purposes: gathering and presentation of KPI measurements and presenting current facility status. These needs from information perspective are addressed by Facility status and KPI measurements objects.

They are 4 main actors (external systems) interacting with this system:

- Experimenter – UAV vertical preparing and performing tests;
- U-space – represented by UTM class on the diagram, involved and responsible for performing flight validation based on prepared flight plan, invoked depending on the mission conditions;
- UAV operator – executes the trial by means of controlling the drone, who might use/need status information provided by the trial controller during the mission execution;
- 5G facility – responsible for implementation of 5G network capabilities supporting execution of trial; deploys runtime configurations contained e.g., in NST and NSD objects.

2.2.3. Trial controller processes

Trial mission consists of several steps that need to be performed. To successfully accomplish the mission's goal, some legal and technical settlements must be assured. From that perspective, the main purpose of the Trial Controller is to manage the execution of those steps according to the well-defined sequence of processes dealing with various aspects of the mission preparation and execution in combined 5G and UAV environment.

At the high level those processes include:

- Definition of the mission – preparation of the mission description: it's purpose, resources, etc,
- Mission validation of which main step is to gather the flight mission approval from U-Space perspective, as well as verification of mission's feasibility from 5G network's capability perspective (availability of required resources),
- Mission preparation – defining sets of required 5G network's resources by trial translator (definition of Network Slice Template, NST)
- Mission implementation managed by trial lifecycle management and performed by trial enforcement module
- Mission execution controlled by trial lifecycle management
- Gathering in-mission measurements performed by KPI monitoring module
- On-line and post mission measurements' data analysis with presentation of its results to the experimenter via web dashboard

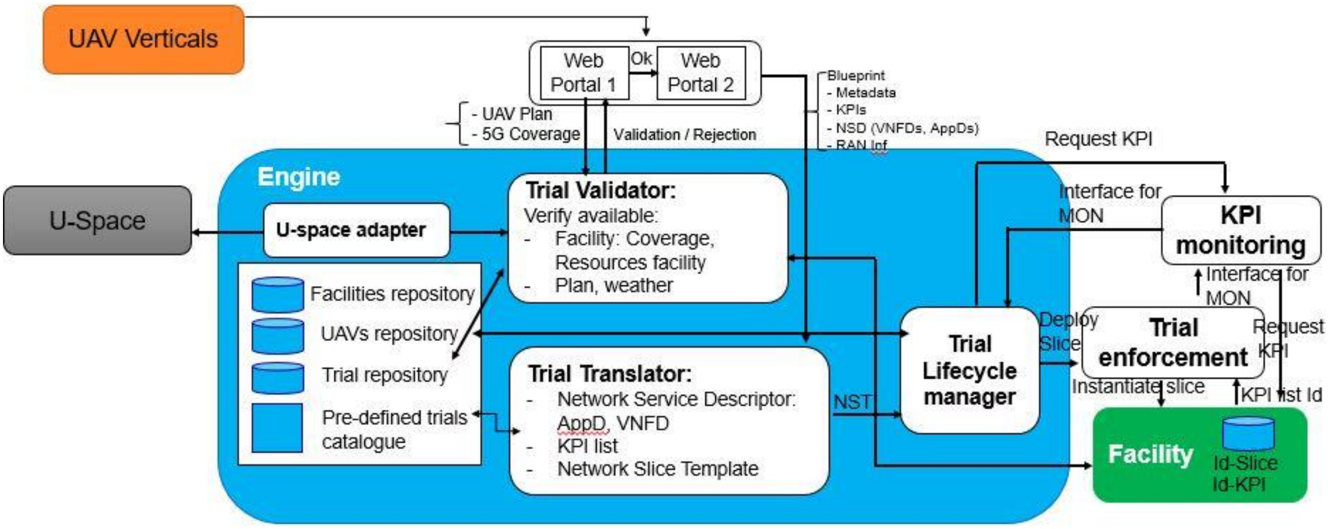

Figure 7: A generic Trial Controller process.

As illustrated in Figure 7, the web portal is divided into two successive parts: first Web portal 1 and then Web portal 2. Web portal 1, serves for the UAV vertical to provide the flight plan and the second web portal is used for configuration of telecom network serving the mission.

The web portal 1 sends this request to the trial validator (see 2.4.2) in order to verify the coverage and resources availability from the facility, as well as, the flight plan (dFPL) to UTM (U-space domain). It might be also possible to gather (import) the existing dFPL from the UTM. For this purpose, it communicates with the U-Space via defined U-space Adapter and with the Facility via defined APIs.

The trial validator needs to save the different information about facility, UAV and the trial status in the different repositories. Finally, it returns the response to the web portal 1, containing validation or rejection of the mission request. In case the mission is rejected by the trial validator, the latter also returns the reason of the rejection (e.g., unavailable of the target facility, U-space rejects the flight plan).

After validation, the web portal 2 sends the requirements provided by verticals (Scenario description, KPIs, RAN information) to trial translator. The translator will focus on the translation to the required submodule. Thus, the trial translator prepares the Network Slice Template (NST) based on the received requirements and the Network Service Descriptor (AppD, VNFD).

As next step, the NST is sent to the Trial Lifecycle Manager (LCM), used to request the slice deployment. LCM sends this request to the trial enforcement, which instantiates the slice in the facility. This one creates a list for the KPIs related to this slice and returns its Id and address, that are sent to the KPI monitoring submodule, and then to LCM to allow the interface for the monitoring.

LCM requests KPI monitoring submodule to perform statistics collection, which uses the KPI-Id to take results (following the principle of push/publish). A generic sequence diagram for the trial controller process is illustrated in Figure 8.

During the execution of the mission defined measurements are passed to data aggregator of KPI Monitoring. Some of the information, vital to U-space processes like telemetry information or key KPI parameters (e.g. failure in radio network), are also passed to U-space through U-Space adapter.

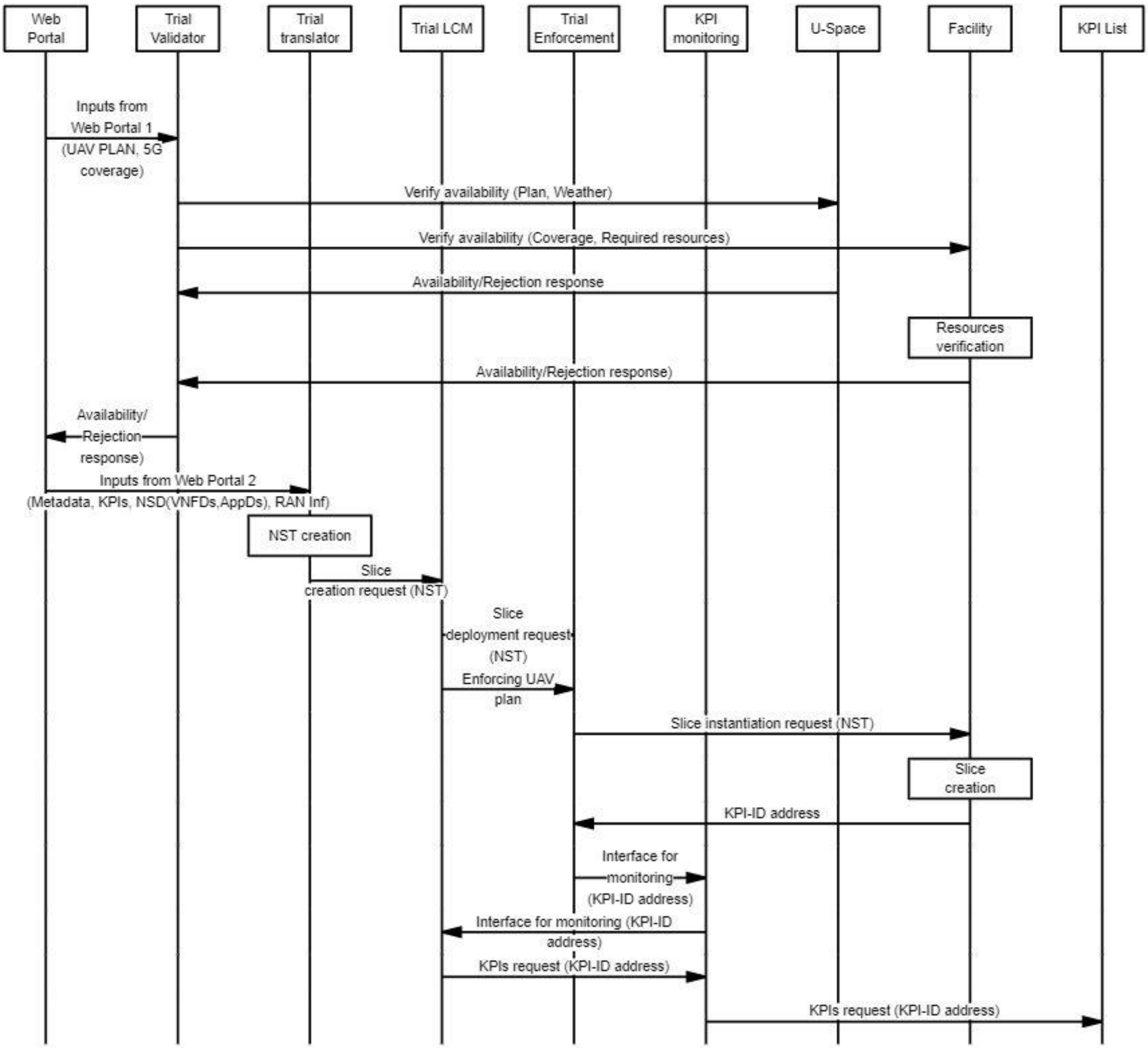

Figure 8: A generic sequence diagram of the Trial controller process.

2.2.4. Work forces organization

5G!Drones brings a new dimension connecting 5G networks with UAV verticals, and the trial controller is the main element supporting this solution. In order to tackle the definition of this architecture, the partners have been organized into work forces (WFs) to better address architecture submodules and functions. In specific, each WF focuses on a specific submodule and is composed of the relevant partners from the concerned domains and operations.

The web portal has been organized into two WFs, where each is related to one of the two submodules of this module (trial planning submodule and dashboard submodule). The trial engine gathers WFs on the different repositories: UAV repository, 5G facility repository and VNF repository. In addition, it also gathers WFs on the submodules trial translator, trial validator and lifecycle manager. The latter is organized by interfaces to the two submodules of the trial enforcement module, i.e., configuration & deployment and management & monitoring. As for the trial enforcement module, it is organized by interfaces to the MANO and RAN, to the cloud, and to UAV operator. Finally, the KPI monitoring module gathers work forces on the different data types (network data, cloud data and U-space data).

Furthermore, it also includes WFs on the two submodules of this module, which are data aggregator and data analysis. The organization of the WFs and the involved partners is shown in Table 1.

Web portal: INV, FRQ, DRR, UMS, RXB, CAF, NOK, THA
Planning module: AU, INV, DRR, CAF
Dashboard module: AU, FRQ, UMS, RXB, INV, CAF, NOK, THA
Trial engine: UO, DEM, AU, EUR, ORA, NOK, CAF, UMS, FRQ, INV, DRR, AIR, THA, RXB, MOE
UAV repository: CAF, FRQ, INV, UMS, RXB, DRR, UO
5G facility repository: AU, UO, DEM, EUR
VNF repository: FRQ, CAF, DRR, INV, AIR, UMS, AU, NOK
Trial translator: AU, EUR, UO, THA, CAF
Trial validator: RXB, FRQ, DRR, INV, AU, THA, MOE, CAF, EUR
Lifecycle manager (Interfaces to management and monitoring): DEM, AU, EUR, UO, NOK, AIR, CAF
Lifecycle manager (Interfaces to configuration and deployment): AU, EUR, UO, NOK, AIR, CAF
U-Space adapter: RXB, FRQ, DRR, INV, CAF, HEP, UMS
U-space adapter: RXB, FRQ, DRR, INV, CAF, HEP, UMS
Trial enforcement: AU, EUR, DEM, UO, NOK, UMS, CAF, DRR
Interfaces to MANO and RAN: AU, EUR, DEM, UO, NOK, CAF, DRR
Interfaces to Cloud: AU, EUR, DEM, UO, CAF
Interfaces to UAV operator: UMS, CAF, INV
KPI monitoring: ORA, AU, EUR, DEM, UO, NOK, HEP, RXB, UMS, DRR, FRQ, INV, CAF, THA
NW data: ORA, AU, EUR, UO, NOK, CAF, THA
Cloud data: ORA, AU, EUR, UO, CAF, THA
U-space data: INV, FRQ, DRR, RXB, UMS, CAF, THA
Data aggregator: FRQ, UMS, CAF, NOK, THA, HEP
Data analysis: UMS, INF, CAF, NOK, THA, HEP

Table 1: Organization of the work forces

In what follows, we will describe the different modules and submodules of the trial controller architecture.

2.3. Web Portal

5G!Drones web portal is the main module used by the experimenter to access the functionalities of the system. The web portal has two submodules:

- Experiment Planning Submodule – for defining the new experiments;
- Dashboard Submodule – for browsing and modification of the planned experiments and visualization of concluded experiments results.

2.3.1. Trial planning

The trial planning will be divided into 2 phases, utilising 2 web portals. First phase will be focused on UAV mission plan and obtaining the permission to fly. If required, the planned experiment will be submitted to authority for approval via U-space platform. After such approval, the second phase concerning 5G communication functions and MEC functions will be continued in the second portal. It can be common for some facilities, or facility specific, like in case of already existing portal for 5GENESIS.

2.3.1.1. Access to the Web Portal

The portal's access will be restricted to the authorized collaborators of the 5G!Drones project members, called further the "users". Users' accesses are divided into organisations and levels with access rights.

Users should send the registration request to the person (or automatic system) responsible for granting the access. In the response they will get the login and password for the access. User should have the possibility to modify the password.

To access the portal, user will need to submit his login and password. After successful login, user will be allowed to create a new experiment or browse and modify information in the dashboard.

2.3.1.2. Web Portal security

Adequate security is provided by using an HTTPS connection and 2 factor authentication solution.
Elements located in the different networks should use VPN secure connection to communicate between them.
All user activities are logged, and Web Portal security measures are configured to prevent inappropriate activity.

2.3.1.3. Link level security

Link level security ensures authentication, confidentiality, and data integrity of the communicated information between the different hopes of the system. The secure communication between the user

and the web portal is provided by the HTTPS protocol. That prevents the interference of attackers and protect against man-in-the-middle, eavesdropping, and tampering attacks.

2.3.1.4. Planning the experiment

Planning module will help the experimenter to specify different variables of the Use Cases/Scenarios defined and agreed in the document D1.1 "Use Case Specifications and Requirements"

1) User will need to describe the experiment:
   - Select the location (one of 4 trial facilities)
   - Select the date and time of the trial
   - Select the drone or multiple drones (hardware)
   - Considering 5G network coverage, user should for each UAV specify the flight trajectory and additional required parameters (e.g. speed, height, fully autonomous or semi-autonomous mode)
   - Define the non-standard equipment (load) on the board of each UAV. It can be a UE or dongle for 5G, additional (non-in built) camera, IoT device or commercial load (i.e. packet with medicines)
2) The experiment plan will be saved and accessible further with its status in the Dashboard.
3) Saved Experiment Plan will be submitted to Trial Validator for validation. Validation will include U-space inquiry and selected 5G facility inquiry for availability.
4) In case of negative outcome of validation, the experimenter will get the notification in the Dashboard, including the reasons for rejection. The experimenter will have possibility to modify parameters, which caused the refusal.
5) After successful validation in the first step, user will be redirected to the web page of specific facility to complete the second part of the experiment planning, which is related to 5G service. Part of available fields, like date and time, which were considered during the initial validation, should be visible, but not possible to be modified.
6) User will enter additional information required to clearly set-up the experiment:
   - Define or select from predefined templates the required 5G telecommunication services. The default services are:
     - uRLLC link for Command & Control (C2) link and telemetry with required max. latency
     - eMBB link for inbuilt video camera in case of using FPV flight control

     Other services:
     - Additional eMBB link for sending the video from inbuilt or additional camera carried by drone, which is not used for FPV flight control
     - Additional eMBB or mMTC link for sending additional sensors (IoT) readings

- Slice metadata – user will be able to give his requirements about KPIs, which will define suitable slice type (uRLLC, eMBB or mMTC)
- RAN Info – user will need to give the IMSI / IMEI information, RAN specific parameters (specify what parameters)
- Network Service Descriptor – NSD characterisation file, including the path to the VNFD or AppD and KPIs relevant for the service

7) All input data will form Trial Service Descriptor (TSD), which will be sent to Trial Translator.
8) After validation of the plan from 5G facility point of view, the experiment will be ready for enforcement. It will be visible in Dashboard with its status. It will be also editable, but any modification will trigger new validation process. In case the experiment is not validated, a notification that includes the cause of refusal would be return to the experimenter.

2.3.1.5. Functional Breakdown Structure and Scenario Description Language for Experiment Planning

The Functional Breakdown Structure (FBS) is a detailed tree describing all the functions, which are required by the experimenter to define his test.

When looking from the left to the right side, it describes the functions by answering the question "how?". Looking from the right to the left, it should answer to the question "why?". Each function should be described by active verb + measurable noun.

FBS is helpful in identifying the functionalities, planning their implementation, calculating development effort and overseeing the development progress. Figure 9 shows the Functional Breakdown Structure for Web Portals (UAV and 5G).

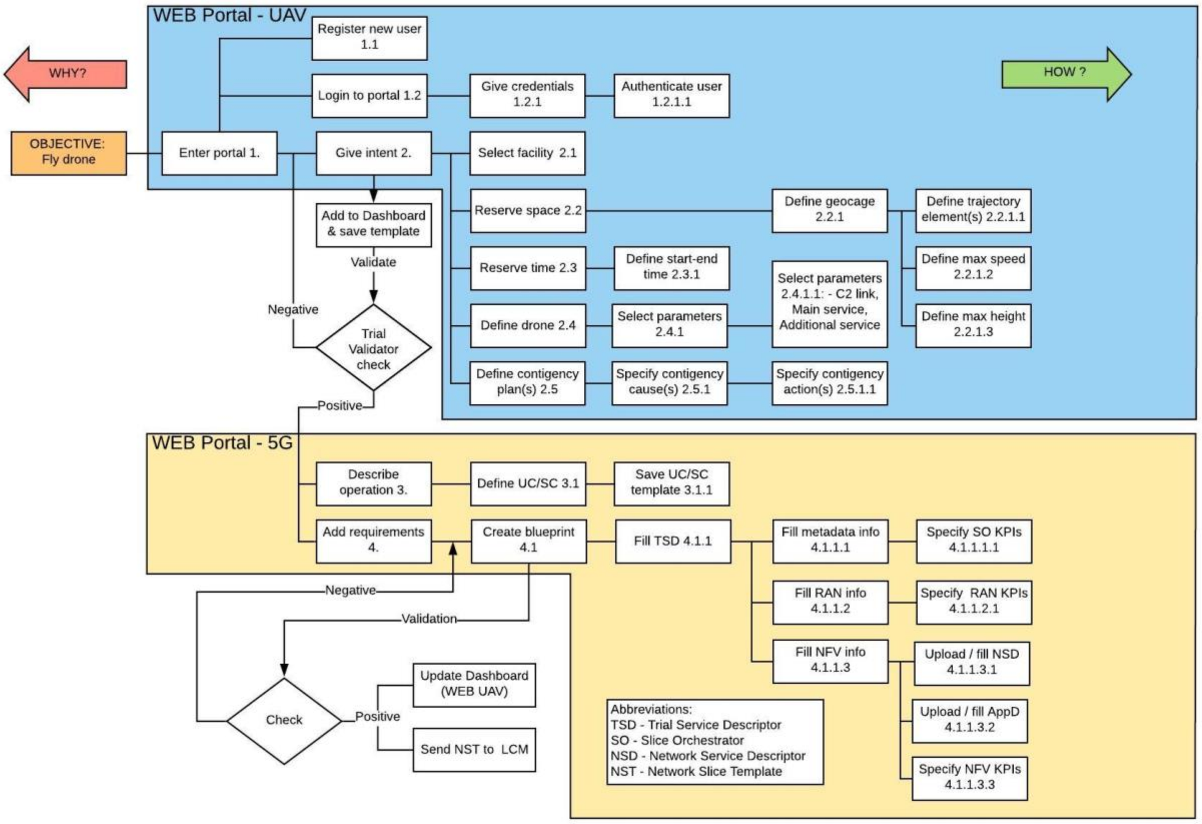

Figure 9: Functional Breakdown Structure for Web Portals (UAV and 5G)

Based on the Functional Breakdown Structure the Scenario Description Language was defined, with all the details and information elements, which are required to work with Web Portals 1 and 2, and to define the experiment. Based on this, the prototype APIs were designed in Swagger Editor. The results of this work are not directly included in this document to not overload it. They will be used in the next phase of the project, during the implementation of the web portals. This also contributes toward the definition of a final Scenario Description Language, which will be reported in the next release of the deliverable (D2.4).

2.3.1.6 Additional functionality enhancing productivity

1. Experimenter should have the possibility in both Web Portals to save the templates, to speed up the new experiment creation.
2. Experimenter should have possibility to duplicate the existing experiments, by selecting them, entering modifications through web portal 1 and web portal 2, and storing them under the new name.
3. Calendar, showing free slots for experiments can help to plan efficiently the experiments.

2.3.2. Dashboard

The 5G!Drones Dashboard is a graphical user interface for authentication, experiment planning, managing and analyzing.

Dashboard has two main parts as depicted in Figure 10:
1. List View and
2. Analysis and Replay View.

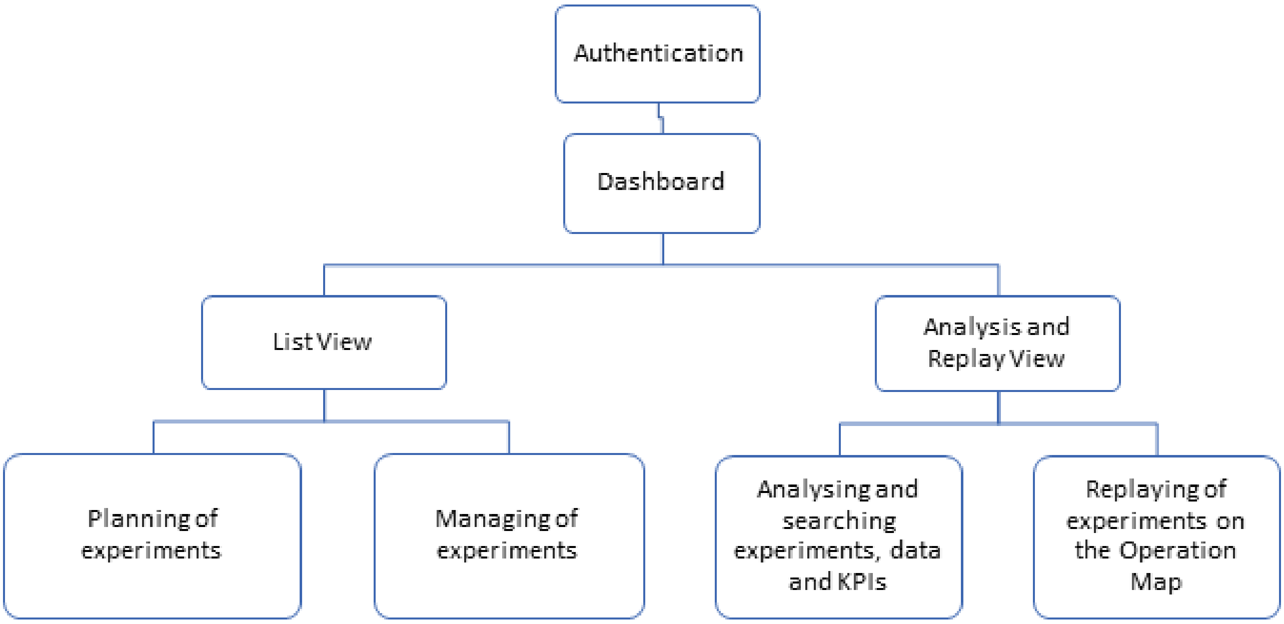

Figure 10: Dashboard overview and hierarchy

Dashboard - List View
Dashboard's list view is a place, where it's possible to view all the experiments with their statuses. Each defined experiment is accessible, editable and viewable through the dashboard list view.

Dashboard List view characteristics:
- Sign Up and Log In part
- In the basic view, the experiments are presented as the single line with the most important parameters: name, date created, date of experiment, owner, UC/SC number, actual status. More details are shown after selecting the experiment.
- It should be possible to sort the list of experiments by all fields
- Experiments before activation are modifiable by the users. Editing the planned experiment will be possible in the "Experiment Planning" module. Depending on modifications, new validation process can be required
- Each mission execution, automatic or requiring manual operation will start through the dashboard.
- After selecting the experiment, more details will be presented, depending on the status.
- Viewing the on-going experiment data feeds will be possible thanks to dashboard integrations with GCS and other applications.
- The Operations Map showing all ongoing activities (the UAV's position, route, planned activities and objects, 5G services coverage etc.

Dashboard – Analysing and Replay View

- Analysing or replaying the finalised experiments
- Possibility to replay the entire experiment with objects, activities, locations, data on the Operations Map, go back and forward in the time
- Possibility to analyze 5G network KPI-s
- Dashboard will enable the finalised mission analysis, which is common for all scenarios. For more specific investigations, dashboard will give the possibility to download the stored information
- Possibility to search for certain data, objects, locations, events, jump to certain time, make filtering of the messages or events

2.4. Trial Engine

The trial engine is the module responsible for translating the description of the scenario to a full UAV and network service components to run over the 5G facilities. Furthermore, the trial engine module is in charge of managing the lifecycle of the trial. This module is composed of three submodules which are the trial translator, the trial validator and the lifecycle manager. In addition, a number of repositories are also considered in the trial engine in order to perform its functions at the different levels.

2.4.1. Repositories

A number of repositories were identified for the trial execution engine, to organize the data storage necessary for the experiments. This includes the 5G facility repository, the VNF repository, the UAV repository and the trial repository.

2.4.1.1. VNF repository

The VNF repository holds the different virtualized network functions required to run UAV scenarios on the top of the 5G trial sites. The use of these VNFs will therefore depends on the target scenario. Table 2 lists several VNFs considered for the “VNF repository”, along with some deployment characteristics.

VNF	Technology to use		Resource usage		
	VM	Container	CPU	Memory	Storage
Software pilot	-	++	+	+	+
IoT data aggregator	-	++	+	+	+
VNF-Cache	+	++	+	+	++
Transcoder	-	++	+	+	+
Streamer	-		+	+	+
Mission Critical Services	++	-	+	+	+

3D mapping	++	-	+	++	-
(-) Less likely (+) Likely (++) More likely					

Table 2: List of VNFs in "VNF repository".

As shown in the above table, different VNF are considered for the VNF repository. An important VNF is the Software pilot VNF. The latter reflects UAV operator software responsible for communicating with and controlling the UAVs. This VNF is therefore considered for all the use case scenarios. Furthermore, additional VNFs are also considered for different scenarios. This includes transcoder, streamer and VNF-cache for video processing, Mission Critical Services for the scenario monitoring a wildfire, 3D mapping VNF for the scenario 3D mapping and supporting visualization for UTM.

2.4.1.2. UAV repository

The UAV repository holds information about hardware available for use-cases, including available sensors, availability in time & location, and flight characteristics.

Where possible, the UAV repository will access information about the UAV from U-Space services. In the context of the project, this will allow experiences with the UAV repository to drive recommendations for associated standards developments organizations. This is expected to have synergies with ongoing work in U-Space e-Registration services, particularly in defining connectivity models for UAVs. The data model for UAS registration from e-Registration services is shown in Figure 11.

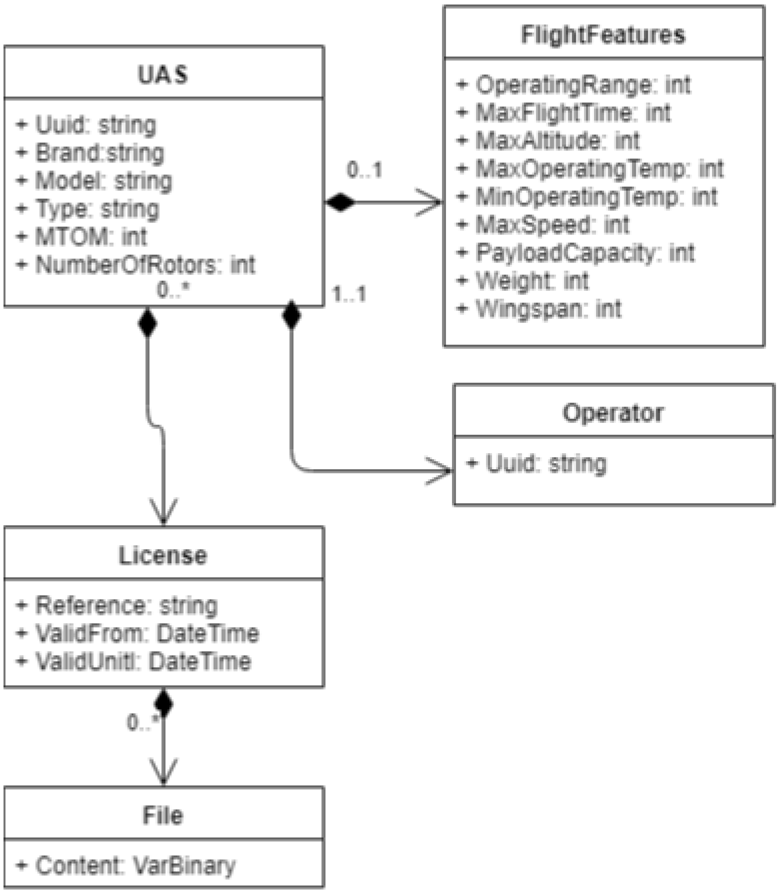

Figure 11: eRegistration UAS Data Model

The UAV repository will not hold information related to the trials in which a given UAV will be used. These characteristics will be defined instead during the trial definition.

2.4.1.2.1. UAV repository interfaces

The UAV repository will implement a basic persistent storage interface, providing methods to create, read, update, delete, and list (CRUDL) UAV records.

The UAV repository will additionally provide server-side filtering for listing records. This will allow clients of the UAV repository to search for UAVs appropriate for their use-case (e.g., listing UAVs that are available in a given location during a given date range) while minimizing reimplementation efforts of filtering records throughout the Trial Controller.

2.4.1.2.2. UAV descriptor data model

The UAV descriptor data model has the structure shown in Figure 12.

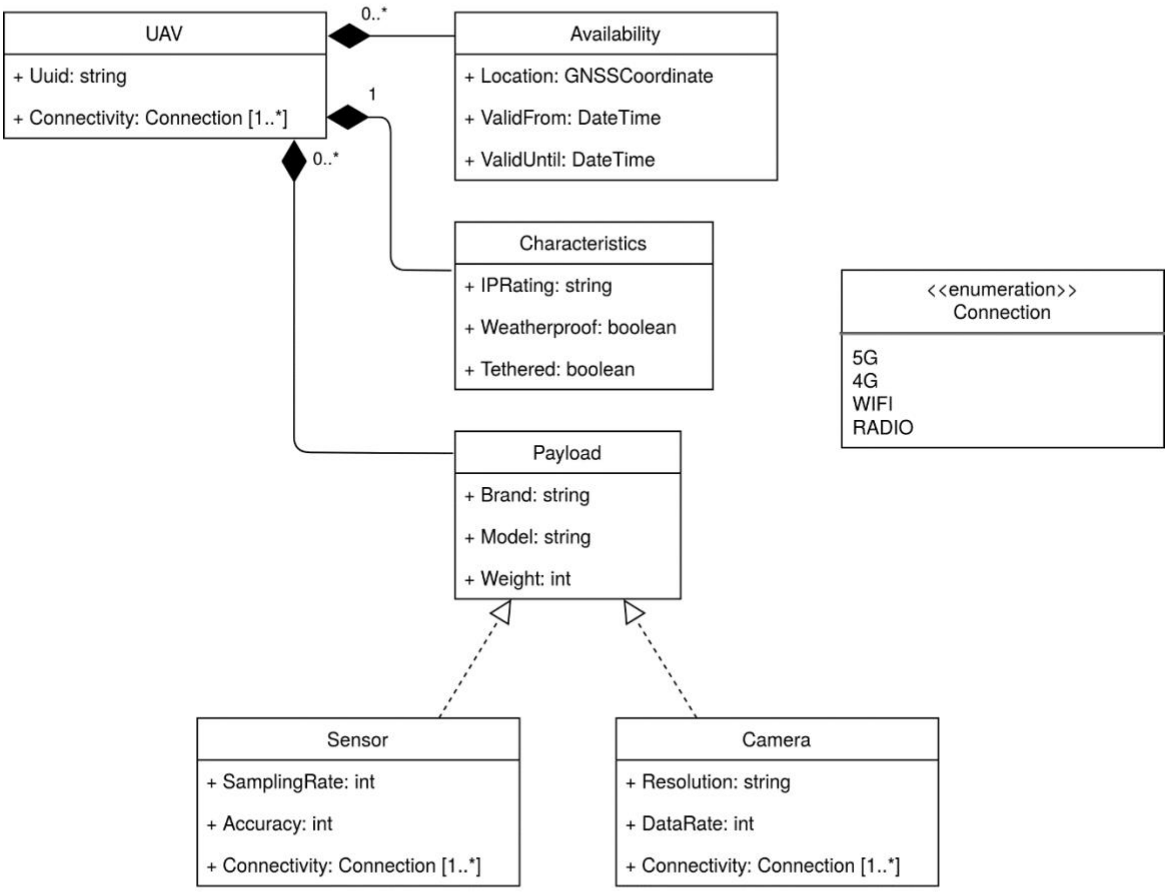

Figure 12: UAV Descriptor Data Model

Table 3 describes in detail the fields associated with a single UAV description.

Element Name	Attribute Name	Type	Description
UAV Descriptor for a UAV used in 5G!Drones trials	Uuid	String	UUID string uniquely identifying the UAV in a national registry. This UUID will be used as required to query U-Space e-Registration services for information already recorded therein.
	Connectivity	Connection [1..*]	One or more supported connectivity modes (e.g., 5G, 4G, Wi-Fi)
Availability [0..*] Zero or more records indicating availability of the given UAV in a	Location	GNSS Coordinates	GNSS coordinates at which this UAV is available
	ValidFrom	DateTime	Date from which this UAV is available at the associated location

given location over a given time frame	ValidUntil	DateTime	Date until which this UAV is available at the associated location
Characteristics Additional physical characteristics of the UAV that may not be available from the U-Space eRegistration service	Tethered	Boolean	True if this UAV must be tethered, false otherwise
	IP Rating	String	The Ingress Protection rating of the UAV, defined in international standard EN 60529 (British BS EN 60529:1992, European IEC 60509:1989).
Payload [0..*] One or more payloads carried by the UAV	Brand	String	Brand of the payload
	Model	String	Model of the payload
	Weight	Integer	Weight in grams of the payload
Camera [0..*] One or more camera payloads carried by the UAV, defining additional camera-specific metadata	Resolution	String	The camera resolution
	DataRate	Integer	The data rate of the camera in kbps
	Connectivity	Connection [1..*]	One or more supported connectivity modes (e.g., 5G, 4G, Wi-Fi)
Sensor [0..*] One or more sensor payloads carried by the UAV, defining additional sensor-specific metadata	SamplingRate	Integer	Sampling rate of this sensor in Hz
	Accuracy	Integer	Percentage accuracy of this sensor
	Connectivity	Connection [1..*]	One or more supported connectivity modes (e.g., 5G, 4G, Wi-Fi)

Table 3: UAV Descriptor Fields

2.4.1.3. 5G facility repository (NCSRD)

A 5G facility repository is planned to be created that will contain information about, as well as describe the underlying 5G facilities. This information includes 5G Facility availability per component, the KPIs that are available to measure in each platform. It will also be possible to choose the Slice type to be deployed, which will be attached and coupled with the Domain (e.g. RAN, Edge, Backhaul). In Figure 13, the data model for the 5G Facilities is shown:

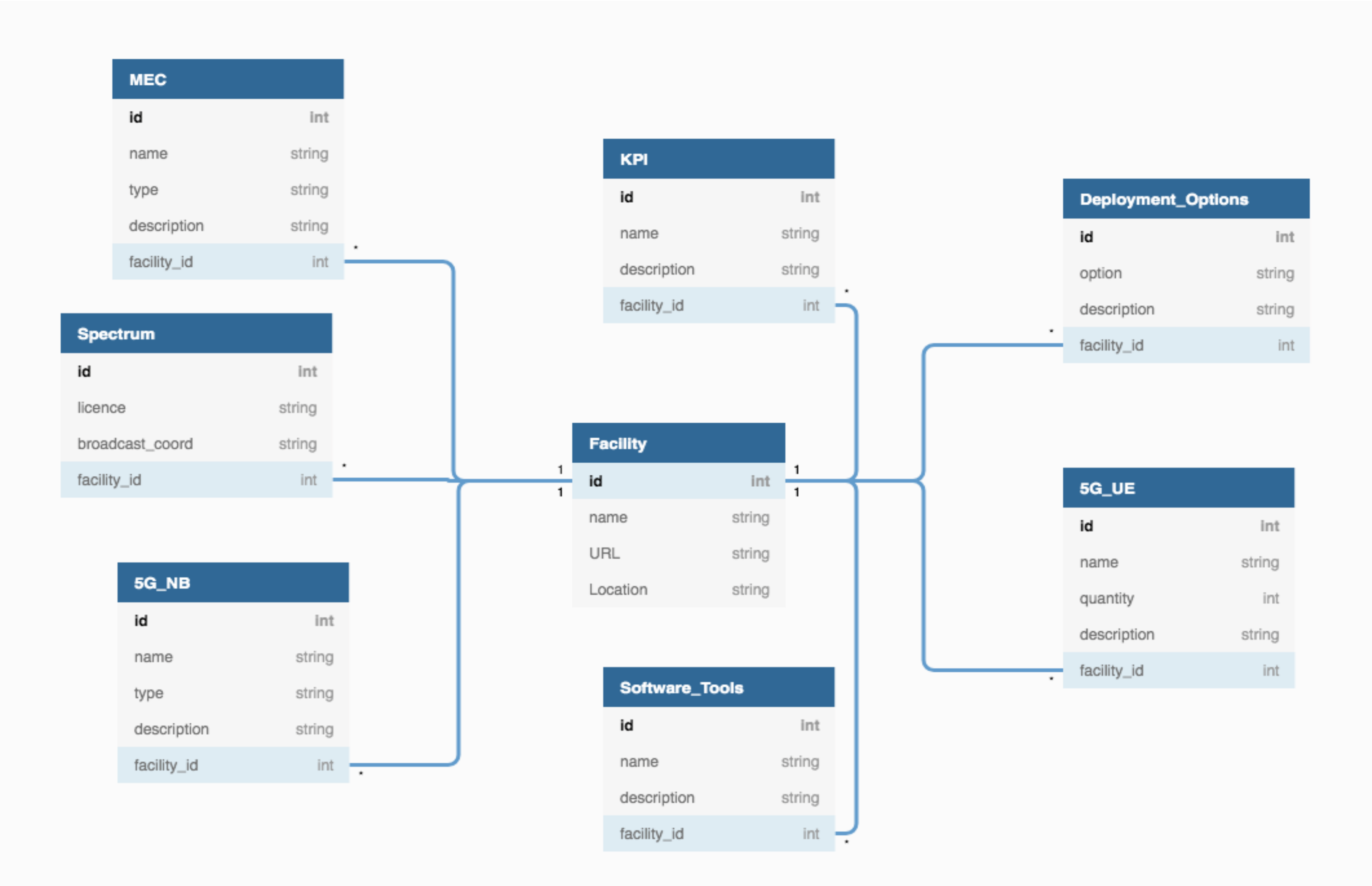

Figure 13: Data model for the 5G Facility repository

For a more detailed view of the fields associated with the facilities, Table 3 is presented:

Element Name	Attribute Name	Type	Description
Facility Facilities registered to be used	ID	Int	ID of the facility
	Name	String	The name of the facility
	URL	String	The URL of the facility to be used
	Location	String	Location of the facility (optional)
KPI [*…*] A list of all the KPIs that are available associated with each facility	Name	String	Name of the KPI
	Description	String	Short description (optional) of the KPI involved

5G NB [1...*] 5G NBs available in each facility	Name	String	Name of the NB
	Type	String	Type of the NB
	Description	String	Short Description (optional)
Spectrum [1...*] The licences and broadcasting co-ordinates available for each facility	Licence	String	Licence for this facility
	Broadcast coordinates	String	The coordinates that the broadcasting is available
5G UE [1...*] The end-user equipment available in each facility	Name	String	The name of the UE available
	Quantity	Int	The number of available UEs
	Description	String	Short Description (optional)
Deployment Options [*…*] The deployment options, as defined by the 3GPP 5G options, available for each facility	Options	String	The option (e.g. 3a) that is available
	Description	String	Short Description (optional)
MEC [1..*] The MEC available in the facility	Name	String	Name of the MEC
	Type	String	Type of the MEC
	Description	String	Short Description (optional)
Software tools [0...*] Any other software tool that is available in the facility and needs to be registered	Name	String	Name of the tool available
	Description	String	Short Description (optional)

(e.g.monitoring probes)			

Table 3: Data fields for 5G Facilities Repository

2.4.1.4. The trial repository

The trial repository can be considered as the centre piece of the trial controller's persistence storage, and it includes attributes referencing both UAVs and 5G facilities (as depicted in Figure 14). In addition to providing methods to create, read, update, delete, and list (CRUDs) all the trial records, it should enable the status verification of a given trial.

Feeding the trial repository comes after a trial is validated. It will provide server-side filtering for listing records. This will allow to check the status and progress of a given trial (e.g., for a specific use-case, or per a specific facility).

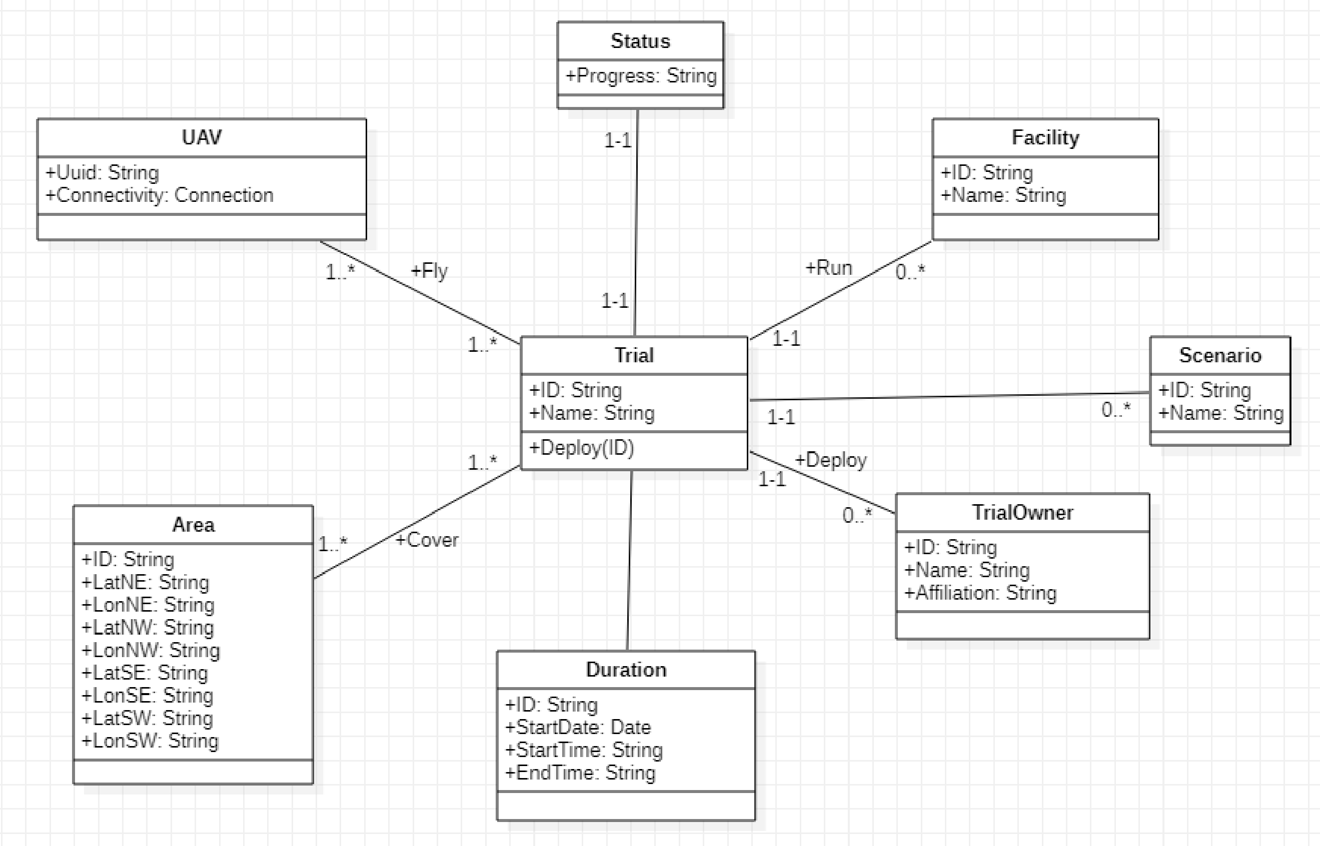

Figure 14 - Trial Descriptor Data Model

The description of the trial attributes is listed in Table 4 - Trial Descriptor Attributes

Element Name	Attribute Name	Type	Description
UAV UAV(s) used in the	Uuid	String	UUID string uniquely identifying the UAV in a national registry. This UUID will be used as required to query U-Space e-

trial; detailed in 2.4.1.2.			Registration services for information already recorded therein.
	Connectivity	Connection [1..*]	One or more supported connectivity modes (e.g., 5G, 4G, Wi-Fi)
Duration Date and duration of the trial	StartDate	DateTime	Date at which the trial is scheduled to begin
	StartTime	String	Time when the trial will begin
	EndTime	String	Time until which the trial is running
Facility Facility where the trial will be deployed; detailed in 2.4.1.3,	ID	String	ID of the facility
	SiteName	String	Name of the trial site
Area This defines the area where the trial will take place. It can be captured from a MAP using LAT/LON/Altitude coordinates.	ID	String	ID of the area
	LAT/LON/Altidude coordinates	String	Defines the borders of the designated area to run the trial.

Table 4 - Trial Descriptor Attributes

2.4.2. Trial validator

The trial validator is a gate check mechanism made of simple rules and binary decisions which would decide if the trial can be performed or not. In simple words, the output of the trial validator will be a Go (green light) or a No-Go (red light). The trial validator will be used by the Airboss [9] (service provided by RXB) and by UAV Operators personnel out in the field. It will have a simple web portal which interacts with various components of the trial and gives output only to the web portal 1.

Input

The trial validator receives input from the following components of the trial and checks if the status is a Pass (ready) or Fail (not ready):

- U-space adapter
- Facilities repository
- UAVs repository

- Trial repository
- Coverage
- Pre-defined trials catalogue

The data from the above-mentioned entities will be accepted in the form of JSON messages.

The only entity that requires manual input from the Airboss personnel is the "Pre-flight check".

Output

The output of the trial validator will be sent to the web portal 1 and/or displayed on the web portal. The output will be in such a way that, the status of each signal is sent and displayed on the web portal, and the final decision is also sent and displayed on the web portal.

A case where all the signals are true, and the decision is a "Go would look like Figure 15 and a No-Go decision, for instance, if the U-space adapter check failed, it would look like Figure 16.

Figure 15 - Trial validator web portal output for "Go" decision

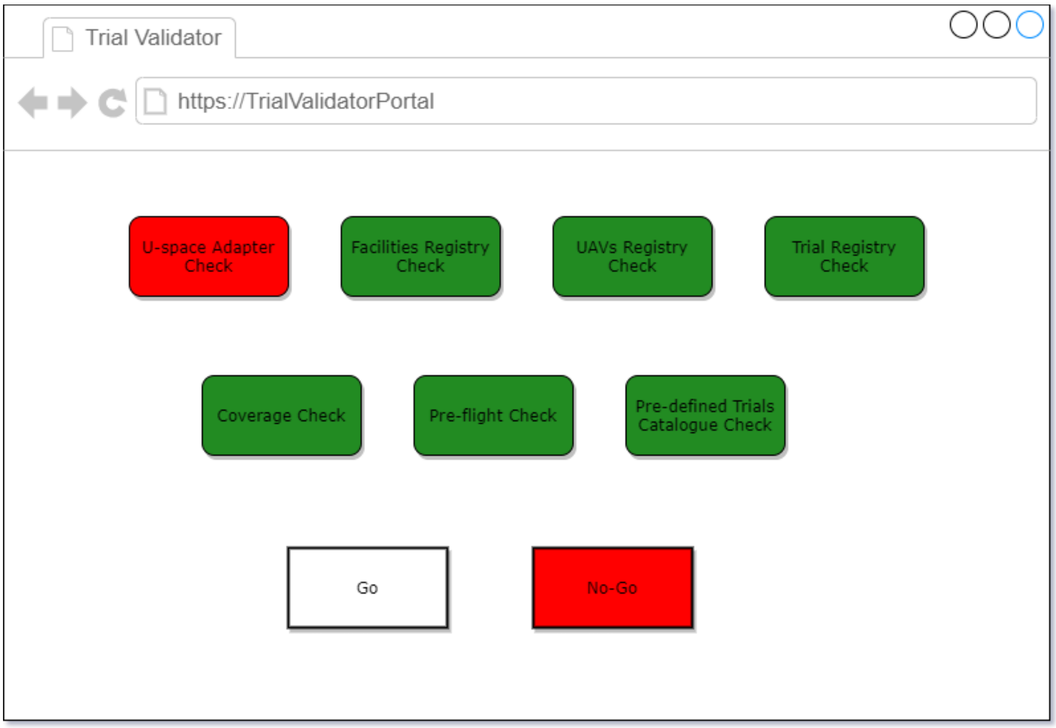

Figure 16 - Trial validator web portal output for "No-Go" decision

Working Mechanism

The trial validator follows a decision tree where, an AND gate is used for a "Go" decision, and an NOR gate is used for a "No-Go" decision. It is designed in such a way that only if all the signals are true, a "Go" decision is triggered, and even if one of the signals is false, a "No-Go" decision is triggered. The figure below shows the model of the system.

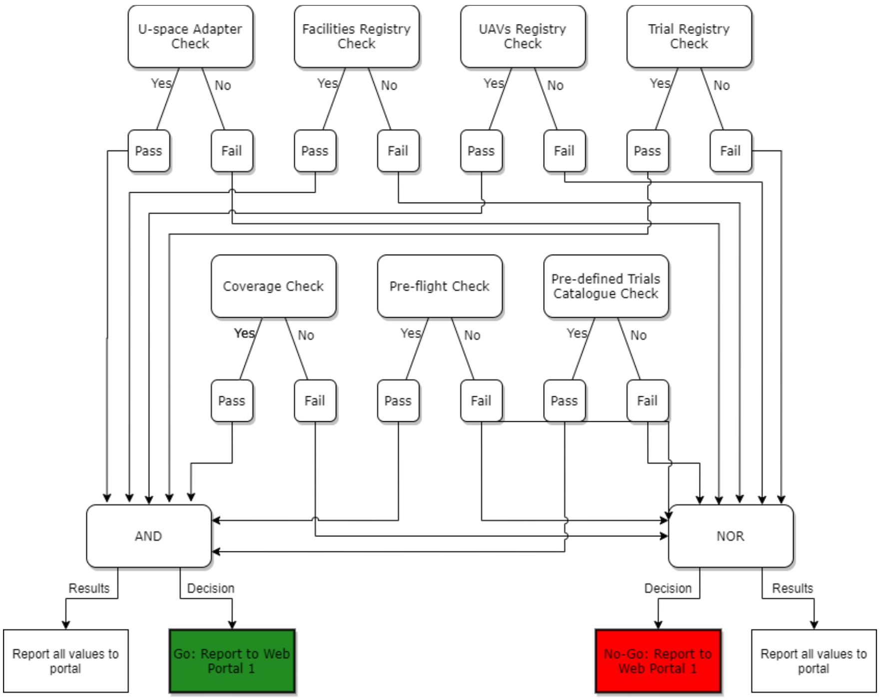

Figure 17 - Trial validator decision tree

2.4.3. Trial translator

The main objective of the trial translator is to map the trial requirements entered in the web portal by the UAV verticals, to the required components in terms of 5G facilities and UAVs.

Indeed, the necessary information for a such trial are provided in form of Blueprint through the Web Portal 2, which creates a Trial Service Descriptor (TSD) including KPIs, trial duration, RAN information, NSD and VNFDs or AppDs, etc.

Thus, the trial translator takes as input this TSD (in form of json file) and translates it into a template called the Network Slice Template (NST) that will be used to create the slice.

```
{
  "metadata": {…
  },
  "ranSubSlice": {…
  },
  "networkServiceSubSlice": {…
    }
}
```

Figure 18: Network Slice Template format (5GEVE)

The Network Slice Template consists of three principle components, as illustrated in Figure 18:

- MetaData: Includes some information about the slice and the trial duration.
- Ran Information: includes UE list, (the radio part here contains the list of the User Equipment (Drones) that shall be deployed in the slice), the throughput, the latency required in the network and whether the SubSlice can be interrupted or not for another slice.
- Services Information: represents the NFV part containing information about the virtual functions that will be used in the trial.

Figure 19 shows an example of the Network Slice Template.

```
"metadata": {
  "name": "string",
  "provider": "string",
  "version": "0.1-ALPHA",
  "startDate": "datetime",
  "endDate": "datetime",
  "category": "int1"
},
```


(a) Metadata


```
"ranSubSlice": {
  "area":"string",
  "subslices":[{
    "throughput":"int9",
    "latency":"real",
    "interruption":"boolean",
    "TrafficOrientation":"int1"
  }],
  "ue-list": [{
    "imsi": "int16"
  }]
},
```


(b) RAN Information


```
"networkServiceSubSlice": {
    "name": "MEC app package of a robot control application",
    "version": "1",
    "provider": "pfrag",
    "checksum": "ignored",
    "userDefinedData": {
      "region_id": 3
    },
    "appD": {
      "appDId": "6ee7f285-8247-4693-af55-6ad6c454726e",
      "appName": "robot-control-app",
      "appProvider": "pfrag",
      "appSoftVersion": "1.0",
      "appDVersion": "1.0",
      "mecVersion": [⋯
      ],
      "appInfoName": "robot-control-app",
      "appDescription": "This is a application for controlling a mobile robot
      "virtualComputeDescriptor": {⋯
      },
      "swImageDescriptor": [⋯
      ],
      "virtualStorageDescriptor": [⋯
      ],
      "appServiceRequired": [⋯
      ],
      "appServiceOptional": [⋯
      ],
      "transportDependencies": [⋯
      ],
      "appTrafficRule": [⋯
      ],
      "appDNSRule": [⋯
      ],
      "appLatency": {⋯
      },
      "terminateAppInstanceOpConfig": {⋯
      },
      "changeAppInstanceStateOpConfig": {⋯
      }
    }
  },
```


(c) Services Information

Figure 19: Example of the Network Slice Template (5GEVE)

2.4.4. Lifecycle manager

The LCM (Lifecycle manager) sub-module is responsible for managing the lifecycle of the trial execution. This sub-module will communicate with the trial enforcement module to configure and run the required 5G components with the associated UAV operator(s) to run the target scenario. The trial LCM enables the automation of the experiments. The LCM is not responsible to validate changes during the trial planning as the trial validator takes care of it. The LCM validates change during the trial, but the main control and responsibility of the trial belongs to UAV operator(s).

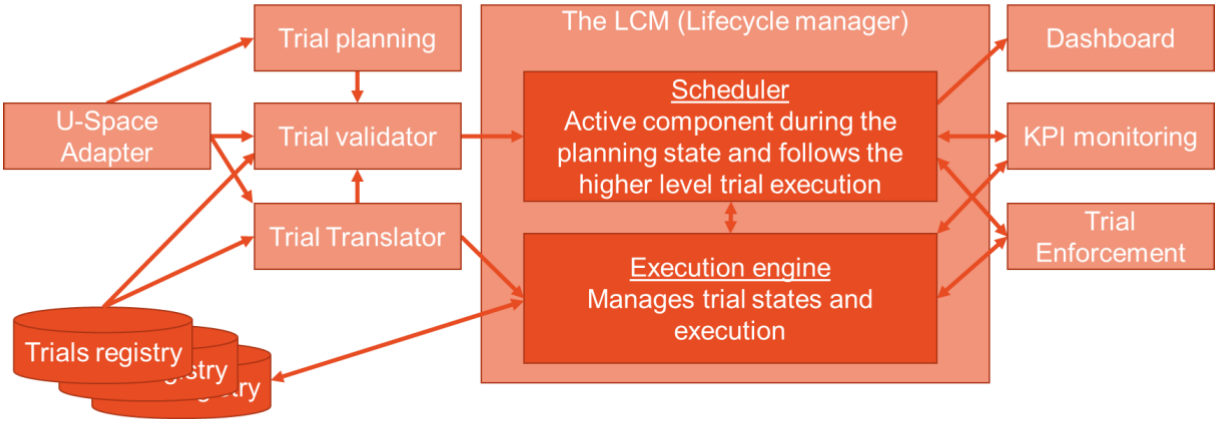

Figure 20: The Lifecycle manager internal components and interfaces from the LCM point of view

Figure 20 summarizes the LCM internal elements, interfaces and interactions from the LCM point of view. The 5G!Drones' LCM actual internal sub-components follow lightly 5GENESIS ELMC (the Experiment Life Cycle Manager) design [10]. In addition, there are many similarities to 5GEve Experiment Lifecycle Manager [11]. One of the differences is that the 5G!Drones' LCM has an active role already in planning phase. The LCM's scheduler is responsible in high-level managing the execution of the trial according below mentioned states, while an Execution Engine includes the logic for managing the execution of each experiment stage. The scheduler starts execution engine after checking that trial has all needed resources available. This check happens before change from the pre-trial state to the trial execution state. The LCM is not responsible for creating alarms or notifications related to UAV's parameter tracking like actual value versus operating range or maximal flight time.

The Trial planning module related inputs are coming via the Trial validator to the LCM during the planning state. During the trial execution and post-trial state the LCM acts according beforehand set rules and adopts it sub-state based on incoming changes. The LCM receives different types of inputs from the trial validator, the trial translator, different registries, the trial enforcement (different state related information etc.) and the KPI monitoring (KPI data). The LCM sends request to the trial enforcement (deploy slice) and the KPI monitoring (request KPIs) or data to the different registries, the dashboard's list view. Via dashboard the LCM informs the experimenter the LCM's state and related data.

Trials have three common high-level states, which have several sub-states from the LCM point of view. These basic states are reflected from 4.2 Mechanisms for flight planning three phases: Preflight process, Inflight and Postflight analyses. In addition, in 2.5.2.1 Operator lifecycle has defined four different primary states for UAV operator "Unconfigured", "Inactive", "Active" and "Finalized", where the entry point to trial is a create state and end point is a destroy state.

The pre-trial state sub-states are:

- **Available** - This state means that services are ready for trial planning from the test facility, the UAV and the UTM services point of view. The LCM is operational on this step and tracks that pre-defined items like the planning tool is available to the users.
- **Planning** - There is authenticated user or user groups, who can start trial planning. The planning steps include the SORA process and this state is controlled by the Trial planning module. The planning time input comes from the Trial Validator which indicates the trial requirements related for the UAV plan, the test facility and the 5G coverage. Input for this state includes validation results like Pass or Fail. The Fail validation results with reasons for failure will be collected by the Trial validator, not by the LCM. The Trial Translator indicates trial state related to different pre-defined network services and this information comes to LCM via Trial Validator. In this state the LCM sends the slice deployment request to the trial enforcement, which instantiates the slice in the facility.
- **Ready for trial –** Plan is validated and approved; all systems and components are available. The LCM tracks in this state that there is no existing or coming condition change that blocks trial.
- **Delay** - The trial is delayed due to, for example, a dramatical chance in the weather. The LCM tracks that there is no existing or coming condition change that blocks trial and cause trial to be moved directly to the terminated state or back to the planning state.

The trial execution state sub-steps are:

- **Execution –** The trial and related services are running. For example, the UAV has started the trial and 5G BTS's are on-air state. The LCM tracks changes in data and different modules states. The LCM receives trial's KPI values from the KPI -monitoring module. The UAV operator is fully responsible for trial operations during the execution state and the LCM can only give the notification or the alert. The LCM can't, for example, set trial to Abort state without the UAV operator approval. The LCM communicates, updates and received status of the trial with and to the Trial repository sub-module and dashboard.
- **Abort** - Due to component, module failure or dynamic change requested by UTM etc. trial is aborted and is going to be terminated, but the trial system including different 5G and facility related services safe shutdown are ongoing during this state.
- **Change –** Mission change during the flight due to mission critical changes, for example, at public safety scenarios based on changes in wildfire situation. This state reflects in flight states like MissionPrioritization and EnteringEmergencyMission in Figure 43: In flight states of the drone.

The trial post-trial step sub-states are:

- **Post-processing** – The trial active execution state is end and the trial related application services are post-processing data
- **Terminated –** The trial is ended while relevant data are stored to the appropriate databases. There is no possibility to start new trial planning, while system is in Terminated state.
- **Out-of-Service –** There are facilities, U-Space etc. related restrictions like bank holidays, power outage, which blocks services.

The LCM may support multiple simultaneous trials. The Trial validator in the planning state controls the amount the trials. If there are requested to run different trials at same time, by default trials are served and prioritized based on reservation order.

2.5. Trial Enforcement

The Trial Enforcement component of the Trial Controller will be responsible for the execution and automation of the trials planned, as well as provides monitoring for the trial status. In order to accomplish this, plugins for the 5G components will be developed that will activate when a request from the Trial Engine, specifically the LCM, arrives. Then they will contact the 5G infrastructure or abstraction layer in order to run the predefined trial scenario through sequential steps.

Trial Enforcement will be composed from one sub-module, Configuration and Deployment. During the pre-trial stage it is responsible for the preparation of the trial with actions such as network slice creation and network service deployment. These responsibilities include the on-boarding of VNFs or CNFs, whether UAV-related functions or network-related.

During the trial stage, it will have as a primary function the runtime configuration and monitoring of the trial progress. This refers to the steps, status, and result of trials executed but not the data generated during it. It is also responsible to run the test scenarios linked to the trial. The module will be also responsible to provide an interface for the facility owners and verticals, in order to show the monitoring results. In order to perform runtime configuration and collect the metrics, the module will have to communicate with the 5G components using the infrastructure and UAV operator plugins.

As already mentioned, in order to support the Trial Enforcement, infrastructure plugins will have to be developed. There will be interfaces created that will be able to communicate with the 5G components with the goal to facilitate the execution and monitoring of the trials. These will include:

- Interfaces to 5G Infrastructure
- Interfaces to UAV Operators

2.5.1. Interfaces to 5G Infrastructure

In the context of the trial enforcement module, as illustrated in the trial controller process in Figure 7, the deployment of slices is triggered by the trial lifecycle manager. Most of the configuration and deployment operations in this context pertain to Day-1..N operations:

- Day-1: defines the configuration pushed by the network managers/orchestrators that are common to all network slice instances.
- Day-2...N: extends to the on-going configurations pushed for the day-to-day operation of network slice instances.

The north-bound interface of the network managers/orchestrators must offer the capability of managing the lifecycle of network services and Network Slice Instances (NSIs), offering all the necessary abstractions to allow the complete control, operation and supervision of the network slices lifecycle throughout the trial.

The stages related to the lifecycle and operation of the network slices are described in what follows, enabling a better understanding of the API capabilities for the configuration and deployment.

Prior to the instantiation phase, the preparation triggers the creation and verification of Network Slice Templates (NSTs), their on-boarding, and the preparation of the necessary network environment to be used to support the lifecycle of NSIs. These operations are part of the trial validation.

2.5.1.1.1. Instantiation, Configuration and Activation

During instantiation and configuration, all resources shared or solely dedicated to the NSI have been created and are configured to a state where the NSI is ready for operation. The activation step includes any actions that make the NSI active (i.e., if dedicated to the network slice, otherwise this takes place in the preparation phase). Network slice instantiation, configuration and activation can include instantiation, configuration and activation of other shared and/or non-shared VNFs.

2.5.1.1.2. Run-time

In the Run-time phase, the NSI is capable of handling traffic to support communication services. The run-time phase includes supervision (e.g. for KPI monitoring), as well as activities related to modification: upgrade, reconfiguration, NSI scaling, changes of NSI capacity, etc.

2.5.1.1.3. Decommissioning

The Decommissioning phase includes deactivation of the NSI as well as the reclamation of dedicated resources (e.g. termination or re-use of VNFs) and configuration of shared/dependent resources. After decommissioning the NSI does not exist anymore.

2.5.2. Interfaces to UAV operator

2.5.2.1. Operator lifecycle

The UAV operator will be abstractly modelled in the context of the Trial Enforcement module as a virtual network function (VNF) adhering to the lifecycle shown in Figure 21.

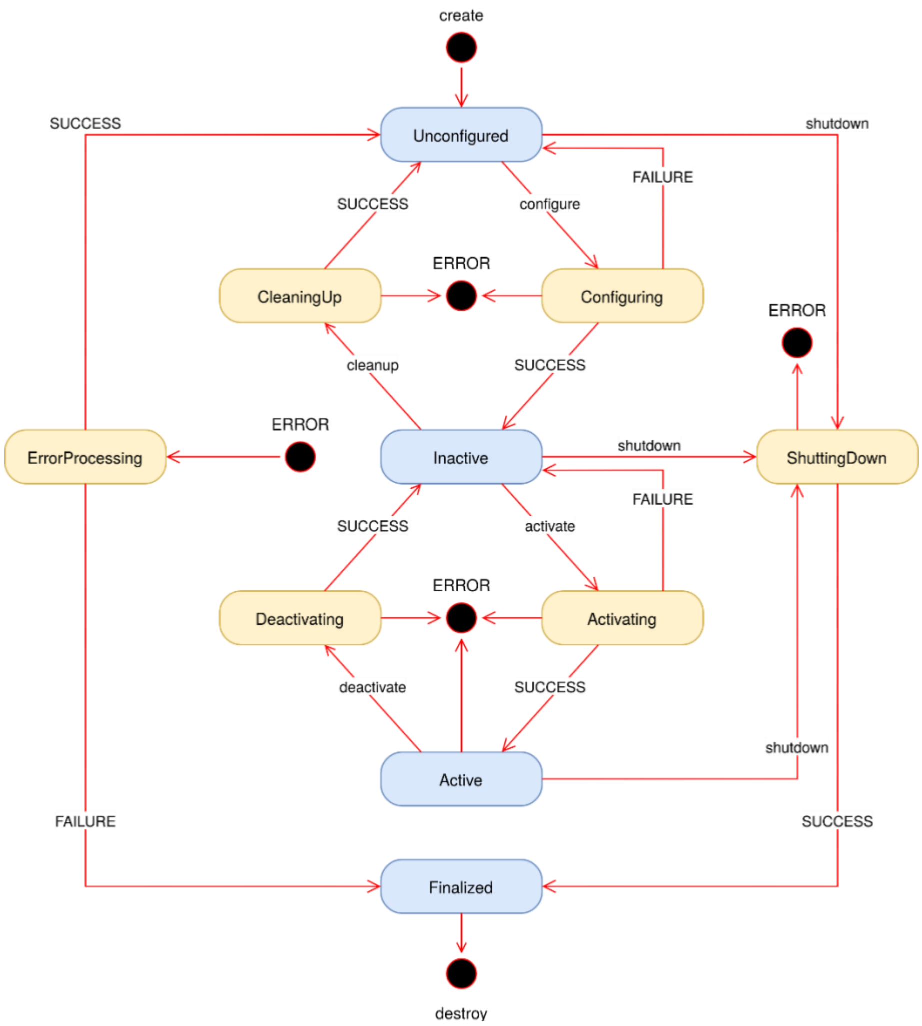

Figure 21: Operator Lifecycle
Source: Adapted from [12], used under CC BY 3.0

This lifecycle describes 4 primary states (*Unconfigured, Inactive, Active,* and *Finalized*) and 6 transition states (*Configuring, Activating, Deactivating, CleaningUp, ErrorProcessing,* and *ShuttingDown*) which

are detailed in Table 5 and Table 6, respectively. The Configuration & Deployment module manages transitions between these states and provides output from the Trial Controller through 4 trigger events (*configure, activate, cleanup,* and *shutdown*). Note that the *deactivate* event is expected to be managed internally by the UAV operator rather than originating from the Trial Controller.

Unconfigured	This is the state of the UAV operator immediately after initialisation. The UAV operator will be represented by a VNF running on edge infrastructure provided by the trial facility. The onboarding and initialisation of this VNF is not managed by *Interfaces to UAV Operator*.
Inactive	The *Inactive* state allows the operator VNF to be (re-)configured without affecting an operational flight.
Active	The *Active* state represents an ongoing trial. In this state, the operator VNF is flying UAVs and reading, processing, and outputting data to and from the Trial Controller related to trial KPIs and mission status.
Finalized	The *Finalized* state exists for introspection and debugging. This is a terminal state from which the only valid exit is destruction of the operator VNF.

Table 5: Primary states

Configuring	In the *Configuring* state, the operator VNF acquires or verifies any resources that it will hold throughout its lifetime. If successful, the operator VNF moves to the *Inactive* state.
CleaningUp	In the *CleaningUp* state, the operator VNF releases or cleans up any resources it acquired during the *Configuring* state. If successful, the operator VNF moves to the *Unconfigured* state.
Activating	In the *Activating* state, the operator VNF performs final preparations in order to start executing a trial. This includes establishing communication with hardware (e.g., UAVs identified for use in the mission). If successful, the operator VNF moves to the *Active* state.
Deactivating	In the *Deactivating* state, the operator VNF performs cleanup that may be required to reverse the changes of the *Activating* state. This state is purely internal and will not be triggered by the Trial Controller as it may release resources that are required during flight. The operator VNF is responsible for executing this transition after terminating a mission. If successful, the operator VNF moves to the *Inactive* state.
ErrorProcessing	In the *ErrorProcessing* state, the operator VNF responds to errors that occurred during operation. Note that this state is an abstraction of the implementation of a given operator VNF, and that operator may decide to handle specific errors in a more explicit manner.

ShuttingDown	In the *ShuttingDown* state, the operator VNF prepares itself for termination. Note that at the end of this transition, for debugging purposes, the operator VNF will move to the *Finalized* state rather than being destroyed.

Table 6: Transition states

2.6. Data Monitoring

This section describes which Data monitoring are collected and integrated, how they are used for KPI assessments.

2.6.1. Data types

Data types that can be given to Trial Engine for data monitoring purpose can be provided by user side (Android API, application-level) or by network side from 5G facilities.

At UAV-side, link quality should be monitored in order to evaluate the state of connection. For instance, UAV C2 connection state needs to be checked regularly in order to trigger fail-safe procedure in case of connectivity loss.

UE reachability and location, or location of a specific UE within a geographical area, can be monitored at network side provided by 5G facilities (typically AMF and UDM entities). It is particularly crucial for troubleshooting if no data can be provided by UAV.

More generally, monitoring data at 5G facilities are get from two sides: RAN and NFVO. For full details, please refer to 3GPP TS 28.552 [13] about performance measurements for 5G Network Functions, TS 28.554 [14] about 5G Key Performance indicators and TS 32.455 [15] for EPC KPI. TS 23.288 [16] and TS 28.533 [17] for NWDAF (Network Data Analytics Function), Network Exposure or network data analytics services could be used for advanced analytic services (statistics, predictions, recommendations) but only in Release 16 or 17.

Hereafter we give only the main data types relevant for UAV use cases.

A first level of monitoring can be given by slice creation/deletion and number of UE per slice. NFVO performs monitoring operations of the NFVI to collect information regarding operations and performance management.

More precise data can be provided by NF Element Management System. Generic management services of 5G NF enable management system to subscribe/unsubscribe for different type of analysis information in stream batch or event modes (i.e., load level information of Network Slice instance). Data Collection feature permits Management system to retrieve data from various sources (e.g. NF such as AMF, SMF, UPF), as a basis of the computation of network analytics. Generic management services (TS 28.532 [18]) enables OAM to request and get different type of information from NF (i.e., load level information of Network Slice instance). They can be used for retrieving data for individual UEs or groups of UEs (e.g. UAV reachability) within OAM services, and also to retrieve global UE information (e.g. number of UAV in a geographical area).

In addition to these types, we also consider monitoring and performance of usage of virtualization resources at MEC (ETSI GS MEC 010-2 [19]).

Monitoring Data from UAV side: connection state, service load reliability (error rate, throughput), maximum age of information (jitter, latency)	**Monitoring Data at 5G Facilities**	
	At RAN	At NFVO
Link quality per UE: Radio Channel conditions (RSRP, RSRQ, CQI), RRC setup success rate, Packet Error rate Latency (inter-packet gap), round-trip-time (ICMP) Jitter Throughput in average Application-level statistics (IoT data, video analytics)	**Link quality per UE per slice**: "Latency-eNB-CN": Measured RTT between the RAN and CN "Bandwidth": Bandwidth of cells Aggregated per slice: "Latency-RAN" : Latency at the RAN "Uplink-data-rate": Uplink data rate "Downlink-data-rate" : Downlink data rate "Packet-Loss-rate": Packet loss at the RAN after attempts (RLC layer) "IP-rate": PDCP Packet rate	General purpose: - "Latency-edge" : Latency from CN to Edge host - "Latency-VIM" : Latency from CN to VIM Aggregated per slice or per CNF (Container Network Function): "CPU-utilization" "Memory-utilization" "Number-instances": Number of container instances per CNF
	Link quality per UE via MEC: (under investigation): • RSRP and RSRQ • CQI • IP addresses of UE	
	Slice Monitoring: "Slice-deployment-duration" "Slice-time-decommissioning"	**Slice Monitoring:** Time to create a slice Time to release all slice resources
Reliability (at application layer): maximum tolerable packet loss rate with the maximum tolerable end-to-end latency; it is considered only when the network is available	**Availability**: 'Cell Availability' (length of time that a cell is available for service) **Continuity**: time between failures **Recoverability**: time to recover a failure	

Table 7: generic monitoring data types

Data collected can also be sent periodically, per batch, event, stream to a server for further processing, such as telemetry, troubleshooting and forecast issues. The period should be adapted to the type of

data and the use cases requirements (e.g., the 3 seconds max delay before activating UAV fail-safe procedure for C2). For instance, the period for retrieving data (throughput, latency, error rate) for service level reliability depends of data usage (telemetry, video transmission, payload), e.g., to ensure that the video quality is enough but avoiding to overload the network by too much information. Maximum age of information should be defined by the application, typically 140ms for a video at 25 frames per second.

Additional data can also be collected periodically at various locations by UAV side for further processing: number of neighbouring cells, terminal category, speed, acceleration.

In fact, there are two ways to collect monitoring data:

1) to get monitoring data in real-time from 5G facilities (e.g., to check the availability of network resource during the flight in order to alert the UTM/pilot in case of troubles)
2) to retrieve a collection of data from live networks for further processing (e.g., to collect statistics of network quality for predicting network resources availability in the context of setting up UAV flight planning).

The period of time for collecting this data is around 30 seconds or more in order to avoid jeopardizing real-time traffic. Cell load (gNodeB CPU utilization, number of active users, number of UE in RRC connected state, number of simultaneous transmitting UE DL/UL), average cell throughput and CQI, BLER in average, are few examples but not an exhaustive list.

The KPI monitoring component will manage a table of connected UAV, and manage it at slice creation and release time, as well as when exceptions will occur (e.g., unexpected disconnection, network performance under expected values).

In addition to networking/computing data, UAV telemetry is another data type that can be captured during the trials. UAV telemetry constitutes the flight operations metrics that are output by sensors and controllers on the aerial platform. Additional parameters such as gimbal position data, camera info might be included if required. Most of the flight controllers and commonly used protocols specify a set of measurable parameters. UAV telemetry as referred to in this document is a combination of those parameters output by flight controllers used in the project. As an example, UAV telemetry includes parameters such as GPS position, mission status, flight mode, gimbal angles, raw IMU data etc.

The UAV telemetry architecture focuses on the data that is encapsulated by the UAV platform and can be measured on-board. Thus, explicit support for external KPIs such as two-way connectivity parameters is not explicitly supported.

As various flight platforms are used, the systems can largely be divided into two groups: open-source MAVLink-based and proprietary (e.g. DJI) drones.

Getting MAVLink data is used via getting the log parameters and shipping them to the KPI storage. A reference implementation can be found in [20].

Where DJI Onboard SDK is supported, a similar approach will be used. An example of architecture is described in [21]. Where no support for DJI Onboard SDK exists, DJI Mobile SDK will be used to get the telemetry. Reference documentation can be found in [22].

In all the cases, telemetry data will be transmitted through the connectivity which “Network Data” work group will provide. UAV telemetry scope starts with the UAV and ends at the edge of the network. This means that UAV telemetry solutions are network-agnostic and can be used through 4G, 5G, WiFi etc.. In case of custom MAVLink data shipper or a DJI Onboard SDK, an onboard single-board computer (SBC) will be used to gather the data and it will connect to an internet through a provided device (e.g.

a 5G dongle or use a wired network sharing via a smartphone). In the case of DJI Mobile SDK, the mobile device that is used for controlling the drone will provide the network connectivity.

The data will be sent to the KPI Storage to be ingested into ElasticSearch database for further analysis. No pre-processing on the data will be done to retain maximum fidelity. The amount of data will vary greatly depending on the mission and UAV platform. Theoretical maximums of the telemetry data can reach several megabytes per second, as for example IMU data is very high frequency. On the other side, if that data is not needed, the package can be trimmed down significantly. Exact amount will be fine-tuned in the first feasibility tests.

Proof of concept has been done by HEP in [20]. A python application was created that connects to the Pixhawk flight controller, reads the telemetry data and sends it to ElasticSearch for storage. The concept was proven to be working and requiring relatively little effort to ship the telemetry data to the database. One shortcoming of the PoC application was that all the data points had to be queried separately and there was no way to get a full list of readings in one easy command.

2.6.2. Data aggregator

The KPI monitoring service with its interface as described in section 3.3 offers the possibility to push data into the data aggregator component.

The backend implementation of the KPI data management functionality is based on the open source Elastic Stack for data aggregation, storage and analysis.

The Elastic Stack consists of its core parts Elasticsearch, Logstash, Beats and Kibana [23].

Elasticsearch is a search and analytics engine. Logstash is a server-side data processing pipeline that ingests data from multiple sources simultaneously, transforms it, and then sends it to a "stash" like Elasticsearch. Kibana allows to visualize data with charts and graphs in Elasticsearch.

2.6.3. Data storage

Elasticsearch is a search and analytics engine, part of the Elastic Stack.

The standard elastic stack features allow users to store their data in form of so-called indexes – much like tables in a conventional database. An entry in an index is a document which corresponds to a data record in a conventional database. Documents can have arbitrary fields and don't need to have the exact same structure. Although querying an index is done using common fields all documents in an index share. These fields, their types and processing rules are defined in the index mappings.

All the above functions can be performed by a user via the GUI or by tools written by the user which use the ELK APIs. The base format for ELK documents and for working with the ELK APIs is JSON.

Data input for the trials is done via the interface as described in section 3.3.

The data storage component allows third parties to access and visualise data based on open standards and interfaces via Kibana. See Figure 22 for an example.

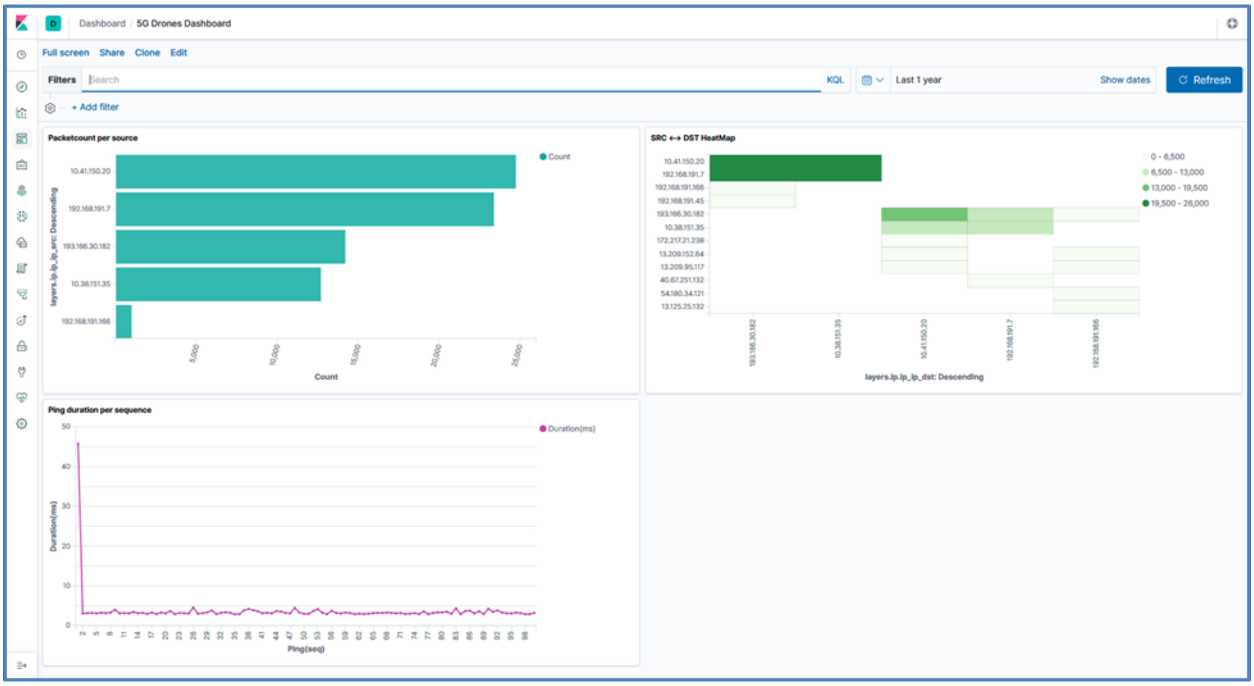

Figure 22: Example KPI Dashboard

2.6.4. Data analysis

2.6.4.1. Data analysis process

The data analysis part of the project will be divided into two parts. The first one concerns UAV and the second one concerns the 5G network.

Data analysis regarding UAV domain will target the following features:

- Flight data analysis
  - Get visibility on the performance of the UAV
  - While controlling the drones, pilots should be very focused and, at the same time, aware of the flight environment. Providing advanced UAV data analysis allows understanding the different parameters involved in the drone flight
  - By using prepared templates, data analysis tools help generating reports for civil aviation authorities and meet regulatory reporting requirements
- Maintenance
  - By analysing data gathered on the UAV, we can anticipate problems and avoid that they occur during a flight by recommending proactive maintenance
  - Report and track services performed
  - Follow the progress of maintenance cycles and better manager fleet of drones
- Alerting
  - By setting threshold data values when monitoring the UAV's equipment and environmental factors that can impact flight performances, data analysis tools can help alerting and notifying drone users of the potential problems

Analysing data from 5G networks can be used in many different ways. It allows to understand the functioning of the network, to know for example where the majority of users are located at a given

instant or at what time of day or night such part of the network is overloaded or not has available resources. By understanding the operation of the network, it is easier for the operating people to optimize it. The analysis of these data makes it possible to detect malfunctions or their imminent arrival and thus anticipate maintenance in a proactive way. Data analysis is a key element to find possible bottleneck in different network element likes gNBs, network core function etc. during the trials, while causing different kind of traffic load to 5G system. Data analysis helps to locate and deep-dive to gaps between 5G system, defined KPI targets for the UAV industry needs and actual trials performance. Finally, data analysis can, for example, recognize attacks and therefore improve network security.

2.6.4.2. Data analysis tools and techniques

To actualise the aforementioned needs for analysis, a combination of ready analysis and visualisation software available and implementations of analysis techniques will be utilised in order to provide comprehensive insights into collected data.

Widely used, available open source software will act as a basis for the analysis work. For instance, in 2.6.2 Data aggregator and 2.6.3 Data storage, Elastic Stack is utilised, and a part of it, Kibana, can be used for data visualisation. In terms of statistics and other advanced analysis algorithms, capabilities of available software will be put to use. However, specific trial related data analysis tasks likely require development of new solutions. Some trial related data analysis tasks may be solved with simple statistical application while others may require usage of deep neural network tools with computationally intensive training phase. One considerable option to develop and implement such tools and techniques is Python and its extensive libraries.

In Elastic Stack, Kibana is one of the open source products provided, and its capabilities can be utilised to visualise data and analytics. Kibana functions on top of Elasticsearch and provides an effortless way to search and navigate data indexed in Elasticsearch. Moreover, Kibana is a powerful tool to visualise the saved logs, metrics and analysis results. Kibana offers a possibility create dashboards, which can also be shared and embedded in further applications. For reference, see Figure 23.

Figure 23: An example data visualisation dashboard in Kibana

The section 2.6.1 Data types describes the data that will be used in analysis. As previously introduced, the analysis primarily targets features within the two categories: UAV domain and 5G network. The target will dictate the data types necessary for specific analyses.

One simple, but commonly used example of the data to analyse in the IT industry is to track system optimal performance via CPU load, memory or power consumption. This same applies to 5G network equipment. If the measurements show that equipment usage is too low during different use cases, it indicates that equipment is too expensive comparing user's needs. If the load is too high, it indicates a bad system design, possible SW / HW based anomaly or even a critical system failure due to limited resources.

Entropy of network traffic

Calculating the entropy of IP addresses and ports in a network is one of the indicators used to detect certain threats. In fact, a sudden change in entropy may indicate a Denied of Service attack (D) DoS attack or a port scan in progress.

Attributes frequency distributions

Efficient bot detection is a crucial security matter and has been widely explored in the past years. Bots exhibit specific communication patterns: they use particular protocols, contact specific domains, hence can be identified by analysing their communications with the outside. The frequency distributions of protocol attributes may capture the specificity of botnets behaviour. This approach is lightweight, can handle large amounts of data, and shows better accuracy than state-of-the-art techniques.

The 5G!Drones project indicates if 5G networks have enough features and resources to support the UAV industry by gathering data during the trials and analysing it. Different data analysis tools and analyses pinpoints the needed development areas of the 5G networks and further helps to update 5G related standards for UAV industry requirements.

2.6.4.3. Interfaces

Data analysis components will access and share data from UAVs, UTM, 5G system and 5G facilities via following interfaces:

- Data aggregator
- Web portal dashboard
- Life cycle manager
- Different registries like Trials registry
- 5G facility

2.6.4.4. Business impact of Data analysis

Nowadays, data is more accessible than ever and are of special value for businesses. To improve efficiency in business processes and functions, every organization collects in the best possible way related information. However, very few companies have realized the importance of efficiently analyzing data that leads the business or even the industry, in a direction of improvement, change or even innovation. Data trends can provide hidden insights to identify problems and help provide alternative ways of working. Moreover, it can make companies more efficient, productive, and even help predict future market trends.

5G!Drones Data Analysis WF except for its technical role will also focus on locating and analysing appropriate data and providing visualization of results on values that will create business and market

related impact in the drones industry through the use of 5G. It is important to map out the creation of value by utilizing analytics to establish a balance between the need for immediate technical value and business value leading to essential business impact and an exploitable competitive advantage. To do this it is essential to locate the related data values, define the analysis process that will result in delivering tactical business value, and identify how these activities will be maintained and evolve in business impact for the drone industry.

Within this framework, the WF will focus on identifying/proposing data values that may have potential business impact in the drone industry and need to be further analyzed and metrics/visualization to be obtained. Overall, the drone business partners will be queried in order to assess the potential business impact from the data analysis results and link specific data analysis findings to the project's business processes and business models (monitored in T1.1 Analysis of the UAV business and regulatory ecosystem and the role of 5G technology).

Although, the activities described above will mainly take place at a future stage of the project and will be reported at future deliverables as T2.4 progresses and data analysis mechanisms become available/operational, the Data Analysis WF has already co-aligned its technical activities with this business scope (e.g. business impact) and the activities of T1.1 (Analysis of the UAV business and regulatory ecosystem and the role of 5G technology). So far, although at a preliminary stage, the WF can report that specific data values of business interest have been spotted that may have impact on the proposed business models and processes and might be worth to be further analyzed. Such data values of business interest indicatively are:

- low latency and drone responsiveness,
- 5G network connectivity/coverage/signal quality and drone efficiency/autonomy,
- 5G data rate/bandwidth and drone image/live video efficiency/quality,
- number of connected drones/devices per unit area and new drone usages
- performance parameters of 5G MEC based applications

2.6.5. KPI assessment

General Key Performance Indicator (KPI) metrics can cut across different part of the trial execution. Starting from the deployment stage of the trial, the VNF instantiation, UAV operations and overall 5G metrics. Different KPI can be collected at different stage of the operation. Table 8 describes the list of possible KPI metrics that can be collected from the trial controller during the overall operation of the use case.
The list of KPI metrics that can be accessed or collected through the trial controller during the trial of the use case include the following in the table below

KPI Metrics	Descriptions
Network Capacity	Network capacities including latency, downlink and uplink speed, are set of KPIs required for the overall performance of a 5G network. Individual use case deployment can have their targeted network capacity. For example a peak use data rate between 50Mbps and 1Gb/s is required for specific deployment scenarios and use cases. The 50 Mbps as a minimum target value is in line with the 3GPP targets [24] that foresee ~30 Mbps uplink data rate for a 4K video streaming, without audio.

Overall Latency	Latency is important for the accurate control of the UAV in the case controlling it over the mobile network (e.g. with 5G radio interface). Considering that various parameters may influence the KPI value, such as the height and the speed of the drone. For example an average case for control latency requires 10 msec delay according to the 3GPP target values for different services, such as 8K video live broadcasting, LIDAR mapping and HD patrol surveillance and remote UAV controller through HD video.
Service creation time/Trial deployment time	Service creation time / Trial deployment time from the control center, this time will include all service preparation time at the control center. The idea of this performance metrics is to ensure that not much time is used for starting the operation.
Control center metrics	Control center metrics can include, number of drones, possible number of instantiations, rate for map update, speed/BW for translating received streams
Processing metrics	Processing metrics include KPI that can be collected when use case outputs are being processed. This is required to get enough KPIs required throughout the entire operation of the use case. For example, after reception of video stream data from the MEC, KPI metrics will be collected to know the speed to processing this into the 3D map, KPI to be assessed include processing time of video stream, time of processing application
VNF related Metrics	This include KPI metrics that can be acquired due to the use of 5G VNFs. Metrics that can be collected include the CPU utilization, memory utilization, Rate of packet sent/received between VNFs, VNF instantiation time, etc.
Trial operational metrics	This includes KPI metrics that can be measured during the operational phase of the trial. For example, metrics include the synchronization time of different radio to be used (UWB. eNB, 5GNR etc)
UAV related metrics	This includes all form of metrics that can be collected from the UAV deployment and are relevant to define 5G KPIs.

Table 8: list of possible KPI metrics

2.7. U-Space adapter

2.7.1. General

Chapter 4.2.6 in D1.3 [4] identifies IRPs (Integration Reference Points) with U-space, Portal, Trial Scenario Execution Engine, Trial Architecture Management Plane and the 5G!Drones Enablers.

Within this document, Chapter 2.1.2 provides an introduction on U-space, actors & roles in U-space and how they are mapped to the 5G!Drones project ecosystem – the U-space adapter as focal point for integration between U-space and the 5G!Drones project is introduced.

This interaction points expose and consume APIs with:

- Portal – to reuse existing products & work e.g. and especially in the area of mission planning
- Trial Scenario Execution Engine – e.g. for flight approval processes
- Trial Architecture Management Plane – e.g. for high priority slices / communication in non-nominal situations and retrieving information on network capabilities
- 5G Facilities (via Abstraction Layer) – e.g. retrieving dynamic information like UAV telemetry or up to data information on e.g. network capabilities

Based on the expected dataflow between these actors, information exchange will be necessary for

1. Operation Plans (Flight Plans)
2. Telemetry Data (Position Data)
3. Aeronautical Information Management Data (Airspaces, Geofences…)
4. Alerts (Critical information / advisories in non-nominal situations)
5. Registration Data (Drones, Pilots, …)
6. Network Coverage Data

For 1-5, data models and service specifications will be based on existing work done in the GOF USPACE project. A summary of this work is provided at the end of this section, the respective documents are made available to 5G!Drones Project Partners if they are not published by SESAR before this document is delivered.

6, Network Coverage Data is a new information exchange service, which is described in more detail in the following section.

2.7.2. Network Coverage Service

2.7.2.1. Service Identification

The purpose of this chapter is to provide a unique identification of the service and describe where the service is in terms of the engineering lifecycle.

Name	Connectivity Service
ID	*Unique identity (e.g. URN, to be defined in the implementation phase)*
Version	0.0.1
Description	The Connectivity Service provides three-dimensional information about data connectivity conditions along a flight route or in an area of interest. It provides information where connectivity conditions are or are not good enough for safe and reliable data connectivity that adheres to a certain

	service level, provided by individual connectivity providers.
Keywords	IP connectivity, data connectivity, data coverage, mobile communication, mobile connectivity, mobile coverage, cell connectivity, cell communication, cell coverage, LTE, 4G, 5G, command and control, C2
Architect(s)	Thomas Wana / Thomas Lutz / 5G!Drones Project Partners
Status	Provisional

Table 9 - Service Identification

2.7.2.2. Operational Context

This section describes the context of the service from an operational perspective.

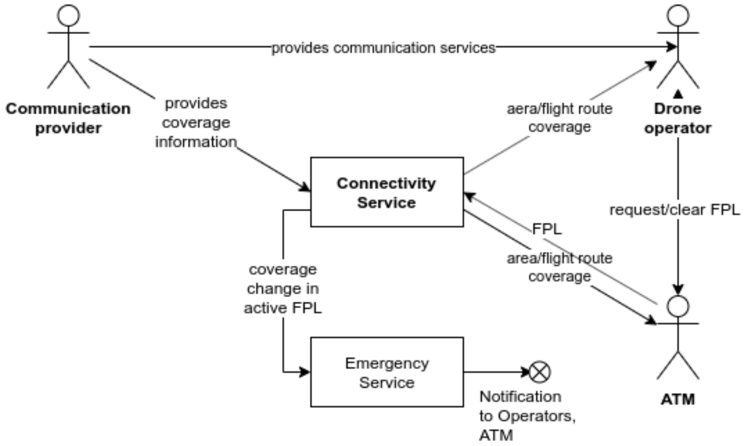

Figure 24 - Operational model diagram

An example service use in a controlled flight environment (CTR):

- A drone operator wants to fly a mission from A to B.
- In order to estimate the general feasibility of the flight, among other things, the connectivity situation in the general area of the flight has to be checked. The Connectivity Service provider provides area coverage information.
- If the flight is feasible, a concrete route has to be planned. After considering weather, airspace restrictions, aircraft performance, etc., one or more route candidates are created by the drone operator, which are checked against the Connectivity Service whether the minimum service level (for example: continuous C2 availability) is met along the route. If requested, the Connectivity Service can also alter the route to guarantee connectivity along the route.
- The drone operator files a flight plan a few days ahead of ETD with ATC and for Radio Communication Agency if regulation needs it.
- ATC also checks with the Connectivity Service if the flight planned route meets the minimum service level requirements, and if not, rejects the FPL.

- A few days later, before the flight actually commences, the drone operator rechecks the flight planned route whether the connectivity service level requirements are still met (together with meteorology, NOTAMs, etc.), and, where necessary, alters the route. Then, clearance is requested from ATC to commence the flight. ATC also checks the requirements again to be able to issue a clearance.
- During the flight, due to an outage at the communication provider, a certain segment of the flight planned route ahead of the aircraft loses connectivity. For this end, the link quality could be used as key performance indicator as mentioned in section 2.6.1. The Connectivity Service identifies this situation and alerts the Emergency Service for the affected flight plans.
- The drone operator has to re-plan the rest of the flight, and coordinate the changes with ATC, again with assistance of the Connectivity Service, to stay on a route that meets the connectivity minimum service level requirements (e.g., Link quality).

Flights in uncontrolled airspace or U-space will follow a similar sequence; Service Providers might / will be different depending on the local legislation.

2.7.2.3. Requirements

This service is based on requirements captured in D1.1 and on requirements from the U-space domain as listed below:

Requirement Id	Requirement Name	Requirement Text	References
REQ-AIRPASS-D31-PACM-0010	Communication for Procedural ATC Interface	The on-board system should provide a wireless data link and protocol to coordinate procedural directions from ATC services with the UAS ground control station	GOF U-space requirements
REQ-AIRPASS-D31-EACM-0010, REQ-AIRPASS-D31-MNCM-0010, REQ-AIRPASS-D31-TICM-0010, REQ-AIRPASS-D31-DFCM-0010, ...	Communication for Emergency Management, Communication for Monitoring, Communication for Traffic Information, Communication for Dynamic Geofencing, ...	Additional communication requirements like above, but for different use-cases: Emergency Management, Monitoring, Traffic Information, E-Identification, Geofencing, ...	GOF U-space requirements
REQ-DREAMS-D32-	Definition amendments are proposed to include the U-	"Two different definitions are proposed:	GOF U-space requirements

OPER.0008	Space context: COM (Communication)	1) ATS COM: 'ATS communication services' means aeronautical fixed and mobile services to enable ground-to-ground, air-to-ground for ATS purposes. 2) SWIM-COM: 'SWIM communication services' means fixed and mobile services to enable end systems, either at fixed location, mobiles or in flight, to exchange digital information for ATM/ANS purposes. "	
REQ-IMPETUS-D31-INTR.0012	DTM-UAV Interface	The UAV shall provide continuous information about its position to the DTM, ensuring that at least this direct link with U-Space is not compromised.	GOF U-space requirements
REQ-IMPETUS-D31-DECO.0017	Legacy networks	Legacy networks such as cellular and GPS networks shall be used to support drone operations and provide communications between different roles. The networks can be used to communicate U-space services needed to carry out safe drone operations. The system will programmatically communicate with these networks for facilitate safe drone operations.	GOF U-space requirements
REQ-TERRA-D32-FPER-0190	General Communications availability	The selected communication infrastructure shall ensure the connectivity of the ground segment with the external systems with which the system shall interface.	GOF U-space requirements
REQ-TERRA-D32-FPER-0192	General Communications latency	V2I latency has to be lower than 3 second.	GOF U-space requirements

REQ-TERRA-D32-FPER-020	Connectivity	The selected communication infrastructure shall provide connectivity between the central system and all nodes.	GOF U-space requirements
REQ-DROC2OM-D21-PERF.0010	WP2-GENUS-PER-001	The C2 Link System shall offer, for all addressed data exchanges, an end-to-end availability of provision of at least 99.3 %	GOF U-space requirements
REQ-DROC2OM-D21-PERF.0020	WP2-GENUS-PER-002	The C2 Link System shall offer, for all addressed data exchanges, an availability of use of at least 99 %	GOF U-space requirements
REQ-DROC2OM-D21-PERF.0030	WP2-GENUS-PER-003	The C2 Link System shall offer integrity performance in terms of packet error rate measured at the interface between network and logical link layer of at least 10-3	GOF U-space requirements
REQ-DROC2OM-D21-FUNC.0050	WP2-GENUS-FUN-005	The C2 Link System shall provide communication links for the whole duration of flights as well as prior to take-off and after landing.	GOF U-space requirements
REQ-DROC2OM-D21-FUNC.0080	WP2-GENUS-FUN-008	The C2 Link System shall support air-ground communications for drones.	GOF U-space requirements
REQ-DROC2OM-D21-FUNC.0100	WP2-DATLI-FUN-001	The C2 Link System shall be compatible with data links which will support all security related countermeasures to prevent identity theft, theft-of-service and eavesdropping threats.	GOF U-space requirements

REQ-DROC2OM-D21-FUNC.0200	WP2-TERST-FUN-001	The C2 Link System shall be compatible with a 3GPP LTE/LTE-Advanced or 5G NR terrestrial communication system operating in the 3GPP defined frequency bands.	GOF U-space requirements
REQ-DROC2OM-D21-FUNC.0220	WP2-TERST-FUN-003	When using a 3GPP LTE/LTE-Advanced or 5G NR terrestrial communication system, the C2 Link System shall be able to satisfy the baseline traffic profile requirements listed in Section 3.1.*	GOF U-space requirements
REQ-DROC2OM-D21-FUNC.0240	WP2-INTSE-FUN-001	The C2 Link System shall define an interface layer for multi-network service integration, including terrestrial and satellite networks relying on the IP protocol for global interconnection.	GOF U-space requirements
REQ-DROC2OM-D21-FUNC.0420	WP2-MULOP-FUN-001	The C2 Link System shall allow deployment of competing C2 Link Service providers and operators in same geographical locations.	GOF U-space requirements
REQ-DROC2OM-D21-FUNC.0450	WP2-MULOP-FUN-004	The C2 Link System shall allow Interworking, i.e. having the C2 Link data sent from the drone to ground network through a provider, and reaching the U-Space infrastructure servers through another provider	GOF U-space requirements

Table 10 - Requirements from U-space

2.7.2.4. Other constraints

2.7.2.4.1. Operational Nodes

Operational Node	Remarks
Connectivity provider	A provider of communication services like a Mobile Network Operator or a Satellite Data Communication Provider.

Table 11 - Operational Nodes providing the Connectivity Service

Operational Node	Remarks
UAS operator	Performs Drone services. The drone operator plans and conducts drone missions.
ATM	Air Traffic Management
USSP	U-space Service Provider
CIS	Common Information Service
End-user	Entity typically consuming services from UAS operators.

Table 12 - Operational Nodes (directly) consuming the Connectivity Service

2.7.2.4.2. Operational Activities

Operational Activity	Remarks
Get area and flight route coverage	Returns information about connectivity coverage for a certain area or flight route for a particular technology and communication provider.
Notify about changes in coverage	For a given area or flight route, get notifications about changes to connectivity.
Provide communication services	The communication provider provides its infrastructure to the drone operators for data communication.

2.7.2.5. Service Interfaces

The following diagram depicts the Service Interfaces of the Connectivity Service, and their allocations to the Service Provider and the Service Consumers, respectively:

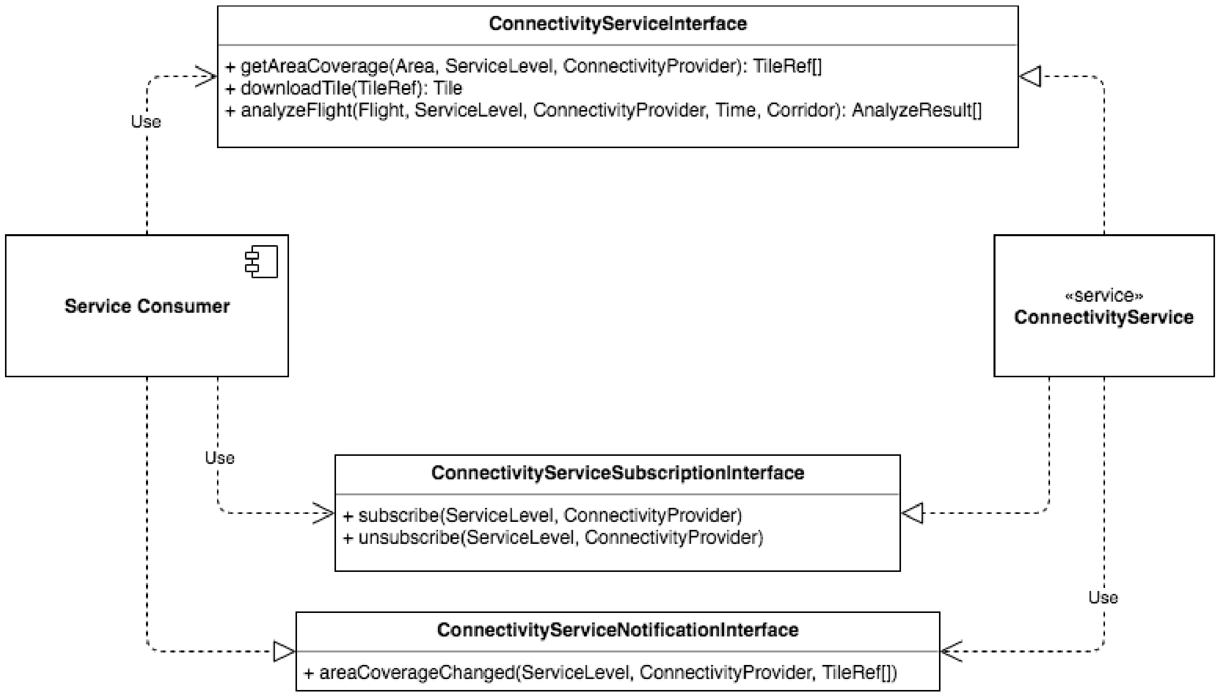

Figure 25 - Connectivity Service Interface Definition diagram

Service Interface	Role (from service provider point of view)	Service Operation
ConnectivityServiceInterface	Provided	getAreaCoverage downloadTile analyzeFlight
ConnectivityServiceSubscriptionInterface	Provided	subscribe
		unsubscribe
ConnectivityServiceNotificationInterface	Required	areaCoverageChanged

Table 13 - Service Interfaces

2.7.2.6. Service Data Model

This section describes the information model, i.e., the logical data structures to be exchanged between providers and consumers of the service.

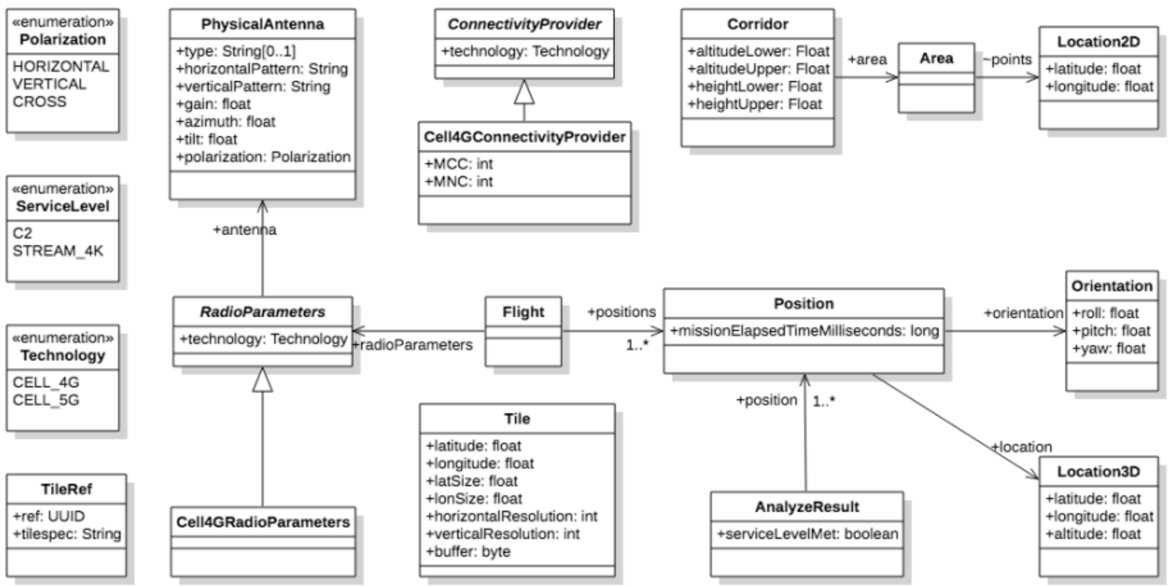

Figure 26 - Connectivity Service Data Model diagram

The following table describes the entities and their attributes in greater detail.

Element Name			Description
Flight			The Flight encapsulates a complete flight route, including spatial orientation of the aircraft for every position, and the communication equipment used on the aircraft.
	Attribute Name	**Type**	**Description**
	positions	Position[]	The positions (locations and orientation in space) that make up the flight route.
	radioParameters	RadioParameters	Information about the communication equipment used during the flight.
Element Name			**Description**
Position			A position in a flight route. Contains information about the location (3D), orientation and time.
	Attribute Name	**Type**	**Description**
	orientation	Orientation	Orientation of the aircraft in space at that location.
	location	Location3D	Location (3D) of the aircraft
	missionElapsedTimeMilliseconds	long	Estimated number of milliseconds elapsed from the start of the flight. Used to calculate aircraft speed between the positions.
Element Name			**Description**
Orientation			Information about orientation of an aircraft in space.
	Attribute Name	**Type**	**Description**
	pitch	float	Pitch (rotation around the transverse axis), in decimal degrees

	roll	float	Roll (rotation around the longitudinal axis), in decimal degrees
	yaw	float	Yaw (rotation around the vertical axis), in decimal degrees
Element Name		**Description**	
Location2D		A location in space, without altitude information	
	Attribute Name	**Type**	**Description**
	latitude	float	Latitude in decimal degrees (WGS 84)
	longitude	float	Longitude in decimal degrees (WGS 84)
Element Name		**Description**	
Location3D		A location in space, including altitude information	
	Attribute Name	**Type**	**Description**
	latitude	float	Latitude in decimal degrees (WGS 84)
	longitude	float	Longitude in decimal degrees (WGS 84)
	altitude	float	Altitude in decimal degrees (Meters AMSL)
Element Name		**Description**	
AnalyzeResult		Result of a flight route analyzation in regard to connectivity coverage, for a particular Position.	
	Attribute Name	**Type**	**Description**
	position	Position	The Position that was analyzed.
	serviceLevelMet	Boolean	Whether the requested service level is met at the Position.
Element Name		**Description**	
RadioParameters		Communication equipment (physical) and logical communication information. Abstract class, needs technology-aware specialized implementation.	
	Attribute Name	**Type**	**Description**
	technology	Technology	The technology of the radio parameters.
Element Name		**Description**	
CellRadioParameters		Communication equipment (physical) and logical communication information, for mobile communication.	
	Attribute Name	**Type**	**Description**
	technology	Technology	The technology of the radio parameters. Fixed CELL
	…	…	List of required attributes for is likely subject to change.
Element Name		**Description**	
PhysicalAntenna		A physical antenna used for communication.	
	Attribute Name	**Type**	**Description**
	type	String [0..1]	A well-known type specifier of the antenna. Optional; can be used instead of specifying the rest of the attributes if the antenna type is registered in the System
	horizontalPattern	String	Horizontal antenna pattern string
	verticalPattern	String	Vertical antenna pattern string
	gain	float	Antenna gain, in dBi
	azimuth	float	Horizontal orientation of the antenna on the aircraft, in decimal degrees

	tilt	float	Vertical orientation of the antenna on the aircraft, in decimal degrees
	polarization	Polarization	Antenna polarization
Element Name		**Description**	
ConnectivityProvider		Abstract class that represents a connectivity provider, e.g. a provider of communication services like a Mobile Network Operator or a Satellite Data Communication Provider. Needs technology-aware specialized implementation.	
	Attribute Name	**Type**	**Description**
	technology	Technology	The technology of the connectivity provider.
Element Name		**Description**	
CellConnectivityProvider		A connectivity provider that offers mobile data connectivity.	
	Attribute Name	**Type**	**Description**
	technology	Technology	The technology of the connectivity provider. Fixed CELL
	MCC	int	Mobile Country Code
	MNC	int	Mobile Network Code. MCC and MNC together uniquely identify the Mobile Network Operator globally.
Element Name		**Description**	
Corridor		A 3D area in space, much like an Airspace. The vertical limits can either be defined as meters above MSL or meters above ground level, in which case the respective pairs of lower and upper bounds attributes shall be used.	
	Attribute Name	**Type**	**Description**
	altitudeLower	float	The lower bounds of the Corridor, in meters AMSL.
	altitudeUpper	float	The upper bounds of the Corridor, in meters AMSL.
	heightLower	float	The lower bounds of the Corridor, in meters AGL.
	heightUpper	float	The upper bounds of the Corridor, in meters AGL.
	area	Area	The horizontal limits of the Corridor.
Element Name		**Description**	
Area		A 2D area of space, without altitude information.	
	Attribute Name	**Type**	**Description**
	points	Location2D[]	The area is a closed polygon, and these are the points that make up the polygon.
Element Name		**Description**	
TileRef		Reference to a Tile, suitable for download from the Connectivity Service.	
	Attribute Name	**Type**	**Description**
	ref	UUID	A unique identifier that can be used to download the Tile.

	tilespec	String	The tilespec (short code that describes the location of the Tile) or the referenced Tile
Element Name		**Description**	
Tile		The Tile contains 3D aerial coverage information in a raster of a certain resolution. It is described in greater detail in an external Tile File specification document.	
	Attribute Name	**Type**	**Description**
	Latitude	Float	Latitude of the upper-left corner of the area covered.
	Longitude	Float	Longitude of the upper-left corner of the area covered.
	latSize	Float	Height of the Tile, in WGS 84 degrees. Typically 1.0
	lonSize	Float	Width of the Tile, in WGS 84 degrees. Typically 1.0
	horizontalResolution	int	Horizontal resolution of the raster, in arc seconds (WGS 84). Typically 2.
	verticalResolution	int	Vertical resolution of the raster, in meters.
	buffer	byte[]	The actual 3D array that contains the raster's values.

Table 14 - Service Data Model Description

2.7.2.7. Service Interface Connectivity Service Interface

This Service Interface is the main point of interaction for Service Consumers. It provides methods to fetch area coverage and conduct flight path analyses. It is provided by the Connectivity Service.

The ConnectivityServiceInterface realizes the Request/Response Message Exchange Pattern (MEP), where the Service Consumer calls Operations at the Service Provider and the Service Provider answers synchronously with a result. This MEP is most suitable for the synchronous, 1:1 nature of the included Service Operations.

2.7.2.7.1. Operation getAreaCoverage

The getAreaCoverage operation produces information about three-dimensional area connectivity conditions for a certain Service Level and a certain Connectivity Provider. It basically answers the question where in three-dimensional space can the requested Service Level be provided by the Connectivity Provider right now.

The information is returned as a number of "Tiles", which are basically 3D grids of a certain resolution that carry the Boolean information "Is the service level met?" for every position in the grid. These Tiles are produced at the Connectivity Provider and passed on to the Connectivity Service, which provides it to its Consumers via this Operation. It is a point-in-time view on the 3D coverage information of the given Connectivity Provider.

2.7.2.7.2. Operation downloadTile

The downloadTile operation is used to download the actual Tile data for a given Tile reference (TileRef). TileRefs are obtained from the getAreaCoverage call and from the areaCoverageChanged call in the ConnectivityServiceNotificationInterface.

The Operation provides the Tile data based on an input Tile reference.

2.7.2.7.3. Operation analyzeFlight

The analyzeFlight operation is used to answer the question "where on the given flight route is the given Service Level met for a particular Connectivity Provider?" It can also help with route planning by providing the option to alter the route in certain limits for locations so that the complete route fulfils the Service Level requirements.

The Connectivity Service brokers with the Connectivity Provider so that the given flight route is evaluated on their premises. The Connectivity Service then returns the results to the Consumer.

2.7.2.8. Service Interface ConnectivityServiceSubscriptionInterface

This Service Interface provides Subscribe operations to Service Consumers. It is provided by the Connectivity Service.

The ConnectivityServiceSubscriptionInterface and the ConnectivityServiceNotificationInterface together realize the Publisher/Subscriber MEP. As the connectivity information in a certain area constantly changes, the notification for such changes is posted to a Publisher/Subscriber topic. Service Consumers can attach to those topics and get asynchronously notified about changes to areas of their interest.

2.7.2.8.1. Operation subscribe

The subscribe operation allows a Service Consumer to subscribe to changes in area connectivity coverage.

Whenever the connectivity information for a certain Service Level and Connectivity Provider happens to change, a notification is posted in a dedicated topic. Service Consumers can subscribe to that topic to be notified about those changes.

2.7.2.8.2. Operation unsubscribe

As the opposite Operation of subscribe, this Operation allows a Service Consumer to stop receiving notifications about changes for a certain Service Level and Connectivity Provider.

This removes the Service Consumer from the list of Consumers to be notified.

2.7.2.9. Service Interface ConnectivityServiceNotificationInterface

This Service Interface is provided by and implemented on the Service Consumer's side. It is called to notify the Service Consumer about changes it subscribed to via the Operations in the ConnectivityServiceSubscriptionInterface.

The ConnectivityServiceSubscriptionInterface and the ConnectivityServiceNotificationInterface together realize the Publisher/Subscriber MEP. As the connectivity information in a certain area constantly changes, the notification for such changes is posted to a Publisher/Subscriber topic. Service Consumers can attach to those topics and get asynchronously notified about changes to areas of their interest.

2.7.2.9.1. Operation areaCoverageChanged

This Operation is called on the Service Consumer's side whenever the coverage information for a certain Service Level and a certain Connectivity Provider changed.

Whenever the connectivity information for a certain Service Level and Connectivity Provider happens to change, a notification is posted in a dedicated topic. If the Service Consumer subscribed to that topic, it will receive notifications via this Operation.

2.7.2.10. Service Dynamic Behaviour

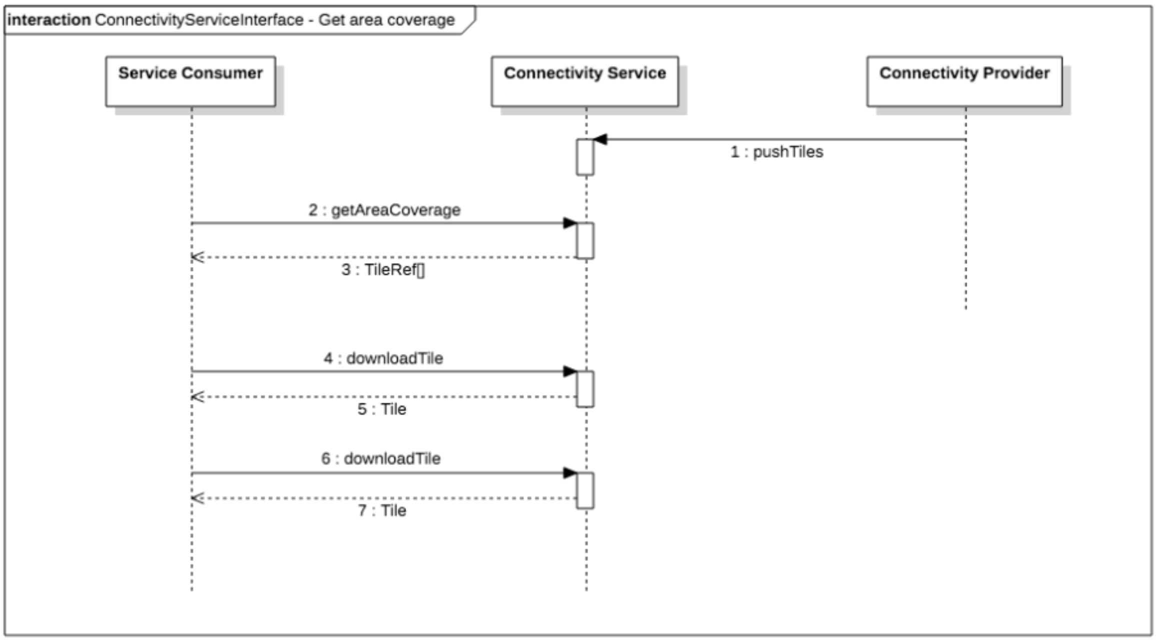

Figure 27 - Connectivity Service Operation Sequence Diagram – Get area coverage

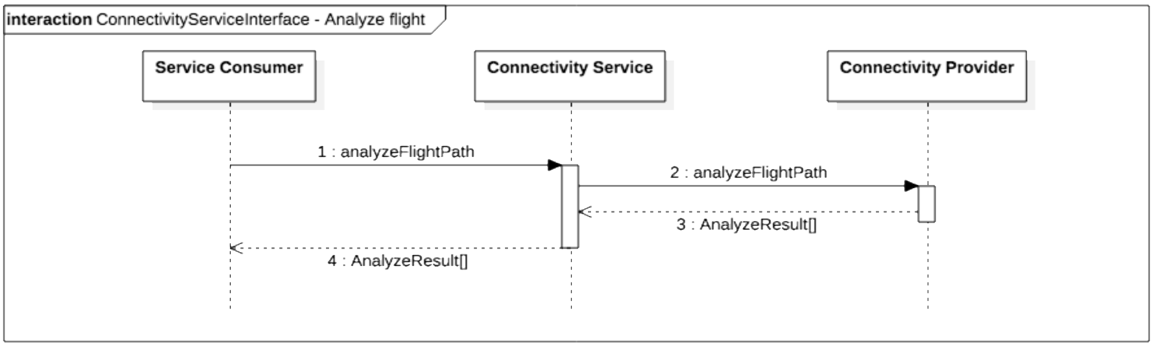

Figure 28 - Connectivity Service Operation Sequence Diagram – Analyze flight

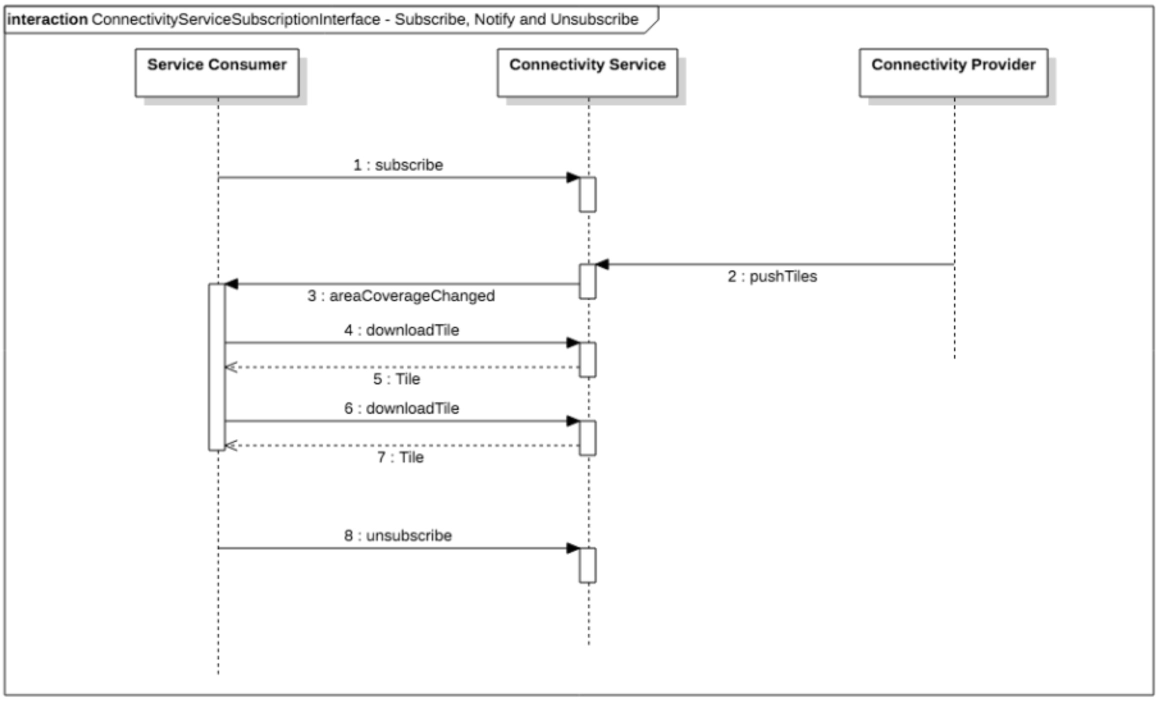

Figure 29 - Connectivity Service Operation Sequence Diagram – subscribe, areaCoverageChanged and unsubscribe

2.7.3. Existing U-space related Information Exchange Services

As summary, diagrams for the service interfaces and data models of existing information services are provided in this section.

Data models and service specifications are based on existing work done in the GOF USPACE [6] project. The full documents even if not published by SESAR were made available to 5G!Drones Project Partners for the sake of work performed and reported in this deliverable.

The traffic telemetry service takes care of exchanging position data. It was designed to be used for live data feeds, large scale deployments with large data volumes, therefore it is built on a publish / subscribe pattern. The data structure is comprehensive, still only a small subset (necessary for e.g. rendering on a map) is mandatory.

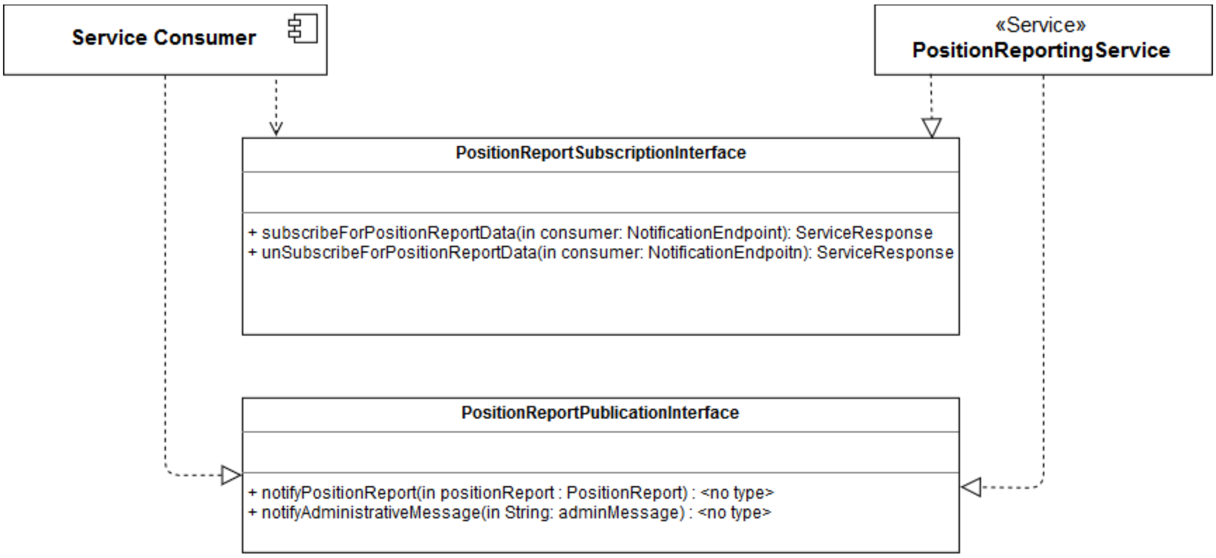

Figure 30 - Traffic/Telemetry Interface Definition diagram

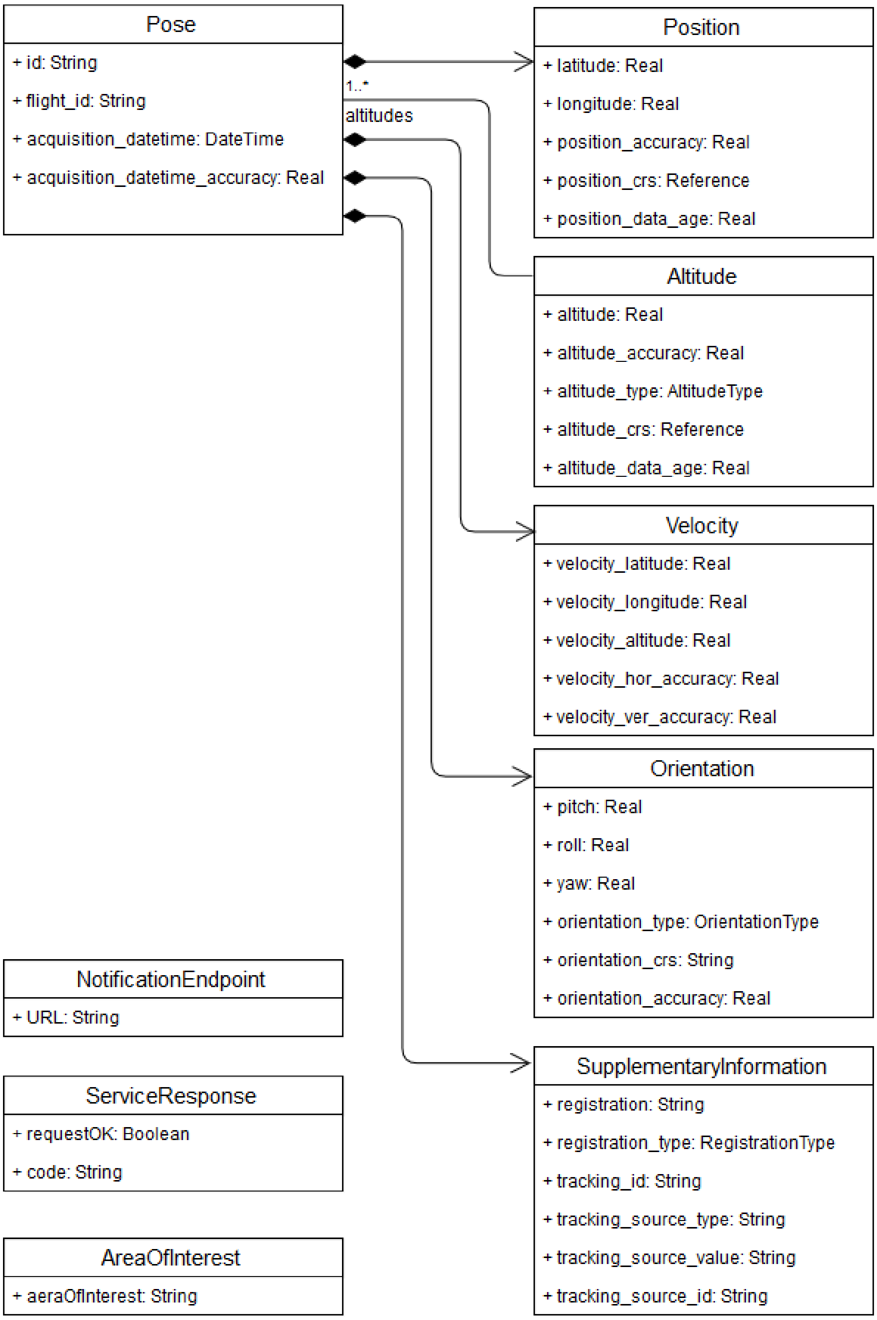

Figure 31 - Traffic/Telemetry Service Data Model diagram

The operation plan service is designed to exchange data a flight intends. It covers 4D trajectories and contingency plans and allows to exchange information on single, swarm and formation flights.

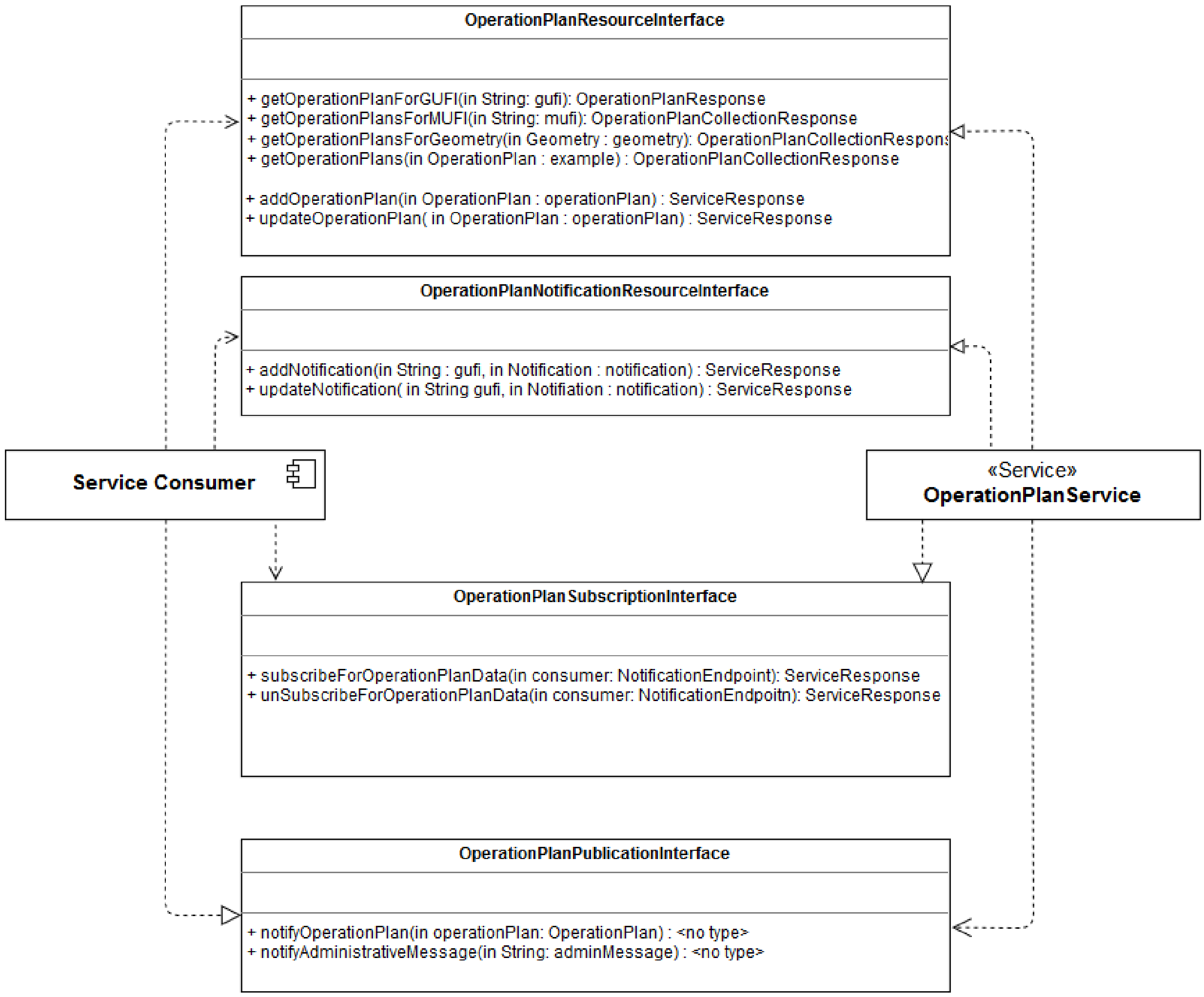

Figure 32 - OperationPlan/Notifications Service Interface Definition Diagram

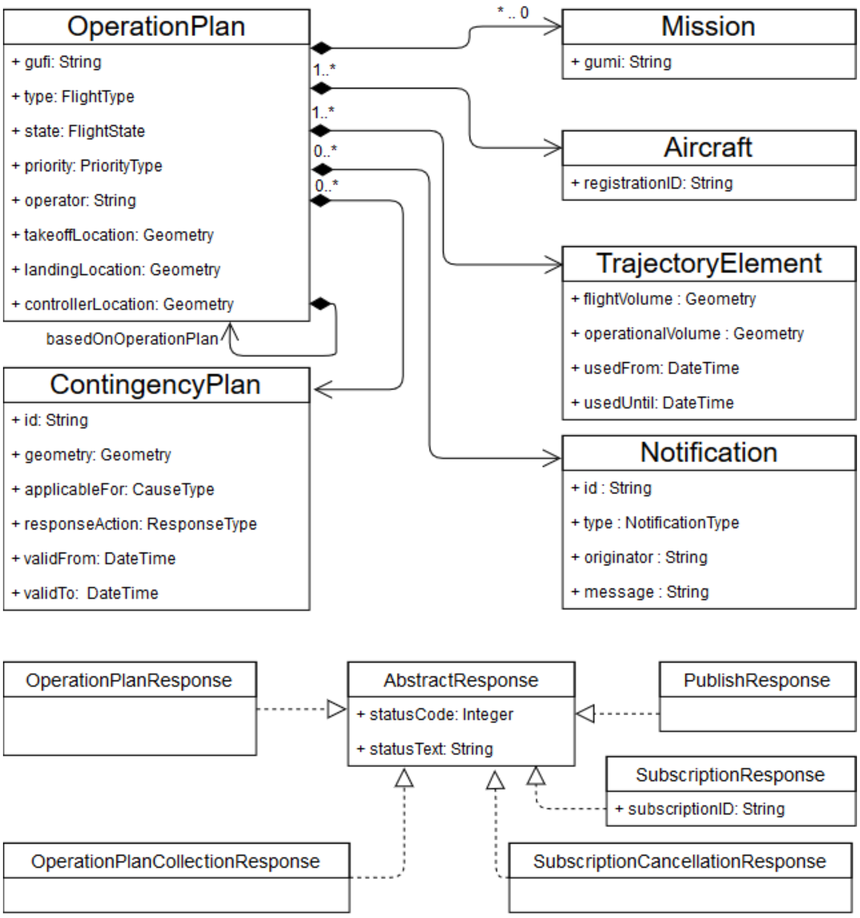

Figure 33 - OperationPlan/Notifications Service Data Model diagram

Alerts are simple structures to communicate in non-nominal situations. They can be related to relevant other information objects, like operation plans, telemetry data or aircraft.

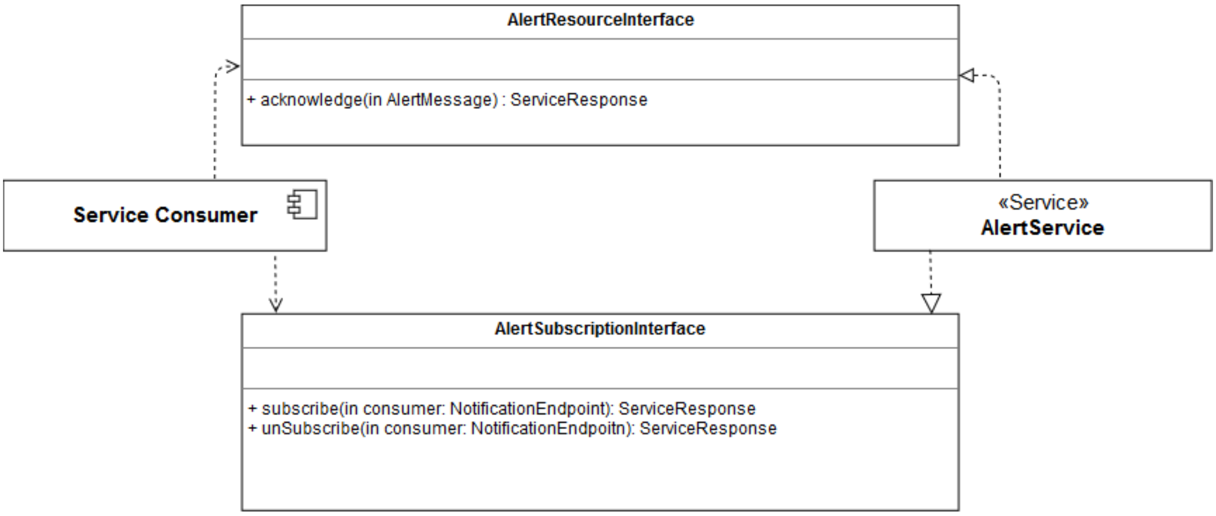

Figure 34- Alerts/Notification Interface Definition Diagram

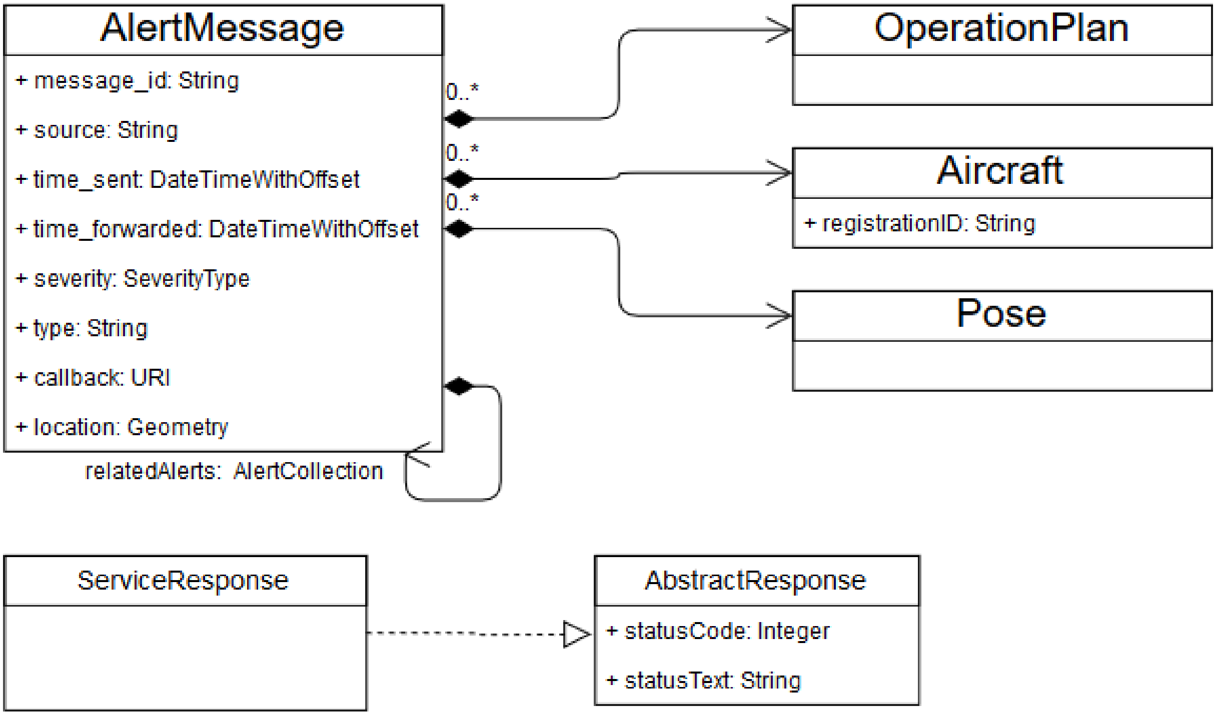

Figure 35 - Notifications Service Data Model diagram

The Aeronautical Information Service shall provide geo awareness, especially in interaction with existing ATM systems. Geo awarenes might require instant notification of consumers, therefore this service relates to the Alert service. The service allows to exchange information on actual aeronautical information as well service provision as well, enabling for dynamic lookup of available services for a specific (air)space.

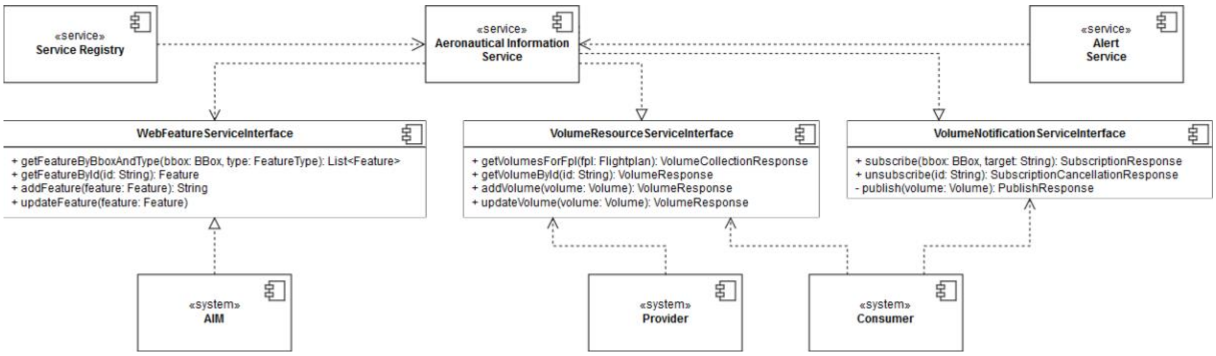

Figure 36 - Aeronautical Information Service interface definition diagram

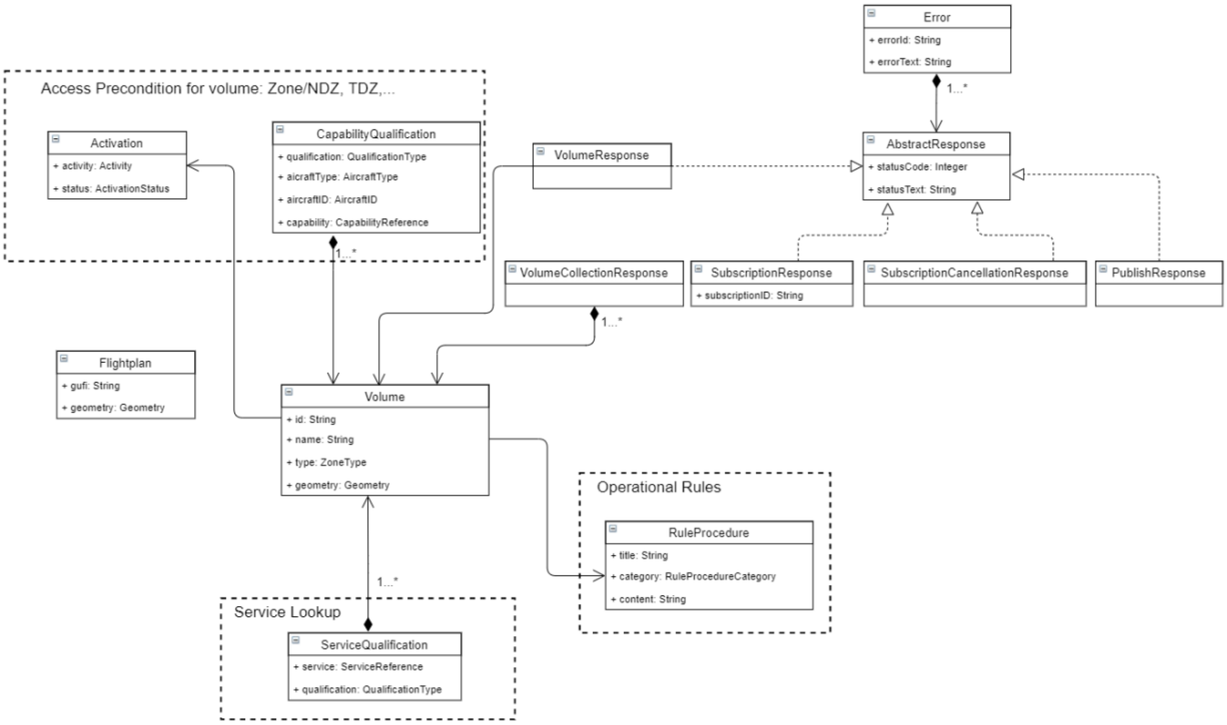

Figure 37 - Aeronautical Information Service data model diagram

3. REFERENCE POINTS BASED ON THE TRIAL CONTROLLER ARCHITECTURE

3.1. Web Portal-Trial Engine reference point

3.1.1. Web Portals reference points

For the experimenter the Web Portal is the entry point to the tool created by 5G!Drones project and the place where he will interact with it.

The Web Portal will use the REST APIs with JSON arguments and JSON responses. All requests will be possible only over HTTPS.

The Web Portal 1 is flight planning part and will guide the experimenter through the wizard forms. During this process, the module can fetch the data previously defined in the registries of the Trial Engine: pre-defined trials and UAV registry. Alternatively it can be possible to upload all the parameters in the form of configuration file.

At the end of this process, the Experiment Planning module will transfer the data to the Trial Validator, which will process the request and will come with the outcome of validation.

The Web Portal 2 is used to setup 5G facility environment. Each facility has its specific interface, so the Web Portal 2 will be different, managed by facility and exposed to the experimenter as a link from Web Portal 1. The configuration blueprint defined manually with help of wizard, fetched from facilities registry

or uploaded as the file, will be transferred to Trial Translator and processed. The result and further recommendations in case of failure should be presented in Web Portal 2, if still open, or in Dashboard.

3.1.2. Dashboard reference points

Dashboard will display the status of the experiment based on information received from Web Portal 1 and 2, Trial validator and Trial translator, Trial Life Cycle Manager. It will also allow access to KPI Monitoring functions and selected registers for listing and modification of the content.

3.2. Trial Engine-Trial Enforcement reference point

The Trial Engine-Trial Enforcement provides APIs required to request the deployment of a such slice. Indeed, the Trial enforcement is communicated by the Trial Engine through the Life Cycle Management (LCM) component. When the LCM receives a Network Slice Template (NST) including information needed for the Slice deployment, it sends a request to the Trial enforcement in order to enforce the slice deployment in the target facilities allowing the run of scenarios.

Thus, LCM module will communicate with the trial enforcement in order to configure and run the required 5G components, and also with the associated UAV operators to run the target scenario. The underlying APIs related to configuration and deployment module are:

- Configuration and deployment of network services, possibly across multi trial sites when required, as to deploy end-to-end network slices.
- On-boarding the required VNFs, including both UAV-related and network-related functions.
- Runtime configuration of network services to support the running experiments.

3.3. Trial Engine-KPI Monitoring reference point

The Trial Engine-KPI Monitoring provides interfaces to services for data aggregation, storage and analysis.

The interface is a REST API with JSON arguments and JSON responses. Authentication to the API is performed via HTTP Basic Auth. Versioning may be done with /v1/, /v1.1/, /v2/, etc. added at the start of the API path.

All API requests must be made over HTTPS. Calls made over plain HTTP will fail. API requests without authentication will also fail.

The interface uses conventional HTTP response codes to indicate the success or failure of an API request. In general: Codes in the 2xx range indicate success. Codes in the 4xx range indicate an error that failed given the information provided (e.g., a required parameter was omitted etc.). Codes in the 5xx range indicate an error with the endpoint.

Data formats that are agreed in chapter 2.7.3 shall be reused as the dataObject within the KPIdata interface call to allow component overarching analysis and visualisation. Individual data format can still be put into the data store for solitary analysis.

Note:

- All entities producing timestamped trial-data MUST be time synchronized
- Timestamps must be provided in ISO 8601 format.

Initial Registration as depicted in Figure 38 is required and, if required by the e.g. Trial Validator, allows to verify KPI readiness before an experiment is started.

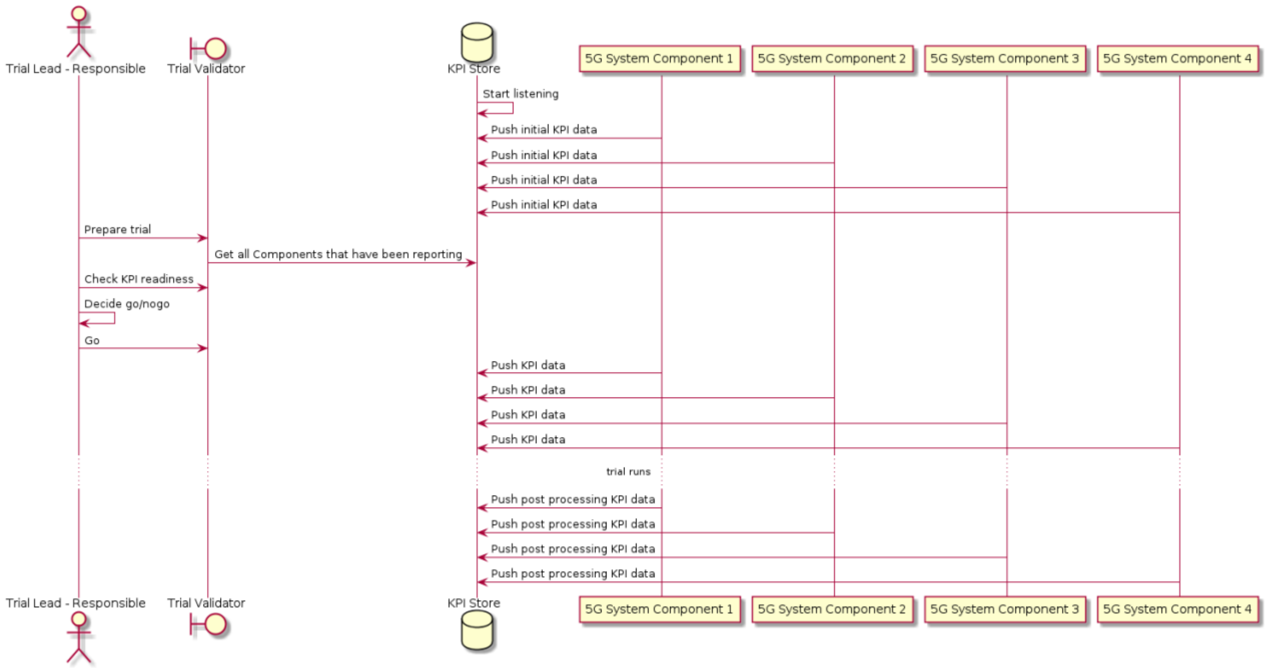

Figure 38: KPI Store - Initial Registration

3.3.1. Near Real Time Interface

3.3.1.1. Data Format

Following data items need to be provided as part of KPI data.

Element Name	Attribute Name	Required	Type	Description
POST KPI data	KPIdataID	Required	String	UUID string uniquely identifying the KPIdata element - idempotency key.
	ComponentID	Required	String	UUID string uniquely identifying the component that reports KPI data
	TrialID	Required	String	UUID string uniquely identifying the Trial.
	Task	Required	String	Type/Name of the KPI Event
	TaskCorrelationID	Required	String	UUID string uniquely identifying the individual KPI event
	Timestamp	Required	DateTime	Exact timestamp of the KPI event (mandatory ISO 8601).

	DataObject	Required	Object	Data Object

3.3.2. Post Processing Interface

Additional to the Near Real Time Interface it is also possible to aggregate and import data to the KPI store in a manual process post trial. The used stack allows multiple different interfaces to do so, e.g. importing network analysis traces into the data storage.

3.3.3. KPI Components

GET the components that have been reporting data for the defined trial.

3.3.3.1. Data Format

Following data items need to be provided as part of KPI data.

Element Name	Attribute Name	Type	Required	Description
GET KPIcomponents	TrialID	String	Required	UUID string uniquely identifying the Trial.

Element Name	Attribute Name	Type	Required	Description
RESPONSE KPIcomponents	TrialID	String	Required	UUID string uniquely identifying the component that reports KPI data.
	KPIdataArray	Object	Optional	The array of KPI data as in 3.3.1.1. Data Format.

3.4. Interfaces to the U-space

As described in Chapter 2.7, information exchange between trial controller and the U-space will be managed by U-space adapter component, responsible for exchanging the information between 5G facilities (numerous trial controller components used during different stages of the experiment) as well to assure the connection to different local/national instances of U-space components (e.g.: UTM, CIS, USSP, FIMS).

At the planning stage, the multidimensional features of this interface should be taken into account, including in particular:

- Communication modes (online, offline, push)

- Openness to adapt to the new regulations (ability to extend interface specification with additional information)

- Security constrains

- Interface performance, especially when sending location data (telemetry link)

- The ability to queue events, especially for data requests that require long-time calculations

- Other information, like licenses, terms of use, etc.

We emphasize that in the 5G!Drones project, we will not focus on all of above aspects, but only on those necessary to implement the project's use of cases.

This service specification is intended to be read by service architects, system engineers and developers.

The basic interface to the U-space represents the connection that need to be set up between UTM (e.g. CIS) systems in U-space and trial controller's components (through U-space adapter) to assure information exchange for the purpose of the following principal processes:

- (i) Submission and processing of dFPL (drone flight plans),
- (ii) In-flight telemetry information exchange
- (iii) In-flight 2-way verbal communication (CDDLC) implementation
- (iv) 5G specific planning data

U-space interface adapter will be mainly described using an OpenAPI, initiative concept, which defines widely accepted methods and standards for creation of RESTful interfaces. It is an open and globally supported approach, with well-defined and supported API's building process and tools.

OpenAPI Specification (formerly Swagger Specification) is an API description format for REST APIs. An OpenAPI file allows to describe entire API, including:

- Available endpoints (/users) and operations on each endpoint (GET /users, POST /users)
- Operation parameters Input and output for each operation
- Authentication methods
- Contact information, license, terms of use and other information.

The U-space interface for 5G!Drones projects is created using the experience gained during SESAR GOF USPACE and PansaUTM[1] projects.

(i) Submission and processing of dFPL (drone flight plans)

Interface type: off-line

It is assumed to manage a flight plans in two main scenarios:

- dFPL will be created using UTM platform via www interface. Using UTM's API, drone and 5G systems will be able to query the UTM for an active flight plan and its features.

[1] PansaUTM is an operationally implemented UTM system that enables the creation and management of drone flight plans, procedural and radar management of drone traffic in controlled airspaces. Based on the experience gained from DroneRadar and PANSA (Polish Air Navigation Agency), best practices will be used to complement the GOF project with elements that appeared during the operational implementation.

- when creating a mission in the Trial Controller, mission data will be sent to the UTM system. After being processed by the UTM system, the Trial Controller will receive feedback on acceptance, rejection or suggestion to change the flight plan.

dFPL process should also address issues related to the GDPR and planning of priority flights.

(ii) In-flight telemetry information exchange

Interface type: on-line

The Traffic - Telemetry service furthermore provides a means for the operational nodes of the 5G!Drones project to consume position reports from the U-space participants for further processing.

The Position Reports sent to U-space should include (based on the GOF project)

- The current 3D position of the drone, expressed in the agreed measurement, to the precision expected in the airspace concerned.
- The uncertainty in the reported position
- The precise time at which the position has been measured, if available
- The means by which the position has been determined, and/or some identifier of the origin of the report – so as to help the tracking service combine multiple sources of reports for the same flight.
- If available the current speed vector of the vehicle, together with its uncertainty
- The identity of the vehicle, if available
- The identity of the operator of the vehicle, if available
- The identity of the mission plan being executed – if any and if available
- In the absence of the vehicle's e-ID identifier, if possible, a temporary identifier for the flight might be assigned by UTM to ease the job of the tracker e.g., SQUAWK.
- Other information

The In-flight telemetry interface should be highly efficient and safe. The following aspects should be respected:

- To track the Drone positions in real-time
- Information about security level on the transmission layer
- Information about SLA of the communication channel
- Different access levels to users with different credentials

(iii) In-flight 2-way verbal communication (CDDLC) implementation

Interface type: on-line, push

CDDLC (Controller Drone Data Link Communication) is a DroneRadar concept developed on the basis of the well-known, operationally implemented CPDLC system used in manned aviation. The concept was first presented at the JARUS conference in Chengdu in 2018. Its functionality is based on the need to create a universal method of communication between air traffic services and the operator. CDDLC,

as a rule, fulfil 3 basic paradigms of secure communication: guarantee that the message has been delivered, displayed / understood and confirmed. Those 3 basic aspects of communication are critical, especially since the quality of the communication layer on the drone operator's side is unknown. In other words, the CDDLC protocol must be resistant to the poor quality of internet connections and the unpredictable behaviour of the mobile application, e.g. smartphone no power case, application crash, etc.

It should be particularly emphasized that CDDLC is a communication protocol that issue recommendations to the operator. CDDLC does not take in anyway control of the drone and does not give direct instructions to the flight controller. CDDLC can send to the operator and / or controller controlling the drone information about the need to take certain action, e.g. land now, fly from the zone, send information about geofencing, etc.

Priority aspects of flights will be conveyed through CDDLC protocol.

During the 5G!Drones project, the following basic interface functionality will be tested: communication between the U-space <-> drone operator and sending information about the nofly zone to the drone and/or drone controller software.

(iv) 5G specific planning data

Interface type: on-line, off-line, push

The undeniable value of the 5G!Drones project is the ability to identify telecommunications network specific features, that would be needed to be taken into consideration for SORA evaluation. This is still ongoing process to discover and identify necessary network related features and their correlation with flight parameters that are used for risk analysis of flights.

For example, in places where high quality 5G transmission with low latency will be ensured (based on the reliable information of high quality network coverage), it will be possible to create low-separation flight locations allowing to acknowledge more dFPL at the same time with smaller required space separation.

As a result, the following aspects of U-space adapter interface should be covered:

- Support for flight planning (off-line) – passing of specific, non dFPL related, information (e.g. changes in radio network impacting network coverage vital to U-space services)
- During flights (on-line) enabling the transfer of information on the degradation of certain features (e.g. information about the impact of the failure of the base station)

All of that information will be used by stakeholders in the process of granting permission for flight as a part of SORA analyses and on-line emergency risks analysis.

3.5. Interfaces to the facility

The interfaces to the facility reflect the Southbound Interfaces (SBI) provided by the 5G facility or by the 5G!Drones enablers. The latter are developed in context of WP3 to enable the execution of the trials. Different interfaces can be distinguished.

Trial validation interface: this interface is exposed by the facilities in order to check the availability of the resources for running the trial. It is mainly used by the trial validator during the phase of preparation of the trials. The trial validator communicates through this interface the requested time for performing the trial. If the resources are available, the facility might thereafter reserve the resources for the specified period.

Network slices management interfaces: these interfaces are exposed by the facilities to enable the management of the network slices. The underlying operations include the following:

- NSI creation interface: allows the instantiation of NSI associated to NST. This implies the allocation of the resources to satisfy the slice requirements.
- NSI modification interface: allows modifying a NSI.
- NSI termination interface: it allows terminating a NSI. This will be translated into releasing the resources allocated to the NSI.

KPI monitoring interface: based on the requested KPIs, the facility will return the set of captured KPI values. The content provided by this interface will be consumed by the KPI monitoring module.

3.6. Interfaces to the UAV operator

Reference points to the UAV operator derive from the generic lifecycle described in Section 2.5.2.1. These reference points are separated into Configuration and Monitoring interfaces.

3.6.1. Configuration interfaces

This section describes event triggers that can be raised by the *trial enforcement* module in order to manage the behaviour of an active operator virtual network function (VNF).

3.6.1.1. Configure

This event is exposed to the *trial enforcement* module in order to configure the operator VNF immediately after its creation. The payload associated with this event describes configuration parameters for resources that the operator VNF should hold throughout its entire lifetime.

3.6.1.2. Activate

This event is used by the *trial enforcement* module in order to initiate a UAV trial. The payload associated with this event must contain:

- The high-level UAV trial descriptor (as defined in Section 2.3.1)
- The descriptors for the UAVs identified for use in this trial (as defined in Section 2.4.1.2.2)

3.6.1.3. Cleanup

This event is used by the *trial enforcement* module in order to release resources acquired during the *Configuring* transition.

3.6.1.4. Shutdown

This event is used by the *trial enforcement* module in order to initiate shutdown of the operator VNF. The operator VNF will only act on this trigger event if it is safe to do so (i.e., it will not initiate shutdown if any UAVs are currently operational).

3.6.1.5. Deactivate

This is an event that should be triggered internally by the operator VNF and so is not exposed to the *trial enforcement* module.

3.6.2. Monitoring interfaces

The *Monitoring* reference points represent general status data ingested by the trial controller from operator VNFs. These interfaces do not provide telemetry or application data – these data streams are instead processed by other modules with pre-existing ingestion pipelines (e.g., telemetry data is processed by the U-Space Adapter).

3.6.2.1. Operator VNF Status

This section describes reference points ingested by the *trial enforcement* module related to the operator VNF status.

3.6.2.1.1. Lifecycle State

The current state (whether primary or transition) of the operator VNF per the lifecycle described in Section 2.5.2.1.

3.6.2.1.2. Connection Status

The connection status of UAVs managed by this operator VNF. The payload returned by this reference point should indicate whether these UAVs are connected & whether they have any outstanding errors.

3.6.2.1.3. Configuration Parameters

The configuration parameters with which this UAV operator was configured. The set of configuration parameters outlined here is dependent on the specific UAV operator implementation in use. In order to differentiate between the different UAV operator VNFs this payload should define at a minimum the type and version of operator VNF providing the data.

3.6.2.2. Trial Progress

This reference point provides detailed, implementation-specific info for the current state of the operator VNF. The intended consumer of this data is the experimenter via the Dashboard and therefore this data should emphasize a human-readable description of the progress.

This progress data must be provided during the *Active* state for all UAV operators and should describe the current task being executed by UAVs.

This progress data may additionally be provided in other states during which the operator VNF implementation is doing significant work. An example would be in the *Activating* state, which may report subtasks like:

- Step 1/5: validation mission descriptor
- Step 2/5: establishing connection to UAVs
- Step 3/5: performing pre-flight checks
- Step 4/5: waiting for final flight authorization
- Step 5/5: transitioning to active flight

The below table summarizes the reference points based on the trial controller architecture.

Reference points	Description
Web Portal-Trial Engine	Exposes the functionalities of the trial controller to the experimenter (in terms of trial planning and status report)
Trial Engine-Trial enforcement	Enable the LCM to enforce the trial via the configuration and deployment of network services, on-boarding of the required VNFs, and run time configuration of network services
Trial Engine-KPI monitoring	Interfaces exposing services for data aggregation, storage and analysis
Interfaces to the U-space	Enable the exchange between the U-space adapter and the U-space: Submission and processing of dFPL, In-flight telemetry information exchange, In-flight 2-way verbal communication implementation, and 5G specific planning data
Interfaces to the facility	Interfaces exposed by the facility allowing the validation of the trial, the management of the network slices (by the trial enforcement) and the exposure of the KPIs (to the KPI monitoring module)
Interfaces to the UAV operator	Interfaces to the UAV operator virtual network function (VNF). They allow the configuration and the monitoring of this VNF by the trial enforcement

Table 15: Summary of the reference points based on the trial controller architecture

4. SUPPORTING MECHANISMS AND ALGORITHMS

4.1. UAV traffic modeling

The data generated and sent from the drones can guide the configuration of the network in a way to achieve a better quality of service. 5G!Drones trial controller considers analysing the UAV traffic, at the level of the KPI monitoring module, to capture different statistical information. This later can be provided to the experimenter. Moreover, it can also provide a basis allowing optimized configuration of the network. While UAV traffic information are expected to be captured from the flying UAVs, having prior information on their traffic can help in preparing the network to accommodate such applications. It is therefore very important to consider traffic flow model for UAVs

Traffic types

It is very important to distinguish between the different types of UAVs' traffic as they are associated with different data rate and size. We categorize UAV traffic into three subsets, as shown in Figure 39: 1) telemetry data representing the status information of the UAVs (e.g., battery information, GPS coordinates, vehicle's speed, etc.), 2) IoT data from the on-board sensors (e.g., gas, temperature and humidity, etc.), 3) and streaming data captured, for example, from the on-board video camera.

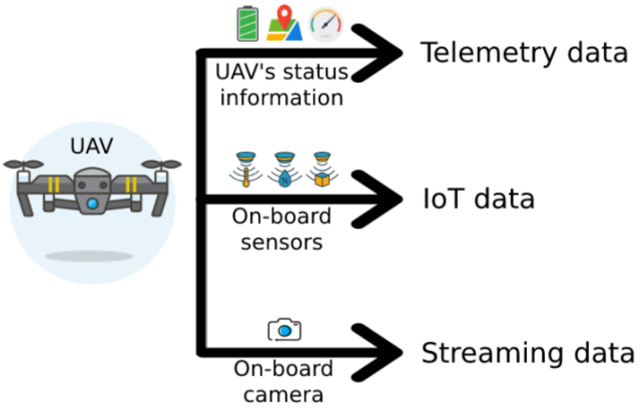

Figure 39: UAV's traffic types

Another consideration is to classify UAVs based on the amount of the generated data. For instance, while some drones can send data occasionally (e.g., per event), others can be associated with higher frequency. Similar to [25], we can classify UAVs into some three subgroups, corresponding respectively to UAVs sending data with low, medium and high frequencies. This can also be extended to the consideration of more subgroups. Non-uniformity of income distribution between population is usually characterized by the Gini coefficients [26]. Let $K_{G,i}$, (with i = 1,2,3) be the Gini coefficient for i_{th} traffic type corresponding respectively to telemetry data, sensor data and streaming data. We also assume that the non-uniformity of distribution corresponds to Pareto law; its parameters for each network service can be calculated as follow:

$$\alpha_i = \frac{0.5(K_{G,i}+1)}{K_{G,i}}, i = 1, 2, 3$$

The relative number of UAVs in the 'high frequency' subgroup K_3 is given as:

$$F_3 = \sigma_3^{\frac{\alpha_3}{\alpha_3 - 1}}$$

where, σ_3 is the data amount percentage produced by the 3rd subgroup (high frequency) for the 3rd traffic type (Streaming data). Let us consider σ_2 the data amount percentage produced by the 2nd and the 3rd subgroups for the 2nd traffic type (IoT data), the relative number of "middle" subgroup can be giving as:

$$F_2 = \sigma_2^{\frac{\alpha_2}{\alpha_2 - 1}} - F_3$$

At last, the relative number of UAVs in the first subgroup (low frequency) can be found as:

$$F_1 = 1 - F_2 - F_3$$

Packet arrival rate

The intersection of the different subgroups and traffic types allows the segregation of nine segments. Let denotes by λ_{ij} (i,j = 1,2,3) the packet arrival rate per a UAV in a busy hour, where i refers to the traffic type and j to the subgroup.

The share of transmitted packets for a UAV from the jth subgroup initiating a service from the ith subset is denoted by β_{ij}; i, j = 1,2,3. Taking into consideration the previous expressions and that $\sum_j \beta_{ij}$, the following system of equations can be defined

$$\beta_{i1} = 1 - (1 - F_1)^{\frac{\alpha_i - 1}{\alpha_i}}$$
$$\beta_{i2} = 1 - (1 - F_1 - F_2)^{\frac{\alpha_i - 1}{\alpha_i}} - \beta_{i1}$$
$$\beta_{i3} = 1 - \beta_{i1} - \beta_{i2}$$

The expression of β_{ij} can also be given as

$$\beta_{ij} = \frac{F_j \lambda_{ij}}{\sum_j \lambda_{ij} F_j}$$

To solve the system of nine equations with nine unknowns λ_{ij} (i, j = 1, 2, 3) it's necessary to add to the input data the parameter value λ_{11}, which can be estimated on a basis of statistical information concerning UAV's telemetry data. The rest of solution can be found as:

$$\lambda_{12} = \frac{\lambda_{11} \beta_{12} F_1}{\beta_{11} F_2}$$
$$\lambda_{13} = \frac{\lambda_{11} \beta_{13} F_1}{\beta_{11} F_3}$$
$$\lambda_{ij} = \frac{\gamma_i \beta_{ij} \sum_j \lambda_{1j} F_j}{\gamma_1 F_j}; i = 2, 3; j = 1, 2, 3$$

Data size

Using the data arrival rates, we can compute some relevant information, such as the total traffic data size. Let W_i be the average size of a packet related to the ith traffic type. The data size for each traffic type can be given by the below equation:

$$D_i = W_i \sum_j \lambda_j F_j$$

The total traffic data size can therefore be computed as

$$D = \sum_i W_i \sum_j \lambda_j F_j$$

4.2. Mechanisms for flight planning

UAV flight planning is a complex task involving many stakeholders and aggregating and processing information from various sources. It should be clearly emphasized that at the time of writing this document, there are no general, constituted guidelines from European legislator for U-space flight planning process exploiting the telecommunication network. This study utilises the best knowledge and experience of consortium members to develop recommendations for the use of 5G networks in the following three phases:

- Pre-flight process
- Inflight
- Post flight analyses

Overall system safety is the highest priority in this task. Some of the planning elements, used in this document may seem redundant, however, they are representing the result of extensive experience of companies participating in 5G!Drones project.

Flight planning mechanisms, especially which will utilise the telecommunications networks, are the subject of this study and require the determination of:

- Process actors
- Role of actors
- Business processes
- Various interconnection reference points required for interaction with different entities, depending on current and local conditions of the U-space providers

It is assumed that the telecommunication operator together with the newly created service broker (B2B, U-space adapter) will perform functions in the services model: 5GaaS. Those services model will be used on demand.

The flight planning process must include elements related to the safety of all airspace users. Factors determining the parameters of the 5G network for planning flights should consist of:

- Airspace classification
- Risk associated with the flight
- Aviation regulations
- U-space regulations
- Radio communication spectrum and equipment regulation

Set of parameters necessary to plan a UAV flight using 5G!Drones (1st proposal)

No	Feature	Description
1	RAN SLA	Guaranteed 4D radio coverage (3D + time) with SLA information for individual services (C2 link, Video broadcast, latency with and w / o handovers, etc ...)
2	POS – Possible Obtainable Service	Obtainable 5G service with expected SLA
3	5G system capacity	Maximum system capacity

4	5G infrastructure as a service	Deployment of own services on the operator's infrastructure, e.g. MEC
5	Prioritization	Possibilities of prioritizing the 5G (e.g. for public order services)
6	TTP – Time to provision	Expected / guaranteed service provisioning time
7	RAN contingency	Contingency plans in boundary layers
8	UTM/DTM interfaces	Two-way information exchange with UTM / DTM class systems to exchange flight plans and I consent information
9	System governance	Information on the method and time of archival data storage
10	Supplemental services	List of supplemental services

Table 16 Proposed 5G network related parameters to be evaluated during flight plan analysis

Actors of the process

No	Actor	Role	Description
1	End user	Beneficiary	E.g. Buyer of the goods, which are supposed to be delivered by means of drone delivery
2	Business provider	Define expectations	E.g. Shop owner, selling goods to end customers, who defines and orders delivery through specialized parties operating drones
2	Drone Operator	Performing a safe flight in accordance with regulations	E.g. Party, who accepts delivery orders and executes them
3	5G Network Owner	Telecommunication Operator	Provider of the facility (5G network), which serves the drones' missions
4	5G service broker (name to be adopted after discussions) U-space Service provider	Process orchestration	Entity, which is designated to operationally manage the fair access to U-space according to regulations

5	CIF / UTM / DTM provider	Management compliant of permits to fly	Dedicated entity which provides fly control services
6	Civil Aviation Authority	Supervision	Entity, which provides business and regulatory governing rules of the usage of airspace
7	Radio Communication Authority	Supervision	Entity which provides business and regulatory rules of the usage of radio spectrum and equipment

Table 17: Parties involved in flight planning process

Business process

The UAV flight planning process requires access to reliable information about the capabilities of the 5G network. The information used in flight planning process and risk analysis must come from trusted and reliable sources in which the development process of information, services, analysis complies with XYZ standards.

The process by which the pre-flight analysis is to be performed should consider, at least:

- Type of the flight (VLOS, BVLOS)
- Flight category (Open, Specific, Certified)
- ARC
- GRC
- Additional Drone equipment
- C2 link support
- Risk of interferences
- Reliability of UAV control software
- Type of equipment used in FPV
- Interfaces between key components
- Radio communication equipment

At this stage, we propose that the development of a flight planning solution is not artificially limited to any assumptions. The assumptions made today must be flexible enough so that they can be quickly and effectively adapted to the needs specified in the U-space concept by the European Commission.

The following illustration shows the possible flight planning scenarios including 5G!Drones outcomes.

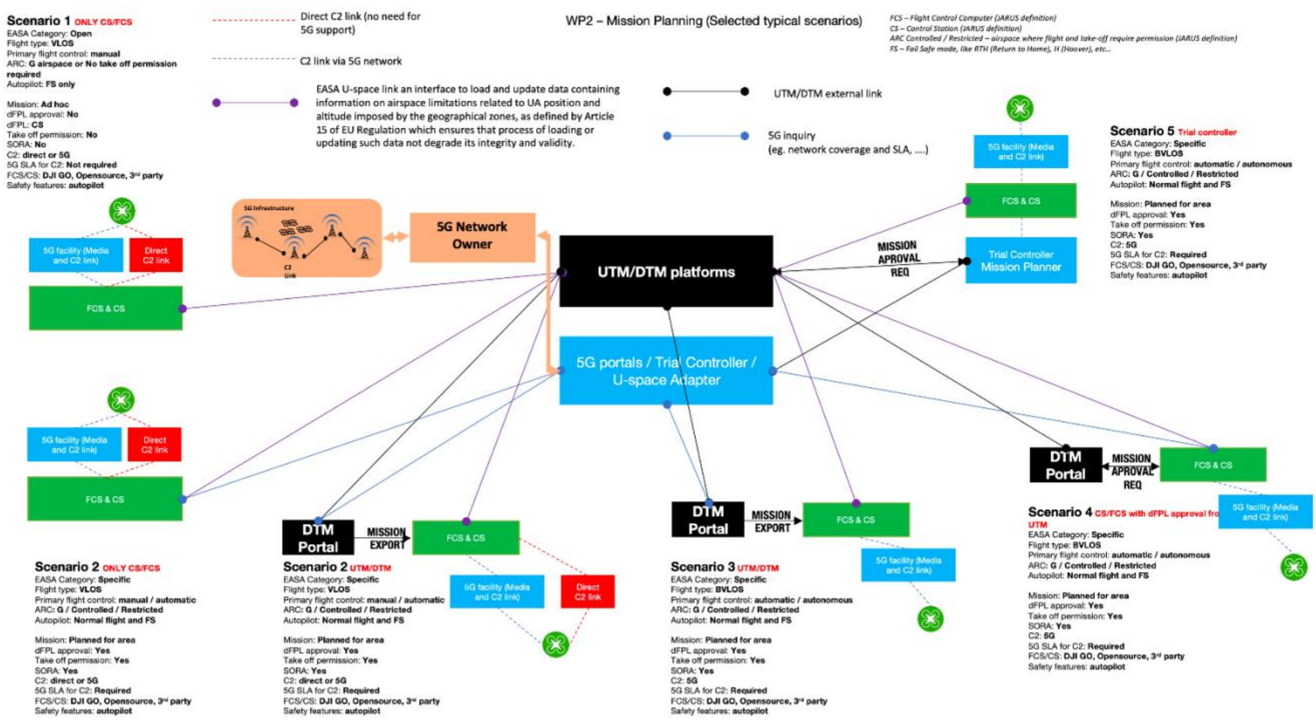

Figure 40: Flight planning scenarios

Standard scenarios defined by the regulator should be reflected in 5G solutions, simplifying the process of meeting the requirements. Some of those scenarios are illustrated on Figure 40. Depending on the mission characteristics, different scenarios for requesting, obtaining and validation of mission approval are possible and feasible: ranging from not requesting the mission approval at all (scenario 1) to the most advanced situation from 5G perspective (scenario 5), in which Trial controller would need to fulfil all tasks to prepare and submit mission approval request. Most probably it would be a common approach, that based on the business needs or convenience, different methods for obtaining missions' approvals will be in use. Regardless of the approach, Trial controller should be able to handle different cases: either allow to run the mission based on the mission approval obtained beyond the Trial controller (e.g. directly via DTM portal) or being able to handle the mission approval on their own (with built in functionality of mission planner) as well as being able to import the mission from DTM or other valid source.

The mission itself can be divided into 2 phases:

- Preflight – activities related to Flight Planning Process
- Inflight - activities related to the preflight inspection, flight itself and landing

In following sections both phases are described in more details.

4.2.1. Flight planning process

As mentioned in previous section, flight planning is a complex process relying on many stakeholders. It must assure, that planned mission will be safe, secure, legal, controlled and will comply with all obligatory regulations, especially related to the aviation and U-Space. Flight planning will involve many

parties (mentioned in Table 17) and might require multiply iterations and would need to gather and provide to authorities many mission specific parameters. When missions supported by 5G are considered, even more additional information would be required (quality of the signal, reliability of the control system, susceptibility to interferences, guaranteed latency, SLA, architecture of the mission supporting systems) to describe - specific to 5G network – parameters (see Table 16), which would be necessary to properly evaluate mission related risks.

The general, overall mission planning process is depicted on Figure 41.

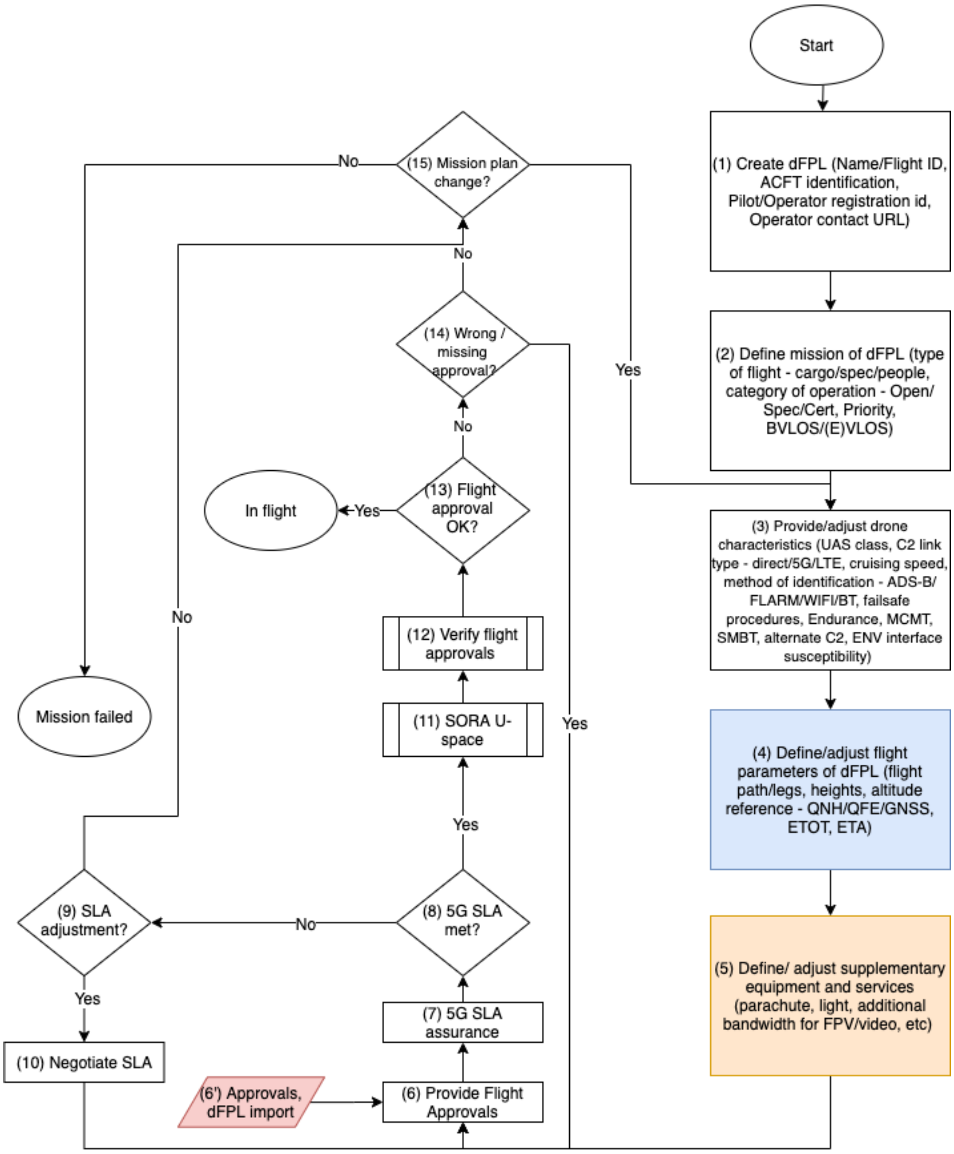

Figure 41: Mission planning - drone flight plan (dFPL) in 5G

Process begins with the creation of the drone flight plan (dFPL). At the first step (1) basic identification information should be provided:

- Unique id of the mission
- Unique id of the drone (ACFT – aircraft identification)
- Unique id of the drone's pilot or operator (registration id)
- Unique pilot/operator locator during the mission, which would provide the contact with operator/pilot in case of emergency (URL)

Next, general information about planned flight classification should be provided (2):

- Flight specific information (monitoring/cargo/spec/people/…)
- EASA category of operation (open/specific/certified)
- Type of the flight (VLOS – Visual Line of Sight, EVLOS – Extended Visual Line of Sight (navigation supported by remote spotters), BVLOS – Beyond Visual Line of Sight)

Information provided in next steps (3, 4, 5, 6) describes the mission in more details. During the process of mission validation (11, 12), it may happen, that below parameters would need to be adjusted according to current conditions (14, 15). It means that obtaining flight plan approval can be an iterative process consisting of more than one cycle of filling and submitting dFPL description.

First group of such parameters describes specific parameters of particular drones to be used during the mission (3). These parameters include:

- UAV class
- C2 link type to be used during the mission to control the drone (direct (RC), 4G/LTE/5G, etc)
- Cruising speed of the drone during the mission
- Telemetry - Method to be used during the flight for the purpose of exchange of information about the drone's position and identification (e-Identification, ADS-B – Automatic Dependent Surveillance-Broadcast, FLARM – "Flight Alarm", WIFI/BT, etc)
- Failsafe procedures – provide description of emergency procedures in case of e.g. lost control connection
- Endurance describing maximum real flight time ability (must be based on real calculation of batteries' capacity and drone's power consumption, not based on factory or average values)
- MCMT – Minimum Continuous Mission Time, minimum uninterrupted time required to complete the mission
- SMTB – Supplementary Mission Battery Time, describes the available time buffer to let the ATS to know the maximum estimate of the time by which the ongoing mission can be extended/delayed in case of such a necessity
- Alternate C2 – provides the information if the drone supports alternate C2 link in case of the failure of the primary C2 link
- ENV interference susceptibility

Another group of parameters (4) focuses on the parameters describing the mission itself:

- Flight geography (Mission) devided by legs as a result of mission assessment (e.g. LTE/4G/5G coverage, terrain profile, etc.)
- Heights of flight in each leg
- Altitude reference used – QNH – atmospheric pressure adjusted to mean sea level, QFE – refers to altitude relative to the take-off position or GNSS
- ETOT – Estimated Take Off Time
- ETA – Estimated Time of Arrival

Besides above parameters, depending on the mission characteristics and results of a SORA (11), supplementary information might be necessary (5). It includes for instance information, that drone is equipped with special equipment like light source (eg. strobe) or parachute.

When telecommunication networks are used as a bearer for C2 or other services, additional parameters (SLA agreements) might be required (7):

- Provided RAN SLA for defined mission (covering 3D area of the mission and defined mission time) for all services (like C2, additional bandwidth)
- TTP
- RAN contingency
- 5G infrastructure as a service capability
- And other specified, discovered during 5G!Drones project

Depending on the U-space regulations of local U-space provider, also supplementary documents and information like additional approvals might be required and thus should be attached to the dFPL (6, 6').

Before the SORA risk analysis and flight plan approval is released, all the required 5G related SLAs must be agreed and confirmed (8, 9, 10). When all the information consisting of core dFPL (1, 2, 3, 4, 5), 5G services related SLA agreements (7, 8, 9, 10) and additional approvals (6, 6') are collected, SORA risk analysis (11) and flight approval by authorities (12) is performed. As a result (13), flight approval might be released or recommendations for further mission adjustments is provided (14, 15). If the recommendations can be applied and the mission can be adjusted, another turn of SORA risk analysis and flight approval is performed. Otherwise mission would not obtain acceptance and should be cancelled.

As indicated in above diagram and mentioned in previous section, process should allow to use/import dFPL prepared outside of the trial engine (6, 6').

When the dFPL for the mission is validated, operator can proceed to inflight phase described in next section.

4.2.2 Inflight process

Key actions to be performed by drone's operator or pilot during the inflight phase are depicted on Figure 42.

Before the flight may be commenced with or without planned mission, pre-flight checking of the drone must be performed (20). It should at minimum cover following checks:

- Drone pre-flight inspection (according to the Drone Manual)
- Check weather conditions
- Check aeronautical information (AIP+NOTAM) for flight location
- Check U-space restrictions
- Verify failsafe, emergency mechanism (return to home, backup C2, etc)

If during the checklist any deficiencies are found, flight may be performed (21), according to the MEL (Minimum Equipment List). It might be required (24) to adjust the flight plan (25), if certain parameters impacting flight parameters are changed e.g. replacement of the batteries with different capacity/parameters (23).

If the mission is to be started from the place, where permission to take off is required (22, 27), pilot/operator should request the permission before taking off.

During the flight, operator/pilot should monitor the current situation and respond accordingly to different events (30):

- In case of approaching (31) to restricted (e.g. controlled, non-classified) airspace with intention to enter the restricted area, operator/pilot should request permission to enter the airspace; when permission is granted with certain conditions (32), they should be applied to current mission and confirmed to airspace controllers (38)
- In case of the request to give the right of way (33), operator/pilot should respond to such a request and adjust the mission accordingly (34)
- In case of emergency e.g. loss of control or bad weather conditions (35), operator/pilot should confirm emergency event to authorities (36) and perform corrective actions (37) related to the type of emergency

At any time during the mission operator should be prepared to abort the mission (38), reroute the drone to the nearest safe landing or crash zone (39).

It must be noted, that during the flight only operator/pilot controls the drone (except the situation, when the C2 control connection is lost). It is his responsibility to react properly to requests from authorities. There is no automatic handover of the control over the drone to such authorities.

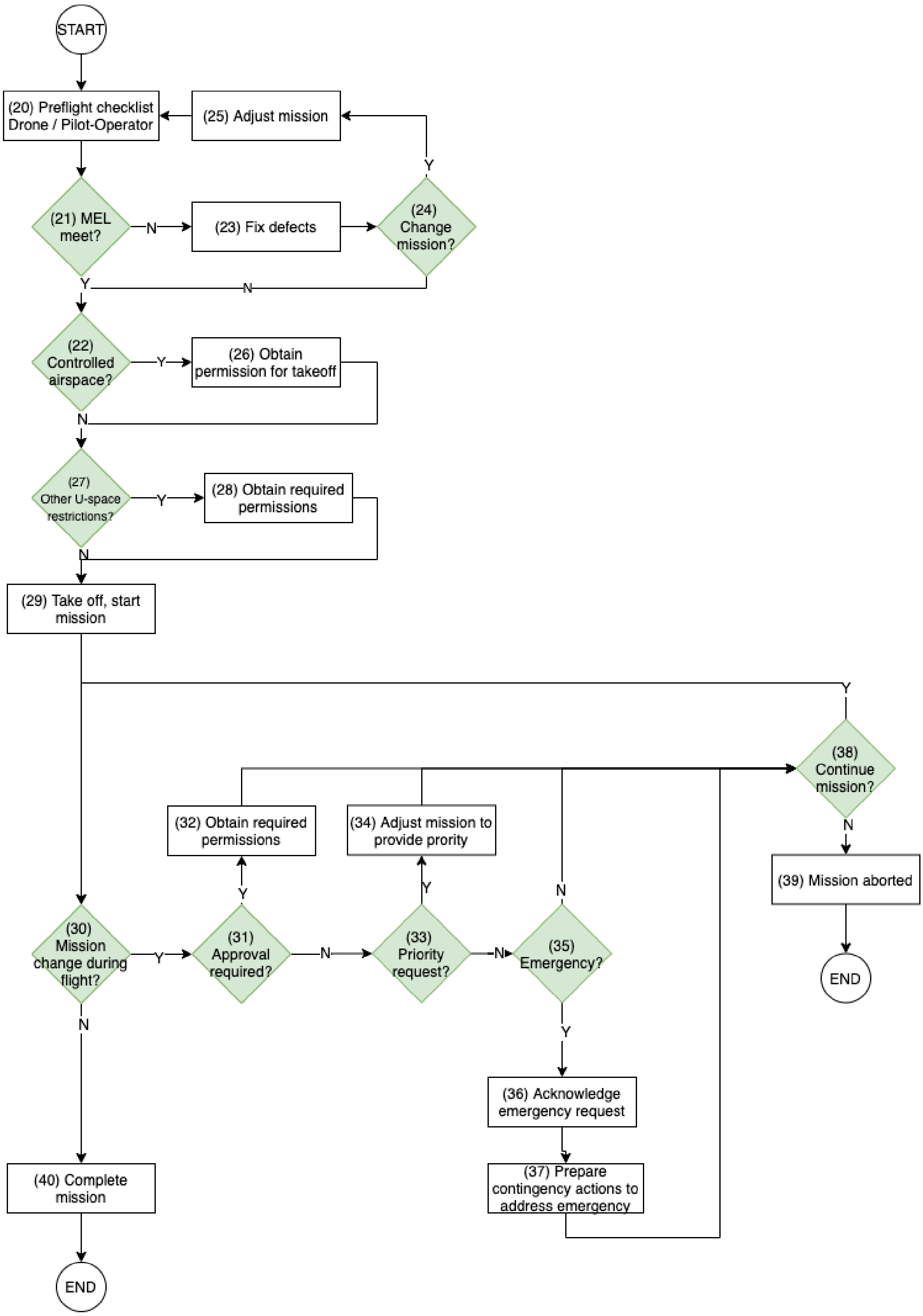

Figure 42: In flight operation performed by drones' pilot/operator

During the flight, drone can be in different states, which are depicted on Figure 43. Those states correspond to the events and actions that can happen during the flight.

At the beginning, by performing checklist procedure (21), drone changes its state from Inactive to PreflightChecking. As a result of checklist procedure, drone moves either into ReadyForFlight state or into NotReadyForFlight state, in which certain corrective actions need to be performed (23, 25).

After TakeOffPermision is granted, either if it is not required or as a result of administrative actions (26, 28), drone can start its mission and turns into InFlight state.

During the flight, due to different conditions impacting mission, drone should be capable of performing certain actions:

- Turn into FlightApproval state while performing operation of requesting in flight approval (31, 32)
- Turn into MissionPrioritization state in case of the request to give the right of way (33, 34)

In case of any emergency condition (35), drone moves into InEmergencyFlight mode, which is preceded by EnteringEmergencyMission state, during which all required corrective/procedural actions (like reporting or acknowledging emergency situation to ATS) are performed (36, 37).

If emergency condition is waived and mission can be continued (38), drone turns back into InFlight state. Otherwise, if emergency persists or mission couldn't be completed, mission should be aborted (39). As a result drone starts to fly in Rerouting mode back to starting point, nearest landing or crash zone.

As a result of mission successfully completed, rerouted or failsafe flight, flight ends with DroneLanded state, which can be turned into Inactive state.

In case of lost C2 link, there is one dedicated, additional state: NoC2linkFlight. In this state drone flies automatically. Drone can turn into this state, as a result of C2 link loss, from any "flying" state: InFlight, InEmergencyFlight or Rerouting. In case of C2 link restoration during the NoC2linkFlight state (before activation of FailSafeFlight), drone comes back to the previous state according to below schema:

InFlight -> NoC2linkFlight -> InFlight

InEmergencyFlight -> NoC2linkFlight -> InEmergencyFlight

Rerouting -> NoC2linkFlight -> Rerouting

In case of activated FailSafeFlight mode due to NoC2linkFlight, when C2 link is restored, drone should turn into EnteringEmergencyMission. Operator/pilot should decide (38) whether to continue mission or to abort the mission as described above.

When the drone is landed, postflight activities and analysis can be performed.

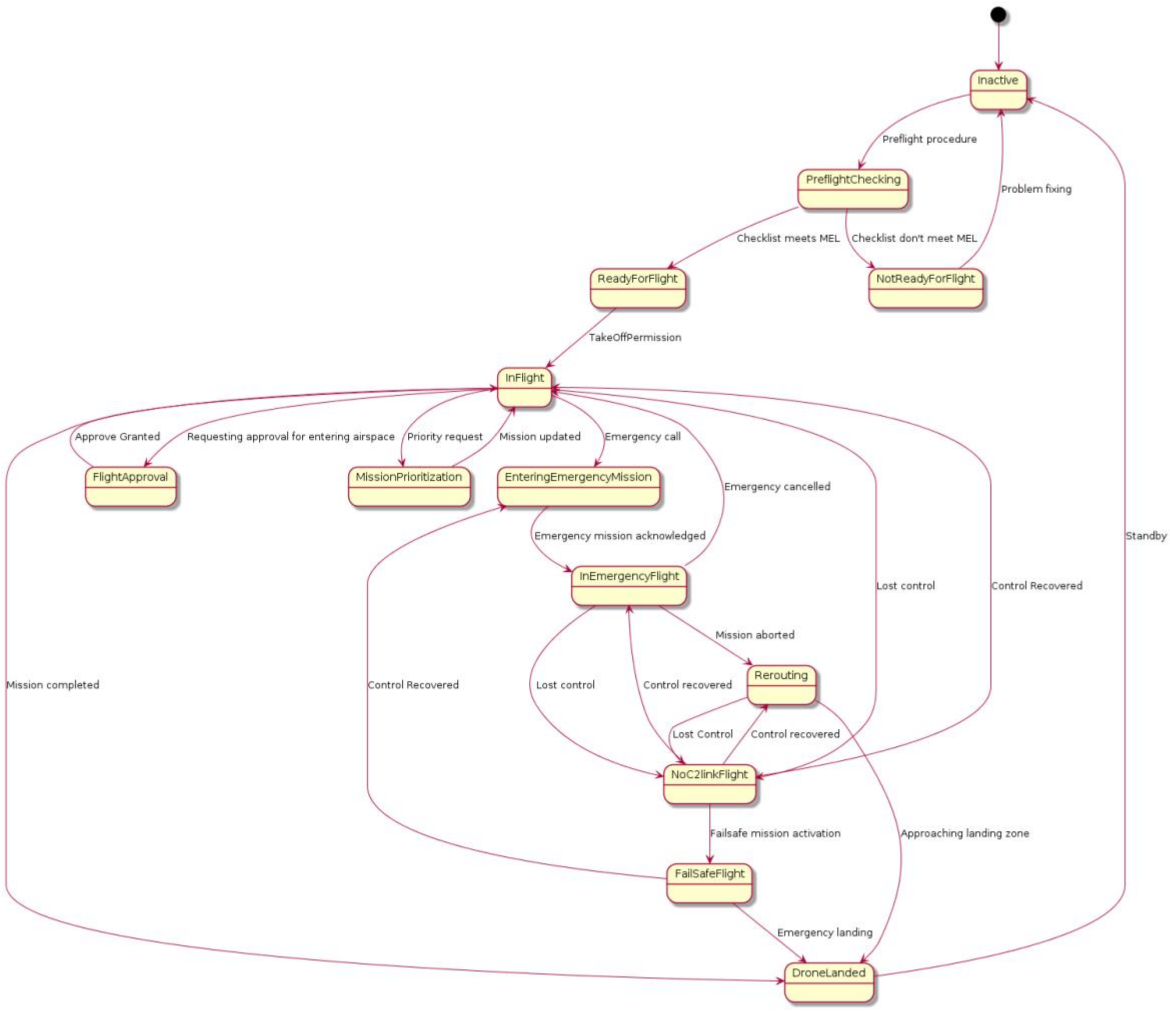

Figure 43: In flight states of the drone

4.3. Security mechanisms

Security is divided into both physical and cyber security. At the same time, it must be taken into account that it is also possible to attack the Trial controller through UAVs and IoT sensors.

4.3.1. Identity and access management

Access to the Trial Controller's interfaces depends on the requesting user (principal), especially the roles/permissions assigned to this user. We have identified different types of actors in previous sections, which should have different permissions on the Trial Controller, such as:

- **Experimenter**: allowed to submit a trial through the Web Portal, monitor the trial progress, terminate a trial; view statistics about the trial; download the mission to the drone, supervise during the flight, and terminate the flight. Also, an Experimenter should be allowed to perform these actions only on the trials (s)he owns/managers, not others.

- **UAV operator**: allowed to initiate, configure and monitor transitions in the state of operation, ingest telemetry and other sensor data. Also, an UAV operator should be allowed to perform these actions only on UAVs (s)he owns/operates.
- **IoT Device Manager**: allowed to manage specific IoT devices (s)he owns through the web portal.

Also the trial controller is responsible for deploying network slices with security controls (relying on security enablers) ensuring only authorized actors may do critical actions (corresponding to specific data flows in the data plane) such as:

- C2 commands/control messages from UAV operator to UAV
- MCS data between MCS participants
- Sensitive video streams (or other sensor data) from UAV to UAV operator
- Management messages from IoT device managers to IoT devices
- IoT sensor data from IoT to IoT owners (on 5G-ready UE, e.g. smartphones).
- Video and data stream to authorised users

In order to enforce such access control, we may assign security roles to users (incl. devices), each role corresponding to a specific type of actor, e.g. Experimenter, UAV operator, IoT device manager/owner, UAV; and define permissions for each role according to the above description. Note that roles are contextual, in as much as the permissions depend on which resource is being accessed. For example, the Experimenter role's permissions must be scoped to the user's owned trials (the ones (s)he executes). Therefore, a conventional RBAC (Role-Based Access Control) system does not suffice, an ABAC (Attribute-Based Access Control) system should be preferred.

Besides, before we can assign roles, users must be identified, and one or more authentication mechanisms are required to enable users to prove their identity to the Trial Controller and other controlled/managed entities (e.g. UAV, IoTs).

Therefore, we provide **an Identity and Access Management (IAM) system** to support these various features, namely:

- Identity management (user attributes, lifecycle from onboarding to offboarding);
- Credentials management (for user authentication, such as passwords, secret keys, etc., depending on the authentication mechanism).
- Privilege management, more specifically group/role management here
- Authentication policy management and enforcement (more or less complex authentication flows)
- Authorization policy management and enforcement (ABAC policies).

With regards to an identity management and authentication framework that suits web services best according to state-of-the-art standards, we also make sure the IAM system supports OAuth 2.0 and/or OpenID Connect (OIDC). In this context, user first authenticate with a *direct authentication* method to the OIDC Provider (or OAuth Authorization Server) endpoint of the IAM system. Such authentication may be a username and password (so-called weak authentication method, not recommended), or OTP, or X.509 certificate based on PKI described in the next section, or FIDO (stronger authentication methods) for example. If this authentication succeeds, the user is issued an access token (and ID token) by the OIDC provider, and may use it to authenticate to all services trusting the OIDC provider (or the IAM service in general), e.g. Trial Controller and its attached components, 5G facility, etc.

Besides, the use of security tokens such as OAuth/OIDC access tokens enables the Trial Controller to propagate the identity (including several user attributes) in a standard way from the web portal, throughout the various Trial Controller's modules, and down to the 5G facility, and therefore enables access control based on original requester's attributes (and more) to take place on all modules' interfaces. This assumes that all inter-module requests include the security tokens (typically in headers of HTTP/REST API requests).

Security controls called PEPs (Policy Enforcement Points) are to be deployed not only in the Trial Controller but also in the 5G data plane (5G facilities) in form of VNFs to enforce the access control policies from the initialization of a trial to its termination.

Last but not least, access control policies will be expressed, managed and orchestrated via the Security Policy Management and Orchestration described in 4.3.3.

4.3.2. Digital Certificate Services (PKI)

For authentication of users to the 5G!Drones system or other users (e.g. Experimenters, IoT device owners, IoT devices, UAV operators, UAVs), as well as strong authentication of internal components of the system to the users or to each other (e.g. servers, applications, VNFs, MANO components), we need a scalable and strong authentication mechanism such as X.509 certificates issued by one or more Certification Authorities (CAs). The common infrastructure to support these is usually referred to as Public Key Infrastructure. In the context of 5G!Drones, we call it the **Digital Certificate Services**.

Digital Certificate Services are responsible for managing and providing access to CAs – especially the Root CA that represents the Root of Trust of the system - and associated CRL/OCSP endpoints for certificate revocation checking. They also provide APIs to create (and revoke) ad-hoc subordinate CAs for specific trials, therefore specific network slices, depending on security requirements. Using slice-specific CAs strengthens the isolation of slices, as communications may be mutually-authenticated by certificates and endpoints configured to trust only a single slice-dedicated CA.

Top-level CAs issue certificates to:

1. End entities of the 5G!Drones system (e.g. Trial Controller's modules, aforementioned IAM services) and end-entities communicating with the 5G!Drones system, including any SSL client or servers (e.g. HTTPS) or IPsec endpoint.
2. Any slice-specific (subordinate) CAs created for a given trial, if any.

For every CA, there are associated CRL/OCSP endpoints that enable certificate validators (e.g. in authentication processes) to check the revocation status of any certificate issued by that CA.

The Digital Certificate Services are complementary to the IAM services, especially the authentication services, e.g. OIDC provider, as certificate may be used for initial authentication of users to the OIDC provider (before the token is issued). The OIDC provider and all IAM services in general are configured to trust the Root CA managed by the Digital Certificate Services as the root of trust.

4.3.3. Security Policy Management and Orchestration

In order to enable management and orchestration of security policies, verticals may and should express security requirements as part of the requirements in the Blueprint they provide to the Trial Controller's Web Portal 2 (see section 2.4.3), and then turned by the Portal into security policies in the NSD and specific Security VNFDs, Security AppDs, etc. as part of the TSD (Trial Service Descriptor), corresponding to Security VNF / Applications playing the role Security Policy Decision and Enforcement Points (PDP/PEP).

The RAN information part may also be adapted to cope with authentication, confidentiality and integrity requirements on communications, in as much as not all UEs may support the required communication security mechanisms, e.g. resource-constrained IoT devices.

As described in 2.4.3, the Trial translator translates the TSD into the NST (Network Slice Template), the *Services Information* part of which will include the security descriptors (security VNFDs, AppDs, etc.).

The NST is then sent by the Trial LCM to the Trial Enforcement for slice instantiation. The Slice manager in the 5G facility receives the NST with security descriptors from the Trial Enforcement for slice creation; therefore the slice manager should be augmented with or connected to a ***Security Policy Orchestrator*** to handle the security part. The Security Policy Orchestrator is responsible – in co-operation with the slice manager and MANO components – for deploying the vPEPs (Policy Enforcement VNFs / MEC apps) enforcing the security policies in the data plane, with policy-compliant configurations, and connecting them to the security services in the control plane, mentioned in the previous section, i.e. IAM services for authentication, token and identity information retrieval, authorization decision; and Digital Certificate Services for checking certificate revocation status.

4.3.4 Physical security

Since 2007, an increasing number of cyber-attacks to the UAV systems have been reported due to popularity of drones. When launching cyber-attacks, adversaries target the radio links of the UAV systems, which carry information such as data requested by cellular UEs, control signals and global positioning system (GPS) signals for UAVs' navigation. For example, with interception of these information, adversaries are able to steal data transmitted and requested by drones or even directly manipulate operating drones by taking advantage of their control signals. Since both data and control signals are transmitted through the radio links, ensuring the security of these wireless communication channels has become an important aspect of the whole UAV system's security. In [27] threats for UAV´s radio links are identified and listed with likelihood and impact of identified threats are evaluated in table.

Threat	Likelihood	Impact
Jamming	High	Low
Eavesdropping	High	Medium
Hijacking	Medium	High
Spoofing	Medium	High
DoS	High	High

Figure 44: Threats, likelihood and impact of identified cybersecurity threats of UAVs [27]

In [28] authors mentioned that UAV´s existing cyber-physical threats and vulnerabilities are following:

- Prone to Spoofing, incl. GPS spoofing
- Prone to Malware Infection
- Prone to Data Interference & Interception
- Prone to Manipulation
- Prone to Technical Issues
- Prone to Operational Issues
- Prone To Natural Issues
- Prone to Wi-Fi Jamming

While 3GPP security mechanisms provide reliable links for non-malicious bad radio conditions but they do not protect against all possible threats, for instance DDoS and radio jamming. Protecting against DDoS attacks and radio jamming is something that is left for implementation and deployment, e.g. to re-route traffic via other base stations if one is jammed, or scaling mechanisms and selective dropping/throttling in case of DDoS. Therefore, the appropriate level of cyber-resilience in the 5G

system and 5G in general needs to be understood and addressed in a much broader way (see section 5) – 5G standards or, for that matter, any other technical standards will only be part of a much bigger picture [29].

Nowadays, security aspects represent one of the most significant barriers for the adoption of largescale Internet of Things (IoT) deployments. In this sense, being able to certify and communicate the security level of a certain device is crucial for their acceptance [30]. In 5G!Drones, four of the trialled use cases will feature IoT sensors: UC1 Sc4 ("UAV Logistics"), UC2 Sc1 ("Monitoring a wildfire"), UC2 Sc3 ("Police incl. Counter-UAS") and UC3 Sc2 ("UAV-based IoT data collection").

In conclusion, it should be noted that in the case of the Trial controller architecture, appropriate measures must be taken to ensure both cyber and physical security. The security layer covers all elements of the trial controller.

4.3.5 Security tests

The first line of defence against cyberthreats and cybercrimes is to be aware and get ready. In [31] authors developed a taxonomy for cyber range systems and evaluate the current literature focusing on architecture and scenarios, but including also capabilities, roles, tools and evaluation criteria [31].

In complement to the design of a cybersecurity suite adapted to the needs of 5G!Drones, it is also necessary to evaluate the aforementioned cybersecurity solutions and perform subsequent tests as follows [4]:

- Vulnerability Scanning;
- Security Scanning;
- Penetration testing;
- Risk Assessment.

All UAV components (e.g., position, velocity, and attitude control) heavily depend on the communication link. Preliminary results showed that fuzzing techniques can detect various software vulnerabilities, which are of particular interest to ensure security in UAVs. In [32] authors performed successful cyber-attacks via penetration testing against the UAV both connection and software system. As a result, authors demonstrated real cyber-threats with the possibility of exploiting further security vulnerabilities in real-world UAV software in the foreseeable future [32].

Based on 5G!Drones deliverable D4.1 (Integration plan), the following trials are planned:

- Feasibility trials (tests);
- Preliminary trials (Phase 1 i.e. during the 2nd iteration of integration in months M13-M18);
- Preliminary trials Phase 2 i.e. during the 3rd iteration of Integration in months M19-M27);
- Final trials.

Security tests are performed together with trials, because then it is possible to test in as realistic conditions as possible.
In conclusion, it should be noted that the security mechanisms support the trial controller in all phases of the trials. Security mechanisms must be designed to work with all elements of the Trial controller, because the security of the entire system is as weak as its weakest element.

5. CONCLUSION

This deliverable provided an initial definition of the trial controller architecture for launching 5G!Drones use case scenarios on the top of 5G trial facility. For this end, this deliverable expanded the high-level architectural design introduced in D1.3, by further detailing the trial controller architecture and its modules. The proposed architecture supports the experimenters in describing their scenarios, reinforce the execution of the trials on the top of the 5G facilities, and enable the collection of different KPIs. The introduced Functional Breakdown Structure reflects an initial definition of the Scenario Description Language for experiment planning and provides a basis for the implementation. The proposed architecture also interconnects 5G and U-space domains. Moreover, the deliverable addressed different reference points based on the trial controller architecture. These reference points contribute towards the definition of the APIs of the trial controller, which will be tackled in the next release of this deliverable (D2.4). Furthermore, the deliverable also emphasized with some initial algorithms and mechanisms that can be considered to support safe & secure preparation and deployment of UAV trials over 5G facilities. It is to highlight that the underlined technical work reported here is under progress and the introduced architecture in this deliverable will be further detailed in next update of this deliverable namely D2.4.

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