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Drones4Safety

Research & Innovation Action (RIA)

Inspection Drones for Ensuring Safety in Transport Infrastructures

Recommendations for Standardisation and Policy Making

D8.5

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Executive Summary

The project Drones4Safety (D4S) aims at developing a system of autonomous, self-charging, and collaborative drones that can inspect a big portion of transportation infrastructures in a continuous operation, including bridges and railway lines. The concept of operations developed in D4S includes features that are advanced compared to today's standard operations as described in standard scenarios or covered by Pre-defined Risk Assessments (PDRAs); these features include autonomous operations beyond visual line of sight (BVLOS), swarming and autonomous re-charging. The D4S use cases are less ambitious than the D4S Concept of Operations (ConOps) in order to remain within the boundaries of operations for which regulatory approval can be obtained with justifiable effort, so as to fall into the requirements of standard scenarios, missions covered by Pre-Defined Risk Assessment or the Open Category.

Both the use cases and the ConOps will require or benefit from a number of U-space services and infrastructure and the objective of this deliverable is to inform standardization and regulatory decision making bodies which of these services most benefit the D4S infrastructure inspection services and should hence, from the project's point of view, constitute a priority for upcoming standards and regulations. In addition to this analysis, recommendations concerning Standardization and Major Policy Recommendations; the Development of Relevant Standard Scenarios and PDRAs; and R&D Needs will be formulated.

The approach outlined in this deliverable is twofold: firstly, we review the U-space service as defined in the European U-space Concept of Operations and discuss which of these are required of benefit for D4S ConOps and use cases. Secondly, after the flight trials have taken place and been analysed, we will present some lessons learned from these where they can inform upcoming standards and regulations. This latter part is not yet included in this edition of deliverable D8.5 and will be added to an amended version after the flight trials.

This deliverable will be updated once the D4S flight trials have been completed and analysed.

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Acronyms

Acronym	Description
AIP	Aeronautical Information Publication
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATS	Air Traffic Services
BVLOS	Beyond Visual Line of Sight
CISP	Common Information Service Provider
CNS	Communication, Navigation and Surveillance
D4S	Drones4Safety
EASA	European Aviation Safety Agency
GAMZ	Geodetic Altitude Mandatory Zones
GCS	Ground Control Station
GM	Guidance Material
IFR	Instrument Flight Rules
MTOM	Maximum Take-Off Mass
OPL	Overhead Power Line
PDRA	Pre-defined Risk Assessment
RFL	Railway Feeder Line
SORA	Specific Operation Risk Assessment
STS	Standard Scenarios
UAS	Unmanned Aerial System
UMZ	U-space Mandatory Zone
USSP	U-space Service Provider
VALS	Vertical ALert and information Service
VCS	Vertical Conversion Service
VFR	Visual Flight Rules
VLL	Very Low level
VLOS	Visual Line of Sight

1. Introduction

Drones4Safety (D4S) aims at developing a system of autonomous, self-charging, and collaborative drones that can inspect a big portion of transportation infrastructures in a continuous operation. Major parts of the technical infrastructure have been or are presently being developed in D4S; in addition, a concept of operations has been defined along with two use cases that will allow testing the concept and the technology in real operations. One of the Use Cases is a bridge inspection whilst the other Use Case is a railway line inspection.

Whilst the concept of operations is, in principle, free from such constraints, the use cases must comply with today's regulations in the countries in which the use cases are conducted in order to obtain approval for the planned operations. Whilst the concept of operations, described in deliverable D5.1 'Specification of the Multi-Drone Swarm System' takes an ambitious stand and introduces swarm operations as well as autonomous navigation and operations beyond line of sight, such operations are not compatible with today's regulations (including Standard Scenarios and Pre-Defined Risk Assessments, or PDRA). Therefore, the use cases are less ambitious in scope and design and sacrifice some of the attributes of the concept of operations, to make them compatible with today's regulations.

The regulatory situation in Europe is both a constraint and an enabler for drone inspection of transportation infrastructure. The learning from the execution of the D4S use cases as well as the requirements of the concept of operations must therefore be formulated in the form of recommendations for standardisation and policy making to ensure that regulation and technology development go hand in hand. This deliverable attempts to formulate these recommendations.

The U-space services U1-U4 are defined by ISO and the CORUS Concept of Operations. These services, as enablers for both of the concept of operations and the case studies, have therefore been chosen as a starting point to formulate these recommendations.

2. The Drones4Safety Concept of Operation and Use cases

2.1 The D4S Concept of Operations

The Drones4Safety Concept of Operations is described in D4S deliverable D5.1 'Specification of the Multi-Drone Swarm System' (edition date 31.3.2021), particularly in section 3. This section will not attempt to replicate the relevant sections from D5.1 but gives a high-level overview and provides some changes and learning after the publication of the deliverable.

Mission Phases

The planning and execution of an inspection mission takes place in three phases;

- Mission preparation phase: the mission is prepared in terms of its objectives, the start and end point and relevant data and constraints such as geofences and meteorological information.
- Mission operation phase: the inspection mission starts with the take-off of the drone and/or swarm of drones and includes the inspection mission itself as well as recharging when needed; the allocation of tasks to each drone as well as the coordination between the drones in a swarm and the communication to the grounds control station are parts of the operation phase.
- Mission conclusion phase: once all tasks are concluded, and the mission ends the drones/drone swarm is retrieved; inspection and telemetry data is analysed and uplinked to the cloud as far as this has not happened already in the operation phase.

Swarm management
The drone swarm is based on collaborative mission planning. This involves the allocation of specific tasks to each drone in the swarm and a collaborative path planning process to ensure the trajectory of each drone does not conflict with other trajectories or, if need be, that the drone swarm can fly in formation. The inspection itself begins and includes telemetry reporting, energy monitoring, progress monitoring and the inspection flight itself. Swarm access management is performed to determine the presently active constituents of a drone swarm.

Communication
During the mission operation phase the following communication channels are open:

- Drone to ground (D2G) communication between ground control station and the drone for telemetry and mission monitoring;
- Drone to drone (D2D) communication for swarm coordination activities;
- Drone to cloud (D2C) communication where each drone reports telemetry data, energy management data and inspection images/results to the cloud.

Note that whilst the Drones4Safety concept of operations is agnostic with regard to the specific communication technology to be used in each of these phases, technology choices had nevertheless to be made in the preparation of the two D4S use cases.

Charging
The charging process has three distinct steps: (a) the cable grasping phase in which the drone connects to the cable, either an overhead power line (OPL) or a railway feeder lines (RFL) depending on the infrastructure being inspected; (b) the energy harvesting phase in which the drone recharges the battery, either through inductive coupling in the case of an AC power line or through direct contact in the case of a DC power line; and (c) the decoupling phase.

2.2 The Selected D4S Use Cases

The following sections briefly introduce the railway and bridge use case design (limited to the ones on which on field tests in real scenarios are included) for the validation of the main D4S functionalities, according to what has been discussed and investigated up to M30.
Additional information, also on other UCs investigated at least for the bridge side, are briefly reported in D7.1 “Report on the System Integration and Validation”.

The updated description of the UCs will be reported in D7.2 (railway UCs) and D7.3 (bridge UCs) according to the activities actually carried out and the technologies, indeed, tested.

Bridge Use Case

One of the bridge use-case will be conducted on a portion of a long viaduct belonging to an occasionally used railway route.

The viaduct is a reinforced concrete wall piers structure with 144 bays for a total length of about 3.7 km and a maximum high of about 20 m. The missions will be focused on a portion consisting of four 25 m bays, for a total length of about 100 m, a maximum height of about 10m (with a pier height of about 7 m) and a transversal dimension of the deck of about 6m. This portion of the viaduct is inserted in an easy-to-access, sparsely populated area.

The drone swarm system used during this mission will consists of two multirotors with MTOM under 2 kg, with one front camera, one downward camera, one front stereo-camera, one depth camera and on-board IMU.

Each platform features several risk mitigation measures such as geofencing, recovery functions, flight terminator, obstacle avoidance sensors.

For the purpose of the case study, particular safety arrangements will be taken in order to keep the risk of the operation basically equivalent to the one of the A2 open category, according to the current ENAC (Italian NAA) regulation. Such arrangements, which are schematically shown in Figure 1, do not impair the testing of the system functionality.

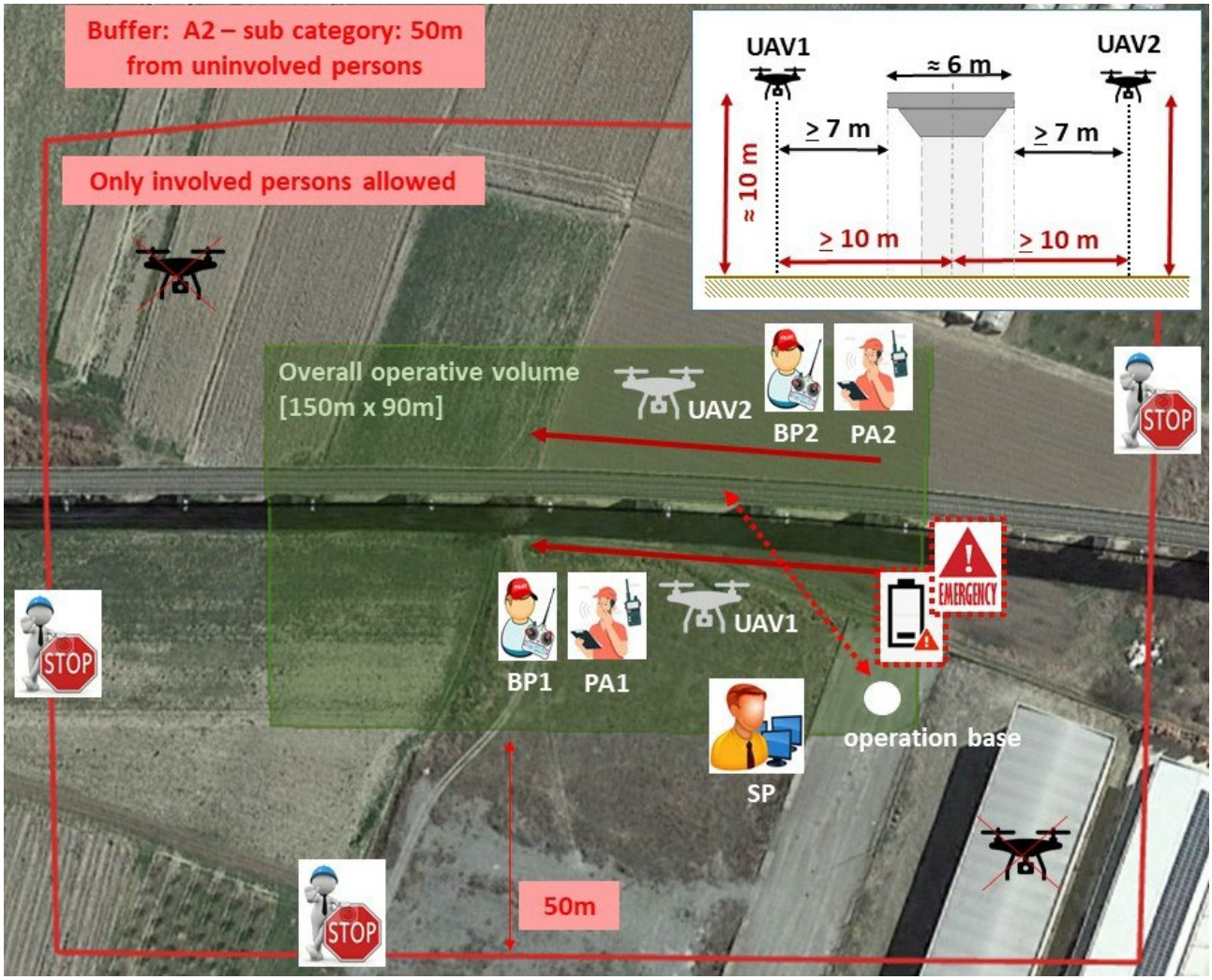

Figure 1: Drones4Safety - Proposed mission scheme of bridge use case

The swarm will be controlled by one single "swarm pilot"", driving the operation by means of a GCS, and two safety "backup pilots" able to take over control of each drone, in case of need. The flight mode of the swarm system can be considered an "automatic operation" according to the European Regulation definitions [EASA, "Annex 1: Acceptable means of compliance (AMC) and guidance material (GM) to commission implementing regulation (EU) 2019/947 – issue 1," in ED Decision 2019/021/R, 9 October 2019]. Two different flight modes can be run: "Standard automatic" (the drone follows the path plan input by the "Swarm Pilot") and "Position control" (the drone hovers in the air, this mode can be activated at any time by any of the backup pilots).

According to the safety analyses, all the flights planned will be carry out in compliance with daytime, VLOS conditions, 15 m above ground maximum flight height, within a controlled area, in a sparsely populated region, without traffic overpassing the viaduct, and in an uncontrolled airspace. In order to guarantee a proper

horizontal separation, the two drone operation volumes do not interfere one each other, as schematically shown in Figure 1. Concerning the duration of the operations, 4 to 6 flights of about 15 minutes are supposed to be planned.

During the mission, the following main functionalities are supposed to be validated: simultaneous swarm inspection flights (planned from the previously acquired 3D point cloud model), AI detection algorithm especially of elements, simulation of flight to/from recharge point and/or of battery recharge by at least one of the drones of the swarm.

Railway Use Case

As for the bridges, several test sites for railway use-cases have been selected to cover the different types of missions, i.e.:

1. damages to the electric traction overhead contact lines,
2. tracks and roadbed deformation,
3. obstacles on tracks,
4. 3D map generation, and
5. target objects inventory creation.

After a proper analysis, which took also into account the electrification type (AC/DC), the restrictions to flying, the accessibility of the area, the safety implications both from the railway and the aviation point of view, coverage of the use-cases, regulatory and authorization processes, presence of damages, etc., several flight missions have been conducted on both conventional and high-speed lines using standard drones in order to create maps and to acquire sample datasets of images and, possibly, damages, to feed the AI algorithms.

Figure 2: Drones4Safety railway use case

The multirotor drones used for these missions had an MTOM under 2 kg and were equipped with an RGB camera for front and downward acquisitions. The flight operations have been conducted under the specific category, as defined by the current Italian regulation, and, in particular, under the prescriptions of the Italian Standard Scenario IT-STS-02 (see Section 3.2 of this document).

3. The Regulatory Situation Relevant for the D4S Use Cases

3.1 Recent Evolution of the Regulatory Situation

This sub-section reports the basic information about the European Regulation for the aspects of interest for the Drones4Safety project, with a main focus on the U-space provisions. This content is given here to help the reader understand the recommendations about regulatory aspects given in section 5 of this document. For a more detailed anlysis of the regulatory framework for drones and how it impacts the design choices made for the Drones4Safety ConOps and use cases, please make reference to deliverables D2.2 Regulatory Gap/Barriers Analysis (initial) and D8.6 Regulatory Gap/Barriers Analysis (final, please note that D8.6 will be published on May 2023, together with the final issue of this document).

The European Aviation Safety Agency (EASA) has been developing and enforcing rules on some of the U-space services noted in the ConOps and UAS rules, procedures and characteristics. Evidently, these rules had and will have an impact on the current level of services implementation in some of the EASA Member States and they will spotlight gaps and stand as a support for the integration of the services. The regulatory environment stands as a threshold, therefore, is essential for the scope of the analysis.

Implementing Regulation (EU) 2019/947 which refers to the rules and procedures of the operation of UASs
Delegated Regulation (EU) 2019/945 focusing on its Annexes where UASs are categorized based on their capabilities
Commission Implementing Regulation (EU) 2021/664, 2021/665, and 2021/666 that are focusing on U-space specifically
Commission Implementing Regulation (EU) 2020/639 which integrates the Implementing Regulation (EU) 2019/947 introducing the IT-STS
Commission Implementing Regulation (EU) 2020/1058 which integrates the Implementing Regulation (EU) 2019/945.

Commission Implementing Regulation (EU) 2021/664

This piece of regulation, part of three, is very important as it sets the first regulation steps for the U-space. It will be in-forced starting with January 2023, therefore, most of the Member States don't have these rules in place and will focus on developing and implementing the requirements.

General points

When Member states define UAS geographical zones for safety, security, privacy or environmental reasons as provided for in Implementing Regulation (EU) 2019/947, they may impose specific conditions for certain or all UAS operations or allow access only to UAS equipped with certain technical features.

The access by UAS operators to such U-space airspace should be conditioned on the use of certain services ('U-space services') that allow the safe management of a large number of UAS operations, respecting also applicable security and privacy requirements.

Member States should establish U-space airspace and U-space airspace requirements, including additional U-space service with the support of a risk assessment.

In order to allow UAS to safely operate alongside manned aircraft, specific coordination procedures and communication facilities between relevant air traffic service units, USSPs and UAS operators are necessary. Those coordination procedures and communication facilities are laid down in Commission Implementing Regulation (EU) 2017/373 as amended by Implementing Regulation (EU) 2021/6658.

Member States should ensure that common information services are made available for every U-space airspace to enable non-discriminatory access to U-space airspace and services for UAS operators, with particular regard to safety. Member States should however be able to designate a single common information service provider to provide the common information services on an exclusive basis in respect of all or some of the U-space airspaces under their responsibility.

This regulation should establish requirements for common interoperable open communication protocols between authorities, service providers and UAS operators, as well as data quality, latency and protection requirements for the information exchanged, necessary for safe and interoperable operations in the U-space airspace.

UAS operators should operate in U-space airspace only if they make use of the U-space services that are indispensable to ensure safe, secure, efficient and interoperable operations. U-space service providers should

provide at least the following mandatory U-space services: a network identification service, a geo-awareness service, a UAS flight authorization service and a traffic information service.

In order to allow unmanned aircraft to safely operate alongside manned aircraft in U-space airspace, rules providing for effective signaling of the presence of manned aircraft by means of surveillance technologies are necessary. Those rules are laid down in Commission Implementing Regulation (EU) No 923/2012 as amended by Implementing Regulation (EU) 2021/6668.

In order to ensure the safe operation in a given U-space airspace and with the support of a risk assessment, Member States should be able to require that other U-space services such as a weather information service and a conformance monitoring service are mandatory.

To ensure the provision of safe and high-quality U-space services, this Regulation lays down a common certification scheme for certifying USSP and, when designated by the Member States, for a single common information service provider, as well as a set of rules for regular monitoring of compliance with the applicable requirements.

The U-space services providers and single common information service providers should establish a system of record keeping that allows adequate storage of the records and reliable traceability of all their activities, covering, in particular, all the elements of their management systems.

Article 6 – UAS operators

UAS operators may provide U-space services to themselves. Before each individual flight, the UAS operator shall submit an UAS flight authorization request to its USSP, through the UAS flight authorization service. When ready to start the flight, the UAS operator shall request the U-space service provider for the activation of the UAS flight authorization. Upon receiving the confirmation of the activation for the UAS flight authorization from the U-space service provider, the UAS operator shall be entitled to start its flight. The U-space service provider may introduce changes to the authorization during any phase of the flight and, in such cases, shall inform UAS operators about them. Where UAS operators are not able to comply with the UAS flight authorization deviation thresholds, they shall request a new UAS flight authorization. UAS operators shall provide contingency measures and procedures. They shall make their contingency measures and procedures available to the U-space service providers.

3.2 Relevant Standard Scenarios and PDRA

This section collects basic information about the Standard Scenarios (STS) and Pre-Defined Risk Assesments (PDRAs) defined in the European Regulation and in the National Regulations of interest for the Drones4Safety project. This description is given here to help the reader understand the recommendations about SS and PDRAs given in section 5. For a more focussed understanding of how SS and PDRAs work and their impact on the regulatory assessment of the Drones4Safety operations, please make reference to deliverables D2.2 Regulatory Gap/Barriers Analysis (initial) and D8.6 Regulatory Gap/Barriers Analysis (final, please note that D8.6 will be published in May 2023, together with the final issue of this document).
For the operations in the Specific Category, **Standard Scenarios (STS)** are defined in the regulation. These scenarios define the conditions when UAS operators can start an operation after having submitted a declaration to the competent aviation authority, instead of applying for an authorization. The EU Regulation Commission Implementing Regulation (EU) 2020/639 introduces two Standard scenarios:

- **STS-01 "Urban VLOS":** Operations in **VLOS** at a maximum height of **120m**, at a ground speed of **less than 5 m/s** in the case of untethered UAS, **over controlled ground areas** that can be in populated (e.g. urban) environments, using UAS with MTOMs of **up to 25kg.** As defined in Article 2(21) of the Implementing Regulation, a controlled ground area is "the ground area where the UAS is operated and

within which the UAS operator can ensure that only involved persons are present". So, the operator must at least be familiar with the intended area of operations. The drone must have a CE mark class 5.

- **STS-02 "Rural BVLOS":** Operations **BVLOS** with the UAS at **not more than 2km from the remote pilot**, if visual observers (VOs) are used, at a **maximum height of 120m**, over **controlled ground areas** in sparsely populated environments, using UAS with MTOMs of **up to 25kg**. However, the launch and the recovery of the UAS is required to be performed in VLOS. The main mitigation means are provided by the VOs who assist the remote pilot in scanning the airspace for the presence of other users. Without the assistance of VOs, the range can be up to 1km, if the UAS flies a pre-programmed flight, allowing it to scan the airspace itself. With VOs the range can be extended up to 2km. The drone must have a CE mark class 6.

The EU STS will become applicable from January 01, 2024 since drones bearing a class mark C5 or C6 are not yet available on the market. Some states already published national STS, similar to the European ones. In this case the declarations based on national STS, which are valid only in that state, can be required by the UAS operator until December 31, 2023 and shall cease to be valid from January 1, 2026 However, if no STS is available in a country, Pre-defined Risk Assessments (PDRA) S-01 and S-02 cater for exactly the same operation of the EU STS, but they do not require using a drone bearing a C5 or C6 class label. In addition to S-01 and S-02, EASA published three further PDRAs (G-01, G-02, G0-3), of which one in particular (PDRA G-03 - Linear inspections, agricultural works) is of particular interest for the Drones4Safety project.
As the two use cases are deployed in Italy, some information about the current Italian regulation are reported herebelow. ENAC, the Italian Civil Aviation Authority, published national standard scenarios and Pre-defined Risk Assessments (PDRA) to support specific category declarations and authorisation requests by the operators (see Section 3.2.1). In particular, two standard scenarios and 9 PDRAs are currently available in Italy[1] together with a guideline for their usage:

Standard Scenario IT-STS-01: Urban

Standard Scenario IT-STS-02: Non Urban

IT-PDRA-01: flight close to obstacles over non-populated area

IT-PDRA-02: flight with NOTAM over non-populated area

IT-PDRA-03: flight with Visual Observers (VO) over non-populated area

IT-PDRA-04: flight close to obstacles over controlled ground area in Urban environment

IT-PDRA-05: flight with NOTAM over controlled ground area in Urban environment

IT-PDRA-06: flight with Visual Observers over controlled ground area in Urban environment

IT-PDRA-07: flight close to obstacles over Urban area

IT-PDRA-08: flight with NOTAM over Urban area

IT-PDRA-09: flight with Visual Observers over Urban area

As said before, in the current times we are living a transition between national and European provisions, so the applicability of the described PDRAs is evolving and under continuous review. At the moment when this document is finalized, only IT-PDRA-01, IT-PDRA-04, IT-PDRA-05, IT-PDRA-06 are considered applicable

[1] https://www.enac.gov.it/la-normativa/normativa-enac/linee-guida/lg-2020001-nav (scenarios and PDRAs in English, guideline in Italian) all links available at 09th November 2022

by ENAC, being IT-PDRA-03 and IT-PDRA-02 superseded by EASA G-01 and G-02, while IT-PDRA-07, IT-PDRA-08, IT-PDRA-09 are no longer aligned with the provisions of the Specific Operations Risk Assessment (SORA, see D2.2 and D8.6 for further information).

Although the Drones4Safety use cases are deployed in a ”simplified” way, so falling within the Open Category or in Standard Scenarios (within the Specific Category, see Section 2.2), the ”regular” operations once Drones4Safety system will be deployed will make use of PDRAs (excluding for the moment ”fully autonomous” and formation flights or swarming, which are not yet covered in the regulation). In particular, the most interesting SS and PDRAs for the project are Euopean STS-02 ”Rural BVLOS” and G-03 ”Linear inspections, agricultural works”, while as regarding the Italian PDRAs, IT-PDRA-01 ”flight close to obstacles over non-populated area” is the one deemed useful for Drones4Safety. For more information about how the Drones4Safety ConOps and use cases interact with the mentioned SS and PDRAs, the reference is deliverable D8.6.

4. The Relevant U-space Services

4.1 Overview of U-space Services

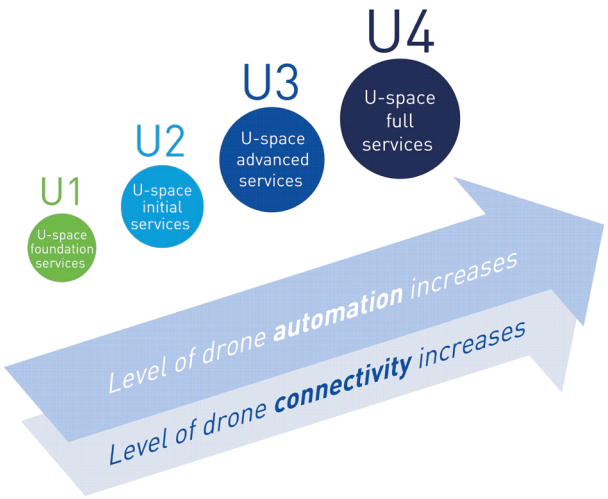

Figure 3: U-space levels, from U-space Blueprint

Figure 3 presents the U-space services as presently defined in Europe; there are four deployment levels, related to the implementation timeframe (Source: U-Space Blueprint). These U-space services will be discussed in greater detail in the subsequent sections (Source: CORUS-XUAM, U-space ConOps, edition 3.10)

TABLE 1: OVERVIEW OF U-SPACE SERVICES ACCORDING TO CORUS CONOPS VERSION 3 AND 3.10

U-space service (ConOps 3.10)	Description	U-space service (ConOps 3)	U-level	Remarks
Registration	Operators of many UAS shall be registered and some UAS shall be registered. Hence there needs to be a registry and a registrar (the operator of the registry) who is approved by the competent authority.	Registration (e-registration)	U1	209/947 Article 14
		Registration Assistance	U1	Services may be offered to assist routine registrations, presenting a user interface that is simplified and/or partly filled in with standard information.
Network identification	UAS in U-space to regularly inform U-space of enough information to supply the Network Identification service Authorised users and systems can obtain information about a currently active UAS.	e-identification	U1	2021/664 Article 8 Network Identification
		Position report submission subservice	U2	2021/664 Article 8 Network Identification

U-space service (ConOps 3.10)	Description	U-space service (ConOps 3)	U-level	Remarks
Tracking	Process that uses position reports and builds a model of where the object is most likely to be now and where it is most likely to be in the near future.	Tracking	U2	Not mentioned but might be inferred in the description of the Traffic Information Service in 2021/664
Surveillance Data Exchange	U-space must be able to display information about manned aircraft and UAS traffic shared by other USSPs and relevant TAS units USSPs must share surveillance data with: - USSPs - ANSPs - CISP when designated	Surveillance Data Exchange	U2	2021/664 Article 8 Network Identification Reception of ATM surveillance data by U-space is part of the Traffic Information Service
Drone Aeronautical Information Management	This is the drone equivalent of the Aeronautical information management service	Drone Aeronautical Information Management	U1	947 Article 15 EU 2021/664 Article 5 Common Information Service
Geo-awareness	Provides the following information to UAS operators concerning the U-space airspace: - applicable operational conditions and airspace constraints; - UAS geographical zones; - temporary restrictions applicable to airspace use. Geo-Fence provision (includes Dynamic Geo-Fencing)	Geo-awareness	U1	Partially: 2019/947 Article 15
		Geo-Fence provision (includes Dynamic Geo-Fencing)	U2	2021/664 Article 9 Geo-awareness service
Operation Plan Preparation / Optimisation service	A service likely to be provided by a USSP to develop and optimise plans for flights and send those plans for authorisation.	Operation plan preparation / optimisation	U2	
Risk Analysis Assistance	Specific operations require SORAs analysing risks associated with the operation. It is expected that a service will be offered to support this analysis using the draft operation plan as well as information coming from the Drone Aeronautical Information Management service, various Environment services and the Traffic Information service.	Risk Analysis Assistance	U2	see Annex I to EASA ED Decision 2019/021/R - Acceptable Means of Compliance (AMC) and guidance material (GM) to Commission Implementing Regulation 2019/947 [3]

U-space service (ConOps 3.10)	Description	U-space service (ConOps 3)	U-level	Remarks
Flight Authorisation service	The Flight Authorisation Service receives U-plans and performs a number of safety-related activities. The Flight Authorisation service must be deployed in a robust and reliable manner because of its safety criticality. The Flight Authorisation service maintains a pool of data containing the histories of all submitted U-plans that have not yet been archived (archiving occurs at some time after the U-plan is ended or cancelled (without ever flying). Access to this pool is controlled.	Operation Plan processing	U2	Partly covered in 2021/664 Article 10 UAS flight authorisation service
Strategic Conflict Prediction	The Strategic conflict prediction service may be invoked by the Flight authorisation service, before the flight takes place, because a new operation plan has been submitted or because a previously submitted operation plan has changed. When more than one USSP provide services in an airspace this activity needs to include all operations plans across the USSPs.	Strategic Conflict Resolution	U2	2021/664Article 10 UAS flight authorisation service In ConOps v3 Strategic Conflict Prediction and Resolution were one service
Strategic Conflict Resolution	Strategic conflict resolution is undertaken by changing one of the pair of conflicting trajectories so that there is no longer “intersection.” It is expected that the strategic conflict resolution service will search for non-conflicting alternatives by applying automatically generated changes from a standard set of “recipes” to the filed plan(s) and testing the result. (E.g. take off delay) Those that resolve the problem (and do not cause another problem) will be proposed to the operator who will refine the plan further before resubmitting or changing it.			2021/664 Article 10 UAS flight authorisation service In ConOps v3 Strategic Conflict Prediction and Resolution were one service
Dynamic Capacity Management	Dynamic Capacity Management matches demand with capacity and has two threads. Demand may be regulated to match capacity, or capacity may be changed to match demand. Practically, limiting the number of flights in a particular volume of air, is the first and simplest approach to Dynamic Capacity Management Service.	Dynamic Capacity Management	U3	

U-space service (ConOps 3.10)	Description	U-space service (ConOps 3)	U-level	Remarks
Tactical Conflict Prediction	The Tactical conflict prediction service requires that the positions of all aircraft be known and frequently updated in the airspace volume being served, and further that the precision with which these positions are known can be reliably determined.	Tactical Conflict Resolution	U3	We assume that tactical conflict prediction and resolution services are implemented on the ground and not as a function distributed among the aircraft. Tactical conflict prediction and resolution have been implemented as one service in ConOps v3
Tactical Conflict Resolution	On receiving a conflict alert from the Tactical conflict prediction service, the Tactical conflict resolution service issues advice or instructions to aircraft to change their speed, level or heading as needed to resolve these conflicts. These instructions should reach the pilot (or piloting system) rapidly and reliably. Tactical conflict prediction and resolution can be implemented as advisory services or as systems giving instructions.			We assume that tactical conflict prediction and resolution services are implemented on the ground and not as a function distributed among the aircraft. Tactical conflict prediction and resolution have been implemented as one service in ConOps v3
Monitoring	The monitoring service retrieves data from the tracking service and combines it with the flight plan (from the Flight authorisation service); obstacles (Geographical Information Service); other air vehicles (Traffic Information service); geo-fences (Geo-awareness service) and weather information (Weather Information service).	Monitoring	U2	Partially covered by 2021/664 Article 13 Conformance monitoring service
Legal Recording	The service should record all inputs to U-space and allow the full state of the system at any moment to be determined to support accident and incident investigation; research and training; and post-processing can identify high risk situations and adapt parameters for risk assessment of future operations.	Legal Recording	U2	2021/664 Article 15(g)
Emergency Management	The Emergency management service of U-space has two aspects: (a) assistance to a drone pilot experiencing an emergency; (b) communication of emergency information to those who may be interested (other pilots, manned aviation, air traffic services, police, military and similar)	Emergency Management	U2	2021/664 Article 13 Conformance monitoring service

U-space service (ConOps 3.10)	Description	U-space service (ConOps 3)	U-level	Remarks
Incident / Accident reporting	The incident/accident reporting service allows drone operators and others to report incidents and accidents (including drone identifiers and operation plan identifiers) to help later investigation. The service maintains the reports for their whole life-cycle. The system is secure and only gives access to authorised persons. The Accident and Incident reporting service is a client of the Legal Recording service.	Incident / Accident reporting	U2	Partially covered by 2021/664 Article 15(d) Services was split into Incident / Accident reporting service and Citizen Reporting service In ConOps v3
		Citizen Reporting service	U2	
Traffic Information	A traffic information service provides the drone pilot or operator with traffic information and warnings about other flights – manned or unmanned - that may be of interest, generally because they have some risk of collision with the pilot's own aircraft.	Traffic Information	U2	2021/664 Article 11 Traffic information service
Navigation Infrastructure Monitoring	The service provides up to date status information about navigation infrastructure and is used before and during operations. The service should give warnings of loss of navigation accuracy. Specifically, the GNSS service can provide GNSS signal monitoring, Position Velocity and Time (PVT) and Integrity calculation.	Navigation Infrastructure Monitoring	U2	
Communication Infrastructure Monitoring	The service to provide up to date status information about communication infrastructure for use before and during operations. The service should give warnings of degradation of communications infrastructure.	Communication Infrastructure Monitoring	U2	
Digital Logbook	The digital logbook service extracts information from the legal recordings to produce reports relevant for whoever is using the service. It shall give users access to their own information only.	Digital Logbook	U2	
Weather Information	The weather information service will collect and present relevant weather information for the drone operation. This includes hyperlocal weather information when available/required.	Weather Information	U2	2021/664 Article 12 Weather information service
Geographical Information Service	The Geographical Information Service (GIS) provides a 3D model of terrain and obstacles for use during planning, updated continuously for use during flight.	Geospatial information service	U2	This service was called Geospatial information service in ConOps v3.

U-space service (ConOps 3.10)	Description	U-space service (ConOps 3)	U-level	Remarks
Population density map	Collects and presents the relevant density map for the drone operation to assess ground risk. Used by the Operation Plan Preparation / Optimisation service	Population density map	U2	
Electromagnetic interference information	Collects and presents relevant electromagnetic interference information for the drone operation. The service shows where there may be a risk to the C2 link or other aspects of drone function due to radio frequency emissions. Used by the Operation Plan Preparation / Optimisation service	Electromagnetic interference information	U2	
Navigation Coverage information	Provides (static) information about navigation coverage. This can be specialised depending on the navigation infrastructure available (e.g. ground or satellite based). Used by the Operation Plan Preparation / Optimisation service	Navigation Coverage information	U2	
Communication Coverage information	Provides (static) information about the communication coverage. It can be specialised depending on the communication infrastructure available (e.g. ground or satellite based).	Communication Coverage information	U2	
Procedural interface with ATC	The procedural interface with ATC is a mechanism for coordinating the entry of a flight into controlled airspace before the flight takes place. The operation plan processing service will invoke the service and establish if ATC can accept or refuse the flight as well as requirements and process to be followed for the flight.	Procedural interface with ATC	U2	
Collaborative interface with ATC	The collaborative interface is offering communication between ATC and the appropriate representative of a drone flight, which could be the remote pilot, the drone itself in case of automated flight or in some cases the USSP. The collaborative interface with ATC is expected to used while a drone is close to or in a controlled area.	Collaborative interface with ATC	U3	

U-space service (ConOps 3.10)	Description	U-space service (ConOps 3)	U-level	Remarks
Vertical Conversion Service	The VCS ensures the conversion of altitudes between barometric and geodetic reference systems to both manned and unmanned aircraft in Geodetic Altitude Mandatory Zones (GAMZ).		U3	The Vertical Conversion Service (VCS) and the Vertical Alert and Information Service are elements of the proposed ICARUS suite of services; they are not mentioned in ConOps v3
Vertical Alert and Information Service	The Vertical Alert and Information service (VALS) alerts GA pilots and UAS / UAS pilots in any Geodetic Altitude Mandatory Zones (GAMZ) to any risk of collision with ground obstacles, using APIs (Application Programming Interfaces) from the ANSP and the USSP respectively.		U3	The Vertical Conversion Service (VCS) and the Vertical Alert and Information Service are elements of the proposed ICARUS suite of services; they are not mentioned in ConOps v3

USSPs must provide at least the following services within the U-space airspace:

- Network identification service, providing the identity of UAS operators and the location and trajectory of UAS during operations.
- Geo-awareness service, providing information on operational conditions, airspace limitations or existing time restrictions.
- UAS flight authorisation service, which ensures conflict-free operations with other UAS operating in the same volume of airspace. The concept is similar to the ATC clearances issued to manned flights.
- Traffic information service, which alerts operators of air traffic that may be found near the aircraft.

Additionally, Member States may require that one or both of the following services are also provided:

- Weather information service, supporting the flight planning and execution phases and enhancing the performance of other U-space services.
- Conformance monitoring service, warns of non-compliance with the granted flight clearance and informs operators of any deviation from it.

4.2 U-space Services in D4S

TABLE 2 analyses which of the U-space services are required or benefit the D4S Concepts of Operations as well as the two use cases railway inspection and bridge inspection.

TABLE 2: U-SPACE SERVICES RELEVANT FOR D4S CONOPS AND USE CASES

U-space service	Description	D4S Concept of Operations	Railway inspection in near future (one or more drones, BVLOS; linear trajectory)	Bridge inspection in near future (one or more drones, VLOS; non-linear trajectory; loss of GPS signal possible)
Registration	Operators of many UAS shall be registered and some UAS shall be registered. Hence there needs to be a registry and a registrar (the operator of the registry) who is approved by the competent authority.	Yes; of the operator and the drone (mindful of the conflict of authority between railway and air authorities)	Operator yes, drone yes	Operator yes, drone yes
Network identification	UAS in U-space to regularly inform U-space of enough information to supply the Network Identification service Authorised users and systems can obtain information about a currently active UAS.	Yes For European USSPs registration automatically involves Network Identification, an electronic ID (Damiano to check whether this is common in Europe)	Yes	Yes
Tracking	Process that uses position reports and builds a model of where the object is most likely to be now and where it is most likely to be in the near future.	Yes for BVLOS operations; also to be sure drones do no conflict with infrastructure	Yes, to protect infrastructure and vehicles	No, because VLOS
Surveillance Data Exchange	U-space must be able to display information about manned aircraft and UAS traffic shared by other USSPs and relevant TAS units USSPs must share surveillance data with: - USSPs - ANSPs - CISP when designated	Yes	Yes	No
Drone Aeronautical Information Management	This is the drone equivalent of the Aeronautical information management service	Yes	Yes	Yes
Geo-awareness	Provides the following information to UAS operators concerning the U-space airspace: - applicable operational conditions and airspace constraints; - UAS geographical zones; - temporary restrictions applicable to airspace use. Geo-Fence provision (includes Dynamic Geo-Fencing)	Yes	Yes	Yes

U-space service	Description	D4S Concept of Operations	Railway inspection in near future (one or more drones, BVLOS; linear trajectory)	Bridge inspection in near future (one or more drones, VLOS; non-linear trajectory; loss of GPS signal possible)
Operation Plan Preparation / Optimisation service	A service likely to be provided by a USSP to develop and optimise plans for flights and send those plans for authorisation.	Yes	No (depends on whether this service will be mandated; one may not have priority over other flights if the service is available and others use it)	No (depends on whether this service will be mandated)
Risk Analysis Assistance	Specific operations require SORAs analysing risks associated with the operation. It is expected that a service will be offered to support this analysis using the draft operation plan as well as information coming from the Drone Aeronautical Information Management service, various Environment services and the Traffic Information service.	Yes	Yes, unless operating according to BVLOS PDRA	Yes, if SORA is required (unless open category or standard scenarios)
Flight Authorisation service	The Flight Authorisation Service receives U-plans and performs a number of safety-related activities. The Flight Authorisation service must be deployed in a robust and reliable manner because of its safety criticality. The Flight Authorisation service maintains a pool of data containing the histories of all submitted U-plans that have not yet been archived (archiving occurs at some time after the U-plan is ended or cancelled (without ever flying). Access to this pool is controlled.	Yes	Yes because BVLOS entails need for authorization	No, if operating in open category or standard scenarios
Strategic Conflict Prediction	The Strategic conflict prediction service may be invoked by the Flight authorisation service, before the flight takes place, because a new operation plan has been submitted or because a previously submitted operation plan has changed. When more than one USSP provide services in an airspace this activity needs to include all operations plans across the USSPs.	Yes	Probably Yes	No (when operating in open or standard scenario)

U-space service	Description	D4S Concept of Operations	Railway inspection in near future (one or more drones, BVLOS; linear trajectory)	Bridge inspection in near future (one or more drones, VLOS; non-linear trajectory; loss of GPS signal possible)
Strategic Conflict Resolution	Strategic conflict resolution is undertaken by changing one of the pair of conflicting trajectories so that there is no longer "intersection." It is expected that the strategic conflict resolution service will search for non-conflicting alternatives by applying automatically generated changes from a standard set of "recipes" to the filed plan(s) and testing the result. (E.g. take off delay) Those that resolve the problem (and do not cause another problem) will be proposed to the operator who will refine the plan further before resubmitting or changing it.	Yes	Yes; only changes to the schedule, not the trajectory are possible (the drone needs to follow the defined inspection trajectory)	No
Dynamic Capacity Management	Dynamic Capacity Management matches demand with capacity and has two threads. Demand may be regulated to match capacity, or capacity may be changed to match demand. Practically, limiting the number of flights in a particular volume of air, is the first and simplest approach to Dynamic Capacity Management Service.	Yes, see Operation Plan Preparation / Optimisation service	Yes, see Operation Plan Preparation / Optimisation service	No, see Operation Plan Preparation / Optimisation service
Tactical Conflict Prediction	The Tactical conflict prediction service requires that the positions of all aircraft be known and frequently updated in the airspace volume being served, and further that the precision with which these positions are known can be reliably determined.	Yes, see Operation Plan Preparation / Optimisation service	Yes, see Operation Plan Preparation / Optimisation service	No, see Operation Plan Preparation / Optimisation service VLOS is a means to identify and resolve tactical conflicts

U-space service	Description	D4S Concept of Operations	Railway inspection in near future (one or more drones, BVLOS; linear trajectory)	Bridge inspection in near future (one or more drones, VLOS; non-linear trajectory; loss of GPS signal possible)
Tactical Conflict Resolution	On receiving a conflict alert from the Tactical conflict prediction service, the Tactical conflict resolution service issues advice or instructions to aircraft to change their speed, level or heading as needed to resolve these conflicts. These instructions should reach the pilot (or piloting system) rapidly and reliably. Tactical conflict prediction and resolution can be implemented as advisory services or as systems giving instructions.	Yes, see Operation Plan Preparation / Optimisation service Double-check with Emad and Peter whether operations plan can be changed following tactical conflict resolution in automatic (and not supervised) mode	Yes, see Operation Plan Preparation / Optimisation service; hovering the only means to resolve conflicts	No, see Operation Plan Preparation / Optimisation service; VLOS is a means to resolve tactical conflicts
Monitoring	The monitoring service retrieves data from the tracking service and combines it with the flight plan (from the Flight authorisation service); obstacles (Geographical Information Service); other air vehicles (Traffic Information service); geo-fences (Geo-awareness service) and weather information (Weather Information service).	Yes	Yes	No, see comments concerning flight tracking service and flight authorization service
Legal Recording	The service should record all inputs to U-space and allow the full state of the system at any moment to be determined to support accident and incident investigation; research and training; and post-processing can identify high risk situations and adapt parameters for risk assessment of future operations.	No, depending on implementation details	No	No
Emergency Management	The Emergency management service of U-space has two aspects: (a) assistance to a drone pilot experiencing an emergency; (b) communication of emergency information to those who may be interested (other pilots, manned aviation, air traffic services, police, military and similar)	Yes	Yes	Yes; flying under GPS loss can pose a risk to operations; push a button and the USSP handles the emergency

U-space service	Description	D4S Concept of Operations	Railway inspection in near future (one or more drones, BVLOS; linear trajectory)	Bridge inspection in near future (one or more drones, VLOS; non-linear trajectory; loss of GPS signal possible)
Incident / Accident reporting	The incident/accident reporting service allows drone operators and others to report incidents and accidents (including drone identifiers and operation plan identifiers) to help later investigation. The service maintains the reports for their whole life-cycle. The system is secure and only gives access to authorised persons. The Accident and Incident reporting service is a client of the Legal Recording service.	Yes, because mandatory	Yes, because mandatory	Yes, because mandatory
Traffic Information	A traffic information service provides the drone pilot or operator with traffic information and warnings about other flights – manned or unmanned - that may be of interest, generally because they have some risk of collision with the pilot's own aircraft.	Yes	Yes	Yes
Navigation Infrastructure Monitoring	The service provides up to date status information about navigation infrastructure and is used before and during operations. The service should give warnings of loss of navigation accuracy. Specifically, the GNSS service can provide GNSS signal monitoring, Position Velocity and Time (PVT) and Integrity calculation.	Yes	Yes	Yes
Communication Infrastructure Monitoring	The service to provide up to date status information about communication infrastructure for use before and during operations. The service should give warnings of degradation of communications infrastructure.	Yes, important enabler for swarm flights; does not monitor comm infrastructure GCS-drone	Yes,	Yes,
Digital Logbook	The digital logbook service extracts information from the legal recordings to produce reports relevant for whoever is using the service. It shall give users access to their own information only.	No	No	No

U-space service	Description	D4S Concept of Operations	Railway inspection in near future (one or more drones, BVLOS; linear trajectory)	Bridge inspection in near future (one or more drones, VLOS; non-linear trajectory; loss of GPS signal possible)
Weather Information	The weather information service will collect and present relevant weather information for the drone operation. This includes hyperlocal weather information when available/required.	Yes	Enabler for safer and more efficient ops, although operations could take place without	Enabler for safer and more efficient ops, although operations could take place without
Geographical Information Service	The Geographical Information Service (GIS) provides a 3D model of terrain and obstacles for use during planning, updated continuously for use during flight.	Yes for planning, Even the GIS service exists it needs to be complemented with terrain, bridges, railway lines; D4S provides no dynamic update of the maps – sensors are used for collision Not necessary for ops since obstacle avoidance through sensors	Useful for planning, although D4S creates an own 3D map If the GIS service exists it needs to be complemented with terrain, bridges, railway lines; D4S provides no dynamic update of the maps – sensors are used for collision Not necessary for ops since obstacle avoidance through sensors	Useful for planning, although D4S creates an own 3D map If the GIS service exists it needs to be complemented with terrain, bridges, railway lines; D4S provides no dynamic update of the maps – sensors are used for collision Not necessary for ops since obstacle avoidance through sensors and we operate in VLOS
Population density map	Collects and presents the relevant density map for the drone operation to assess ground risk. Used by the Operation Plan Preparation / Optimisation service	Yes, needed for SORA	No if operating in standard BVLOS scenario Yes if SORA is needed	No if operating in open or standard scenario Yes if SORA is needed
Electromagnetic interference information	Collects and presents relevant electromagnetic interference information for the drone operation. The service shows where there may be a risk to the C2 link or other aspects of drone function due to radio frequency emissions. Used by the Operation Plan Preparation / Optimisation service	Yes D4S drones are also providers of information The D4S drone is protected against high EMI from powerlines; hence it will be able to operate under high electromagnetic fields	Yes, useful although maybe not mandatory	Yes, useful although maybe not mandatory

U-space service	Description	D4S Concept of Operations	Railway inspection in near future (one or more drones, BVLOS; linear trajectory)	Bridge inspection in near future (one or more drones, VLOS; non-linear trajectory; loss of GPS signal possible)
Navigation Coverage information	Provides (static) information about navigation coverage. This can be specialised depending on the navigation infrastructure available (e.g. ground or satellite based). Used by the Operation Plan Preparation / Optimisation service	Yes (ARIC is implementing functionality for augmentation of navigation accuracy)	Yes	Yes
Communication Coverage information	This service provides (static) information about the communication coverage. It can be specialised depending on the communication infrastructure available (e.g. ground or satellite based).	Yes	Yes	Yes
Procedural interface with ATC	The procedural interface with ATC is a mechanism for coordinating the entry of a flight into controlled airspace before the flight takes place. The operation plan processing service will invoke the service and establish if ATC can accept or refuse the flight as well as requirements and process to be followed for the flight.	Yes, useful in a CTR Otherwise No	No Since the use case is not inside a CTR	No Since the use case is not inside a CTR
Collaborative interface with ATC	The collaborative interface is offering communication between ATC and the appropriate representative of a drone flight, which could be the remote pilot, the drone itself in case of automated flight or in some cases the USSP. The collaborative interface with ATC is expected to used while a drone is close to or in a controlled area.	Yes, useful in a CTR Otherwise No	No Since the use case is not inside a CTR	No Since the use case is not inside a CTR
Vertical Conversion Service	The VCS ensures the conversion of altitudes between barometric and geodetic reference systems to both manned and unmanned aircraft in Geodetic Altitude Mandatory Zones (GAMZ).	Useful if inspection takes place in an airspace in which on-board piloted aviation operates	No because operations do not take place in an airspace in which on-board piloted aviation operates	No because operations do not take place in an airspace in which on-board piloted aviation operates

U-space service	Description	D4S Concept of Operations	Railway inspection in near future (one or more drones, BVLOS; linear trajectory)	Bridge inspection in near future (one or more drones, VLOS; non-linear trajectory; loss of GPS signal possible)
Vertical Alert and Information Service	The Vertical Alert and Information service (VALS) alerts GA pilots and UAS / UAS pilots in any Geodetic Altitude Mandatory Zones (GAMZ) to any risk of collision with ground obstacles, using APIs (Application Programming Interfaces) from the ANSP and the USSP respectively.	Useful if inspection takes place in GAMZ	No because operations do not take place in an airspace in which on-board piloted aviation operates	No because operations do not take place in an airspace in which on-board piloted aviation operates

5. Recommendations for Standardisation and Policy Making

5.1 Recommendations Concerning Standardization and Major Policy Recommendations

This section will be added after the D4S flight trials have been completed and analysed.

5.2 Recommendations Concerning the Development of Relevant Standard Scenarios and PDRAs

This section will be added after the D4S flight trials have been completed and analysed.

5.3 Recommendations Concerning U-space Service

The following U-space service are required for the use-cases:

- Registration
- Network identification
- Tracking
- Surveillance Data Exchange
- Drone Aeronautical Information Management
- Geo-awareness
- Risk Analysis Assistance
- Flight Authorisation service
- Strategic Conflict Prediction

- Strategic Conflict Resolution
- Dynamic Capacity Management
- Tactical Conflict Prediction
- Tactical Conflict Resolution
- Monitoring
- Emergency Management
- Incident / Accident reporting
- Traffic Information
- Navigation Infrastructure Monitoring
- Communication Infrastructure Monitoring
- Weather Information
- Electromagnetic interference information
- Navigation Coverage information
- Communication Coverage information

The following U-space services are required for the Concept of Operations (in addition to the U-space services required for the use cases):

- Operation Plan Preparation / Optimisation service
- Geographical Information Service
- Population density map
- Procedural interface with ATC
- Collaborative interface with ATC
- Vertical Conversion Service
- Vertical Alert and Information Service

This section will be updated after the D4S flight trials have been completed and analysed.

5.4 R&D Needs

This section will be added after the D4S flight trials have been completed and analysed.

6. Conclusions and Outlook

This deliverable aims at formulating recommendations to that the Drones4Safety Concept of Operations and the results of the flight trials in the use cases can inform standardisation and regulatory decision making. An analysis of the U-space services was conducted to identify which of these services are required (a) to enable the Concept of Operations and (b) accompany the D4S flight Trials. In addition to this analysis, recommendations concerning Standardization and Major Policy Recommendations; the Development of Relevant Standard Scenarios and PDRAs; and R&D Needs have been formulated.

This section will be updated after the D4S flight trials have been completed and analysed.

7. References

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