D6.3 System under test requirements and certification v2

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Table of content

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Acronyms and Abbreviations

Acronym	Title
ADOC	AirHub Drone Operations Center
AED	Automated external defibrillator
AGL	Above Ground Level
AMC	Acceptable Means of Compliance
API	Application Programming Interface
ATM	Air Traffic Management
BVLOS	Beyond Visual Line of Sight
C2CSP	C2 Link Communications Service Provider
C2 Link	Command and Control data link
CAA	Civil Aviation Authority
CIS	Common Information Service
CONOPS	Concept of Operation
CTR	Control zone
CU	Command Unit
EASA	European Union Aviation Safety Agency
EC	European Commission
EMS	Emergency medical services
ENAC	Ente Nazionale per l’Aviazione Civile
CEN	Comité Européen de Normalisation
EN	European Norm
EU	European Union
HTCE	High Tech Campus Eindhoven

FR	Functional requirements
NFR	Non-functional requirements
HSR	Hospital San Raffaele
IAM	Innovative Air Mobility
IAS	Innovative Air Services
ICAO	International Civil Aviation Organisation
IL&T	Inspectie Leefomgeving en Transport
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LLab	Living Lab
MVP	Minimum Viable Product
NOTAM	Notice to Airmen
OPP	Operation Plan Preparation
OSO	Operational Safety Objective
OULU	University of Oulu
PDRA	Pre-Defined Risk Assessment
RMZ	Radio Mandatory Zone
RP	Remote Pilot
RTK	Real-time kinematic positioning
SDK	Software Development Kit
SORA	Specific Operation Risk Assessment
STS	Standard Scenario

TARTU	Tartu Science Park
UA	Unmanned Aircraft
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UMS	Unified Modelling Language
USSP	U-space (UTM) Service Provider
UTM	UAS Traffic Management
ZAR	Ayuntamiento (Municipality) of Zaragoza

Executive Summary

This document is written under the framework of Work Package 6 (“UAM services case studies, specifications and benchmarking”) of Flying Forward 2020, which received funding from the European Union’s Horizon 2020 Research and Innovation program under Grant Agreement No. 101006828.

This document features the requirements for the implementation and first results of the Demonstrators of the Living Labs involved in this phase of the project.

The first set of requirements regard the components developed by the technical partners of the project in the frameworks of WP2 (“Digital Toolbox”) and WP3-5 (“UAM toolkit”), actualized in Minimum Viable Products (MVPs) that FF2020 project advances for the benefits of the UAM stakeholders. The “UAM toolkit” employs the Geospatial infrastructure, the Regulatory framework and the Governance model, while the “Digital Toolbox” utilises the former to ensure the seamless integration of the Urban Air Mobility (UAM) services as a part of the smart city information systems. The description of the components and the current collections of the system requirements are given.

The second part of the document shares insights regarding the requirements for the actual implementation of Demonstrators, starting from Demonstrator 1, which is the UAM infrastructure that FF2020 formalises as the “UAM Blueprint” and is implemented by all the Living Labs. The following sections features all the technologies, safety requirements, organizational aspects and stakeholders involved for the remaining Demonstrators, implemented by each Living Lab (LLAB).

The High Tech Campus in Eindhoven (HTCE) implemented its Demonstrators successfully, while San Raffaele Hospital (HSR) and the Municipality of Zaragoza (ZAR) are in the phase of preparation. By comparing the description of those Demonstrators with their status described in the Deliverable 6.1, Specification of the UAM, one can observe what the progress of the European UAM domain development facilitated by FF2020 allows at its edge and what limitations remain. The description of the demonstrators reflecting the UAM Blueprint brings useful details to the European UAM stakeholders to help them plan their activities, implement or utilise needed organisation, architecture and technology to benefit from the UAM.

The revised and updated version of the UAM Blueprint is presented in Appendix 1. Due to the growing demand for UAM-associated details, the document evolved from a list of the UAM-relevant taxonomy to a guide clarifying the important elements of the UAM as well as the implementation and the application of the concept. The document is still a work in progress and expected to evolve within the future deliverable. As a separate document reflecting the UAM state of the art by the end of the FF2020 project, the UAM Blueprint, validated through the series of the demonstrators, will be available to the UAM stakeholders.

Introduction

The year 2021 in Europe was the year of the U-space legislative framework and a lot of debates about how to achieve the implementation of Unmanned Aircraft Systems (UAS) and Urban Air Mobility (UAM) regulations. The debates were caused by rapidly increased interest in the applications of UAS in urban environments, expected challenges to achieve compliance with technical requirements for certain C classes of the Unmanned Aircraft (UA), the lack of a mutual ground of understanding of the UAM concept among a diversity of stakeholders, and a high level of uncertainty regarding the future availability of the UAS Traffic Management (UTM) services. Nevertheless, the Flying Forward 2020 (FF2020) project is progressing towards the practical implementation of its plans, as one of the main objectives of the project is to bring different parties (from aviation and non-aviation sectors) together. This is done by trying to navigate in such a complex and novel field while tackling such (and more) challenges in practice.

Flying Forward 2020 adopts an iterative methodology, meaning that the Living Labs (LLabs) will perform the validation and demonstrative activities in succession. That way, each LLab will test the integration of the UAM services in the respective city infrastructure and will provide valuable feedback to the technical partners of the project for next iterations of their products.

During the Demonstrators, the LLabs will test the designed architecture and technology both outsourced (when available on the market) and developed by the FF2020 technical partners (when available depending on the stage of the product development). Each LLab will integrate all the available components and services deemed necessary to implement the designed use cases. Most importantly, they will test and provide feedback on the FF2020 UAM Toolkit developed by the technical partners, which comprises three main components: the governance model, the regulatory framework and the geospatial infrastructure. The most updated descriptions of each component at the current state are reported in Deliverables D3.2, D4.2 and D4.5, and D5.3, respectively.

The focus of D6.3 ("System under test requirements and certification v2") is the definition of the requirements for the Demonstrators taking place at HTCE, HSR and ZAR, implementing the respective use cases. In particular, the focus will be on the implementation of the elements of the "UAM Blueprint", i.e., the taxonomy developed by the project to comprise the actors, services and components enabling UAM. The next versions of this document will comprise the subsequent Living Labs demonstrating the respective use cases and updated versions of the UAM Blueprint.

This document is structured as follows:

- Chapter 2, "Project background", contextualises the Demonstrators in the project planning;
- Chapter 3, "Project components", illustrates the current status of the components developed by FF2020 technical partners as they will be implemented and integrated in the Living Labs;
- Chapter 4, "Demonstrators", illustrates and updates adopted by the Living Labs, i.e. the UAM Blueprint (Demonstrator 1), and specifies how each Living Lab implements it in each of their use cases.

In summary, whereas D6.1 answered to the question "*What?*" by detailing what the LLabs will accomplish in their Demonstrators, Deliverable 6.2 to 6.4 answer to the question "*How?*" by showing the organisation, architecture and technology put in place to achieve the LLabs' objectives.

1. Project background

The FF2020 Project's mission is to create a common ground for the safe integration of UAM in the European smart cities by taking into account the societal, technological and environmental challenges of the 21th century. Therefore, the solution must be sustainable, resilient (i.e., it must dynamically adjust to interfering variables) and ethically feasible. The solution developed by the technical partners of FF2020 and implemented by the LLABs aims to meet such criteria.

Deliverable 6.1 reported the specifications of everyday practical use cases that would be enabled by UAM in each LLab, subdivided in two categories: (i) monitoring infrastructure, sustainability and surveillance, and (ii) last mile and emergencies air delivery services. In the current phase of the project, the LLABs are testing a prototype of the designed UAM ecosystem. To that extent, while all the LLABs share common regulatory and governance frameworks, they implement different use cases depending on the respective context and users' needs. Since LLABs face different challenges, they will separately evaluate the outcomes against their own expectations. The present series of Deliverable will only report insights and lessons learned from the precedent LLabs, useful for the implementation in the following ones. The Demonstrators evaluation will be part of Deliverable D6.5 ("Evaluation and Regulatory Assessment Results").

Each Demonstrator is implemented through three stages:

- Stage 1, Preparation: Problem specification and requirements elicitation. Validation of the concepts and key technology elements (TRL 1-2).
- Stage 2, Pilot and Validation: Technology demonstration and experimentation mainly in labs or controlled environment to be integrated on the following months in-situ, involving end users and real UAS flights (TRL 3-4).
- Stage 3, Deployment and Monitoring: The partners will make sure that all the regulation and social acceptance of the UAM services to be implemented are assessed; this will be complemented, when necessary, with a detailed technical monitoring, certification and business feasibility of the UAM services (TRL 5-6).

The experience at HTCE informed about the importance of a timely preparation in all the other LLabs. In addition, the regulatory challenges faced by HSR made it necessary to postpone Stage 3. Table 1 shows the consequently revised version of the Demonstrators timeline.

Living LAB	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33
Year	2021	2022												2023							
Month	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Eindhoven (HTCE)	Stage 1	Stage 2	Stage 2	Stage 3	Stage 3	Stage 3															
Milan (HSR)					Stage 1	Stage 1	Stage 1	Stage 1	Stage 1	Stage 2	Stage 2	Stage 2	Stage 2	Stage 3	Stage 3	Stage 3					
Zaragoza (ZAR)				Stage 1	Stage 1	Stage 1	Stage 1	Stage 1	Stage 2	Stage 2	Stage 3			Stage 1	Stage 2	Stage 2	Stage 3				
Tartu (TARTU)							Stage 1	Stage 1	Stage 1	Stage 1	Stage 1	Stage 2	Stage 2	Stage 2	Stage 2	Stage 3	Stage 3	Stage 3			
Oulu (OULU)										Stage 1	Stage 1	Stage 1	Stage 1	Stage 1	Stage 2	Stage 2	Stage 2	Stage 2	Stage 3	Stage 3	Stage 3

Stage 1 (Preparation) — Stage 2 (Pilot and validation) — Stage 3 (Deployment and monitoring)

Table 1- Timeline (updated) of the implementation of the FF2020 demonstrators

2. Project components

The present Chapter reports in detail the "Digital Toolbox" MVP and "UAM toolkit" MVP, that is the technology developed by the technical partners of FF2020 in the scopes of WP2, WP3, WP4 and WP5. The technology has reached the first stage of development ("MVP 1.0") and was tested and implemented in the use cases demonstrated at HTCE. For the next Demonstrators, implemented in HSR and ZAR, the MVP will be tested with the same functionalities.

In the first section, the main components of the technology under development are described. For more detailed descriptions, we refer to deliverables D2.3 ("Digital Toolbox for cities and eco-systems v1"), D3.2 ("A UAM legal, organisational, technical interoperability governance model"), D4.1 ("Regulation framework MVP") and D5.3 ("Digital Geospatial Infrastructure requirements").

In the following sections, functional (FR) and non-functional requirements (NFR) of the Digital Toolbox MVP 1.0 and of each component embedded in UAM toolkit MVP 1.0 are reported.

2.1 Components developed by the project

In this Section, a brief description of the concept behind each component is given. The components of the UAM Toolkit are the following:

- Geospatial infrastructure
- Regulatory framework
- Governance model

The Digital Toolbox is a technology agnostic service layer between a smart city (in this context, the LLab) and technical suppliers, hence it has a role in the pre-service phase. The UAM toolkit can also interface with a UTM platform to make use of the information received by the U-Space service providers.

1. Digital Toolbox

The Digital Toolbox is a technology agnostic platform, providing a ''pre-service'' function for the UAM MVP, meaning that UAM technology suppliers undergo critical assessments of their tech and legal compliance upfront to ensure smooth interoperability of their solutions and a compliancy with EU regulations. Complying with standards and regulations helps cities and organisations to procure technologies in a far more secure and agile way. The concept of the Digital Toolbox is to provide the city/LLab with a reliable UAM solution whereby the different components are modular and compatible due to the open standards provided through the API's. This helps cities/ Llabs to become resilient, sustainable and adaptive for the changes of tomorrow.

In the context of FF2020, the goal of Digital Toolbox is to assess the technology solutions of UAM component suppliers and conclude on their compliance and integration interoperability with any other UAM component in the future.

2. Geospatial infrastructure

The Geospatial infrastructure is a component that allows any type of UAS to describe, understand and share context with other machines, people, and spaces in real life. It integrates by design the concepts of location, activity, identities, time, and assets in a secure, interoperable, and distributed way. The objective is to reliably coordinate UA activity based on dynamically changing real-world conditions published by multiple authenticated and authorized sources (e.g., Agencies, legislation, obstructions, building construction, network connectivity, dead-zones). COSM, i.e. the developed operative system, would enable Governments and Enterprises to manage and coordinate aerial activity in real-time by building a complete and coherent contextual model – both three-dimensional and semantic – of any space (e.g., a campus or a city) by generating knowledge graphs of the relationships and dependencies of assets and policies for that space.

3. Regulatory framework

The regulatory framework is a component created to generate machine executable legislation by analyzing current UAS legislation and by turning them into rules that can be read and executed by the UAS. To this end, the regulatory framework uses four main functions: (i) the semantic analysis, (ii) the rule creation, (iii) the integration with one or more interpretation framework and (iv) the interface with COSM.

Depending on which airspace the UAS is flying, the semantic analysis could analyse the current UAS legislation in order to define specific patterns, which are collected and turned into machine readable data. Such data can be translated into commands for the drone to follow European, national and local legal dispositions.

4. Governance model

The Governance model can be seen as a combination of input from all LLabs and global research on relevant schemes and standards and it is a model that defines actors' identities and functions inside the UAM ecosystem.

The goal of this component is to help create a standardized and interoperable UAM ecosystem able to uniform UAS operations in Europe. To do so, the governance model aims to identify core aspects and components for enabling UAM-service provision and to provide recommendations for facilitating UAM-service interoperability. These insights can be used for the development of the Digital Toolbox, the regulatory framework and the geospatial infrastructure, and to valorise the FF2020 LLABs.

The governance model at this point describes two generic UAM service types: drone delivery services and drone monitoring services. The governance model explains the roles and responsibilities for each of the high-level steps involved. This will be elaborated based on further desk research and input by the LLABs. The legal, technical, semantic and organizational interoperability frameworks have been integrated into the governance model, to provide a comprehensive overview of relevant aspects involved for UAM service provision. The governance model will continue to be created the coming months in interaction with the LLABs and based on the inputs received from the technical partners. Moreover, the development of the different frameworks will help the LLABs in making sure everything is in place to use UAM in the city.

2.2 System requirements of the Digital Toolbox MVP 1.0

1. FR: The platform should send an invitation to register new Users.
2. FR: The Platform should allow to register only Users that have been invited.
3. FR: The platform should allow registered Users (Tech Supplier) to select the correct components category for the service/product to offer.
4. FR: The platform should assign the correct assessments to the service/product, in accordance with the technology / legislation matrix.
5. FR: The platform should provide the User (Tech Supplier) with a dashboard on assessments completion status ('In progress", "Complete") for the onboarded component (product/service), customers, contracts, payments, organisational profile and user rights management.

6. FR: The platform should allow the User (Tech Supplier) to review and edit the assessments in a status "In Progress" and manage their customers, contracts, payments, organisational profile and user rights access.
7. FR: The platform should allow User (City / LLab) to select correct components for procurement of the solution.
8. FR: The platform should connect specific solution to default components in accordance with solution / components matrix.
9. FR: The platform should allow User (City / LLab) to select /deselect the component from the drop-down list.
10. FR: The platform should provide User (City / LLab) with an overview of all Suppliers who registered for specific component (service/product) in a platform.
11. FR: The platform should allow User (City / LLab) the download / upload relevant documents.
12. FR: The platform should provide User (City / LLab) with a final overview of selected solution with correctly ordered components and the total price overview.
13. FR: The platform should provide User (City / LLab) with a dashboard overview of purchased solutions.
14. FR: The platform should require Users' answer on fields that are mandatory.
15. FR: The platform should allow User (Admin) to manage the database of Suppliers, Customers and Users, assessments, solutions, components, resource documents.
16. FR: The platform should provide the Users (Admin) with a dashboard overview of the Suppliers, Customers and Users, assessments, solutions, components, resource documents.

Other FRs which describe additional functions, such as payment service integration, chat buddy function, service ticketing, multilingual site, and others, will be a part of further MVP development.

In regard to NFRs, the basic list of those can be prepared after the final launch of MVP 1.0 and final testing with the HTCE, which is currently still a work in progress.

A set of desired results on the basis of which additional FRs and NFRs will be described for the next versions of the MVP are including (but not limited to) the following:

- The platform allows User (Tech Supplier) to walk through the assessment modules autonomously (no User support is required).
- The platform allows User (City / LLab) to walk through the assessment modules autonomously (no User support is required).
- Living Lab / city has clear understanding of the solutions and use cases offered through the platform.

2.3 System requirements of the UAM Toolkit MVP 1.0

2.3.1 Digital infrastructure

1. FR: The platform should allow a new user to sign up, sign in and log out.

1a. NFR: The platform should allow only users with email, Auth0 or Itsme account to sign up.

2. FR: The user should be able to search any location on the map.

3. FR: The platform should be able to support and show a view of the dynamic digital twin with domains, spaces and actors.

3a. NFR: The platform should be able to support and show a view in real time of the digital twin based on multiple sensors' data.

4. FR: The user should be able to select and modify map styles and map layers (domains, routes, spaces, actors, activities).

5. FR: The user should be able to register new domains and view domains' details**6.** FR: The user should be able to specify coordinates on the map to register a new domain.

7. FR: The user should be able to attach spatial contracts to domains to set custom restrictions on activities.

6. FR: The user should be able to register drones, create and edit drone missions, and view missions' details.

7. FR: The platform should be able to support and show the live video stream coming from the drone.

8. FR: The user should be able to view flights history and replay missions.

9. FR: The system should be able to modify the flight path to allow the drone to dynamically avoid registered objects or obstructions with which it may collide.

9a. NFR: The system should be able to support that the information exchange between the drone and the ground station happens in real-time with minimal delay (low latency).

9b. NFR: The drone will fly within 120 meters from the ground to prevent collisions with regulated aircraft in public airspace.

10. FR: The remote pilot should be able to take back control of the drone at any moment.

11. FR: If a safe route cannot be identified during flight, the system should hand back the drone control to the pilot.

12. FR: If the pilot fails to take control, the system should control the drone to land in a previously identified safe spot.

13. FR: The system relies on the durability of the hardware and the network connection in the area the drone is being operated.

13a. NFR: Total daily system downtime should not exceed 3 seconds.

14. FR: The remote pilot's interface should show the pre-flight checklists.

2.3.2 Regulatory framework

1. FR: The applicable provisions of Regulation 2019/947 will be made available in a machine-readable format.

2. FR: The semantic analysis of Drone Legislation/Regulation should be coherent with the legal interpretation of the law.

3. FR: The output of semantic analysis of Drone Legislation/Regulation should be interoperable with the rule creation function that is used for the interpretation frameworks.

4. FR: The rule creation function should be coherent with the ratio and interpretation of the law and the legal concepts embedded in the law.

5. FR: The rule creation function should be interoperable with one or more interpretation frameworks.

6. FR: The function of interpretation frameworks or the function of the rule creation should be interoperable with the interface with HSML.

2.3.3 Governance model

The main function for the governance model and interoperability framework is to identify key aspects for enabling UAM service provision and recommendations for interoperability, based on desk research and Living Lab experiences. The resulting overview can be used as content for incorporation into the Regulatory Framework, the Geospatial Infrastructure and the Digital Toolbox.

The governance model itself has no (technically) 'functional' aspects, but the following non-functional objectives can be formulated concerning its relation to the other components of the UAM Toolkit:

1. The governance model should provide principles and definitions for interoperability, to help align and focus efforts in the development of the Regulatory Framework, the Geospatial Infrastructure and the Digital Toolbox.
2. The governance model should provide an overview of high-level steps related to generic UAM-monitoring and delivery services, including roles, responsibilities, and relevant legislation.
3. The governance model should provide an overview of legal, organizational, technical, and semantic aspects that enable UAM-service provision by future Living Labs.
4. The governance model and its interoperability framework should provide an overview of identified interoperability considerations that may be incorporated into the Regulatory Framework, the Geospatial Infrastructure and the Digital Toolbox.
5. The governance model should include use cases from the living labs, giving users of the governance model a feel for the application of the interoperability aspects in actual practice, and an understanding of the considerations and implications.
6. The governance model and Interoperability framework should be well-structured so that content to be incorporated in the other components of the UAM Toolbox can be identified easily.

3. Demonstrators

The present Chapter regards the implementation of Demonstrators in the respective Living Labs.

To validate the FF2020 solutions and approach, tests are conducted in 10 demonstrators in collaboration with five Living Labs across Europe: Eindhoven, Milan, Tartu, Oulu, Zaragoza (see Table 2).

Domain	Demonstrator	Description	Living Lab	Differentiator
Infrastructure	Demonstrator 1	UAM infrastructure to be in place as standard (defining requirements)	All	Infrastructure
	Demonstrator 2	5G/6G networks infrastructure adaptation	Oulu	UAM key enabler
Monitoring sustainability, surveillance and	Demonstrator 3	Autonomous monitoring of massive events within a city to secure safety and emergency actuation	Zaragoza	Scenario planning Safety and security
	Demonstrator 4	Autonomous monitoring and predictive interventions of critical infrastructures within the Living Lab area	Tartu	Weather conditions
	Demonstrator 5	Autonomous monitoring and predictive interventions of critical infrastructures within a hospital	Milan	Safety and security
	Demonstrator 6	Autonomous monitoring and predictive interventions of critical infrastructures within the High-Tech Campus in Eindhoven	Eindhoven	Sustainability
Last-mile and emergencies air delivery services	Demonstrator 7	The future last mile and emergency delivery of campuses	Eindhoven	Emergency delivery
	Demonstrator 8	Multi-purpose and specific service drones in OULU	Oulu	UAS urban services Weather conditions
	Demonstrator 9	Precision logistic services for air transport of critical medical and pharmaceutical material	Milan	Health/medicine
	Demonstrator 10	Future precision logistic services for air transport of materials	Tartu	Weather conditions Long-distance delivery

Table 2 - Demonstrators list

The first section of this Chapter defines Infrastructure demonstrators, among which Demonstrator 1 is for all the Living Labs to implement. The following Sections regard each Demonstrator and the related use cases that are going to be implemented in the LLabs. While the previous version of the Deliverable (D6.2) only collected information from HTCE, the current version also contains contributions from HSR and ZAR (D6.3), while TARTU and OULU will follow in the third version (D6.4)

3.1 Infrastructure demonstrators

The infrastructure domain comprises the first two demonstrators:

- Demonstrator 1: Urban Air Mobility (UAM) infrastructure to be in place as a standard (all Living Labs)
- Demonstrator 2: 5G/6G networks demonstrator adaptations (OULU)

Dissertation of Demonstrator 2 is left for the next version of this deliverable, which will also comprise Demonstrators carried out in OULU.

3.1.1 Demonstrator 1

The objective of Demonstrator 1 (D1) is, for all the LLabs, to design the UAM Blueprint following the development of the UAM field.

The UAM Blueprint is a guidance and a taxonomy of elements that are required to implement UAM in practice. It was presented in FF2020 D6.1 in March 2021. Thereafter, significant evolutions have occurred, such as the promulgation of EC Regulation 2021/664[1]. D6.2 highlighted the main elements of novelty that have been considered. In the current D6.3, a complete overview of the current UAM Blueprint is presented in Appendix 1 – UAM Blueprint.

UAM elements have been explored and collected from a broad range of sources. Since the process of developing the UAM domain in Europe as well as in the other parts of the world continues, the European legislation and related industry standards do not yet comprehend all the required performance requirements for all UAM elements. In those cases, the international standards and different UAM concepts have been analysed to form the UAM Blueprint.

Mentioned EC Regulation 2021/664 will become applicable from January 26th 2023. This means that several FF2020 demonstrations will take place before, or at least will be defined in 2022. Consequently, a complete suite of mandatory U-space services may not be already operational in 2022 in all European States involved in the FF2020 demonstrators. In fact, several candidate U-space Service Providers (USSP) and other stakeholders have already reported great challenges to achieve deployment of the required UAM elements by the specified EU regulation date.

Furthermore, the EU Commission Implementing Regulation 2021/664 lists only six (plus possibly Common Information Service, CIS) safety-critical U-space services, while the list of digital services enabling UAM might be much longer.

In fact, project CORUS has proposed a list of 25 services, including some not safety-critical and therefore not necessarily subject to certification by the aviation authorities. In addition, project ICARUS[2] has proposed three additional services to protect drones at Very Low Level (VLL) from the collision with obstacles on the ground and as well to provide a Common Altitude Reference System (CARS) to unmanned and manned traffic in the same volume of U-space airspace.

The evolution of the UAM Blueprint may be summarized in Table 3.

[1] Commission Implementing Regulation (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space.
[2] https://www.u-spaceicarus.eu/

March 2021	August 2022
Commission Implementing Regulation (EU) on a regulatory framework for the U-space not yet adopted	Commission Implementing Regulation (EU) 2021/664 of April 22nd 2021 published in the EU OJ on April 23rd 2021
Applicability of EC regulation unknown	Applicability fixed at January 26th 2023
Draft ISO 23629-12 listed 30 possible UTM services, grouping them into safety-critical (i.e. potentially subject to certification by the CAA), safety-related and operation support	List of services in ISO 23629-12 confirmed, including those potentially not regulated by aviation authorities. Published in July 2022.
Some of the non-mandatory U-space services, already available in parts of Europe (e.g., electronic registration in the Netherlands and RAA anywhere)	Electronic registration services, based on Art. 14 of Commission Regulation 2019/947 became to be available in some of the European countries, such as Italy, Netherlands, Finland, and others. RAA, which means SORA analysis based on an automatic web-based tool accessible by the operator's Fleet Manager, without the direct involvement of any consultant, available to all FF2020 partners https://www.online-sora.com/
Missing elements of the UAM Blueprint left to the discretion of each Living Lab	Some U-space services may not be necessary for the demonstrators. Necessary functions for which a digital service is not yet available (e.g. coordination with the nearest ATS Unit) will be replaced through procedural means.

Table 3 - The changes applied to the UAM blueprint (August 2022) since the first version was issued (March 2021)

In the Sections of the present document dedicated to each Demonstrator, the Living Labs report which elements of the UAM blueprint are implemented to enable their use cases.

3.2 Monitoring, Sustainability and Surveillance domain demonstrators

The monitoring, sustainability and surveillance domain is split up into demonstrators 3, 4, 5 and 6:

- Demonstrator 3: Autonomous Monitoring of Massive Events in a City to Ensure Safety and Emergency Operation (ZAR)
- Demonstrator 4: Autonomous Monitoring and Predictive Interventions of Critical Infrastructures in Tartu Science Park and the City of Tartu (TARTU)
- Demonstrator 5: Autonomous Monitoring and Predictive Interventions of Critical Infrastructures in a Hospital (HSR)
- Demonstrator 6: Autonomous Monitoring and Predictive Interventions of Critical Infrastructures within the High Tech Campus in Eindhoven (HTCE)

3.2.1 Demonstrator 3

Zaragoza municipality celebrates its most important festivities (e.g., Christmas events, Easter religious events, Fiestas del Pilar, Carnival, The Parade of Giants and Big Heads) in its city center. During these days, thousands of people from Zaragoza and another places in Spain meet in the city center.

Figure 1 - Fiestas del Pilar (left), the Parade of Giants and Big Heads (right) and Easter Religious Event (below)

This demonstrator aims to manage the pedestrians' mobility during massive events in the city center with the use of drones. With the images provided by the drones we will be able to collect mobility information to improve future interventions. In parallel, this real-time information will support the prevention of crowd avalanches as well as to keep routes open for emergency situations during mass events in restricted public spaces. The data collected in such way will be released as open data and can be used by scientists, legislators, planners and managers.

The demonstration will take place in two different locations (two use cases) with different types of urban spaces (city center and green area) and different flying conditions. Use case 1 will be the object of the current version (v2) of this deliverable, whereas use case 2 will be covered in the next and final version.

3.2.1.1 Implementation

Zaragoza City Council will hold the Use Case 1 (urban city center) on the 12th of October 2022 to coincide with the Fiesta del Pilar and the Use Case 2 (urban green area) in April 2023 to coincide with Easter activities.

The selection of these two dates is due to the high increase in the number of people in the streets of Zaragoza to enjoy the events on the occasion of these festivities.

In order to carry out the two use cases, some changes had to be made to the documentation due to the entry into force of the European regulations. The Drones unit of the Zaragoza Fire Department has been integrated into the public emergency organization 112 Aragon. The 112 Aragon has become UAS operator and has done all the documentation to do aerial operations according to the European regulation, which conflicts with the Spanish regulation.

In addition, a series of specific permits have been obtained for the use case 1 area.

Stage 1, Preparation

1. LEGISLATIVE FRAMEWORK APPLIED TO THE PROJECT IN SPAIN

The FF2020 project is currently in a stage of legislative transition. In Spain, the existing legislative framework for the use of unmanned aerial vehicles, commonly known as "drones", is complex. the main applicable legislation is as follows:

- *Spanish Legislation:*
    - Royal Decree 1036/2017, of 15 December which regulates the civil use of remotely piloted aircraft, and amends the Royal Decree 552/2014, of 27 June, implementing the Air Regulations and common operating provisions for air navigation services and procedures and Royal Decree 57/2002, of 18 January, approving the Air Traffic Regulations.
- *European Legislation:*
    - Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Agency for Aviation Safety
    - Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and third country operators of unmanned aircraft systems
    - Commission implementing regulation (EU) 2019/947 of 24 May 2019 on rules and procedures applicable to the operation of unmanned aircraft

Currently, Royal Decree 1036/2017 is still in force despite the fact that it should have been repealed in January 2021, coinciding with the entry into force of European regulations. The Spanish Air Safety Agency (AESA) indicates that it is possible that in 2023 it will be published the new Spanish regulations on Drones (UAS) adapting all European aspects to the national regulations.

Therefore, Zaragoza Municipality is currently faced with two regulations that in some respects are contradictory. For example, the European regulation allows night flights, and the Spanish regulation does not allow them except with special authorization.

The drone unit of the Zaragoza Fire Department has been integrated into the "Operadora de Emergencias de Aragón (ODEAR)" created by the public emergency organization "112 Aragon". The "112 Aragon" has made all the documentation based on European regulations, which prevails in certain aerial operations such as those that will be carried out in Zaragoza's use cases. That documentation contemplates different Specific Operations Risk Assessments (SORA) for the

"Open Category" A1, A2 and A3 operations and in the European scenarios STS 01 and STS 02 of the "Specific Category". Likewise, the coordination operational risk assessment and mitigation of operational risk (EARO) has been sent to the military air base of Zaragoza.

Recently, new information has been updated on AESA website (the Spanish National Aviation Authority, NAA) that could affect the demonstrator[3]. This update adds a new restriction to Spanish UAS operations in this specific section that could modify our fly levels and take off-landings location zones:

"...if the take-off mass of the unmanned aircraft is less than 2 kg, and is operated at a minimum horizontal distance to 50 m from persons, by remote pilots with a level of competence at least equivalent to that corresponding to sub-category A2, it is considered acceptable to hold a basic or advanced certificate according to Law 18/2014 or Royal Decree 1036/2017 and to make a declaration of practical self-training". When a European UAS operator wants to fly on "Open Category A2" could fly with 5 m of horizontal distance on "low speed mode".

For that reason, the minimum horizontal distance from persons is 50 m instead of 30 m (or 5 m on "low speed mode").

2. OBTAINING SPECIFIC AUTHORIZATIONS FOR THE AREA OF THE USE CASE 1

In order to perform drone flights in the city center of Zaragoza, additional authorizations must be obtained due to the fact that Zaragoza is very close to the civil airport and to a permanent NATO (North Atlantic Treaty Organization) base.

The procedures carried out are as follows:

- Obtaining authorization to fly in a Zone Restricted to Photographic Flight (ZRVF). Zaragoza is within an area adjacent to a permanent NATO base and is therefore an exclusion zone for the flight of drones carrying a payment card that captures personal data. For the use of this payment card (camera), authorization is required from the Ministry of Defense of the Government of Spain for the capture of images.
- Authorization for the use of take-off and landing zones (T.O.L.A.) in the use case areas: authorization has been obtained for the use of two TOLA zones in the use case 1 area. In this way, specialized aerial operations can be carried out with greater security as they can be done from a height to avoid interference from third parties outside the operation. From these locations the ADS-B AirSense and the Ocusync 3.0 of Zaragoza Fire Department's drones work more safely.
- Authorization to fly in urban areas: for flights in urban areas it is necessary to notify at least 10 days in advance to the Spanish Ministry of General Administration (Ministerio del Interior). This notification will be made in due time and form for testing days and use case days.
- Making a flight plan on Enaire Planea: it is necessary to make a flight plan on the Enaire Planea website in order to communicate all aspects of the operation to the aeronautical manager. Likewise, a NOTAM (Notice to AirMen) is requested in the operation request to notify any user of the operations to be carried out on that day and time.

3. MANDATORY DRONE (UAS) SPECIFICATIONS

- Parachute built into the Drone to fly in urban environment

[3] https://www.seguridadaerea.gob.es/en/ambitos/drones/operaciones-uas-drones/operaciones-con-uas-drones---categoria-abierta-subcategorias-a1-a2-y-a3

- Green strobe light for night flights
- GPS positioning to avoid leaving the contingency zone
- Interface with COSM (either through an on-board CPU with programmable access or through the CU with open SDK)
- Command and Control Link (C2 link) between the drone and its ground station
- Have additional reliable connection to exchange additional data with the Command Unit of the drone on the ground
- Have additional Flight Termination System (FTS), completely independent to avoid common mode failures
- Thermal camera or RGB camera, depending on sequent selection of the use case (day or night)
- Reception of UTM services

Stage 2, Pilot & validation

The implementation of the use case 1 (surveillance over a city massive event) will be done in three dates:

<u>1st TEST DAY</u> 1st visit of VERSES for the preparation of the use case 1. A reconnaissance of the use case 1 area and discussion about all technical aspects related to the operation.

- WIFI: possibility of wired connection and its transfer speed in the two take-off and landing zones.
- Operating zones: the limits of the operating zone are established so that the drones have an electronically limited flight zone.

<u>2nd TEST DAYS</u> 2nd visit of VERSES to install and test the COSM software in the Zaragoza Fire Department drones. Flights will be performed in a test area in the Zaragoza surroundings and in the same area of the use case 1.

<u>3rd TEST DAY</u> 3rd visit of VERSES to finalize any problems not solved in the 2nd TEST DAYS.

<u>4th USE CASE DAY</u> (12 or 13 October 2022 depending on the weather / wind situation -on the 13rd October there is another massive event to bring fruits to the Virgin El Pilar, the route is the same in both days): Realization of the use case. Flights will be on 12 October. If it is not possible to perform the flights due to weather conditions, the use case will be performed on 13 October.

The use case will be carried out by the Drone Unit of the Fire and Rescue Service of the Zaragoza City Council. This unit has four drones and 18 pilots who have all the necessary qualifications to be able to fly drones up to 25 kg in "Open Category" and "Specific Category". The pilots also have the necessary radio operator qualifications to be able to operate these aircraft in the area of influence of an airport or aerodrome.

On the occasion of the FF2020 Project, a DJI Matrice 300RTK Drone has been purchased to fulfill all Spanish requirements for a drone to fly in urban areas. It will allow us to carry out operations with greater safety and to capture images from a greater distance. It will also allow the capture of very high resolution RGB and thermal images.

Demonstration and experimentation of technologies

1. Labelfuse:

In use case 1, the experimentation of people recognition and counting technology will be carried out. For this purpose, a commercial relationship has been established with the company Labelfuse, which has an artificial intelligence software that allows the recognition and counting of people.

VERSES developers will establish a communication channel with Labelfuse to send the images captured by the drone. These images will be sent and processed in real time. In the Command Post a reception device will be established to receive these processed images that will allow to see in real time the number of people in a given area (e.g. Pilar Square).

2. UTM Services:

The implementation of a UTM provider will allow location of all drones in flight in real time. This data will be offered to the National Police and Zaragoza Airport Authorities in order to integrate all authorized bodies in the control of Zaragoza's airspace. The use of UTM is currently planned for use case 2 as the technical complexity of use case 1 makes it inadvisable.

3. COSM Software:

In the use cases the COSM software developed by VERSES will be used. This new software will be tested on the different test days and on the use case days. The aim is to provide operational security. The software will be used to establish fly zones, no-fly zones and safety zones. Additionally, a procedure for receiving emergency locations will be developed, which will automatically process COSM sending automatically the closest drone to that location.

Stage 3, deployment & monitoring

Before the use case 1 flights, test flights will be carried out in a safe external location (Universidad Laboral located in La Puebla de Alfinden), with the participation of VERSES, which will allow us to fully integrate the COSM software in the drones of the Drones Unit of the Fire Department of the Zaragoza City Council.

After the test flights in a safe environment in the outskirts of Zaragoza, test flights will be carried out in the same location of the use case 1 in the same conditions as on the 12th of October. The only significant difference to the day of the use case will be the number of people in the surroundings of the operation area.

The parameters to be monitored during the DEMO days are the following:

- Reliability of the COSM software: during these days the software developed by VERSES will be intensively tested in order to avoid any technical problems during the use case days. The security of the use case flights must be very high as a measure to mitigate the risk of the flights.
- Integration with Labelfuse: these days the integration and sending of images to Labelfuse for the recognition of people will be performed and tested.
- Integration with Astra UTM: Currently the use of UTM in use case 1 is not foreseen, but it is not ruled out. If it is finally integrated, during these days the integration of the COSM software will be tested in the Astra UTM structure for real time localization of the drones and its integration in the control of the Zaragoza airspace currently controlled by the military authorities.

3.2.1.2 Use Case 1: Monitoring of events

The monitoring of the Pilar Day event will take place in the city center where the flower offering to the Virgin of the Pilar takes place. Those attending the offering carry bouquets of flowers along a route (yellow line) through the city center. Once in the Plaza del Pilar, they place their bouquets of flowers on a replica of the Virgin of the Pilar located in the same square.

The drones for this Use case will be located on the rooftops of the Puerta Cinegia building in Plaza España and the Almada Apartments building on the corner of Calle Alfonso I and Plaza del Pilar. From these locations they will be monitoring the large number of people attending the event. in additon to crowd monitoring, the facial recognition and crowd counting will be made feasible as well due to the AI driven software provided by Labelfuse.

Figure 2 – Area interested by the UAS flights during use case 1 of D3 in Zaragoza (enclosed by red line); from the two T.O.L.As. (red dots) the drones will enable the surveillance over the path leading to Pilor Virgin site (yellow line)

Use case specification (CONOPS)

The operational conditions of use case 1 are influenced by the large crowds of people that will be in the city center of Zaragoza at that time. In addition to this fact, which influences the safety of the operation, the European and Spanish regulations require that drones must not fly over people except in emergency situations. Therefore, the flights will have the following characteristics:

- Drones must be fitted with an impact mitigation device (parachute).
- Operating height of 60 m AGL to avoid collisions with antennas and other objects.
- Horizontal separation from people of 5m and reduced speed "Tripod Mode" to comply with "Open Category A2" conditions.

- Operation carried out on the vertical of the buildings as a risk mitigation measure.
- Establishment of a delimited flight area in each of the areas of operation.
- Area of the operations nº1 (Puerta Cinegia Building[4], see Figure 3)
- Area of the operations nº2 (Apartamentos Almada buildings[5], see Figure 4)

Figure 3 - Area of the operations nº1 (Edificio de Puerta Cinegia)

Figure 4 - Area of the operations nº2 (Edificio de Apartamentos Almada)

[4] https://goo.gl/maps/6uGsgXvMipLjNSok7
[5] https://goo.gl/maps/YN8kokyjAQNiTWrA6

3.2.1.3 Stakeholders engaged

Following the UAM blueprint elaborated within FF2020, the stakeholders involved in D3 are reported in Table 5.

Stakeholder	Specification
112 Aragon (ODEAR)	UAS Operator
Local authorities (e.g. Prefect, Municipality or Geozone manager)	Zaragoza Council
Labelfuse	IA persons recognise enterprise
VERSES	COSM software enterprise
Authorised viewer (user) of air situation (e.g. Police or other law enforcement agency)	Police or other law enforcement agency
Pilots of manned aircraft	Operators of manned emergency helicopters and Police Helicopters operating nearby will be coordinated
Airport Operator	Zaragoza Airport will be informed, but normal operations will be carried out of our use case zone
Air Traffic Service Providers (ATSP) (e.g. the control tower)	Zaragoza control TWR
U-space Service Providers (USSP)	Not exist in Spain yet
Digital Logbook Service Provider	ODEAR Drone operator
Legal Recording Service Provider	ODEAR Drone operator
Maintenance Management	ODEAR Drone operator
Operational Plan Preparation	ODEAR Drone operator
Risk Analysis Assistance	Spanish Aeronautical Asesor (www.egmdronconsulting.com)
UAS operator (e.g. Fleet Manager responsible to plan and order the initiation of an operation)	ODEAR remote pilot of Zaragoza Council Firefighters
Remote Pilot and her/his Command Unit	ODEAR Drone operator
Drone owner	Zaragoza Council Firefighters
Citizens	UAM social acceptance survey

Table 4 - Stakeholders involved for D3

3.2.1.4 Services involved

The following services are the ones that are employed to enable the use case:

- Labelfuse: Software persons recognise provider;
- 112 Aragon: Public Emergency Enterprise of Aragon Region;

- UTM Astra: UTM services enterprise;
- Firefighter Unit Drone Zaragoza Council: their pilots and drones will execute all uses cases.

3.2.2 Demonstrator 5

This demonstrator regards autonomous monitoring and predictive interventions of critical infrastructures within a hospital. The drones would be at the disposition of the surveillance and the technical area of the hospital to perform flight patrols on demand.

In D6.1, two use cases were designed, one regarding inspections for building maintenance, and one for the surveillance of the hospital's spaces. The latter use case was selected for demonstration purposes.

3.2.2.1 Implementation

The original timeline of D5 had to undergo changes to reflect the actual state of the activities. A delay of the kick-off of the authorization process for the operations and the requirements posed by the Italian National Aviation Authority (NAA), ENAC, made it necessary to extend the Stage 1 and Stage 2 by several months, as it is shown in Table 1. The Demonstrators flights are expected in early 2023.

Stage 1, preparation

1. Requirements for the UAS operator

During preparation and the earlier months, the selection of the UAS operator required careful evaluation of different propositions. In a joint effort with the project partners, HSR elaborated a list of requirements for the UAS operators that were willing to make an offer to carry out operations for the Demonstrators.

a. MANDATORY UAS SPECIFICATIONS

- Drone Max Take-Off Mass < 20 Kg
- Maximum width < 3 m
- GPS
- Interface with COSM (either through an on-board CPU with programmable access or through the CU with open SDK)
- Position transmission in accordance to prEN 4709-002 ("Direct Remote Identification")
- Command and Control Link (C2 link) between the drone and its ground station
- Have additional reliable connection to exchange additional data with the Command Unit of the drone on the ground
- Have additional Flight Termination System (FTS), completely independent to avoid common mode failures
- Landing pad
- Charging station
- Thermal camera or videocamera, depending on sequent selection of the use case for D5 (either thermal inspection or surveillance)

b. OPTIONAL SPECIFICATIONS

- Extra positioning protocol from navigation satellites, e.g. EGNOS
- 5G connectivity with infrastructure provided by Vodafone/HSR
- Reception of optional UTM services

Provided that the UAS satisfied the requirements, a quotation of the following activities was asked and was the base for the consequent selection.

- FLIGHT AUTHORIZATION FROM ENAC
  - Provide the Flight Manual
  - Provide all the necessary information for the CONOPS (drafted by EuroUSC Italia)
  - Implement AMC (Acceptable Means of Compliance) identified in the SORA analysis performed by EuroUSC Italia
  - Provide the draft of the Operations Manual and implement modifications suggested by EuroUSC Italia
  - Interface with authorities (e.g. ENAC) to gain flight permissions
- R&D
  - Set up reception and use of UTM services
  - Set up interface with COSM (follow provided set of instructions)
  - Record mission data on cloud server

- OPERATIONS (pilot, eventual helpers, insurance and other costs included)
  - 2 days (5 successful operations per day)
  - 6 days (3 consecutive at a time, 5 successful operations per day)
  - Eventual extra day (5 successful operations)

2. Selection of the UAS operator

In total, three offers were received by UAS operators, and two offers were received from a drone manufacturer and a drone seller. The latter two were discarded as they did not satisfy the fundamental role of the UAS operator as the organization taking responsibility for the operations' regulatory compliance and safety. Based on an evaluation of the candidates' monetary offers and their experience, ABZero was the UAS operators that passed the selection.

3. Regulatory permissions

Flight authorization for 'specific' category operations in Italy needs to be issued by ENAC. HSR, with the mediation of EuroUSC Italia, took contacts with the NAA to introduce the project and the intended operations. In particular, it was noted how the use cases proposed by HSR are well aligned with the AAM Strategic Plan (2021-2030) for the development of the Advanced Air

Mobility in Italy, issued by ENAC itself in 2021[6]. The following communications regarded ENAC's recommendations to demonstrate the safety of the intended operations, in particular regarding the UAS operator to carry out BVLOS operations in a densely populated area. In fact, it was deemed necessary that the UAS operator demonstrate their capacity in BVLOS operations in unpopulated areas, before conducting them in the hospital's airspace. For these first operations, a separate flight authorization procedure (in the 'specific' category) must be carried out. For each procedure, ENAC reserves up to 90 days to issue the authorization and eventual additional requirements for the operations. In summary, HSR's UAS operator will perform the following operations:

1- Preliminary operations in unpopulated area; the aim is to demonstrate the capability to conduct BVLOS operations safely;

2- Demonstrator operations in HSR (populated area) to fulfil the LLAB's objectives of FF2020.

For both type of operations the UAS operator used SAMWISE tool for risk assessment assistance, which uses the SORA methodology as recommended by JARUS. The operations manual for the BVLOS operations was prepared by ABZero and reviewed by EuroUSC Italia. All the proper documentation and the authorization form for the preliminary operations were sent to ENAC on June 10th 2022. The same procedures will follow for the BVLOS operations in populated area (HSR) after these flights, now waiting to be authorized. In the Section "Use case specification (CONOPS)" the described operation will be the one concerning the Demonstrator in HSR, for the authorization of which the UAS operator must wait to successfully complete the BVLOS operations in unpopulated area, as required by ENAC. Hence, a few changes may by applied in the following months, which would be reported in the next version of the present deliverable.

4. Technical integration with the UAS

The technical integration of COSM with the UAS was agreed with the involved partners, i.e. VERSES and ABZero (the UAS operator). ABZero's proprietary system is a medical box, called "Smart capsule", comprising both hardware and software for connectivity and for the remote control of the drone. Thanks to the artificial intelligence (AI) on board, the Smart Capsule performs a full active control on the drone (to which it is connected through a physical and electrical connection), keeping the pilot in the control loop if conditions permit (e.g. presence of a stable link between the ground control station and the drone).

The ABzero backend communicates with the outside world through the topics of an MQTT broker. For integration and communication with COSM, two new MQTT topics have been created by ABZero, dedicated to receiving messages in JSON format (provided by COSM), and sending response messages.

When a message is received from COSM, the backend takes care of decoding it and modifying the related start and end location, path, and creating a new transport (in the authorized state), sending the sequence through the Spoke App.

The backend replies for each JSON packet with an acknowledged message on the reply topic. A third topic is shared with the COSM system for sending information during the mission, such as geo-position (GNSS), temperature and humidity data inside and outside the capsule.

Hence, the data flow will proceed as follows (both ways): user ↔ COSM ↔ ABZero back-end web application ("Spoke") ↔ medical box ("Smart capsule") ↔ Drone.

[6] https://www.enac.gov.it/sites/default/files/allegati/2022-Mar/01_Piano%20Strategico%20Nazionale%20AAM_ENAC_web%20en-GB.pdf

The data to exchange from COSM to the drone is the mission waypoints. From the drone to COSM, the data to exchange is the following:

- Current position of the drone (upload frequency = 2 Hz) from the drone to COSM;
  - GPS
  - Altitude
- Battery status
- Proximity sensors data
- Video streaming

The normal flow would require the user to input the mission waypoints in the COSM platform. COSM elaborates the route using the mission waypoints data. During the operation, dynamic routing is performed by COSM using the data from the drone. In the Demonstrators' operations in HSR, proper online dynamic routing is not possible, because the operations in the 'specific' category need to be pre-approved by the Authority, including the flight path. Hence, COSM will be used in the Preparation stage of Demonstrators to create a route to be validated by the UAS operator and to be authorised by the NAA.

Technical integration required that each step was analysed and a protocol to exchange information was shared. The following steps were the subject of technical integration effort:

1) The surveillance coordinator creates a drone mission by selecting waypoints through COSM (input mission waypoints);
   a) COSM sends a JSON file with mission waypoints to the Spoke backend;
2) The operation is created automatically with the mission data in COSM;
3) The remote pilot performs the pre-flight checks and then initiates the mission;
4) The drone flies automatically to the end point (RP supervising the flight, ready and able to take control at any time);
   a) Spoke backend uses the JSON to pass it to the drone via the Smart capsule;
   b) Spoke backend updates both Spoke frontend & Spoke App and COSM with drone position (through the JSON);
5) The drone reaches the endpoint and hovers; all the involved actors who have access can watch the streaming video feed from their devices;
6) The surveillance coordinator can make the drone fly back to home through COSM.

5. Technical integration of UTM services

For regulated and safety-critical services, D-flight is the main UTM (or U-Space) service provider in Italy. COSM is a software that the fleet manager, in this demonstrator, uses for operation plan preparation (and execution). In the vision of the project, this software will be used to run highly automated operations that are deemed safe and non-conflicting with the aerial traffic. Hence, seamless integration with UTM platforms constitutes a great benefit for the creation of the digital environment enabling these type of UAM services.

The complete list of UTM services that will be integrated are listed in the Section "Services involved". In general, D-flight will share with COSM the static and dynamic information about the airspace (no-fly zones, reserved areas etc.). On the other side, COSM will originate mission data to feed to d-flight: the user (i.e., the UAS operator) will create the mission on COSM, which feeds the data to d-flight, resulting in the reservation of the selected volume of airspace from all the other users of the airspace.

Stage 2, pilot & validation

Test flights will be carried out in an unpopulated area, with a two-fold objective: (i) demonstrate the UAS operator's capacity to conduct BVLOS operations, as required by ENAC; (ii) testing the communication between COSM and the UAS owned by ABZero.

Stage 3, deployment & monitoring

In this Stage, the flights will be executed in the hospital's airspace, after the demonstrations of the recommendations for the safety of operations from ENAC are satisfied. Four or five test days, two weeks apart, will be agreed among HSR actors, VERSES and ABZero.

3.2.2.2 Use Case 1: Surveillance of hospital's spaces

The demonstrator's goal is to use UAS to add a new surveillance service within the hospital infrastructures in order to support the current surveillance system.

In this use case, the demonstrator focuses on a service that the surveillance staff of HSR can employ on demand. Whenever an emergency occurs, the surveillance coordinator is alerted, and they can decide to employ a drone to reach the emergency in a short amount of time, in order to shorten the emergency response time. Typical emergencies regard the intrusion of someone in a restricted perimeter, theft or aggressions and disturbances caused by people in an altered state. In this way, the drone is readily dispatched to the emergency site, offering live stream video of the situation, while the surveillance staff is alerted and respond to the specific emergency.

The main advantage of this use case is the risk reduction for the hospital staff charged with safety and surveillance tasks. The drones can be used to evaluate the danger represented by an emergency situation, or for patrols in peripheral areas, allowing for a safer and more efficient dispatch of human resources.

3.2.2.3 Stakeholders engaged

Following the UAM blueprint elaborated within FF2020, the stakeholders involved in D5 are reported in Table 5.

It is noteworthy to mention that the UAS operator will establish a line of communication with the helipad manager of the hospital. During the operations, the communications will occur both ways to ensure that the traffic of the drone and of the helicopters landing in the nearby helipad remain separated.

Stakeholder	Specification
Civil Aviation Authority	ENAC (Italian civil aviation authority)
Pilots of manned aircraft	Operators of manned emergency helicopters operating nearby will be coordinated

Airport Operator	Linate airport operator (SEA) will be informed, but normal operations will be carried out of its jurisdiction
Aeronautical Information Management Provider (AIMP)	ENAV (traditional AIP and charts)
Navigation service provider (e.g. EGNOS)	EGNOS
Air Traffic Service Providers (ATSP) (e.g. the control tower)	Linate control TWR
Registration Service Provider (including updates)	d-flight
Common Information Service (CIS) Provider	d-flight
Drone aeronautical information manager	d-flight
Flight Clearance (Authorisation) service	d-flight
Network Tracking (Surveillance) service provider	d-flight
U-space Service Providers (USSP)	d-flight is the main provider, but not the only one, based on the list in ISO 23629-12
Operational Plan Preparation	Drone operator (ABZero) performs it via COSM (by VERSES)
Risk Analysis Assistance	EuroUSC Italia (https://www.online-sora.com/)
Critical infrastructure Security management	Technical area chief in HSR
Insurers	Drone operator insured in compliance with Regulation 785/2004. No further coordination necessary
UAS operator (e.g. Fleet Manager responsible to plan and order the initiation of an operation)	ABZero
Remote Pilot and her/his Command Unit	UAS operator
Drone owner	UAS operator
Operation Customer	HSR staff (surveillance service)
Citizens	UAM social acceptance survey

Table 5 – Stakeholders involved for D5

3.2.2.4 Services involved

Following the UAM blueprint developed within FF2020, the UTM services employed for this demonstrator are listed in Table 6 along with a brief specification on their implementation.

UAM services	Specification

Network (Electronic) Identification Service (includes e-conspicuity)	For d-flight, this service is named NETWORK REMOTE IDENTIFICATION. d-flight has published an ICD through which their system can receive location data from the GCS and represent flying drones in the airspace volume on a map
Geospatial Information Service	Static information (e.g., Aeronautical Information Regulation and Control and NOTAMs) is offered by d-flight
Geo-Awareness Service	d-flight can receive and publish volumes of airspace reserved by UAS operators, which represents dynamic information
Flight Clearance (Authorisation) Service	d-flight
Traffic information service	Information available through d-flight
Aeronautical Information Management for UAS service	Named "Common information service" as in EC Regulation 2021/664
Geo-fence provision (incl. dynamic geofencing) service	Not intended as a service, however a geofencing function is used by ABZero's system
Operational Plan Preparation (and optimisation?) service	COSM used for this purpose in our Demos (OPP)
Operational plan processing service	Mandatory to use d-flight for this in specific category, unless a NOTAM is used; the information created through the OPP is passed to d-flight to process the plan and gain flight authorization
Risk Analysis Assistance service	SAMWISE (https://www.online-sora.com)
Accident and Incident Reporting Service	Possible accidents or incidents will be reported procedurally, according to EU Regulation 376/2014 through ENAC portal (https://www.enac.gov.it/news/attivazione-del-sistema-eccairs-2)
Navigation Coverage Information service	"GNSS monitoring" by d-flight
Procedural Interface with ATC service	Procedures agreed with Linate ATS
Electronic Registration Service	provided by d-flight in compliance with Art. 14 Regulation 2019/947

UTM Communication Service	Connection between the Fleet Manager Platform and d-flight services via Internet service

Table 6 – UAM services implemented in D5

About the procedural interface with ATC service, normally the coordination of the operations takes place by informing the person responsible for communications by telephone at the beginning and at the end of the authorized operations and of which they are already aware. In case of their particular needs or emergencies, the airport tower or the helipad manager calls the UAS operator and can ask them to delay or temporarily abort the mission (this might especially be the case of the helipad where an emergency helicopter may need to land).

3.2.2.5 Use case specification (CONOPS)

The CONOPS for this demonstrator was drafted, but the final version will be available after the completion of the first step (the preparatory BVLOS flights in an unpopulated area, that precede the ones that will take place in the hospital premises). HSR and the UAS operator (ABZero) initiated discussions with the NAA to ensure they meet all the necessary safety objectives for the demonstrator operations.

In order to reach a lower Ground Risk, it was recommended that the FTS was subjected to design verification by EASA. This would have required time and costs that were not compatible with the ones allocated for the project, as its scope would be out of the one prospected for FF2020. Therefore, an alternative mitigation was introduced, i.e. to subject the buffer area and the adjacent area under control of the personnel involved in the operations. This limitation suffices for the demonstration purposes of FF2020, although the problem of design verification of safety systems like the FTS will have to be dealt with in the future to ensure a level of safety sufficient to allow operations without the need of manual safety measures, thus achieving the UAM vision.

The mitigation introduced above caused the necessity to redesign the drone trajectory to avoid that the adjacent area to control would fall outside the hospital perimeter, in public spaces. In fact, the area under control must be restricted to the staff involved in the operations, making it necessary to bar the access to others. The new trajectory would force the drone to fly not just over roofs, as initially planned. Hence, it is necessary to issue a NOTAM to reserve the airspace during the demonstrations, thus containing the Air Risk.

Area of the operations

The trajectory was planned considering the obstacles in the area (e.g., buildings, appliances, trees), to minimize the flight time and to confine the adjacent area inside the hospital perimeter, for the reasons explained in the previous section. Figure 5 shows the area of the operations and the intended trajectory for D5.

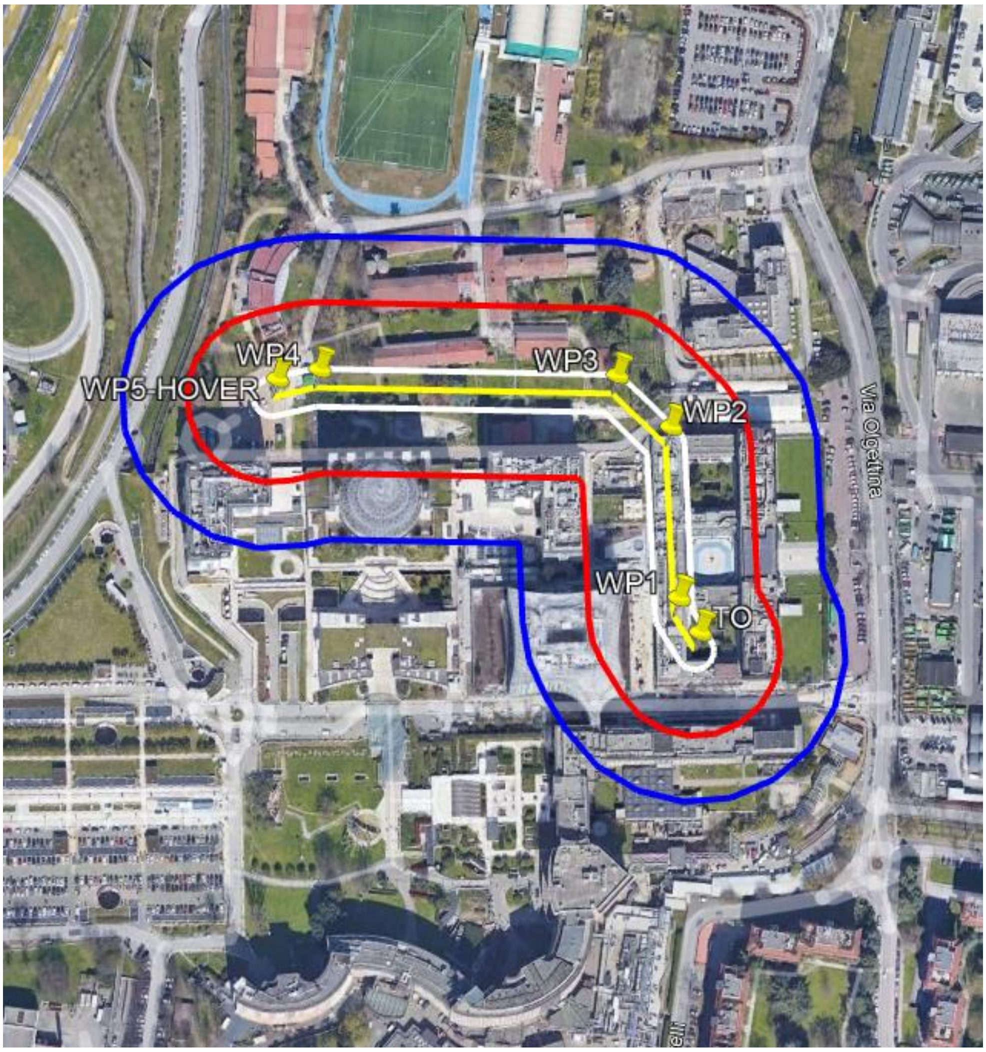

Figure 5 – Flight route (yellow), contingency area (white), buffer area (red), adjacent area (blue) for D5

The contingency area covers the surface spanning 5 meters around the flight path. Buffer area and adjacent area are calculate following the guidelines from ENAC[7] regarding the mitigation M1 (acceptable strategic mitigation M1 for ground risk of SORA) at a mid-high level ("ground risk analysis for RPAS operations"). Following the specified methodology, the buffer area is calculated considering the velocity, the Flight Termination System (FTS) activation time, maximum wind speed and the flight elevation. Hence, the buffer area spans from 40 to 50 meters around the flight path. The adjacent area is calculated adopting the same method, hence its perimeter is distanced 40 to 50 meters from the perimeter of the buffer area.

Description of the UAS system

The drone employed for this use case will be the Dronebase x800 (Figure 6). This drone has a maximum take-off mass of 9 kg and has a wind limitation of 12 m/s.

[7] https://www.enac.gov.it/sites/default/files/allegati/2020-Gen/LG-2017_001-NAV%20Ed.%202%20Jan%202020_con%20Appendice%20%289%20gennaio%202020%29_0.pdf

Figure 6 – Dronebase drone used for the D5

3.2.2.6 Other elements

Other elements of the UAM blueprint relevant to the use case are reported in Table 7.

Other elements implemented	Specification
Security Systems (relevant to the demo-cases)	HSR Security services
Server Infrastructure (relevant to the demo-cases)	The infrastructure is hosted on AWS servers which guarantee robustness, efficiency and reliability
Computing Infrastructure (relevant to the demo-cases)	t2.micro (a subcategory of the EC2 server)
What is the GUI and Visualisation Infrastructure (relevant to the demo-cases)?	COSM

Table 7 – Other elements implemented in D5

3.2.3 Demonstrator 6

The main goal of this demonstrator is to use UAS to strengthen the operational management of High Tech Campus Eindhoven. We do this with two use cases: (1) security of the terrain through autonomous interventions (security support); (2) real estate maintenance planning through autonomous monitoring of buildings (building monitoring).

Currently, security checks are triggered by fixed assets (such as cameras) and required actions are executed by humans. Also regular surveillance of the campus terrain is done by humans. Our hypothesis is that drones can partly replace human intervention, or at least add value to the work of the security guards.

Besides the security function, we also want to validate if the use of autonomous drones can help us with doing predictive maintenance on the inspection of buildings.

Based on our research in the early phase of the project, we foresee a potential business case on these two functionalities.

3.2.3.1 Implementation

In order to implement the use cases of demonstrator 6, a three stage process has been followed that spanned a total of 12 months.

Stage 1, preparation:

The first stage consists of four parts

1. Requirement definition with service partners

Definition of the use cases and why they are interesting for the HTCE and its service partners Trigion and Fortron. This involves the creation of a draft business case per use case that shows the initial value to the service partners, and convinced them to join the project. It also made clear where the most value would be obtained when autonomous drones are added to their daily operations, and how to integrate them best with their work processes.

2. Technical supplier selection

The first part delivered the requirements that were needed to do a proper technology scouting. This list of requirements was used as input for the meetings with a lot of drone technology providers, and resulted in the selection of the Mapture.AI drone-in-a-box system.

3. Regulatory permission

Together with Mapture.AI the proper documentation was created in order to fly their system on the HTCE. This includes a covenant that describes the working agreement with the military CTR (Appendix 2 – EHEH TWR – HTCE – UAM Covenant (concept)), the Concept of Operations (ConOps) and the Specific Operations Risk Assessment (SORA) that were needed in order to obtain the exemption from Dutch Civil Aviation Authority IL&T to fly within the geographic area of the HTCE.

In the end it took a total nine months for Mapture to obtain the permission to fly BVLOS missions with their system at HTCE. We received it just a few days before the final demonstration day and therefore we were not able to prepare properly and use the Mapture system for the intended demonstrations. As a mitigation we used another DJI Mavic drone and flew under the licence of AirHub. Since they did receive the permission to fly BVLOS missions at HTCE in time. For each mission that Mavic drone was placed on top of the Mapture box, simulating the use of the box and able to perform the use cases as intended.

4. Living Lab preparation

The tenants and service partners of the HTCE were informed of the FF2020 project intentions and what they could expect during the demonstration period. Next to their support it was also important that they would be aware of any safety risks when there are drones flying. Next to giving presentations and sharing information via email, also a dedicated website was created that showed information on the UAS operations.

To make sure that HTCE was aware of all drone activity on campus a flight authorization protocol was established, that is to be used by anyone that wants to fly on campus. This protocol makes sure that the fleet manager, safety officer and facility manager are notified of drone operations requests. And they can authorize them if they deem them safe and fitting with HTCE requirements.

Each use case also required some physical preparations in order to integrate drone technology with the existing infrastructure. This mainly this concerned:

- The relaying of sensor triggers to a drone via the OpenDDS protocol; these technical preparations are described in more detail in the use case descriptions, which is described in more detail later on in the security support use case description;
- The instalment of the Mapture drone-in-a-box system; for that system a space was cleared on top of the roof of building HTC 5;
- Power and data outlets were created near the system to power it and connect it to the internet.

Figure 7 - Mapture drone-in-a-box system on the roof of HTC 5

Stage 2, pilot & validation:

During this stage the first test flights are conducted during four scheduled weekend days. These are done during the weekend because then the campus is closed and there are only people present that are aware of the test flights. For these test flights, test scenarios are created that test the different use case elements under controlled conditions. For example: the connection between COSM and the drone or if the sensor triggers are relayed properly to COSM.

Before COSM was used at HTCE, it was first tested at Unmanned Valley. This is a large test site were new drone related technologies can be tested. There COSM went through the necessary safety tests before AirHub deemed it safe enough for use within the HTCE urban environment under their operating license.

Stage 3, deployment & monitoring:

Before the deployment phase starts all the separate UAM elements are tested and deemed safe to use in the larger UAM ecosystem. During deployment everything will come together. All the use cases will be performed simultaneously and the full scope of the HTCE UAM ecosystem is showcased. This was be done during two full days of demonstration during weekdays.

The Mapture system is also evaluated in a broader context with regards to its long-term suitability as a campus security and inspection solution. Therefore, its operational usability is monitored for a 6-month period. The outcome of this operational test period is validation for the business cases of the service partners. It helps with finalising the business cases which is needed to convince the relevant stakeholders to sustainably make use of UAM at HTCE.

3.2.3.2 Use case 1: security support

The High Tech Campus wants to test this use case because it's preparing an investment in the security measures of the terrain. These security measures consist of fences and also of ground-based sensors and thermal/motion cameras. With this test, we want to validate if autonomous drones can replace parts of this new infrastructure and therewith decrease the total investment and in the long run also decrease cost related to human surveillance. Hence, the goal of this use case is to validate that business case.

Area of application

The area of application is the entire campus and more specific the 'outer shell' of the terrain. With this shell we secure the campus after opening hours (5.30 AM – 8.30 PM). After 8.30 PM, fences close and access to the terrain is limited to people with a 24/7 badge access.

During the night time, multiple security officers monitor the terrain from the security lodge and they do routine surveillance checks on the terrain.

Autonomous drones are a potential addition and reinforcement of existing security measures on the High Tech Campus. With this use case we want to support the security guards and potentially save on material cost and labour capacity.

Way of application

When one of the ground sensors or motion cameras in the outer security shell is triggered, a drone with thermal camera autonomously leaves its hangar (Mapture drone-in-a-box system) and flies out for a mission to make an assessment. Since it's after closing hours of the HTCE, the drone takes the shortest way to the trigger point and inspects the environment. Video made by the drone camera is live streamed to the security loge. The security guard in the lodge identifies the source of the trigger and decides whether or not to take action. For example, when there is an unwanted visitor the security guard can make the drone follow him and relay key information to his colleagues about the position of the trespasser. See Figure 8 for a visual representation of the situation.

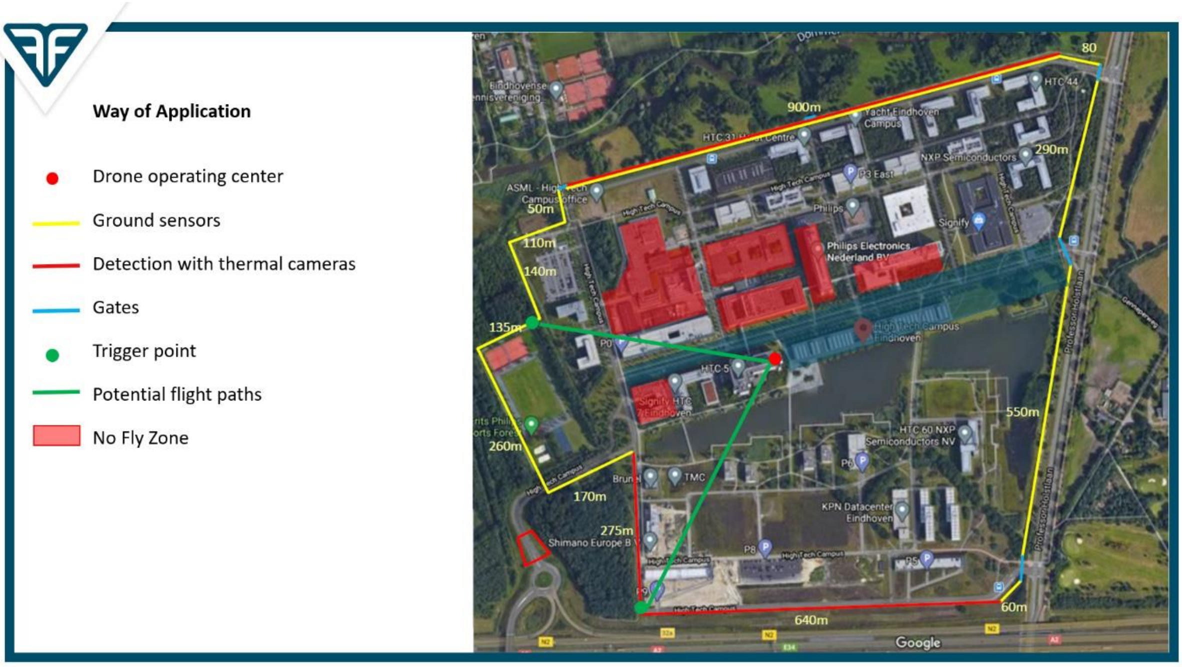

Figure 8 - Aerial view of security support use case

The ground sensors and motion cameras relay trigger information to the drone system via the OpenDDS drone dispatch platform (for more information see http://api.opendds.nl/docs/). This communication protocol lets any internet connected device send information to any type of drone via the use of two REST-API's. One API for receiving the triggers from the trigger devices (ground sensors and motion cameras), and the second API for controlling one or more drone platforms. The GPS coordinates of the sensors are stored on the OpenDDS platform. Also the desired heading of the drone is stored there so that the drone knows where to point its camera when it arrives at the triggered site.

Next to sensor triggered flights, the drone will also perform autonomous surveillance flights during night time based on a set surveillance time schedule. The flights are initiated manually and will follow predetermined waypoint missions. During these waypoint missions the drone will fly over the HTCE and inspects the site for any unwanted visitors.

3.2.3.3 Use case 2: building monitoring

At the moment a lot of time and money is spent on the maintenance of the High Tech Campus real estate. Once a year a heavy inspection of the exterior of all buildings takes place and normally this results in costly repairs, due to its reactive nature. New contracts are in the works to do this preventively and this should result in lower inspection and repair costs. The main inspection costs come from the fact that one or two maintenance engineers physically have to inspect (visually and mechanically) each part of the building façades with an aerial work platform. With this use case, we want to validate if autonomous drones can replace parts of the inspection and predict where maintenance needs to take place. By doing so it should also provide input for the business case to decrease the maintenance costs.

Area of application

The area of application consists of the facades of all the existing buildings that are present on the High Tech Campus. The facades cover the complete height and all sides of a building and can consist of concrete, stone, wood, aluminium, windows, window frames, panels, cavities or insulation. Some facades are straight forward concrete blocks, but others can have complex geometries, non-standard materials or weather sensitive mounting structures.

Due to weather influences, façade materials degrade which can result in such things as concrete rot, cracks in window frames or algae and moss growth. Also mounting structures loosen over time, resulting in panels that can come loose from buildings, posing a serious safety risk.

Once a year the facades are visually and mechanically thoroughly inspected, and all the necessary repairs are made. Additionally, twice a year preventive maintenance will be performed, and it will be decided on a case-by-case basis if repairs are needed or if they can be postponed till the yearly repairs. The additional preventative inspection is done in the same cycle as the standard window washing activities.

Autonomous drones can potentially replace the preventative inspections and the visual part of the yearly façade inspection. The test will also investigate if the drone images can be used by dedicated software that tracks the evolution of defects.

Way of application

During standard operation, an autonomous drone should fly by all the buildings on the High Tech Campus to inspect the facades, three times a year and after a heavy storm. To test this use case only the HTC 32 building is selected for inspection. To minimise the impact on campus residents and for proper daylight conditions, the inspection flights are done during the weekend.

The drone will start its flight from its base station at the roof of the HTC 5 building. It will fly to the bottom left of the HTC 32 building to a minimum height of 2,5 meters. This is a safe height where the drone cannot encounter campus residents. Also ground floor inspection is easily done by a maintenance engineer since it doesn't require the use of an aerial work platform, therefore it is not necessary for the drone to go down to ground level. The drone will subsequently fly to the right side of the building and move up one field of view. It will then fly to the left side of the building where it will again move up one field of view. It will perform this meandering flight path until it reaches the top of the building. From there it will move to the next side of the building and perform the same flight path until it has covered the whole building. See the designed flight path in Figure 9.

Figure 9 - Monitoring drone flight path in front of HTC 32 building

During an inspection flight the autonomous drone will have to fly slow enough and stay close enough to a building so that its camera can detect fine details of the facades. It is crucial that the drone flies close enough to the building so that the resolution of the resulting images is good enough to detect 5 mm defects. While also staying clear of any obstacles that are attached to the building or that are close to the ground.

Video is recorded during the flight and analysed by dedicated inspection software that detects abnormalities. These abnormalities are forwarded to reporting software where a maintenance engineer reviews them and from there subsequent repair action will be taken.

3.2.3.4 Stakeholders engaged

Use case 1 and use case 2 use the same hardware and software, and their concept of operations are identical. Therefore, a large overlap exists between their stakeholders.

The subset of stakeholders of the UAM blueprint that were engaged for use cases 1 and 2 are reported in Table 8.

Stakeholders	Specification
Civil Aviation Authority	IL&T
Military Authority	MIL CTR
Local authorities (e.g. Prefect, Municipality or Geozone manager)	HTCE Management as Geozone manager and Trigion as its security service partner for use case 1, and Fortron as its building maintenance service partner for use case 2

UAS manufacturer (i.e. designers and producers) of drones and other aviation entities	Mapture.AI
Drone Manufacturer (e.g. established in the EU)	DJI
Airport Operator	MIL manage the aerodrome, but operations outside the perimeter
Weather Data service provider	MeteoConsult (DTN)
Navigation service provider (e.g. EGNOS)	EGNOS
Air Traffic Service Providers (ATSP) (e.g. the control tower)	Altitude Angel
Drone aeronautical information manager	Mapture.AI/COSM/ADOC
Drone specific aeronautical information originator	Mapture.AI
U-space Communication service provider (e.g. LTE or 5G)	4/5G from Vodafone
Accident and Incident Reporting Service Provider	Mapture/ADOC
Digital Logbook Service Provider	Mapture/ADOC
Legal Recording Service Provider	Mapture/ADOC
Maintenance Management	Mapture/ADOC
Operational Plan Preparation	Mapture/ADOC
Risk Analysis Assistance	Mapture/ADOC
Critical infrastructure Security management	HTCE safety manager
Insurers	UAS Operator is insured via Driessen & Rappange
UAS operator (e.g. Fleet Manager responsible to plan and order the initiation of an operation)	Mapture.AI
Remote Pilot and her/his Command Unit	Mapture.AI
Drone owner	Mapture.AI
Operation Customer	HTCE management, Trigion and Fortron
Citizens	HTCE residents

Table 8 - Stakeholders engaged by the HTCE (Demonstrator 6)

3.2.3.5 Services involved

Both use case 1 and use case 2 use the same hardware and software, and their concept of operations are identical, therefore the involved services for both use cases are the same. An overview of their involved services is given in the table below.

Because the UAM industry is still in its early days, there are not a lot of existing UAM services readily available on the market. We have procured and integrated the services that are available, or are using workarounds like dedicated software functionalities (instead of connected services) that fulfil the task of certain services when they are not available.

The involved services of the UAM blueprint that are included in use cases 1 and 2 are reported in Table 9.

UAM Services	Specification
Command and Control data Link service	Through COSM via 4G and WIFI.
Network (Electronic) Identification Service (includes e-conspicuity)	Altitude Angel UTM is connected to COSM and they share location information about drone positions.
Geo-Awareness Service	The use case is only related to the airspace above the HTCE. That said, there are no-fly zones on the HTCE and drones are not allowed to fly outside of the HTCE perimeter.
Weather Information service	There is a connection with a weather information service through COSM.
Tracking (and position reporting?) service	Altitude Angel UTM is connected to COSM and they share location information about drone positions.
Aeronautical Information Management for UAS	NOTAMS and related information is received from Altitude Angel.
Risk Analysis Assistance service	www.online-sora.com was used for SORA analysis
Procedural Interface with ATC service	There is a covenant (including procedures) in place with the Eindhoven Military CTR.
Electronic Registration Service	Each operator has a unique registration number.
UTM Communication Service	There is a connection with Altitude Angel and COSM via an API

Table 9 - Services involved in the HTCE Demonstrator 6

3.2.3.6 Use case specification (CONOPS)

Aerial work conducted by Mapture shall at all times comply with the required exemptions and permissions applicable to the privileges granted to Mapture by the Dutch Civil Aviation Authority.

All personnel of Mapture shall adhere to the operational instructions and limitations stated in their Operations Manual (including appendices) and Aircraft Flight Manual(s).

The main aerial work conducted by Mapture, using UAS of the category multirotor with a weight less than 25 kg, covers the following type of operations:

Remote surveillance operations with drones with or without supervision of an operator using RGB or Thermal cameras. These operations typically take place at controlled areas with involved people only, like enclosed industrial areas, harbour areas, factories and airports.

For this aerial work the following special approvals/exemptions are obtained from the Dutch CAA:

- Functional test flights with a UAS without S-BvL (BVLOS) at Twente Airport.
- Remote operations over a controlled ground area according to NL-PDRA-01 (BVLOS).

High Tech Campus Eindhoven (HTCE):

For this particular use case Mapture will conduct aerial work with extra measures obtained by the CTR Eindhoven (Appendix 2 – EHEH TWR – HTCE – UAM Covenant (concept)). The flights will all be held between 0 and 400ft (0-120 meter) AGL. The flight area is limited above the HTCE controlled ground area, as displayed in Figure 10.

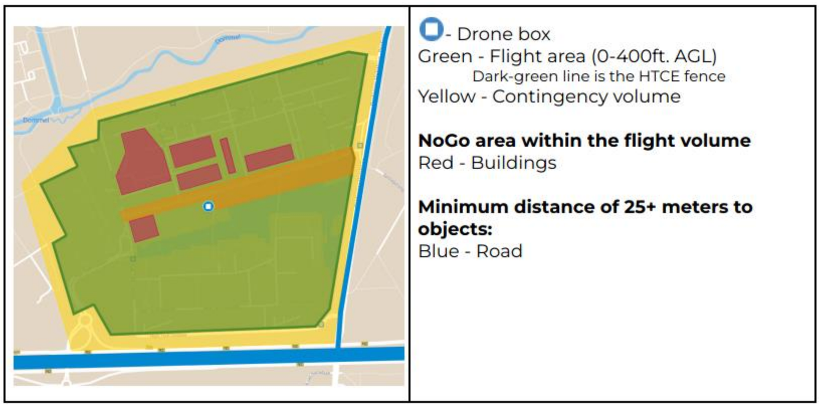

Figure 10 - Flight area of D6

Parts of the ConOps also contain general details that describe the company, crew members and UAS, and external contact details. This information is not listed here due to privacy reasons. What can be shared are the general mission details which are listed in Table 10.

Purpose of the flight	Project - FF 2020
Type of flight	BVLOS
Date of flight(s)	01-2022 /12-2022
Location	High Tech Campus Eindhoven
Maximum altitude / height	120 m AGL
Cruise altitude / height	50 m AGL

Table 10 - Mission details of D6

Table 11 reports the elements considered for the CONOPS of D6 use cases.

CONOPS elements	Specification
Type of UAS Operation	Specific category/BVLOS (no observers)

What is the Flight rule	IFR
Airspace Type	Military CTR
Ground Risk	Sparsely populated area
Airport Related positioning	Inside CTR
Traffic Density	Very low
UTM System	Altitude Angel
Communication Infrastructure	4G/5G
Terrain Data Model System	2D/3D digital maps available

Table 11 – CONOPS elements of D6

3.2.3.7 Other elements

As shown in Annex 1, other elements may be implemented to support UAM services. Table 12 reports the “other elements” implemented at HTVE for D6.

Other elements implemented	Specification
Server Infrastructure	Cloud
Computing Infrastructure	Cloud
GUI and Visualisation Infrastructure	COSM and ADOC
Fixed Sensors	Leaky coax ground based sensors and motion cameras for use case 1.
Other End-user Devices, Gadgets and Infrastructure Elements	Drone-in-a-box system from Mapture.ai. OpenDDS communication protocol to translate trigger signals to the drone. Ground control points for more accurate GNSS localization.

Table 12 – Other UAM elements implemented for D6

3.2.3.8 Main results

The demonstration was carried out with success, which is described in detail below for the security support and building monitoring use cases.

Security support:

- There were several ground sensors, detection cameras and simulated trigger sites connected via the OpenDDS system to COSM. See the image below for a representation of the trigger sites. Hereby it was possible to send sensor information to drones. The triggers can be physically triggered or via an online interface. The maintenance trigger is also used for the building monitoring use case.

Figure 11 - HTCE online sensor trigger interface, including sensor sites.

- During the demonstration days, we mainly used the detection camera on the south east corner of HTCE (number 13 in image above). We were able to successfully trigger it and thus it relayed its location and heading information to COSM. COSM subsequently was able to create the most optimal flight path, taken into consideration no-fly zones and weather conditions. And dispatched the DJI Mavic drone to the trigger site via the planned flight path.

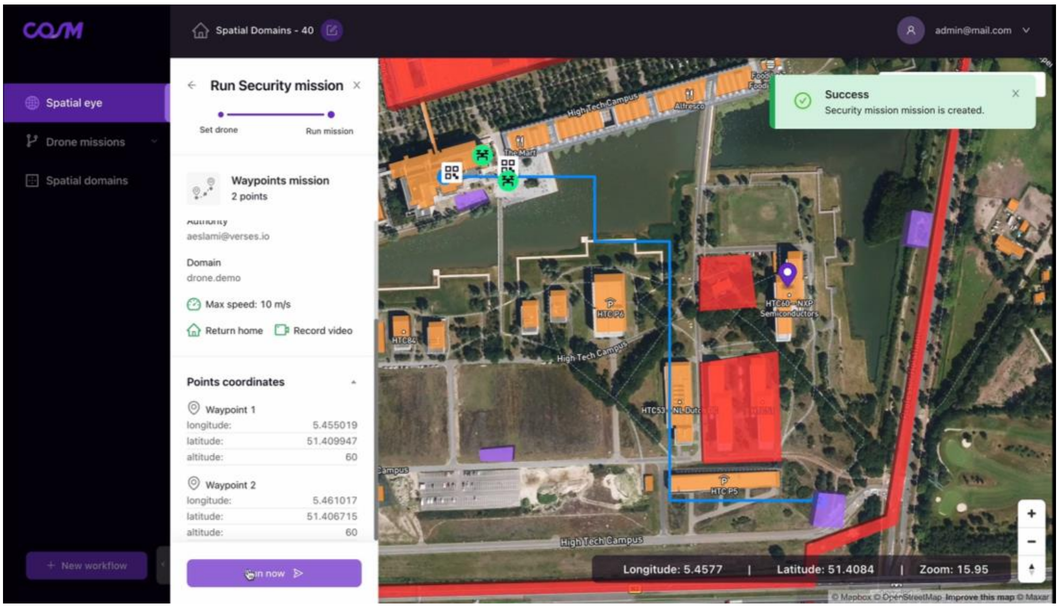

Figure 12 - Routed security flight to trigger site in COSM webinterface

- Video captured by the drone was streamed to a web interface. There, security guards are able to view the video and take action accordingly by taking manual control of the drone.

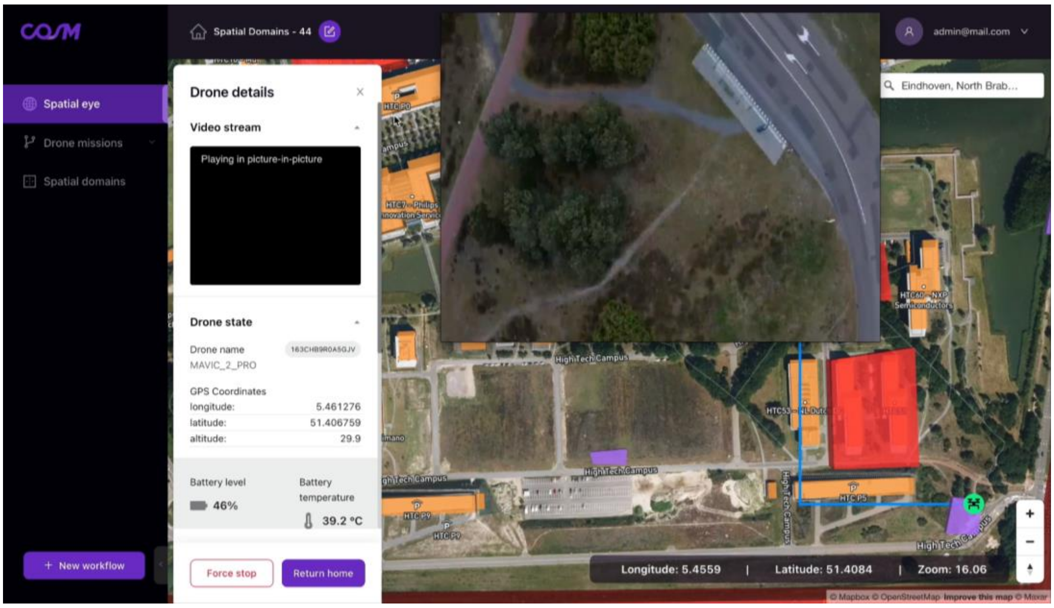

Figure 13 – Arrival of security drone at trigger site while streaming video in COSM webinterface

- At arrival the drone will orient itself to the desired heading and hovers for a minute. If there's no additional manual input, it will fly back to its home location, and autonomously land on top of the Mapture box.

Figure 14 – Drone landed autonomously on top of Mapture box at the end of its mission

Even though the outcome of the security support demonstration is promising, there is still a lot to learn and some hurdles to take before it can be fully operational for day-to-day use. The next iteration of development within the project will no doubt tackle most of these issues towards demonstrations in the next Living Lab.

Considerations for future operational use:

- It is desirable to have a minimum amount of nodes in the communication chain between the trigger site and the drone. Since every separate node can malfunction and cause a safety risk. In our case the communication chain consists of: sensor → sensor management system → OpenDDS → COSM → Mapture box → drone. This chain can be shortened by building a OpenDDS type of functionality directly into COSM.
- The drone constantly needs a direct RF line of sight to the Mapture box while flying. A loss of connection will make the drone fly home. Therefore the drone was only able to fly at a minimum height of 30 meters, since that's the height of the box on the roof of the HTC 5 building. Also because of this reason the drone was not able to fly behind buildings that were taller than 30 meters. A mitigation for this problem is to setup RF repeaters on top of the higher buildings and at ground level. Or use a 4/5G enabled drone.
- Use a drone-in-a-box system that can fly in heavy weather conditions. This is important for maximum deployability of the drone.
- Integrate the drone system with the system that the security company uses. In that way it will also follow the proper protocols for handling and storing images (i.e., GDPR-proof).
- Have an agreement with the CTR that states that you are always flying. In that case you can always start a mission when there’s an urgent security issue. Even though our covenant with the CTR states that we can always fly after we have called them, the time spent towards the call should not be necessary.

Building monitoring:

- Using the OpenDDS triggering system, a maintenance trigger was successfully transferred via API to COSM, and there a maintenance mission was created. This resulted in a correctly generated flight path by COSM: from the Mapture drone-in-a-box system on top of the HTC 5 building to the trigger site in front of the HTC 32 building, taking into consideration the no-fly zone in between. Subsequently the flight path was sent to the drone, it lifted off the box and it followed the route correctly to its destination.

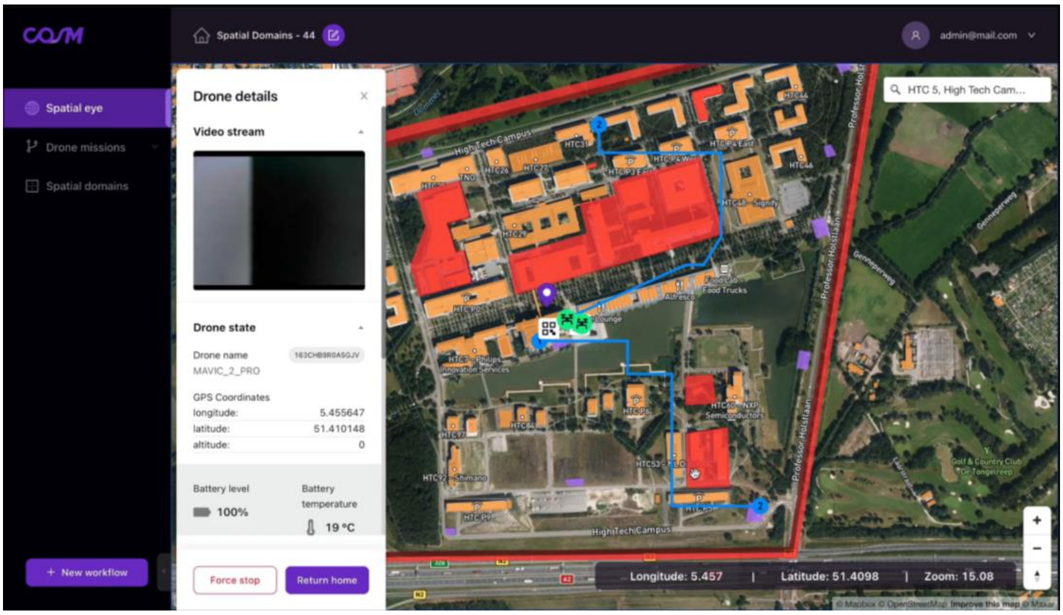

Figure 15 – Building monitoring mission in COSM webinterface

- When the drone arrived at the HTC 32 building it started a meandering path in front of the building. Starting at the bottom right corner, moving to the other end of the building in a horizontal line and when it arrived there moving up vertically 1 meter to start the process over again, until it reached the top of the building. After reaching the top of the building, it flew back to its home location where it landed on top of the Mapture box. During the mission, video of the inspection was recorded and stored for future analysis for building inspectors.

Figure 16 – Image of the drone flying in front of the HTC 32 building

Even though the outcome of the building monitoring demonstration is promising, there is still a lot to learn and some hurdles to take before it's possible to perform this mission BVLOS and autonomously. For example: for us it was only possible to perform this use case when the controller was next to the building due to the RF direct line of sight requirement of the drone. For an autonomous mission it is a hard requirement that the drone flies on 4/5G.

Considerations for future operational use:

- The drone needs to be able to fly close enough to buildings in order to take high resolution images (target = <5 mm detail). This requires ground control points and specialized mapping software for BVLOS missions. Also a drone camera with optical zoom will help for capturing high resolutions images.
- Use a RTK enabled drone for accurate geotagging of the images and potential defects.
- It would be helpful to use dedicated mapping software to make a 3D model of a building on which you can annotate defects. And use asset management software to track the evolution of those defects on buildings.

3.3 Last-mile and emergency air delivery services domain demonstrators

The last-mile and emergencies air delivery services domain is split up into demonstrators 7, 8, 9 and 10:

- Demonstrator 7: The Future Last Mile & Emergency Delivery on Campuses (HTCE)
- Demonstrator 8: Multi-purpose and specific service drones (OULU)
- Demonstrator 9: Precision Logistic Services for Air Transport of Critical Medical and Pharmaceutical Material (HSR)
- Demonstrator 10: Future Precision Logistic Services for Air Transport of Materials (TARTU)

3.3.1 Demonstrator 7

The main goals of this demonstrator are to decrease the carbon footprint of the High Tech Campus and to increase the wellbeing of its residents. There will be three drones (one per service) that will deliver services to the residents of the High Tech Campus:

- Last mile delivery of food
- Express shipping of mail
- Emergency support with automated external defibrillator (AED) equipment

These autonomous drones support daily campus life with last mile delivery and express shipping services where residents can order food or send out mail by drones via a connection to existing digital infrastructure. One drone will be made operational for emergency support services to keep the campus safety level at a high standard. To simulate an emergency situation (e.g. heart attack on campus) the drone will deliver AED equipment to support the emergency scene.

3.3.1.1 Implementation

In order to implement the use cases of demonstrator 7, a three-stage process has been followed that spanned a total of 12 months.

Stage 1, preparation:

The first stage consists of four parts:

1. Requirement definition with service partners

Definition of the use cases and why they are interesting for the HTCE and its service partners Eurest, Swiss Post Solutions and DISC. This involved the creation of a draft business case per use case that shows the initial value to the service partners, and convinced them to join the project. It also made clear where the most value would be obtained when autonomous drones are added to their daily operations, and how to integrate them best with their work processes.

2. Technical supplier selection

The first part delivered the requirements that were needed to do a proper technology scouting. This list of requirements was used as input for the meetings with a lot of drone technology providers, and resulted in the selection of required software and hardware: the AirHub Drone Operations Center (ADOC), DJI Matrice 300 RTK with Zenmuse H20 camera, additional drone batteries and charging box, RTK base station, Nicadrone electromagnet, Valqari landing station, two custom package release systems and several versions of transport containers. We used several different transport container designs because during testing the earlier designs proved to be not so successful.

3. Regulatory permission

Together with AirHub Consultancy the proper documentation was created in order to execute drone delivery missions on the HTCE. This includes a covenant that describes the working agreement with the military CTR (Appendix 2 – EHEH TWR – HTCE – UAM Covenant (concept)), also the ConOps and the SORA that were needed in order to obtain the exemption from IL&T to fly within the geographic area of the HTCE. The exemption was granted in time so that we could perform the BVLOS last mile delivery missions as intended.

4. Living Lab preparation

The tenants and service partners of the HTCE were informed of the FF2020 project intentions and what they could expect during the demonstration period. Next to their support it was also important that they would be aware of any safety risks when there are drones flying. Next to giving presentations and sharing information via email, also signs were posted that showed information on the UAS operations.

To make sure that HTCE was aware of all drone activity on campus a flight authorization protocol was established, that is to be used by anyone that wants to fly on campus. This protocol makes sure that the fleet manager, safety officer and facility manager are notified of drone operations requests. And they can authorize them if they deem them safe and fitting with HTCE requirements.

Each use case also required some physical preparations in order to integrate drone technology with the existing infrastructure. This concerned the installation of four secured lift-off and landing sites, a drone landing station from Valqari and the use of RTK technology for precision landing purposes. These technical preparations are described in more detail in the use case descriptions and demonstration results.

Stage 2, pilot & validation:

During this stage the first test flights are conducted during four scheduled weekend days. These are done during the weekend because then the campus is closed and there are only people present that are aware of the test flights. For these test flights, test scenarios are created that test the different use case elements under controlled conditions. For example: we will test and fly all the last mile delivery use cases simultaneously in combination with COSM and the AirHub Drone Operations Center (ADOC).

Before COSM was used at HTCE, it was first tested at Unmanned Valley. This is a large test site were new drone related technologies can be tested. There COSM went through the necessary safety tests before AirHub deemed it safe enough for use within the HTCE urban environment under their operating license.

Stage 3, deployment & monitoring:

Before the deployment phase starts all the separate UAM elements are tested and deemed safe to use in the larger UAM ecosystem. During deployment everything will come together. All the use cases will be performed simultaneously and the full scope of the HTCE UAM ecosystem is showcased. This was be done during two full days of demonstration during weekdays. The first day was a dress rehearsal and for the second day a lot of press and external stakeholders were invited to behold the UAM future by experiencing multiple drones perform different missions at the same time.

The outcome of this stage is validation for the business cases of the service partners. It helps with finalising the business cases which is needed to convince the relevant stakeholders to sustainably make use of UAM at HTCE.

3.3.1.2 Use case 1: delivery of food

Autonomous drones are a potential addition to the food delivery service on the High Tech Campus. With this use case we want to shorten the delivery time of meals and reduce delivery costs. It is also expected that there will be an increase in meal orders when campus residents will see that their meals are delivered by drones, and subsequently increase revenue for the food delivery service partner Eurest.

Area of application

The area of application is bound by the outer perimeter of the High Tech Campus terrain. Within this perimeter, buildings are visited by the Bring Me Food delivery service of Eurest during lunch time from 11:00 to 14:00, during working days.

One location has been marked as take-off site, and four test landing sites have been marked for autonomous food deliveries. A parking lot in the north west (Landing NW), the rooftop of parking garage in the north east (Landing NE), an open area in the south west (Landing SW), and an open field in the south east (Landing SE), of the campus (see Figure 17).

It is important that the drones never fly over buildings that are listed as no-fly zones (red areas on the map), and not over the Strip (blue area on the map) during the no-fly time zone from 12:00 to 13:00.

Way of application

A customer orders food via the Bring Me Food delivery app. The order comes in at the central ordering system of Eurest in the HTC 5 building. There the meal is made and placed in a transport box that is attached to the bottom of a DJI Matrice 300. The drone then takes off for a landing site. To test various parameters such as delivery time and routing issues, the drone will fly out to the different landing sites at each corner of the campus during separate flights. Upon arrival, the drone lands and the customer retrieves his/her meal from the transport box. Afterwards the drone will fly back to its original take-off location.

Figure 17 - Aerial view of delivery of food take-off location and landing zones

3.3.1.3 Use case 2: express shipping

Autonomous drones are a potential addition to the express shipping service on the High Tech Campus. With this use case we want to shorten the delivery time of packages and reduce shipping costs. And unburden the Swiss Post employees from picking up the express mail and packages. When an express order comes in an employee needs to drop what he/she is doing and pick up the package as soon as possible. Such an order is never planned and therefore a heavy burden to the daily operation.

Area of application

The area of application is bound by the outer perimeter of the High Tech Campus terrain. Within this perimeter, buildings are visited by the SPS Express service of Swiss Post Solutions during working days, to pick up urgent packages that need to be shipped.

One location has been marked as express shipping landing site in front of the Swiss Post building, where a drone landing station from Valqari is placed. Also four test take-off sites have been marked for autonomous express shipping. A parking lot in the north west (Take-off NW), the rooftop of parking garage in the north east (Take-off NE), an open area in the south west (Take-off SW), and an open field in the south east (Take-off SE), of the campus (see Figure 18).

It is important that the drones never fly over buildings that are listed as no-fly zones (red areas on the map), and not over the Strip (blue area on the map) during the no-fly time zone from 12:00 to 13:00.

Figure 18 - Aerial view of express shipping take-off locations and landing zone

Way of application

A campus resident has an urgent package to send places a Swiss Post express order via the Facilitor system. The order comes in at the central mail system (Ubook) of Swiss Post. And after approval the customer receives a shipping label that is subsequently attached to his/her package. The package is placed in a transport box at one of the take-off locations. This transport box is attached to a DJI Matrice 300 RTK drone via an electromagnet. The drone then takes off for the landing station at the Swiss Post distribution center in front of the HTC 29 building. Upon arrival, the drone signals the landing station, triggering the opening of a trapdoor that exposes a storage compartment. The electromagnet releases the package and the landing station transfers the package into the designated storage compartment, where it is locked and secured. A Swiss Post employee will receive a notification to pick up the package. He will then use his/her personal key to open the locker and collects the package for further processing.

Precision landing technology is needed in order to land the drone at the 1,5x1,5 square meter landing area on top of the landing station. We thought of using beacons or vision technology and scan a QR code on top of the landing station but this proved to be very complex when there is a package hanging under the drone. We chose to use a RTK enabled drone in combination with a RTK base station because this should very accurately determine the drone's position in space. The tests during the demonstration days will show if this approach is the right one.

3.3.1.4 <u>Use case 3: emergency support</u>

Autonomous drones are a potential addition to the emergency services on the High Tech Campus. Especially for the use of an AED in the more rural parts of the campus. With this use case we want to shorten the delivery time of AEDs to people that are experiencing a cardiac arrest. It is also very relevant to simulate this use case for when it can be applied to a larger smart city.

Area of application

The area of application is bound by the outer perimeter of the High Tech Campus terrain. Anyone who is present and works within this perimeter is instructed to call the emergency phone number in case of an emergency. When called, the operator follows a script to assess the situation and makes sure that the appropriate emergency medical services (EMS) react to the emergency call.

One location has been marked as take-off site, and four test landing sites have been marked for the emergency drone. A parking lot in the north west (Landing NW), the rooftop of parking garage in the north east (Landing NE), an open area in the south west (Landing SW), and an open field in the south east (Landing SE), of the campus (see Figure 19).

It is important that the drones never fly over buildings that are listed as no-fly zones (red areas on the map), and not over the Strip (blue area on the map) during the no-fly time zone from 12:00 to 13:00.

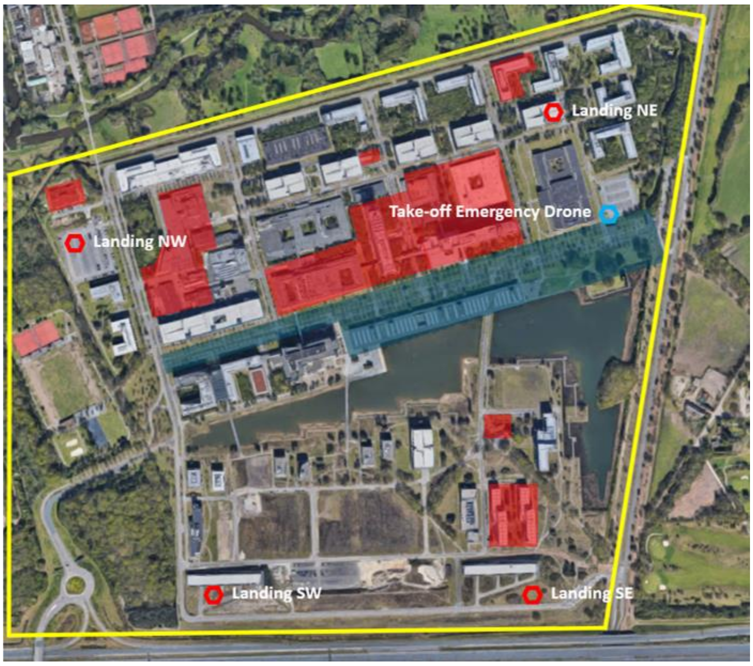

Figure 19 - Aerial view of emergency support take-off location and landing zones

Way of application

A campus resident calls the emergency phone number (on the back of their identification badge) because someone has collapsed in the field during their lunch walk. The operator assesses the situation and decides to send in the AED-equipped emergency response drone to the emergency site. The drone lifts off from its take-off location next to the HTC security lodge. It flies straight to the emergency site - which is at one of the landing zones - where the drone lands and the caller can retrieve the AED payload from a transport box underneath the drone. Upon delivery of the AED the other EMS services are notified by the operator that an AED is present. The drone keeps monitoring the situation from above and continues to provide the operator with situational information. Afterwards, it flies back to its initial take-off location where it will be retrofitted with another AED.

3.3.1.5 Stakeholders engaged

An overview of the engaged stakeholders is given in the table below. Use case 1, 2 and 3 use the same drone hardware and software, and their concept of operations are identical. Therefore, a large overlap exists between their stakeholders.

The engaged stakeholders are reported in Table 13.

Stakeholders	Specification
Civil Aviation Authority	IL&T
Military Authority	MIL CTR
Local authorities (e.g. Prefect, Municipality or Geozone manager)	HTCE Management as Geozone manager and Eurest as its catering service partner for use case 1, Swiss Post Solutions as its postal service partner for use case 2, and DISC as its workplace safety service partner for use case 3.
UAS manufacturer (i.e. designers and producers) of drones and other aviation entities	DJI, Valqari
Drone Manufacturer (e.g. established in the EU)	DJI
Airport Operator	MIL manage the aerodrome, but operations outside the perimeter
Vertiport operator	HTCE
Weather Data service provider	MeteoConsult (DTN)
Navigation service provider (e.g. EGNOS)	EGNOS
Air Traffic Service Providers (ATSP) (e.g. the control tower)	Altitude Angel
Drone aeronautical information manager	COSM/ADOC
U-space Communication service provider (e.g. LTE or 5G)	4/5G from Vodafone
Accident and Incident Reporting Service Provider	ADOC
Digital Logbook Service Provider	ADOC
Legal Recording Service Provider	ADOC
Maintenance Management	ADOC
Operational Plan Preparation	ADOC
Risk Analysis Assistance	ADOC

Critical infrastructure Security management	HTCE safety manager
Insurers	UAS Operator is insured via Coverdrone
Logistic organisations	Eurest, Swiss Post Solutions and DISC
UAS operator (e.g. Fleet Manager responsible to plan and order the initiation of an operation)	AirHub
Remote Pilot and her/his Command Unit	AirHub
Drone owner	HTCE
Operation Customer	HTCE management and Eurest, Swiss Post Solutions and DISC
Citizens	HTCE residents

Table 13 - Engaged stakeholders in D7

3.3.1.6 Services involved

The involved services for use case 1, 2 and 3 are all the same. An overview of their involved services is given in the table below.

Because the UAM industry is still in its early days, there are not a lot of existing UAM services readily available on the market. We have procured and integrated the services that are available, or are using workarounds like dedicated software functionalities (instead of connected services) that fulfil the task of certain services when they are not available.

The involved services are reported in Table 14.

UAM Services	Specification
Command and Control data Link service	Through COSM and ADOC via 4G and WIFI.
Network (Electronic) Identification Service (includes e-conspicuity)	Altitude Angel UTM is connected to COSM and ADOC and they share location information about drone positions. This is a temporary solution until drones will be able to this directly starting from 26 January 2023.
Weather Information service	There is a connection with a weather information service through COSM and ADOC.
Tracking (and position reporting) service	Altitude Angel UTM is connected to COSM and ADOC and they share location information about drone positions. This is a temporary solution until drones will be able to this directly starting from 26 January 2023.
Aeronautical Information Management for UAS service	NOTAMS and related information is received from Altitude Angel.

Procedural Interface with ATC service	There is a covenant (including procedures) in place with the Eindhoven Military CTR.
Electronic Registration Service	Each operator has an unique registration number.
UTM Communication Service	There is a connection with Altitude Angel and COSM/ADOC via an API

Table 14 – UAM services implemented for D7

3.3.1.7 Use case specification (CONOPS)

Introduction

This Concept of Operations describes a food drone delivery operation over the HTCE. The ConOps describes the goal of these operations, at which time(s) they are carried out and in what manner and with which type of UAS the operations are carried out. This section will define and describe the Concept of Operations with its limitations.

Description of the UAS operation

The main goal of this demonstrator is to decrease the carbon footprint of the HTCE, and to increase the well-being of its residents. The last mile and emergency delivery demonstrations, part of the drone delivery main, will take place at the HTCE. For these UAS operations, AirHub will test and validate the operation of three UAS simultaneously in combination with their Drone Operations Platform and COSM. This description summarizes the intentions for these demonstrations. Besides this document, a SORA has been made for each of the flights.

Description of the UAS system

The Food Delivery flight will be carried out with the DJI Matrice 300 including the payload box (see Figure 20). The M300 has a maximum take-off weight of 9kg and has a wind limitation of 15 m/s.

The delivery box weighs 750 g which means that a maximum of 2 kilograms (the UAS itself weighs approximately 6.3 kg including two batteries) of food can be delivered by the UAS. The box has an internal capacity of 10 litres (10.000 cm^3).

Figure 20 - DJI M300 with payload box

For the Express Shipping use case a DJI Matrice 600 is used. The M600 is able to carry up to 6 kilograms of payload. However, this highly depends on the maximum endurance/range that is needed. With 6 kilograms of payload (TB47S batteries), the M600 is capable of hovering 16 minutes, meaning a functional operating time of approximately 10 minutes. Lowering the amount of payload, results in an increase of range which should be tested. This UAS is limited to 8 m/s of wind, with a maximum speed of 18 m/s without wind.

The first test flights (during demo day 1), will be carried out without payload. If the M600 will also be part of demo days 2 until 5, a payload box will made.

The Emergency Support flight will be carried out with the DJI Matrice 300 including a special emergency payload box (see Figure 21 below).

Figure 21 - Emergency support payload box

Operational Volume

The operational volume is made up of the ground area above which the flights will be carried out (and from where the UAS systems will take-off and land) and the airspace in which the flights will take place.

Ground Area

HTCE is located to the southwest of the city center of Eindhoven and to the southeast of Eindhoven Airport (at approximately 6.5 km), the location is part of the city of Eindhoven. The campus is surrounded by a city park to the west and to the north of the campus. To the east, a road forms a barrier between the HCTE and an agricultural area. To the south of the campus lays the highway A2, at approximately 50 meters.

Only businesses are located on the campus area, the campus does not provide any form of residential area. For that reason, the busiest times at the campus are during working days (Monday till Friday) and working hours. Especially in the morning, between 07:00-09:00, during lunch, between 12:00-14:00 and at the end of the working day, between 16:30-18:00. During these timeslots, the UAS will not operate since the ground area cannot be classified as a sparsely populated area. Outside these timeslots, and during weekend days, the campus area is classified as sparsely populated.

Motorized traffic on the campus is minimal. The Campus is designed to encourage motorists to park their vehicles in an indoor parking garage on the outside of the campus in order to proceed on foot to their destination. On the campus, almost all roads can be closed off or reopened by placing retractable barriers on the road to minimize motorized traffic in a specific region of the campus. See the take-off and landing sites at HTCE in Figure 22.

Figure 22 - HTCE map with take-off and landing sites

Airspace

The location of HTCE is inside the CTR of Eindhoven airport. Eindhoven airport is located approximately 6.5 km to the northwest of HTCE. The airspace category is, therefore, class D airspace. HTCE is also located in a radio mandatory zone (RMZ). One of the departure and arrival routes for Eindhoven Airport is located parallel to the A2 highway at approximately 350 meters to the south of the highway and thus in close proximity to the HTCE.

Besides departing and arriving traffic the aircraft density of the airspace is low due to the close location to the airport, the airspace being a controlled airspace zone, and the minimum flight altitude for civil manned aircraft.

Eindhoven Airport has besides a civil role also a military role. The Airport is home to the Air mobility command, part of the Royal Netherlands air force. Stationed at the air base are C-130 Hercules transport aircraft, Gulfstream IV command aircraft and A330 multi-role tanker-transport aircraft. Incidentally, fighter jets and military helicopters do visit Eindhoven airport. Unless during special training flights, the normal approach routes will be followed by military aircraft arriving and departing Eindhoven Airport.

Note: UAS operations at the HTCE will be coordinated with the airport based on the agreements laid down in the covenant.

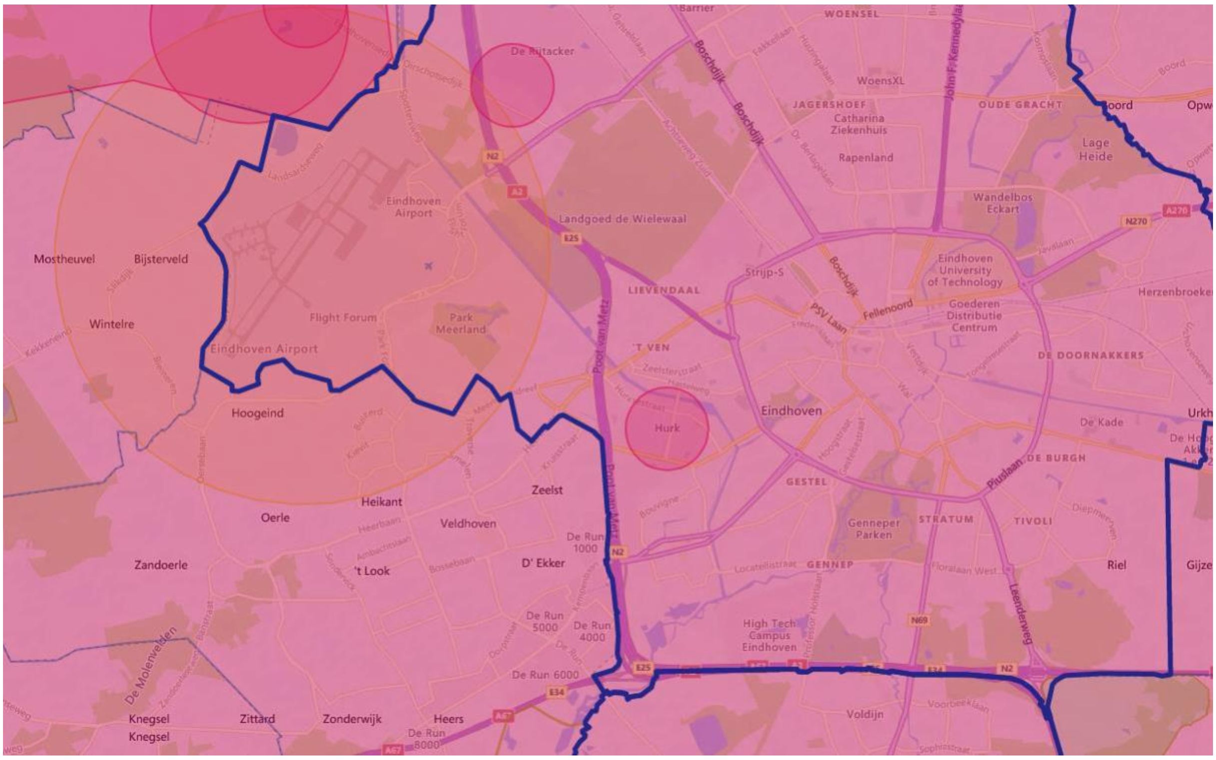

Figure 23 - HTCE and adjacent areas

Adjacent areas

Although the UAS will not normally move outside the operational volume, it is important to consider adjacent areas on the ground and adjacent airspace when planning and conducting an operation.

Ground Area

In case of operations within the HTCE area, the adjacent ground area will be a sparsely populated area up to 100 meters North of the Campus. There is a physical barrier (canal) between the operating site (HTCE) and the adjacent ground area. Beyond 100 meters, the ground area is classified as populated.

On the East, West and Southside of the HTCE, the whole adjacent area can be classified as sparsely populated area. However, it should be noted that the East side of the HTCE is parallel to a road. To the South of the campus lays the highway A2, at approximately 50 meters. In both cases, the flight crew will fly as much as possible parallel to the highway.

Airspace

Because of the limited size of the operational volume for these operations, the adjacent airspace will have the same classification – class D airspace in this case. Coordination with ATC is required before the flight, based upon the agreements that have been made. One of the departure and arrival routes for Eindhoven Airport is located parallel to the A2 highway at approximately 350 meters to the south of the highway and thus adjacent to the HTCE area.

Table 15 summarises the elements of the CONOPS taken into consideration for D7.

CONOPS elements	Specification
Type of UAS Operation	Specific category/BVLOS (with observers at take-off and landing sites)

Flight rule	IFR
Airspace Type (relevant to the demo-cases)	Military CTR
Ground Risk (relevant to the demo-cases)	Populated area
Airport Related positioning (relevant to the demo-cases)	Inside CTR
Traffic Density (relevant to the demo-cases)	Very low
USSP system	COSM and ADOC
UTM System	Altitude Angel
Communication Infrastructure	4G/5G
Terrain Data Model System (relevant to the demo-cases)	2D/3D digital maps available

Table 15 – Elements of the CONOPS considered for D7

3.3.1.8 Other elements

As shown in Annex 1, other elements may be implemented to support UAM services. Table 16 reports the "other elements" implemented at HTVE for D6.

Other elements	Specification
Server Infrastructure (relevant to the demo-cases)	Cloud
Computing Infrastructure (relevant to the demo-cases)	Cloud
GUI and Visualisation Infrastructure (relevant to the demo-cases)	COSM and ADOC
Other End-user Devices, Gadgets and Infrastructure Elements (relevant to the demo-cases)	RTK basestation. Valqari drone landing station. Drone transportation boxes. Electromagnet that attaches a package to a drone.

Table 16 – Other elements of UAM implemented in D7

3.3.1.9 Main results

Although performed in two different ways, the last mile delivery demonstration was carried out with great success, which is described in detail below for the food delivery, express shipping and emergency support use cases. Since these use cases can all use the same software, hardware and infrastructure, the results were the same for all of them:

- Due to RF connectivity issues at landing sites, in the end there was one take-off and landing zone setup for each use case. The event site in the middle of the campus was closed off with a one meter high ribbon and drone operation warning signs. At the other three sites there was a 8x8 meter landing zone with drone operation warning signs setup for safe autonomous take-off and landing. Also communications people were placed at all sites to instruct bystanders and communicate with the central drone operation center that was housed at the roof of the HTC 5 building.

Figure 24 - Last mile delivery take-off and landing sites

- The Valqari delivery tower was commissioned and installed at the HTCE event site. There it was connected to a regular power outlet and hooked up to a 4G modem for data transfer to its server.

Figure 25 – Valqari delivery station with drone hovering above it at event site

- An integration of the Valqari tower and COSM was successfully setup by the teams of Verses and Valqari. This resulted in several API calls that are necessary for the tower to communicate with the M300 drone and vice versa. For example so that the lockers of the station could be opened and a transport box could be placed inside a locker, or that the drone would know if the tower was ready to receive an incoming package.
- Three DJI M300 drones were equipped with different transport containers. Of which two also had a custom made release mechanism installed that is able to release its payload at a desired time.

Figure 26 – The three drones and their payloads that were used for last mile delivery

- During the demo we successfully made the DJI M300 and transport container with payload lift-off from the Valqari station. It was however not possible to land the drone on top of the tower. This was because it was not safe to land on the tower because the blades of the drone were too close to the top edges. It was also not possible to release a package onto the trapdoor mechanism of the tower due to incompatibility of the DJI and Valqari hardware.

Figure 27 – Manually placed M300 on Valqari tower to indicate the hardware incompatibility

- Since this was the first time that COSM was demonstrated for last mile delivery it did not have the option to run multiple flights at the same time. Therefore a general delivery flight was performed that showcased the integration with Valqari and the ability of COSM to land a drone with payload. This included an autonomous flight where a drone with transport box took off from the tower and successfully perform a precision landing on top of a QR code at the event site.

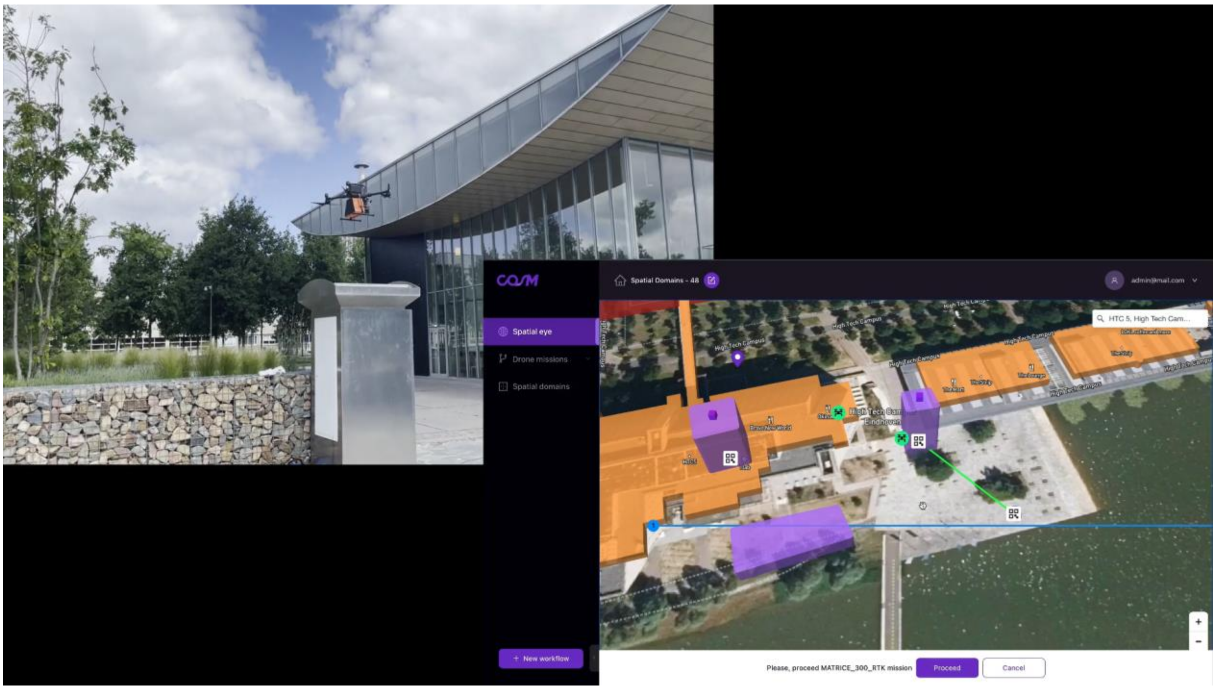

Figure 28 – General last mile delivery flight performed by COSM

- The three different last mile delivery flights were performed successfully at the same time using the Airhub drone operations center (ADOC). The meal delivery drone lifted off the Valqari tower and released its payload at the designated site. The express shipping drone lifted off from the south west take-off location and released its payload at the event site. And the emergency drone lifted off from the event site and released its payload at the roof of a parking garage at the north east end of the campus. After the drones released their payloads they returned to their initial take-off locations. All these flights were planned, managed and performed with ADOC.

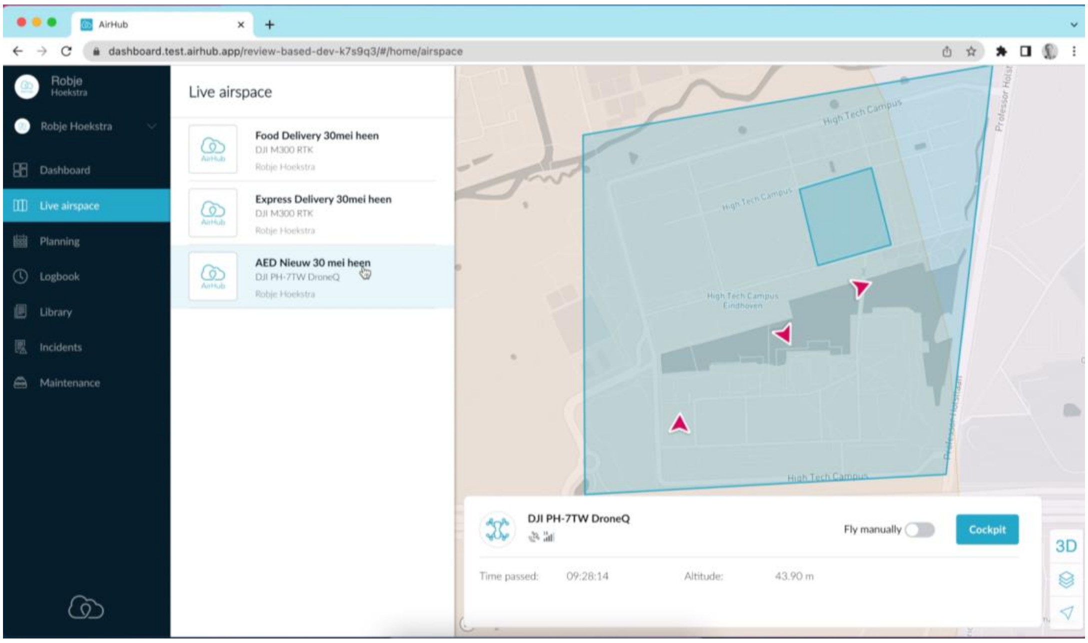

Figure 29 – Simultanious operation of the three drones (red arrows) with ADOC

Figure 30 – Succesful delivery of AED payload at the roof of a parking garage

- Live video streams were setup at all the different take-off and landing sites. In that way the demonstration spectators were able to witness what was happening at the other ends of the campus.

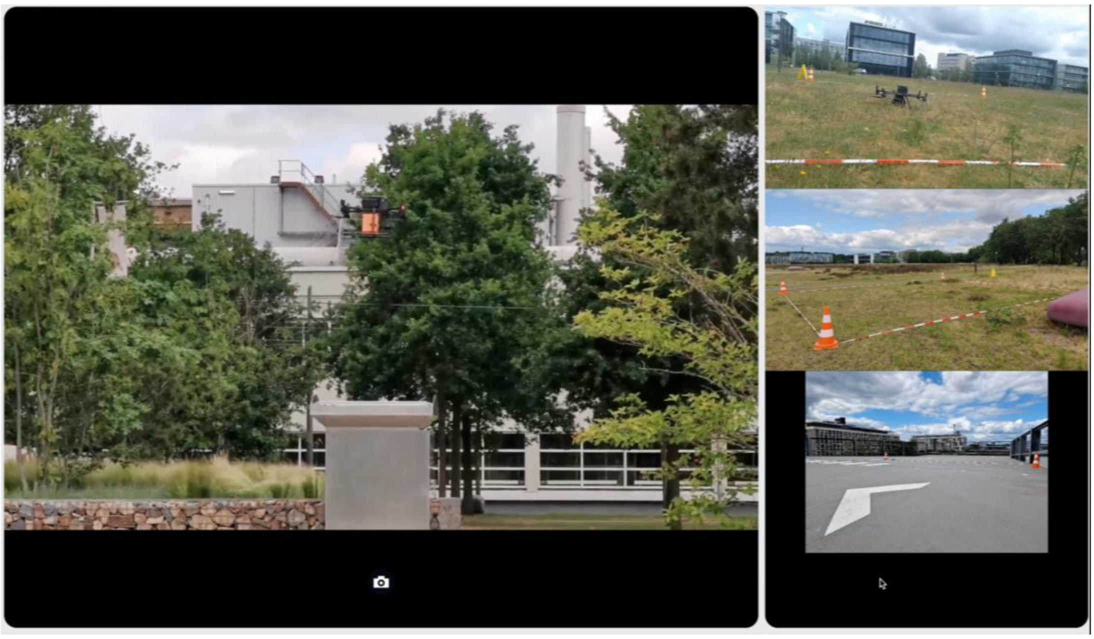

Figure 31 – Video streams of the different take-off and landing sites

Even though the outcome of the last mile delivery demonstration is promising, there is still a lot to learn and some hurdles to take before it is possible to perform these missions fully autonomously. One major requirement is that you need expensive infrastructure in place at the take-off and landing locations that will let the drone safely drop its payload without interacting with people on the ground.

Considerations for future operational use:

- Use a vertiport that is compatible with the type of drone that you are using. Specifically look at the hardware and ask for references that show that they are compatible.
- There is no commercially available package pick-up system for DJI at the moment. Only release systems. A dual use pick-up and release system is however necessary for commercial UAM operations. Electromagnetic systems might be best suited but it can be possible that they interfere with the telemetry of the drone.
- A non-4/5G enabled drone cannot land everywhere. Therefore 4/5G connected drones is needed for last mile delivery.
- Packages come in all kinds of different size and weight. It is usually easier to transport these all at once by electric vehicle and not by drone. Flight operations were done fully automated using the AirHub drone operations center, simulating autonomous flights but lacking full autonomous operations due to the lack of integration with the backend of the service partners. An integration is needed for future operational use.
- UTM data was supposed to be integrated into COSM and the AirHub Drone Operations Center. Most UTM services are free for infrastructure providers but operators need to pay to be connected. Since this was not budgeted and agreed upon in the supplier contracts, there was no UTM integration.
- You need a 5G-drone-in-a-box system with an integrated AED that is always ready to go because emergency support is time critical. Also you need to be allowed to fly over a populated ground area which is not possible at the moment in the Netherlands. Also you need to be allowed to tether the AED with a cable to the ground. Which is also not possible at the moment in the Netherlands due to regulatory restrictions.

3.3.2 Demonstrator 9

In this Demonstator, HSR wants to introduce logistic services for air transport of critical medical and pharmaceutical material. As it was reported in D6.1, there are many benefits from this type of use case: financial value, logistic value and environmental risk value most of all. Two use cases were designed for this Demonstrator, (i) urgent medicine delivery and (ii) biological sample delivery. In an operational environment, both services would be active and use the same system upon request of the hospital staff. For demonstration purposes, use case 1 (urgent medicine delivery) was selected. However, the functions and the equipment employed would be the same for the two use cases, while the users and the flight path would differ.

3.3.2.1 Implementation

The original timeline of D5 had to undergo changes to reflect the actual state of the activities. A delay of the kick-off of the authorization process for the operations and the requirements posed by the Italian National Aviation Authority (NAA), ENAC, made it necessary to extend the Stage 1 and Stage 2 by several months, as it is shown in Table 1. The Demonstrators flights are expected in early 2023.

Stage 1, preparation

1. Requirements for the UAS operator

During preparation and the earlier months, the selection of the UAS operator required careful evaluation of different propositions. In a joint effort with the project partners, HSR elaborated a list of requirements for the UAS operators that were willing to make an offer to carry out operations for the Demonstrators.

a. MANDATORY UAS SPECIFICATIONS

- Drone Max Take-Off Mass < 20 Kg
- Maximum width < 3 m
- GPS
- Interface with COSM (either through an on-board CPU with programmable access or through the CU with open SDK)
- Position transmission in accordance to prEN 4709-002 ("Direct Remote Identification")
- Command and Control Link (C2 link) between the drone and its ground station
- Have additional reliable connection to exchange additional data with the Command Unit of the drone on the ground
- Have additional Flight Termination System (FTS), completely independent to avoid common mode failures
- Landing pad
- Charging station
- Crash-proof delivery container (see "Delivery container" requirements)

b. OPTIONAL SPECIFICATIONS

- Extra positioning protocol from navigation satellites, e.g. EGNOS
- 5G connectivity with infrastructure provided by Vodafone/HSR
- Reception of optional UTM services

c. MEDICAL BOX REQUIREMENTS

As a reference, United Nations packing instructions 650 (IATA), which applies to UN3373 materials, were considered by HSR to ensure that the system would be adequate to transport medicines but also potentially infective cargo. However, during the authorization process by ENAC, HSR became aware that PI650 were not considered safe enough for the transport via drone of dangerous goods like infected blood. At the moment, there are no crash-proof containers available on the market that are authorized for such transport. Hence, in the Demonstrations the transported material will not be in the ‘dangerous good’ category.

To the UAS operators it was given a choice to use a proprietary container or to adapt their system for the attachment to the medical box of a manufacturer already known to satisfy the following requirements:

- Constructed with thermal insulation material
- The completed packaging must be of good quality, strong enough to withstand the normal rigors of transportation without loss of contents as a result of vibration, changes in temperature, humidity, or pressure
- (Completed) packages must be able to withstand a 4' (1.2-m) impact test
- Possibility to expose different labels (e.g. UN3373 label according to IATA DGR-62-EN-PI650)
- Dimension adequate for at least 12 test tubes, including secondary container and cooling element
- Continuous monitoring of internal temperature with data logger
- Continuous monitoring of acceleration with data logger
- Tamper-evident closure

Provided that the UAS satisfied the requirements, a quotation of the following activities was asked and was the base for the consequent selection.

- FLIGHT AUTHORIZATION FROM ENAC
    - Provide the Flight Manual
    - Provide all the necessary information for the CONOPS (drafted by EuroUSC Italia)
    - Implement AMC (Acceptable Means of Compliance) identified in the SORA analysis performed by EuroUSC Italia
    - Provide the draft of the Operations Manual and implement modifications suggested by EuroUSC Italia
    - Interface with authorities (e.g. ENAC) to gain flight permissions
- R&D

- Adapt system for delivery container (if applicable)
- Set up reception and use of UTM services
- Set up interface with COSM (follow provided set of instructions)
- Record mission data on cloud server

- OPERATIONS (pilot, eventual helpers, insurance and other costs included)
  - 2 days (5 successful operations per day)
  - 6 days (3 consecutive at a time, 5 successful operations per day)
  - Eventual extra day (5 successful operations)

2. Selection of the UAS operator

In total, three offers were received from UAS operators, and two offers were received from a drone manufacturer and a drone seller. The latter two were discarded as they did not satisfy the fundamental role of the UAS operator as the organization taking responsibility for the operations' regulatory compliance and safety. Based on an evaluation of the candidates' monetary offers and their experience, ABZero was the UAS operators that passed the selection.

3. Regulatory permissions

Flight authorization for 'specific' category operations in Italy needs to be issued by ENAC. HSR, with the mediation of EuroUSC Italia, took contacts with the NAA to introduce the project and the intended operations. In particular, it was noted how the use cases proposed by HSR are well aligned with the AAM Strategic Plan (2021-2030) for the development of the Advanced Air Mobility in Italy, issued by ENAC itself in 2021[8]. The following communications regarded ENAC's recommendations to demonstrate the safety of the intended operations, in particular regarding the UAS operator to carry out BVLOS operations in a densely populated area. In fact, it was deemed necessary that the UAS operator demonstrate their capacity in BVLOS operations in unpopulated areas, before conducting them in the hospital's airspace. For these first operations, a separate flight authorization procedure (in the 'specific' category) must be carried out. For each procedure, ENAC reserves up to 90 days to issue the authorization and eventual additional requirements for the operations. In summary, HSR's UAS operator will perform the following operations:

1- Preliminary operations in unpopulated area; the aim is to demonstrate the capability to conduct BVLOS operations safely;

2- Demonstrator operations in HSR (populated area) to fulfil the LLAB's objectives of FF2020.

For both type of operations the UAS operator used SAMWISE tool for risk assessment assistance, which uses the SORA methodology as recommended by JARUS. The operations manual for the BVLOS operations was prepared by ABZero and reviewed by EuroUSC Italia. All the proper documentation and the authorization form for the preliminary operations were sent to ENAC on June 10th 2022. The same procedures will follow for the BVLOS operations in populated area (HSR) after these flights, now waiting to be authorized. In the Section "Use case specification (CONOPS)" the described operation will be the one concerning the Demonstrator in HSR, for the

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[8] https://www.enac.gov.it/sites/default/files/allegati/2022-Mar/01_Piano%20Strategico%20Nazionale%20AAM_ENAC_web%20en-GB.pdf

authorization of which the UAS operator must wait to successfully complete the BVLOS operations in unpopulated area, as required by ENAC. Hence, a few changes may by applied in the following months, which would be reported in the next version of the present Deliverable.

4. Technical integration

The technical integration of COSM with the UAS was agreed with the involved partners, i.e. VERSES and ABZero (the UAS operator). ABZero's proprietary system is a medical box, called "Smart capsule", comprising both hardware and software for connectivity and for the remote control of the drone.

The data flow will proceed as follows (both ways): user ↔ COSM ↔ ABZero back-end web application ("Spoke") ↔ medical box ("Smart capsule") ↔ Drone.

The data to exchange from COSM to the drone is the mission waypoints. From the drone to COSM, the data to exchange is the following:

- Current position of the drone (upload frequency = 2 Hz) from the drone to COSM;
  - GPS
  - Altitude
- Battery status
- Proximity sensors data
- Video streaming

The normal flow would require the user to input the mission waypoints in the COSM platform. COSM elaborates the route using the mission waypoints data. During the operation, dynamic routing is performed by COSM using the data from the drone. In the Demonstrators' operations in HSR, proper online dynamic routing is not possible, because the operations in the 'specific' category need to be pre-approved by the Authority, including the flight path. Hence, COSM will be used in the Preparation stage of Demonstrators to create a route to be validated by the UAS operator and to be authorised by the NAA.

Technical integration required that each step was analysed and a protocol to exchange information was shared. The following steps were the subject of technical integration effort:

1) The nurse makes an order for a medicine through the hospital information system;
2) The pharmacist places an order for a drone delivery through COSM (input mission waypoints);
   a) COSM sends the a JSON file with mission waypoints to the Spoke backend;
3) The operation is created automatically with the mission data in COSM;
4) The pharmacist loads the parcel and flags this action via smartphone;
5) The remote pilot performs the pre-flight checks and then initiates the mission;
6) The drone flies automatically to the end point (RP supervising the flight, ready and able to take control at any time);
   a) Spoke backend uses the JSON to pass it to the drone via the Smart capsule;
   b) Spoke backend updates both Spoke frontend & Spoke App and COSM with drone position (through the JSON);
7) The parcel is unloaded by the nurse and flags this action via smartphone;
8) Repeat 5 and 6 for the flight back.

5. Technical integration of UTM services

For this topic, the same requirements of D5 are valid (see Section 3.2.2.1).

Stage 2, pilot & validation

Test flights will be carried out in an unpopulated area, with a two-fold objective: (i) demonstrate the UAS operator's capacity to conduct BVLOS operations, as required by ENAC; (ii) testing the communication between COSM and the UAS owned by ABZero.

Stage 3, deployment & monitoring

In this Stage, the flights will be executed in the hospital's airspace, after the demonstrations of the recommendations for the safety of operations from ENAC are satisfied. Four or five test days, two weeks apart, will be agreed among HSR actors, VERSES and ABZero.

3.3.2.2 Use Case 1: Urgent medicine delivery

The internal transport of medical goods in a hospital heavily relies on human resources that carry the materials on foot. Such mode of transport may be affected by inefficiencies, e.g., due to bottlenecks, and other logistic challenges. Thus, it may benefit from the use of UAS in several aspects. The main advantage that is expected of such a service would be increasing hospital logistics efficiency by reducing transport time and by achieving a better workload distribution, ensuring that the clinical staff dedicate their work time on patient care rather than transporting material. In fact, on multiple occasions during a work-day, clinical staff is required to pick up medicines from the central hospital pharmacy, as it was reported in D6.1.

In this use case, medicines are transported by drones from the pharmacy warehouse to the PallaRia building, which was launched in 2020 to face the demand of intensive care beds and equipment for patients affected with Covid.

3.3.2.3 Stakeholders engaged

Following the UAM blueprint elaborated within FF2020, the involved stakeholders for the last-mile delivery use case are reported in Table 17.

It is noteworthy to mention that the UAS operator will establish a line of communication with the helipad manager of the hospital. During the operations, the communications will occur both ways to ensure that the traffic of the drone and of the helicopters landing in the nearby helipad remain separated.

Stakeholder	Specification
Civil Aviation Authority	ENAC (Italian civil aviation authority)
Pilots of manned aircraft	Operators of manned emergency helicopters operating nearby will be coordinated
Airport Operator	Linate airport operator (SEA) will be informed, but normal operations will be carried out of its jurisdiction

Aeronautical Information Management Provider (AIMP)	ENAV (traditional AIP and charts)
Navigation service provider (e.g. EGNOS)	EGNOS
Air Traffic Service Providers (ATSP) (e.g. the control tower)	Linate control TWR
Registration Service Provider (including updates)	d-flight
Common Information Service (CIS) Provider	d-flight
Drone aeronautical information manager	d-flight
Flight Clearance (Authorisation) service	d-flight
Network Tracking (Surveillance) service provider	d-flight
U-space Service Providers (USSP)	d-flight is the main provider, but not the only one, based on the list in ISO 23629-12
Operational Plan Preparation	Drone operator (ABZero) performs it via COSM (by VERSES)
Risk Analysis Assistance	EuroUSC Italia (https://www.online-sora.com/)
Critical infrastructure Security management	Technical area chief in HSR
Insurers	Drone operator insured in compliance with Regulation 785/2004. No further coordination necessary
Pharmacies	HSR pharmacy
UAS operator (e.g. Fleet Manager responsible to plan and order the initiation of an operation)	ABZero
Remote Pilot and her/his Command Unit	UAS operator
Drone owner	UAS operator
Operation Customer	HSR staff (surveillance service)
Citizens	UAM social acceptance survey

Table 17 – Stakeholders involved for D9

3.3.2.4 Services involved

Following the UAM blueprint developed within FF2020, the UTM services employed for this demonstrator are listed in Table 18 along with a brief specification on their implementation.

UAM services	Specification
Network (Electronic) Identification Service (includes e-conspicuity)	For d-flight, this service is named NETWORK REMOTE IDENTIFICATION. d-flight has published an ICD through which their system can receive location data from the GCS and represent flying drones in the airspace volume on a map

Geospatial Information Service	Static information (e.g., Aeronautical Information Regulation and Control and NOTAMs) is offered by d-flight
Geo-Awareness Service	d-flight can receive and publish volumes of airspace reserved by UAS operators, which represents dynamic information
Flight Clearance (Authorisation) Service	d-flight
Traffic information service	Information available through d-flight
Aeronautical Information Management for UAS service	Named "Common information service" as in EC Regulation 2021/664
Operational Plan Preparation (and optimisation?) service	COSM used for this purpose in our Demos (OPP)
Operational plan processing service	Mandatory to use d-flight for this in specific category, unless a NOTAM is used; the information created through the OPP is passed to d-flight to process the plan and gain flight authorization
Risk Analysis Assistance service	SAMWISE (https://www.online-sora.com)
Accident and Incident Reporting Service	Possible accidents or incidents will be reported procedurally, according to EU Regulation 376/2014 through ENAC portal (https://www.enac.gov.it/news/attivazione-del-sistema-eccairs-2)
Navigation Coverage Information service	"GNSS monitoring" by d-flight
Procedural Interface with ATC service	Procedures agreed with Linate ATS
Electronic Registration Service	provided by d-flight in compliance with Art. 14 Regulation 2019/947
UTM Communication Service	Connection between the Fleet Manager Platform and d-flight services via Internet service

Table 18 - UAM services implemented in D9

About the procedural interface with ATC service, normally the coordination of the operations takes place by informing the person responsible for communications by telephone at the beginning and at the end of the authorized operations and of which they are already aware. In case of their particular needs or emergencies, the airport tower or the helipad manager calls the

UAS operator and can ask them to delay or temporarily abort the mission (this might especially be the case of the helipad where an emergency helicopter may need to land).

3.3.2.5 Use case specification (CONOPS)

The CONOPS for this demonstrator was drafted, but the final version will be available after the completion of the first step (the preparatory BVLOS flights in an unpopulated area, that precede the ones that will take place in the hospital premises). HSR and the UAS operator (ABZero) initiated discussions with the NAA to ensure they meet all the necessary safety objectives for the demonstrator operations.

In order to reach a lower Ground Risk, it was recommended that the FTS was subjected to design verification by EASA. This would have required time and costs that were not compatible with the ones allocated for the project, as its scope would be out of the one prospected for FF2020. Therefore, an alternative mitigation was introduced, i.e. to subject the buffer area and the adjacent area under control of the personnel involved in the operations. This limitation suffices for the demonstration purposes of FF2020, although the problem of design verification of safety systems like the FTS will have to be dealt with in the future to ensure a level of safety sufficient to allow operations without the need of manual safety measures, thus achieving the UAM vision.

The mitigation introduced above caused the necessity to redesign the drone trajectory to avoid that the adjacent area to control would fall outside the hospital perimeter, in public spaces. In fact, the area under control must be restricted to the staff involved in the operations, making it necessary to bar the access to others. The new trajectory would force the drone to fly not just over roofs, as initially planned. Hence, it is necessary to issue a NOTAM to reserve the airspace during the demonstrations, thus containing the Air Risk.

Area of the operations

The trajectory was planned considering the obstacles in the area (e.g., buildings, appliances, trees), to minimize the flight time and to confine the adjacent area inside the hospital perimeter, for the reasons explained in the previous Section. Figure 32 shows the area of the operations and the intended trajectory for D9.

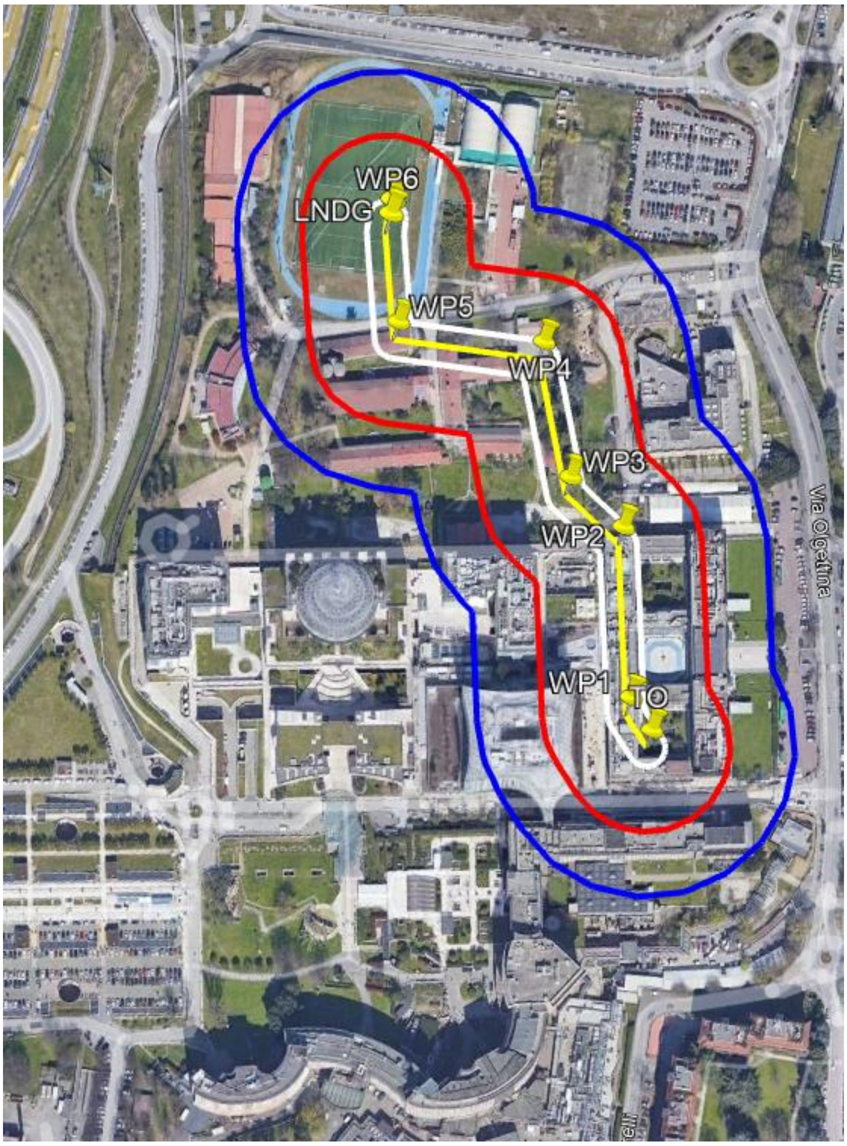

Figure 32 – Flight route (yellow), contingency area (white), buffer area (red), adjacent area (blue) for D9

The contingency area covers the surface spanning 5 meters around the flight path. Buffer area and adjacent area are calculate following the guidelines from ENAC[9] regarding the mitigation M1 (acceptable strategic mitigation M1 for ground risk of SORA) at a mid-high level ("ground risk analysis for RPAS operations"). Following the specified methodology, the buffer area is calculated considering the velocity, the Flight Termination System (FTS) activation time, maximum wind speed and the flight elevation. Hence, the buffer area spans from 40 to 50 meters around the flight path. The adjacent area is calculated adopting the same method, hence its perimeter is distanced 40 to 50 meters from the perimeter of the buffer area.

Description of the UAS system

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[9] https://www.enac.gov.it/sites/default/files/allegati/2020-Gen/LG-2017_001-NAV%20Ed.%202%20Jan%202020_con%20Appendice%20%289%20gennaio%202020%29_0.pdf

The drone employed for this use case will be the Dronebase X4-1000 (Figure 33). This drone has a maximum take-off weight of 25 kg and has a wind limitation of 9.77 m/s, with a maximum speed of 18 m/s without wind.

Figure 33 – Dronebase drone used for the D9

The drone transports the ABZero Smart Capsule (Figure 34), to which it is attached. The users open and close the Smart Capsule to load and unload the parcel without necessarily disconnecting it from the drone. The Smart Capsule serves as a tertiary container when considering packaging instructions PI650. It can monitor the humidity, temperature and agitation that the parcel is subjected to.

Figure 34 – ABZero Smart Capsule

3.3.2.6 Other elements

Other elements of the UAM blueprint relevant to the use case are reported in Table 19.

Other elements implemented	Specification
Security Systems (relevant to the demo-cases)	HSR Security services
Server Infrastructure (relevant to the demo-cases)	The infrastructure is hosted on AWS servers which guarantee robustness, efficiency and reliability
Computing Infrastructure (relevant to the demo-cases)	t2.micro (a subcategory of the EC2 server)
What is the GUI and Visualisation Infrastructure (relevant to the demo-cases)?	COSM

Table 19 – Other elements implemented in D5

Appendix 1 – UAM Blueprint

Document Identification	
Authors	Vadim Kramar, Filippo Tomasello, Ted van Hoof
Internal reviewers	Ruud van Iwaarden, Juha Röning
Work package	6
Task(s) involved	T.6.1, T6.2
Nature	R: Document, report
Dissemination level	Choose one of the following codes: PU =Public, fully open, e.g. web

Version	Date	Contributor	Description
V0.8	15/02/2022	Vadim Kramar (OULU)	Revised the document. Updated the layout. Finalised is the integration of the UAM Blueprint as an Appendix of D6.2 of the FF2020 project.
V0.7	22/01/2022	Filippo Tomasello (EuroUSC)	Developed new sections, presenting the current status of UAM development and international standardisations relevant to UAM. Revised the list of UTM services.
V0.6	24/06/2021	Vadim Kramar (OULU)	Finalised is the integration of the UAM Blueprint as an Appendix of D6.1 of the FF2020 project.
V0.5	01/06/2021	Ted van Hoof (HTCE)	Updated and refined the layout, formatting and content.
V0.4	31/05/2021	Vadim Kramar (OULU)	Accomplished post-revision updates
V0.3	27/05/2021	Filippo Tomasello (EuroUSC)	Accomplished a series of revisions.
V0.2	14/04/2021	Vadim Kramar (OULU)	Updated the list of elements and sources
V0.1	16/03/2021	Vadim Kramar (OULU)	Created the first version of the UAM Blueprint. Added the results of the initial exploration of UAM elements.

1. Introduction

The UAM Blueprint is the UAM guide and the taxonomy of elements that are required to implement UAM in practice. UAM elements had been explored and collected from a broad range of sources. Since the process of developing the UAM domain in Europe and other parts of the world continues, the European legislation and standards do not comprehend all the required UAM elements. In those cases, the international standards and different UAM concepts had been analysed to form the UAM Blueprint (see the list of the sources).

The purpose of the UAM Blueprint is to contribute to increasing the safety of UAS operations in Europe, raising awareness and understanding the UAM elements among the stakeholders, refining UAM elements and unveiling the demand for UAM services within the planned use-cases, enabling the scalable implementation of UAM infrastructure, evolving along with the development of UAS and UAM supportive and enabling technologies and application cases, and gradually becoming the basis for the future UAS and UAM standards.

The document started as the result of activities of the Flying Forward 2020 (FF2020[10]) project funded by the European Commission from the Horizon 2020 Framework Programme. As the working document is to dynamically reflect the current state of European legislation and standardisation as well as UAM and UAS development, the UAM Blueprint will be continuously developed in the course of the project by the project team and those stakeholders that will be willing to contribute. The plan is to finalise the document by the end of the project.

The UAM Blueprint is to be developed in the course of the work and validated through the series of demonstrators and use-cases planned under the FF2020 project. Also, other practical activities, literature reviews and scientific explorations might be conducted to validate the content of the document. The results of the validation will be justified according to the FF2020 justification plan that will end up with the updated use-case specifications based on the UAM Blueprint.

2. What is UAS Traffic Management (UTM)?

The UTM and U-space terms are often confused. Even though sometimes they were used interchangeably, they are not exactly the same. UTM is, in fact, the UAS Traffic Management. That is the system designed and implemented to manage the traffic of Unmanned Aircraft Systems (UAS).

Even though there is no UTM definition in any EU legal act, the definitions of the U-space airspace and the U-space service are given. The U-space airspace "means a UAS geographical zone designated by Member States, where UAS operations are only allowed to take place with the support of U-space service".

Currently, there is no mandatory standard adopted by the International Civil Aviation Organisation (ICAO) defining the term UTM, mainly because operations below the minimum heights standardised in Annex 2 to the Chicago Convention are not relevant for civil aviation on the global scale, and hence out scope of ICAO, based on Art. 44 of mentioned Convention.

For the purpose of the UAM Blueprint, the definition in ISO 23629-12 is used (see Table A1).

Entity	UTM Services Definition	Source
ICAO	A specific aspect of air traffic management which manages UAS operations safely, economically and efficiently through the provision of facilities and a seamless set of services in collaboration with all	UTM Framework (2019)

[10] https://www.ff2020.eu/

	parties and involving airborne and ground-based functions	
EC/EASA	U-space service" means a service relying on digital services and automation of functions designed to support safe, secure and efficient access to U-space airspace for a large number of UAS	Commission Implementing Regulation (EU) 2021/665 (2021)
ISO	Set of traffic management and air navigation services aiming at safe, secure and efficient integration of multiple manned and unmanned aircraft flying in the Designated Operational Coverage (DOC)	ISO DIS 23629-12[11]

Table A1 – Definitions of UTM services from different sources (ICAO, EASA and ISO)

3. Commission Implementing Regulation (EU) 2021/664

Even in the absence of a specific definition of UTM in the common European rules, the European Commission (EC) has adopted Implementing Regulation 2021/664, which establishes requirements for six UTM services and for the additional Common Information Service (CIS), as depicted in Figure A1.

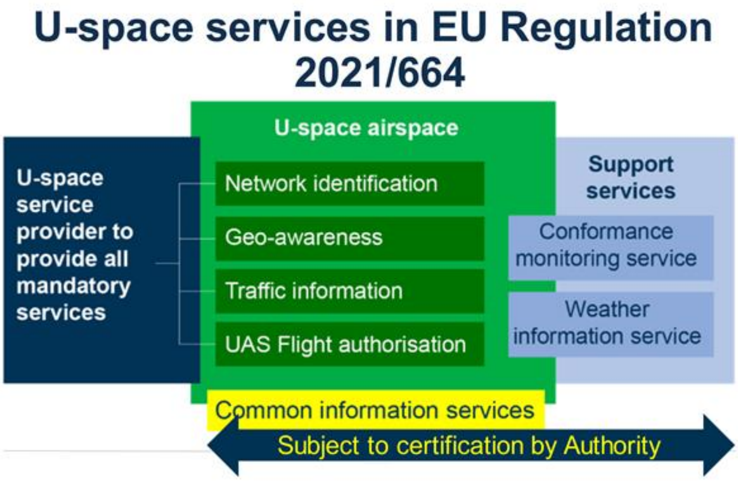

Figure A1 – U-Space services in EU Regulation 2021/664

In the vision of EASA, the main user of these services is the UAS operator, as defined in Art. 2.2 of Regulation 2019/947:

> 'Unmanned aircraft system operator' ('UAS operator') means any legal or natural person operating or intending to operate one or more UAS.

In other words, the UAS operator may be a self-employed Remote Pilot (RP), but also a commercial company (the employer) having recruited or contracted one or more RPs (the employees).

The current vision of EASA on the digital environment created by the U-space service is presented in Figure A2.

[11] https://www.iso.org/standard/78962.html?browse=tc

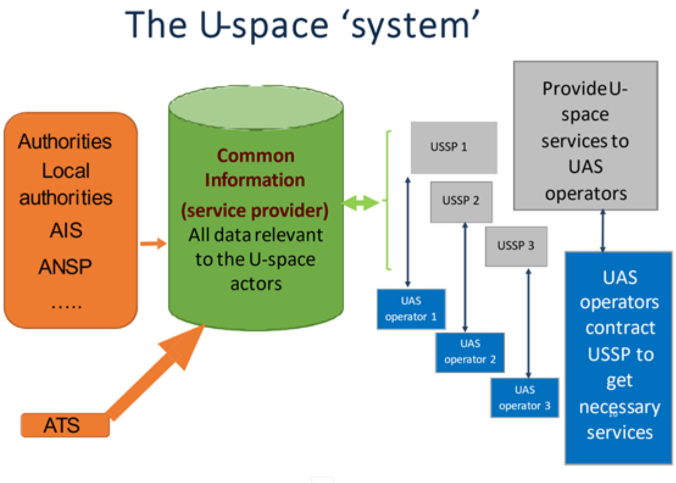

Figure A2 – Current vision of EASA of U-space digital environment

At the core, there is the provider of Common Information (CIS), while the existence of several U-space service providers (USSP) serving an indefinite number of UAS operators is possible.

Using the terminology of the ISO Unified Modelling Language (UML), USSPs are indeed 'service providers', while the UAS operators are 'users'.

However, other entities may be connected to the U-space services, such as 'geozone managers' (e.g. Municipality of Zaragoza or HTCE), final users (e.g. pharmacy), law enforcement agencies (e.g. Police) or else. This is clearly depicted in the overall UTM functional architecture in ISO 23629-5, reproduced in Figure A3.

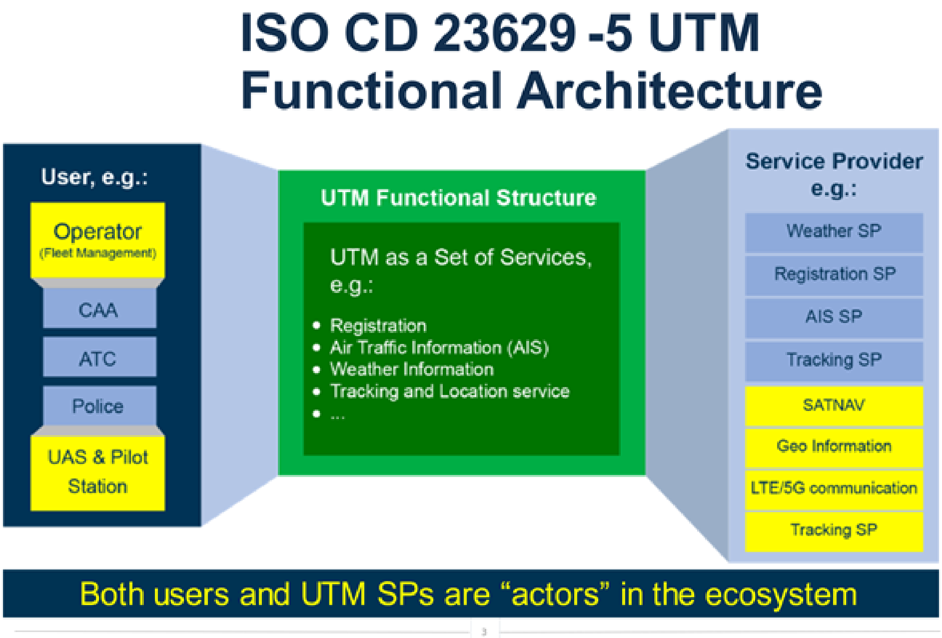

Figure A3 – General UTM functional architecture in ISO 23629-5

4. How many IT entities are under the UAS Operator?

Neither Regulation 2021/664, nor ISO 23629-5 specifies which should be the Information Technology (IT) entities used by the UAS operator to receive, process, analyse, exploit, store and transmit digital information. These entities are obviously necessary since, in essence, U-space services are based on exchanges of digital information.

FF2020 hence assumes that the UAS operator will have managerial control on at least three IT entities exchanging digital information:

a. The Unmanned Aircraft (UA) which indeed is able to transmit and receive information, but only when powered and activated, in particular during a flight;
b. The Control Unit (CU) of the RP, which is however also active only during a flight; and
c. At least one working position of a Fleet Manager, from where the operator may plan the operation, even several weeks in advance, potentially active 24/7 and connected to other users (e.g. pharmacy or other final customers).

The digital ecosystem, in this vision, goes much beyond the UAS flight and even much beyond aviation, as depicted in Figure A4.

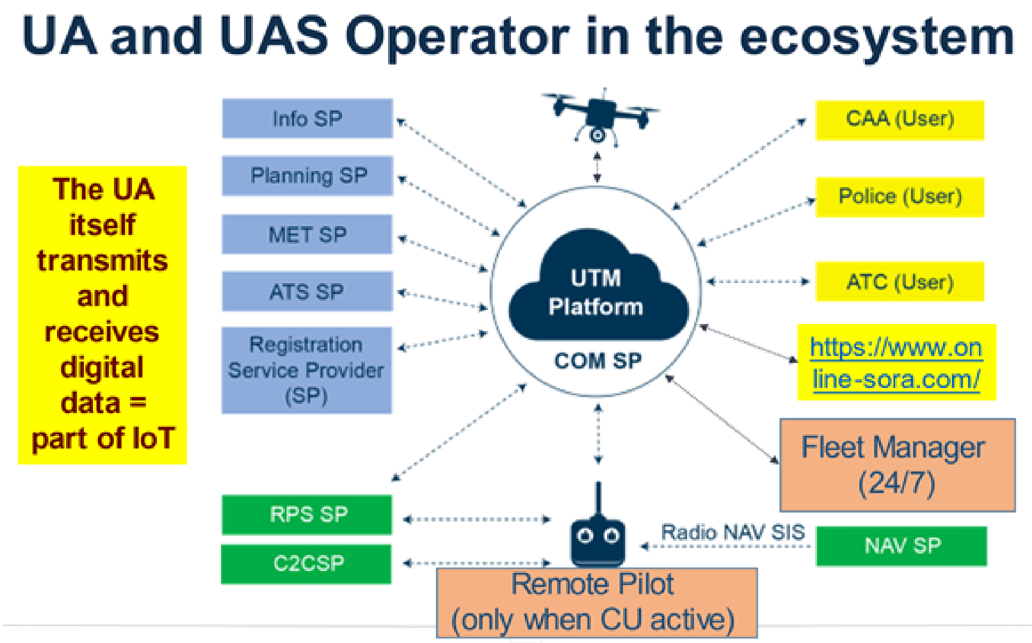

Figure A4 – UA and UAS Operator in the ecosystem

5. The UAM ecosystem

Several entities depicted in the previous figure, including the UA and the CU or ITs providing U-space services, may exchange digital information without human intervention. This means that the envisaged digital ecosystem is already part of the Internet of the Things (IoT) which is the key feature of the so-called 4th industrial revolution, the main stages of which are represented in Figure A5.

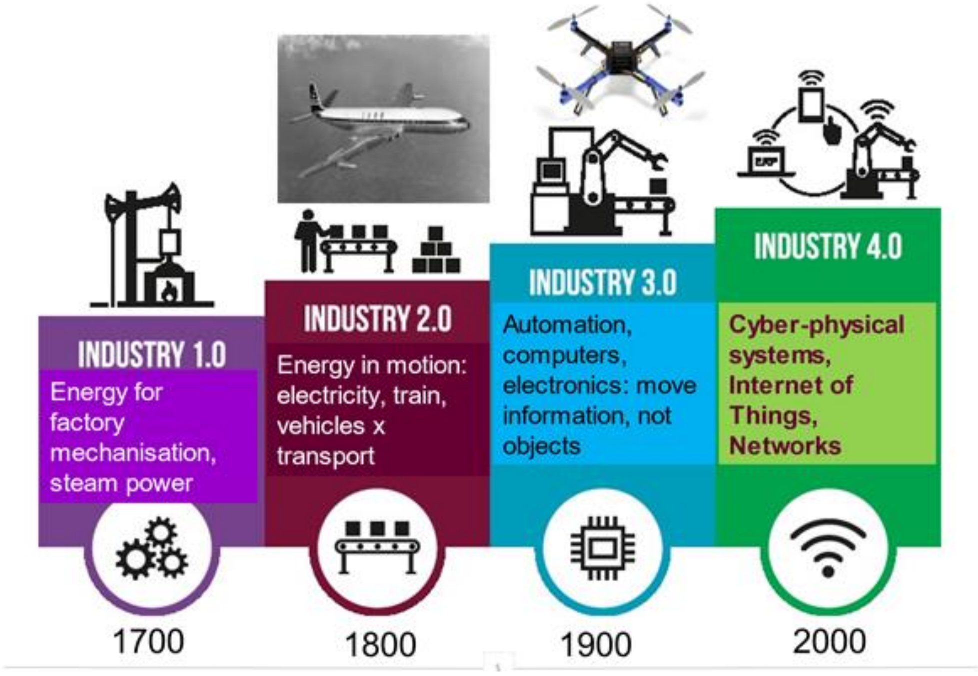

Figure A5 – Stages of the industrial revolutions

The digital ecosystem should hence harmonise several components, such as:

a. The legally binding regulations;
b. The supporting technology and related industry standards;
c. Operators of manned and unmanned aircraft, which may connect through respective IT entities (e.g. the work position of the Fleet Manager);
d. Several USSPs;
e. Safety and quality of involved organisations;
f. And also, entities in the IoT, including the UA, the CU and also the vertiport, which is envisaged in draft ISO 5491 to automatically exchange data with the UA without human intervention.

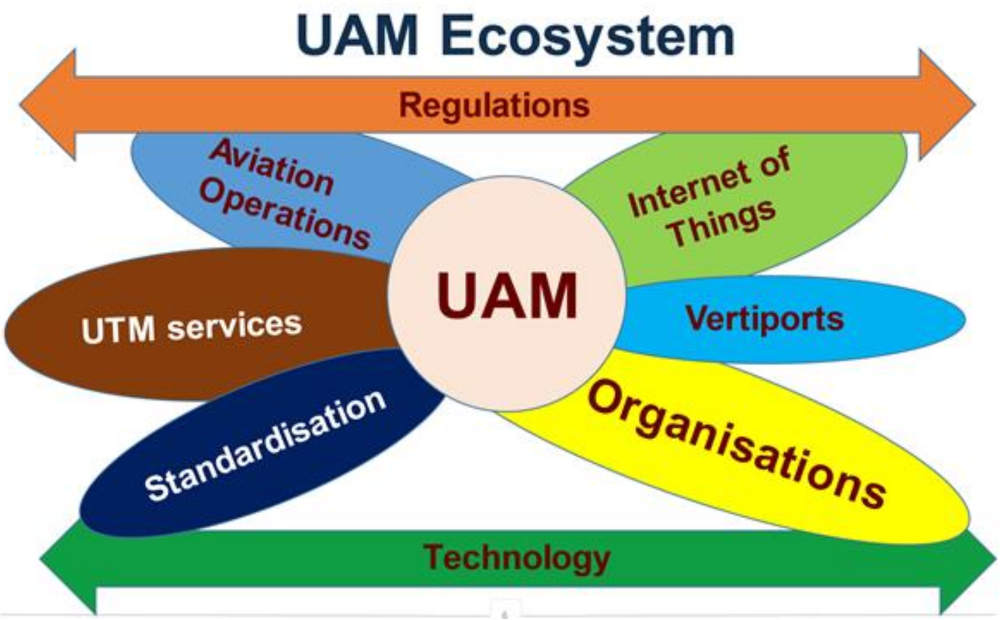

Figure A6 – Components of the UAM ecosystem

The EC Regulation 2021/664 lists only 4 mandatory (plus CIS) and two optional services that are expected to be provisioned by January 26th 2023. Nevertheless, the project CORUS[12] has identified a total of 25 possible digital services. This number further increased to 30, in ISO DIS 23629-12.

It may be interesting to note that, in that standard, the taxonomy of the 30 UTM services comprises three categories, which are shown in Table A2.

Term	Definition
Safety-critical	UTM service providing functions that, if lost or degraded, or as a result of incorrect or inadvertent operation, would result in catastrophic consequences
Safety-related	UTM service providing functions that have the potential to contribute to the violation of or achievement of a safety goal, but whose loss of degradation would not in itself produce catastrophic consequences
OPS support	Web-based tools and information provided by a SP to an UAS operator or its staff, to support safe and efficient planning and execution of a flight mission, as well as and post-flight activities.

Table A2 – Categories of UTM services according to ISO DIS 23629-12

While safety-critical services may be regulated by the aviation authorities, safety-related and operation support might be implemented even in the absence of specific regulations.

In any case, the ICAO Safety Management Manual (Doc 9859, 4th edition of 2018) highlights that for the safety of contemporary aviation, we have to look not only at technology and human errors but also at teams and organisations as well as, while digital exchanges grow, to the 'total system' in which the responsibility of actors originating and exchanging data should be clearly defined.

Aware of the relevance of the organisation, ISO is currently developing a suite of voluntary industry standards, covering virtually all actors involved in the digital ecosystem, as is shown in Table A3.

#	Scope
EN 9100 & ISO 21384-2	Design and Production organizations
ISO 21384-3	UAS Operators and Command and Control (C2 link) Communication Service Provider (C2CSP)
ISO 23629-12	30 UTM services are grouped into three risk categories

[12] https://www.eurocontrol.int/project/concept-operations-european-utm-systems

ISO 23665	Training organisations for RPs
ISO 5015-2	Vertiport operators grouped into three risk categories

Table A3 – ISO standards under development about actors of the digital UAM ecosystem

6. Stakeholders Engaged

Authorities

- Civil Aviation Authority
- Military Authority
- Local authorities (e.g. Prefect, Municipality or Geo-zone manager)
- Authorised viewer (user) of air situation (e.g. Police or other law enforcement agency)
- Other authorities

Aviation user (if any)

- Pilot of manned aircraft

Service Providers

1. Manufactures (i.e. designers and producers) of drones and other aviation entities

- Drone Manufacturer (e.g. established in the EU)
- Drone Manufacturer Representative (e.g. of a manufacturer established in a third country)
- Airport Operator
- Vertiport operator (e.g. based on ISO 5015-2)
- Training Organisations for remote pilots and other personnel involved in flight operations
- Command and Control data link service provider (C2CSP, mentioned in draft Part IV to Annex 6 to the Chicago Convention and in 2nd edition of ISO 21384-3)

2. Providers of classical ATM/ANS services based on Reg. 2017/373

- Aeronautical Information Management Providers (AIMP)
- Weather Data SP
- Navigation SP (e.g. EGNOS)
- Air Traffic Service Provider (ATSP) (e.g. the control tower)

3. Emerging U-Space Service Providers (USSP) based on Regulation 2021/664 complemented by draft ISO 23639-12

- Registration Service Provider (including updates)
- Common Information Service (CIS) Provider (distributed or centralised in every country)
- Drone aeronautical information manager
- Drone specific aeronautical information originator
- Flight Clearance (Authorisation) service
- U-space Communication Service Provider (e.g. LTE or 5G)

- Network Tracking (Surveillance) Service Provider
- Dynamic airspace capacity service
- U-space Service Providers (USSP)
- USSP Conflict management

4. Operation support Service Providers, based on Annex 3 of ISO 23629-12

- Accident and Incident Reporting Service Provider
- Digital Logbook Service Provider
- Legal Recording Service Provider
- Maintenance Management (e.g. https://www.integraerospace.it/about-us/?lang=en)
- Operational Plan Preparation (data provided directly to the UAS operator without intermediary U-space provider)
- Risk Analysis Assistance (e.g. SAMWISE by EuroUSC Italia https://www.online-sora.com/)

5. Service providers not related to flight operations

- Critical infrastructure Security management
- Insurers
- Pharmacies
- Logistic organisations

UAS Operator

- UAS operator (e.g. Fleet Manager responsible to plan and order the initiation of an operation)
- Remote Pilot and her/his Command Unit
- On-board Automation
- Other remote crew
- Drone owner

Other Stakeholders

- Operation Customer
- Citizens
- EASA (e.g. repository established by Art. 74 of Regulation 2018/1139)
- JARUS
- European Institutions
- Universities and academic institutions
- Research projects
- Drone associations
- Flight Model Clubs
- Specialised press

7. UTM Services

Operation safety objectives (OSO) #13 in SORA requires that the UAS operator verifies that the “external services” supporting the operation are suitable for use. No further details are provided in

SORA. Therefore, legislative documents and international standards (e.g. 2021/664 and ISO 23629-12) are analysed to identify the list of such services, see Table A4.

Safety-critical UTM services	Acronym	Description	U-Phase
Aeronautical Information Management for UAS (Common Information Service)	AIMU (CIS)	Ensure the exchange of static and dynamic information among all involved UTM SPs, vertiport operators and other Air Navigation Service Providers, as necessary for safe operations. In a volume of airspace where manned and unmanned aviation coexist.	U2 (Common Info Service by 2021/664)
Collaborative interface with ATC	CIA	Provides automated digital means (e.g. app) for UAS crews to communicate with ATS, different from VHF radiotelephony, when flight is in controlled airspace.	U3
Conformance Monitoring Service	CMS	a) Ensures that the aircraft to be operated in the UTM DOC have adequate technical capabilities for utilising the necessary UTM services and for exchanging the required information within the airspace being flown; and b) Ensure that UA, during their operations, comply with the clearances received through FCS (Flight Clearance Service).	U1 (optional by 2021/664)
Dynamic (airspace) Capacity Management Service	DCM	a) Calculates the traffic accommodation capacity in the DOC based on environmental and UTM services availability and provides this information to FCS, vertiport operators and to authorised UTM users. b) Activates and deactivates temporary segregated areas or other airspace structures in its DOC.	U3
Flight (Authorisation) Clearance Service	FCS	Provides means for: a) UAS operators to enter respective operation plans through web-based tools; b) Confirmation of completeness and acceptability of the operation plan; and c) Before take-off, authorisation to the UAS operator to enter the UTM airspace under the terms and conditions specified by the FCS Provider in the clearance.	U1 (mandatory by 2021/664)
Geo-Awareness Service	GAW	Provides to UAS operators and their crews during the flight, including the pre-flight phase: a) information related to geographical zones in which UAS operations are permitted, subject to certain conditions or prohibited, based on decisions by the competent authorities; and b) relevant data from the AIMU (Aeronautical Information Management for UAS), to support the UAS geo-awareness functions.	U1 (mandatory by 2021/664)

Real-time GIS	RGIS	Provide real time information of vertical distance above ground during the flight, including above tall obstacles, based on accurate cartography, DTM / DSM, and 3D model of the terrestrial obstacles.	NA
Tactical Conflict Management Service	TCM	Provides management of conflicting flights in the UTM DOC at tactical level (after take-off), based on real time information provided by other UTM services, such as CMS, NIS and TRS.	U3
Tracking Service	TRS	Determine the respective positions, vector and intentions of manned and unmanned aircraft based on telemetry messages from aircraft, flight plans and identification information and distribute this information to authorised UTM users including vertiport operators, or other UTM SPs, for the purpose of maintaining safe mutual distances.	U2
Traffic Information Service	TIS	Provide the UAS operator with information on other known or observed manned or unmanned air traffic which may be in proximity to the position or intended route of the UA flight to alert and to help the UAS remote crew to avoid a collision.	U1 (mandatory by 2021/664
Vertical Alert Service	VALS	Alert manned and unmanned aircraft on present vertical distance above the common geodetic reference system from ground, when such distance becomes too small.	NA
Safety-related UTM services	**Acronym**	**Description**	**U-Phase**
Communication Coverage Information Service	CCI	Provides information on UTM COM (communication) coverage (excluding VHF radio-telephony coverage)	U2
Electro-Magnetic Interference Information Service	EMS	a) Provides information on known electromagnetic interferences to radio navigation signals or other signals supporting safe flight in its DOC, during the flight planning phase and during the flight; and b) Provides any issued EM alerts to LRS Provider.	U2
Electronic Registration Service	ERG	Establishes and maintains a registry database, accessible by UAS owners or operators through web-based tools and provides this information to authorised UTM SPs or other UTM users (e.g. law enforcement authorities)	NA
Geospatial Information Service	GIS	Provides UTM users and other UTM SPs geospatial information, including terrain, buildings and other obstacles, useful to plan operations before submission of the operation plan.	U2
Navigation Coverage Information Service	NCI	Provides information on coverage of radio navigation signals	U2

Network (Electronic) Identification Service	NIS	Continuously receive and process the information transmitted by the (direct) remote (electronic) identification (E-ID) function of the UAS, throughout the whole duration of the UA flight and distribute it to authorised UTM users or other UTM SPs, for security and enforcement purposes.	U1 (mandatory by 2021/664
Population Density Information Service	PDI	Provides UAS operators, other UTM SPs and competent authorities with static or dynamic maps on the density of population in each portion of its DOC	U2
Procedural Interface with ATC	PIA	Provides automated digital means (e.g. app) for UAS crews to communicate with ATS, different from VHF radiotelephony, when flight intends to enter controlled airspace, between submission of the operation plan and take-off.	U2
Strategic Conflict Management Service	SCM	Provides traffic conflict management assistance to a UA flight before take-off at strategic level (when the operation plan is submitted): a) comparing the proposed plan to other known operation plans; b) if necessary, developing a de-confliction solution in time, route or height; and c) communicating the solution to the involved UAS operator and vertiport operators.	U2
UTM Communication Service	LCS	Provides communication services for UTM purposes connecting all UTM users, UTM SPs and involved aircraft with the UTM Platform, through links or networks among fixed points on the ground and through terrestrial or satellite mobile communication services with aircraft.	NA
UTM Route Design Service	URD	Designs, documents, validates, maintains and periodically reviews air routes necessary for the safety, regularity and efficiency of air navigation of unmanned aircraft in the UTM context. The UTM routes may also be accessible to properly equipped manned aircraft, meeting the Required Navigation Performance (RNP) specified for the route	NA
Vertical Conversion Service	VCS	Provide automatic translation and readings of barometric height to altitude (i.e. conversion of reference systems, from barometric to geodetic or vice-versa)	NA

Weather Information Service	WIS	Collects, store and process weather information from trusted sources and distributes relevant information on forecast and actual weather to support operational decisions by: a) other UTM actors including UTM SPs and vertiport operators; and b) UAS operators either before or during the flight.	U1 (Optional by 2021/664
Operation support services	**Acronym**	**Description**	**U-Phase**
Accident and Incident Reporting Service	ARS	Provides web-based tools to facilitate mandatory and voluntary reporting of safety, security or privacy related occurrences and transmits these reports to the involved organisation and to competent authorities.	U2
Digital Logbook Service	DLB	a) Provides UAS operators and their crews, web-based tools to log, as minimum, the information required by law or regulations to record the activity; and b) Collects and stores the logged information; and c) Distributes this information to involved operators, crews or competent authorities.	U2
Legal Recording Service	LRS	Receives and stores for three months, unless a different duration is mandated by laws or regulation, all events and communications related to a UA flight for the purpose of possible investigation by involved organisation or authorities competent for aviation safety, security or privacy.	U2
Maintenance Management	MMN	Provides to UAS operators web-based tools to support development and application of UAS Maintenance Programmes	NA
Operational Plan Preparation	OPP	Based on information provided by other UTM SPs, provides web-based tools to UAS operators for preparation and optimisation of the operation plan before submission.	U2
Risk Analysis Assistance	RAA	Provides to UAS operators and to civil aviation authorities web-based tools to support development and evaluation of risk assessments prior to operations	U2, available[13]

Table A4 – UTM Services

[13] https://www.online-sora.com/

8. Concept of Operations (CONOPS)

A version of the Concept of Operations is necessary to develop for every intended series of UAS operations, although some information (e.g., operator and geographical area) may be common across several UAS missions.

The CONOPS shall be based on the content required by EASA AMC 1 to Art. 11 of 2019/947; otherwise, no authorisation could be obtained from the CAA, since Regulation 947, for this aspect is applicable since December 31st 2020 and EU Member States cannot adopt different rules. It should, however, be noticed that State flights (e.g. by the Fire brigade9 are not subject to these EU common rules but subject to national legislation. Should it be so elected, CONOPS and risk assessment for State flights could, however, be based on the EASA guidance.

Additionally, the CONOPS would give evidence whether an intended operation belongs or not to the specific category and whether or not covered by a Standard Scenario (STS) or re-Defined Risk Assessment (PDRA). However, since STS require a CE mark and class label (either C5 or C6) on the drone since these are not yet available on the market, applying the STS may prove difficult. Conversely, PDRA does not require the CE mark and could hence be exploited even in the short term.

It is applicable also to fully autonomous operations. It is necessary to have the CONOPS completed in time to apply and to obtain the regulatory authorisation from the CAA before the actual flights would take place.

Experience suggests giving the CAA 2 or 3 months to authorise the operation unless it would be particularly challenging.

Below are those UAM elements that are used to develop the CONOPS.

UAS Manufacturer

UAS Model

UAS serial number(s)

UAS software Operating System

Avionics

Navigation

Altimetry

Identification technology (Electronic Conspicuity means)

Connectivity Method/Type

UAS Sensors

UAS Mission-specific Payload

Endurance

4D trajectory

The Class of UAS

- C0
- C1
- C2
- C3
- C4
- C5
- C6
- UAS not belonging to any of the Classes listed in Regulation 2019/945

Type of UAS Operation Category

- Open A1/C0
- Open A1/C1
- Open A2
- Open A3
- Specific/STS
- Specific/PDRA
- Specific/SORA required
- Certified

Mode of UAS Operation

- Remotely-controlled
- Visual Line of Sight (VLOS)
- Extended Visual Line of Sight (E-VLOS)
- Beyond Visual Line of Sight (BVLOS)
- Automated flight (AF)
- Follow me
- Automated flight with connection to U-space (AFU)
- Automated Flight with No connection to U-space (AFN)
- Remotely supervised flight (RSF)
- Swarms
- Formation Flights
- Detect and Avoid

Flight rules

- Visual Flight Rules (VFR)
- Instrument Flight Rules (IFR)
- BVLOS below 400 ft AGL

Airspace Type

- Traditional airspace class (as established in 923/2012): A to G. This includes Za inside ATZ or CTR, above the obstacle limitation surfaces, in which case the drone shall follow the ATS procedures established therein.
- Traditional non classified airspace (i.e. Danger, Prohibited or Restricted)
- X: No conflict resolution service is offered.
- Y: Only pre-flight conflict resolution is offered.
- Zu: Pre-flight conflict resolution and in-flight separation are offered in the U-space airspace above urban areas (i.e. to enter manned aircraft need to be electronically conspicuous).

Mandatory Requirements Implementation

The required mitigations will be defined following the application of the SORA methodology recommended by EASA AMC1 to Art. 11 of Regulation 2021/947.

To implement such methodology, the RAA digital service is available, SAMWISE by EuroUSC Italia:

https://www.online-sora.com/

Ground Risk

- Populated area
- Sparsely populated area
- Non-populated area

Airport Related positioning

- Near Airport, but outside controlled airspace
- Inside control zone (CTR)
- Inside controlled Aerodrome Traffic Zones (ATZ)
- Movement area
- Airport, outside movement area

Traffic Density

At the maximum height envisaged for the operation or just above (e.g. departure trajectories from Linate, almost above HSR):

- Very low
- Low
- Medium
- High
- Very high

USSP system

Through which access to UTM may be granted (if required)

UTM System

(e.g. developed by Airbus, AirMap, Altitude Angels, Astra UTM, etc.)

Common Information Service (CIS)

Fleet Management System

Communication Infrastructure

Command and control data link may be in direct Radio Line-of-Sight between the drone and the Command Unit of the Remote Pilot. In this case, no external communication service is necessary to operate the drone. Conversely, a COM SP may be necessary to fly longer distances. This could be provided by 5G, LTE or satellite.

In any case, for fleet management and to connect several digital platforms, COM services are absolutely necessary. These services may provide mobile communication with the drone in flight (e.g.

Network Electronic Identification) or interconnection through ground lines (e.g. between the fleet manager working position and the RAA service).

Navigation Infrastructure

Surveillance Infrastructure

Weather System

ATS Units (e.g. Aerodrome tower)

Ground Traffic Management System

Water Traffic Management System

Railway Traffic Management System

9. Other Elements

Other UAM elements are such that are required to support the UAS operation, benefit from it, integrate it into the business processes or a supply chain.

U-Space Adapter

The concept of the U-Space Adapter had been proposed by 5G!Drones project. The idea is to eliminate the complexity of the possible integration with UTM systems under the lack of technical specification by introducing the holistic view at the adapter as a black box that ensues interoperability while exposing the required interface.

IoT Architecture

To identify users and services potentially involved in the UAS operation.

Digital Twin Implementation

Security Systems

Server Infrastructure

- Cloud SP
    - Azure
    - AWS
    - Google Cloud
    - Other
- Physical

Computing Infrastructure

- Cloud SP
    - Azure
    - AWS
    - Google Cloud
    - Other
- Physical
- Edge

GUI and Visualisation Infrastructure

- Service Provider
- Cloud SP
    - Azure
    - AWS
    - Google Cloud
    - Other
- Physical

Fixed Sensors

Autonomous Vehicles

Other End-user Devices, Gadgets and Infrastructure Elements

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Appendix 2 – EHEH TWR – HTCE – UAM Covenant (concept)

Starting March 26th 2022 there will be frequent UAS flights on the grounds of the High Tech Campus. The High Tech Campus wants to carry out tests with autonomous drones. To facilitate this efficiently for both the operator and Air Traffic Control, the following working agreements have been drawn up.

UAS operators are responsible for obtaining the necessary permits and certifications from IL&T. In addition, the UAS operator is responsible for operating within the established minima.

Dimensions horizontally:

- 51.415588695860954, 5.46419620513916;
- 51.41201544453357, 5.446171760559082;
- 51.405885396668346, 5.449433326721191;
- 51.406059404992746, 5.462028980255126.

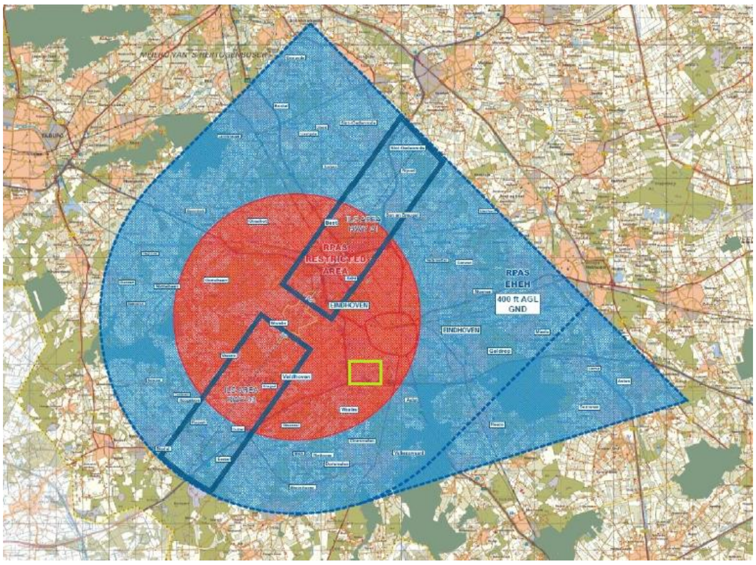
Dimensions vertically:

- 150 m (500 ft) above sea level (AMSL);
- 120 m (400 ft) above ground level (AGL).

- Drone box
Green - Flight area (0-400ft. AGL)
Dark-green line is the HTCE fence
Yellow - Contingency volume

NoGo area within the flight volume
Red - Buildings

Minimum distance of 25+ meters to objects:
Blue - Road



Within opening hours EHEH (0700-2400):

- UAS operator calls TWR (040-2896451) before he wants to use the HTC area.
- TWR grants permission to UAS operator with any additional arrangements.
- UAS operator ensures that they can be reached by phone and that this phone number is continuously monitored during the flight.
- TWR contacts UAS operator to stop the flight if this is required to ensure (flight) safety.
- UAS operator signs off at TWR (040-2896451) after completion of the last flight.
- In case of early closure of TWR, TWR contacts UAS operator to indicate that EHEH is going to close and that they should convert to DutchMill.

Outside opening hours EHEH (2400-0700):

- UAS operator listens during UAS operations DutchMill VFR/INFO on frequency 132.350 to obtain situational awareness.
- At 0700lt the UAS operator calls TWR to ask for permission to use the HTC area.

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