Universitat Autònoma de Barcelona

# U- space configuration impact on safety, capacity and flexibility

Memòria del Treball Fi de Grau

en

Gestió Aeronàutica

realitzat per

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**Títol del Treball Fi de Grau:**
**La configuració U-space impacta en la seguretat, capacitat i flexibilitat**
**La configuración U-space impacta en la seguridad, capacidad y flexibilidad**
**U-space configuration impact on safety, capacity and flexibility**

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**Paraules clau**

- Català: Configuració de l'espai aeri, Corredors, Ruta lliure, UAV, U-space
- Castellà: Configuración del espacio aéreo, Corredores, Ruta libre, UAV, U-space
- Anglès: Airspace configuration, Corridors, Free Routing, UAV, U-space



**Resum del Treball Fi de Grau**

- Català:

  El present treball de final de grau està enfocat a l'estudi del concepte U-space, els seus actuals i futurs serveis i procediments per a permetre l'accés de UAVs a l'espai aeri de manera segura, eficient i flexible, i l'anàlisi dels resultats de simulacions estudiant com a diferents configuracions de l'espai aeri impacten en la flexibilitat i capacitat del sistema.

- Castellà:

  El presente trabajo de final de grado está enfocado al estudio del concepto U-space, sus actuales y futuros servicios y procedimientos para permitir el acceso de UAVs al espacio aéreo de forma segura, eficiente y flexible, y el análisis de los resultados de simulaciones estudiando como diferentes configuraciones del espacio aéreo impactan en la flexibilidad y capacidad del sistema.

- Anglès:

  The present final degree study is focused on the exploration of the U-space concept, its current and future services and procedures to allow the access of UAVs to the airspace in a safe, efficient and flexible way, and the analysis of the results of simulations studying how different airspace configurations impact on the flexibility and capacity of the system.

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*- The challenge is designing a system that can remain relevant as technology progresses and market needs mature without knowing what that future will look like -*

# 1. Introduction

This project arises from the interest in being able to obtain clearly results on the simulation analysis of the Barcelona's very low-level airspace configuration. It is, therefore,
of a work with a mainly analytical character based on the study state of the art of the current development of the different actors, services and technology necessary to achieve a correct implementation of drones in urban spaces.

## Problem Statement

Have you ever wondered what the skies will look like 10 or 15 years from now?
In recent years the drone sector has experienced extraordinary evolution, not only in the global market, but also in the national market. The increasing number of applications in the field civil, possible through continuous technological development of these aircraft point to explosive growth at medium term. The usefulness of drones in the future is not so far from what thousands of people imagined. Currently, there are large technology companies that have already invested in this type of tool, such as Walmart, Facebook, Amazon and Google, also real estate companies, agricultural industry, deliveries, cinema, photography, construction and of course police and fire departments.

We are, therefore, facing a sector with enormous potential for expansion, in which innovation and continuous technological advance is configured as fundamental elements to realize its extraordinary development prospects.

As a result of this new way of flying and the expectations that creates all the possibilities of the sector, several questions of necessary importance arise which have been posed for several years ago from different countries, such as the US, China or Japan. How are these unmanned aircraft going to be managed? How can we integrate a high number of drones in an urban environment? How can we have drones and planes flying at the same time? And the most important, how can we do it safely?

To make all this possible, it is necessary an Unmanned Traffic Management system, which in the case of Europe it's named **U-space**.

## Goals

Based on the different questions that arise in relation to the integration of drones in an urban environment, the main goal of the project is to make a balance between safety and capacity of the different airspace configurations of Barcelona's low-level airspace.

In order to make this comparison, the following objectives are set:

- Collect lessons learned from the U-space projects and demonstrations
- Analyze traffic expectations of the growth and evolution of unmanned air traffic for the coming years.
- Assessment of the types of risk involved
- Study how different airspace configuration will impact flexibility and system capacity and under which safety conditions.
- To determine public acceptance in the city of Barcelona
- To determine actual feasibility of the U-space concept.

How are these objectives going to be addressed?

- Study of the art of the publications provided by SESAR JU program
- Creating simulation scenarios of future Barcelona's U-space configuration using DronAS tool.
- Analyzing simulation results:
  - Number of requested/scheduled/canceled/accepted missions per hour
  - Number of detected conflicts.

# 2. The European UTM: U-space

Within all the concepts and technologies that are currently being developed in the field of drones, one of the most relevant is the future system of low-altitude air traffic management, which is intended to be controlled by an Unmanned Traffic Management (UTM) system , which it will allow efficient and orderly management the large volume of civilian unmanned aircraft that it is estimated that they will be able to use the airspace in the medium-long term.

The UTM concept it’s been developed by European Commission and Single European Sky ATM Research Joint Undertaking [1] (SESAR JU) which they have called U-space. This new segregation of the airspace involves the creation of a set of methods, processes and tools to coordinate the air traffic of unmanned aircraft with manned aircraft allowing drones to circulate in the most automated and safest way possible in areas where coordination is required, either with other drones or with ATC. It must be considered as a flexible airspace, permitting different types of operations, adapting routes depending on the capacity of the scenario in which the unmanned aircraft is located and always ensuring the safety of vehicles, infrastructure and citizens.

The system is oriented of ensuring the smooth operation of drones in all operating environments, and in all types of airspace, but not limited to very low-level (VLL) airspace. This results in an airspace management which allows a lot of freedom at low density, but little freedom at high density. Free conflict aircraft operations will be ensured on a strategic level by the U-space system. In the proposed U-space system, control of air traffic would, in principle, be decentralized. The U-space system would handle information provision (including traffic data and proximity warnings), airspace management and traffic flow control.

Following the U-space blueprint, published on 2017, SESAR JU has initialized 19 projects of demonstration activities, in different European countries with different national authorities, regulatory organizations, corportations and universities, related to initial services such as CORUS [33], DOMUS [34], EuroDRONE [35], PODIUM[36], and many others [2]; the exploration of necessary future implementations and the development of the U-space Concept of Operations [3] (CORUS by Eurocontrol) which aims to address very-low level airspace and the surrounding airspace of an airport. These projects provide a lot of examples where foundation services are already available although the question of to what degree it may be possible to operate hundreds or thousands of drones occupying the same airspace without conflict remains unanswered.

Among the most important functions of the system U-space are:

- Ensure fair and affordable access to the U-space airspace to all airspace users
- Management of the low-level airspace congestion
- Safe operation of drones, providing an airspace management system and defining possible physical limitations of intrusion (geo-fencing).
- Obstacle separation and adverse weather forecast for the safe operation of drones.
- Continuous monitoring of flights.
- Prevent collision between UAS and manned aviation
- Expedite and maintain an orderly flow of UAS traffic;
- Provide information and instructions relevant for the safe and efficient conduct of UAS operations;
- Notify appropriate organizations regarding emergency or abnormal situations with the UAS which may endanger people and goods on the ground or manned aviation
- Ensure that environmental, security and privacy requirements

## General concepts

**What is U-space?**

> *"A set of new services relying on a high level of digitalization and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones"…"An enabling framework to facilitate any kind of routine mission in any category of airspace, from the inspection of infrastructure or delivery of goods to more complex future applications such as urban air mobility*" [4]

Drone, UAV, UAS, RPA and RPAS. What's the difference?

The most widespread and well-known word among the population is "drone", which is the popular name for unmanned aircraft. The following references differ in the way they are used, for example a UAV does not carry passengers but may or may not be piloted by a pilot. In other words, the system that controls it can perfectly be a computer, where the human factor does not intervene.

UAS is the generic term for the manned aircraft system. Unlike the UAV which refers exclusively to the aircraft itself, the system integrates the device, the communications link and the ground station.

RPA Term for unmanned aircraft that are operated by remote control. Applied mainly to devices intended for commercial aviation. Finally, RPAS is used to designate the complete system (aircraft, communication link and ground station) of the unmanned aircraft that are operated by remote control.

**Glossary**

| | |
|---|---|
| *AGL* | Above Ground Level |
| *ATC* | Air Traffic Control |
| *ATM* | Air Traffic Management |
| *ATZ* | Aerodrome Traffic Zone |
| *BVLOS* | Beyond Visual Line of Sight |
| *CONOPS* | Concept of Operations |
| *D&A / DAA* | Detect and Avoid |
| *EASA* | European Aviation Safety Agency |
| *JARUS* | Joint Authority on Rulemaking for Unmanned Systems |
| *NOTAM* | Notice to Airmen |
| *RPA* | Remotely Piloted Aircraft |

| | |
|---|---|
| *RPAS* | Remote Piloted Aircraft System |
| *SERA* | Standard European Rules of the Air |
| *SESAR* | Single European Sky ATM Research |
| *SORA* | Standard Operational Risk Assessment |
| *UAS* | Unmanned Aircraft System |
| *UAV* | Unmanned Aerial Vehicle |
| *UTM* | Unmanned Traffic Management |
| *VFR* | Visual flight rules |
| *VLL* | Very Low Level |
| *VLOS* | Visual Line Of Sight |

## Services

U-space is scheduled for a gradual rollout in four stages, U1-U4. U1 services are in use since 2019 and pre-operational demonstrations of U2 were taking in place in the same moment. The first results of U3-U4 research were completed in the last period of 2019 and expected to have a better approach in 2020.

While this document does not specify technologies associated with these services, its purpose is to provide suggested types of services.

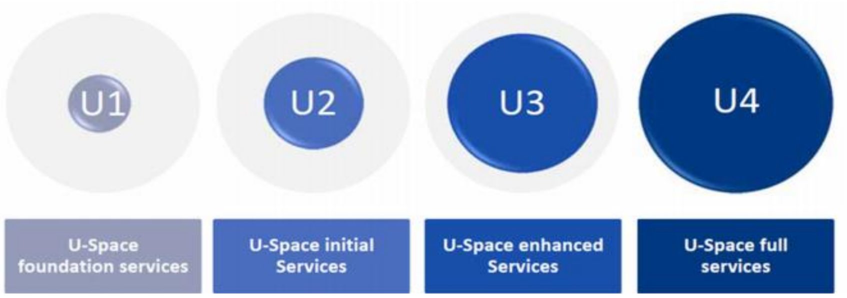


*Figure 1. U-space stages, evolution of services implementation*

*The following exposed services are drawn primarily from Concept of Operation (ConOps) for U-space [5] and the European ATM Master Plan [6].*

### U1. U-space Foundation Services

Target: 2019

These services allow the connection and identification of users and devices, as well as the integration of the geofencing system. This is the first phase developed after the approval of the new European regulation on drones in 2019.

**Identification and Tracking**

- **e-registration**
  The service enables the registration of the operator, drone and pilot with the appropriate information according to Regulation ((EU) 2019/947) [7].

- **e-identification**
  The service allows the identification of a drone operator from a drone in operation which provides access to the information stored in the registry based on an identifier emitted electronically by the drone, this includes the localization of the drones (position and timestamp).

**Airspace Management / Geofencing**

- **Pre-tactical geofencing**
  Provides the operator with geo-information about predefined restricted areas (prisons, etc.) and available aeronautical information (NOTAMs) used during the flight preparation allowing the drone operator to make use of the geofencing capability of the drone.

- **Drone Aeronautical Information Management**
  This service provides the operator with relevant aeronautical information for drone operations. It will connect to the Aeronautical information service (AIS) to guarantee coherent information provision for manned and unmanned operators

## U2. U-space Initial Services

Target: 2022 - 2025

These services will provide support for operations management drones, allowing planning, approval and flight tracking, overflight permits, device tracking, dynamic airspace information, and procedural air traffic control interfaces providing real-time information and the necessary interfaces with ATC.

### Identification and Tracking

- **Registration Assistance**
  Services may be offered to assist such routine registrations, presenting a user interface that is simplified and/or partly filled in with standard information.

- **Tracking (Position report submission)**
  The tracking service cannot be available unless U-space receives a position report in real-time. Position report submission will involve the drone or the remote piloting station or some specific ground equipment being connected to U-space, possibly by mobile internet. It Will be an obligation in some airspaces and optional in all others, they could originate as e-Identification signals, received at the remote piloting station and forwarded to U-space.

- **Surveillance Data Exchange**
  This service allows the information exchange between the tracking service and other sources or consumers of tracks such as Primary radar and drone detection similar systems, for example used at airports.

### Airspace Management / Geo-Fencing

- **Tactical Geo-Fencing**
  The service sends a message to the drone user/operator if a drone flies through the prohibited area, and if it's necessary, warn other drones/aircraft in the affected geo-fence.

### Mission Management

- **Operation plan preparation / optimisation**
  Submits an operation plan to the Drone operation plan processing service

- **Operation Plan processing**
  This service receives operation plans and uses these for a number of safety-related activities maintaining a pool of data containing the histories of all submitted flights that have not yet been archived.

- **Risk Analysis Assistance**
  Preparation of Specific operations involves SORA (Specific Operational Risk Assessment) [13] which involves analyzing risks associated with the operation using the draft operation plan as well as information from the Drone Aeronautical Information Management service, various Environment services, and Traffic Information

### Conflict Management

- **Strategic Conflict Resolution**
  The Strategic conflict resolution service is invoked by the Drone operation plan processing service. It can be invoked because a new operation plan has been submitted or because an already submitted operation plan has changed. Strategic conflict resolution is before flight. The service has two phases. First it detects conflicts, then it proposes solutions.

**Emergency Management**

- **Emergency Management**
  This service receives emergency alerts from operators (e.g. loss of control), and informs relevant actors of the ecosystem.
  - Assistance to a drone pilot experiencing an emergency with his/her drone providing assistance information to manage the emergency situation (emergency landing)
  - Communication of emergent information to pilots, manned aviation or police.

- **Incident / Accident reporting**
  The service allows these reports to mention drone identifiers and operation plan identifiers in order to help the later investigation. The service shall maintain the reports for their whole life-cycle. The system shall be secure and give access only to authorized persons.

- **Citizen Reporting service**
  Allow citizens to report what they have observed when they believe incidents or accidents involving drones have occurred.

**Monitoring**

- **Monitoring**
  Retrieves data from the tracking service and combines it with information related to non-cooperative obstacles and vehicles to provide an air situation status report for authorities, service providers, and operators, including pilots.

- **Traffic Information**
  Provides the drone pilot or operator with traffic information and warnings about other flights – manned or unmanned - that may be of interest to the drone pilot.

- **Navigation Infrastructure Monitoring**
  The service to provide status information about navigation infrastructure. This service is used during operations.

- **Communication Infrastructure Monitoring**
  Provides status information about communication infrastructure. This service is used during operations and should give warnings of the degradation of communications infrastructure.

- **Legal Recording**
  Support accident and incident investigation. The service should record all inputs to U-space and allow the full state of the system at any moment to be determined, also can be used as a source of information for research and training.

- **Digital Logbook**
  Extracts information from the legal recordings to produce reports relevant for whoever is using the service. Drone operators and pilots will be able to see summaries of information for flights they have been involved in; start and end times, places, aircraft ID....

**Environment**

- **Weather Information**
  Provides drone operators with forecast and actual weather information either before or during the flight

- **Geospatial information service**
  Collects and provides relevant terrain map, buildings and obstacles for the drone operation.

- **Population density map**
  Collects and present relevant density map for the drone operation used to assess ground risk.

- **Electromagnetic interference information**
- **Navigation Coverage information**
- **Communication Coverage information**

**Interface with ATC**

- **Procedural interface with ATC**
  Service addressed to coordinate an entry of a flight into controlled airspace. The interface works before flight. ATC can accept or refuse the flight, if it's accepted ATC can describe the requirements and process to be followed for the flight-

## U3 U-space Advanced Services

Target: 2025-2030

**Geo-Fencing**

- **Dynamic Geo-fencing**
  The service will keep the drone up-to-date with geo-fencing information, even during flight.

**Mission Management**

- **Dynamic Capacity Management**
  Addressed to limit the number of flights in a particular volume of air by regulate demand to match capacity, or change the capacity to match demand.

**Conflict Management**

- **Tactical Conflict Resolution**

**Interface with ATC**

- **Collaborative interface with ATC**
  This service provides information to the operators or the drones to ensure separation management when flying. the drone may receive the information and this deconfliction is set for the in-flight phase.

## U4. U-space Full Services

Target: 2030 - ?

The services that offer integrated interfaces with manned aviation will become effective, the U-space will provide complete support, relying on a very high level of automation, connectivity and digitization both in the drone and in the U-space system.
Developing a detect and avoid system compatible with manned aviation should reduce the risk in all types of airspace enabling the development of all integrated services to the U-space.

## U-space Volumes

The division of the different operating zones is focused on the very low-level operations. When we talk about VLL airspace, ConOps [5] divides it into three different zones, X, Y and Z, differentiating between them according to the services offered in each one, and therefore which are the operations that can be carried out and its access and entry requirements.

The conflict resolution is if not the most, one of the most important purpose to motivate these volume divisions, hence reduce the probability of a collision.
Considering the numbers of drone flights expected, the ground and air risk, citizens acceptance factors and services needed the following division has been designed.

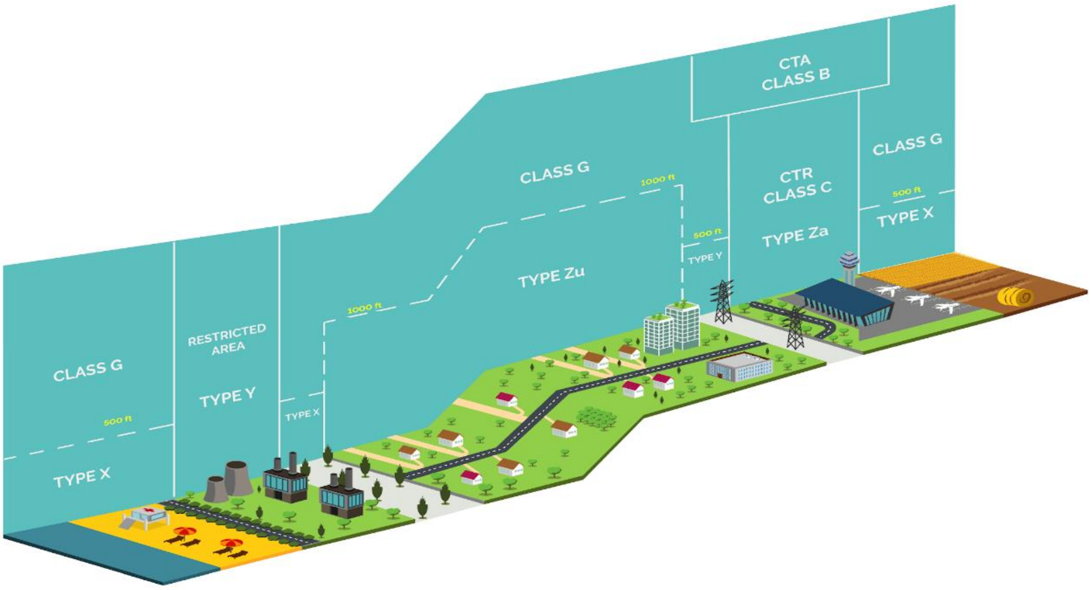


*Figure 2. U-space volume type distribution example*

### X Volume - "Conforming UAS operators"

Focused on non-populated areas and low demand for U-space services, either in cultivation fields, areas of the city where there are very open spaces, farms … Are thought to be used for open category operations as long as it's performed below 400-500 ft (120 - 150 m)

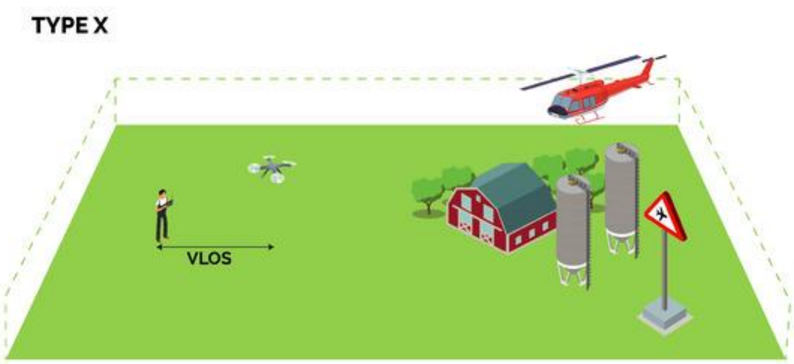


*Figure 3. U-space volume type X scenario*

This is the lowest risk volume with only a few basic requirements on the operator, the pilot or the drone to access.

- There is no conflict resolution and no operation plan is needed either.
- Pilot remains responsible for the correct separation
- Be aware of other airspace users
- VLOS flights are possible.
- Other types of operation as BVLOS in X require significant attention to air risk mitigation

### Y Volume - "Collaborating UAS operators"

Oriented to areas where there is significant air traffic or over a densely populated area which means a medium risk. The demand to fly BVLOS creates the necessity of this segregation, which may help to limitate few areas such as national parks, prisons, football stadiums, manufacture zones… This volume encompasses flights which conform to their plans have an acceptably low probability of encountering each other.

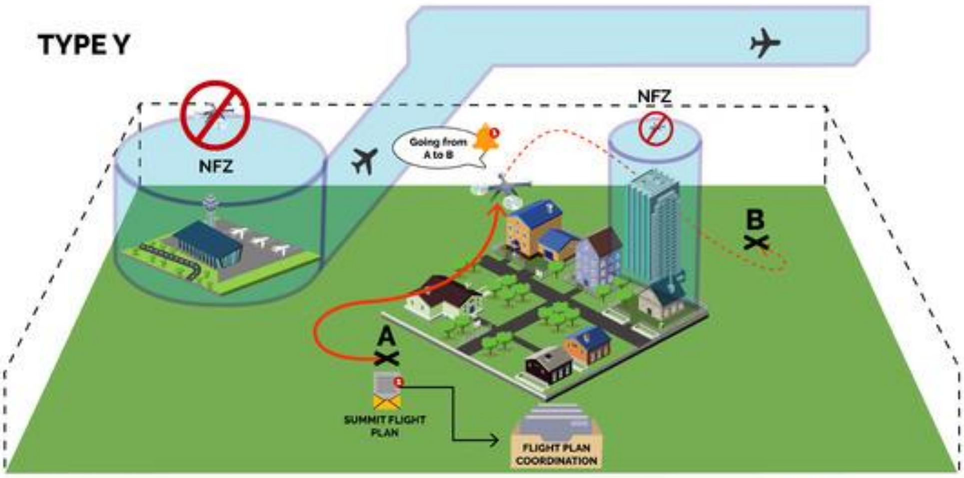


*Figure 4. U-space volume type Y scenario*

- Strategic conflict resolution before take-off. These pre-flight conflict resolutions will reduce the residual risk of collision to a very low level
- No tactical separation service offered.
- Traffic information
- Flight Restriction Zones

The access requirements to Y are the following:

- Approved operation plan.
- Remote piloting station connected to U-space
- Aircraft tracked
- Minimum performance requirement for position reporting: in some areas the reporting of start of flight and end of flight may be sufficient
- Drone operator responsible for ensuring position reports are sent on request.

**Z Volumes - “Coordinating UAS operators"**

Z volumes is intended to be the most higher density operations volume in areas where traffic demand exceeds the capacity of Y or there is more risk, therefore is the volume in which more services are allocated, more connectivity is needed and, above all, more organization.
Formalizing operations in this volume is the most complex and riskiest task, since the expected traffic is located in urban areas, which is where most flights are expected to take place. In this zone are allowed BVLOS as well as VLOS and automatic drone flight.

In this volume U-space should be fully integrated with ATM with centrally coordinated tracking & deconfliction and a tactical re-routing & capacity management service..

- Strategic (pre-flight) and tactical (In-flight) conflict resolution where only one entity is responsible for aircraft separation

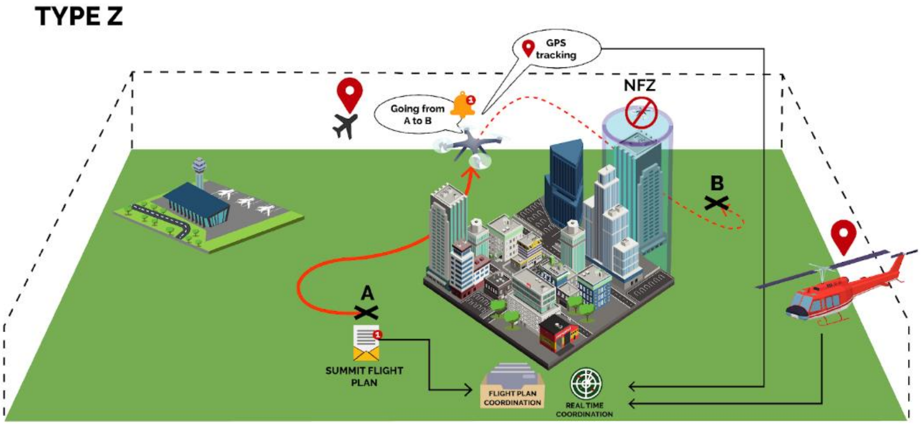


*Figure 5. U-space volume type Z scenario*

The access to Z requires:

- Approved operation plan
- Continuous connection from the pilot to U-space Z region.
- Submission of the position reports of the aircraft.

There is a differentiation within this volume that resides in the tactical conflict resolution service, if the separation is provisioned by U-space, the Z volume is named Zu, on the other hand, if air traffic controllers are in charge of providing the separation, then the volume is named as Za.

**Za - Controlled Airspace**

- ATCO in charge (tracking shown on ATC displays)
- Limited to a subset of services
- Flights planned in U-space, used to coordinate the entry and operation (FP can be used by ATC).
- Separation as if it were another aircraft taking into account micro weather due the smaller dimensions.
- Real-time communication needed between UAS and ATC.
- Tactical conflict resolution service provided by ATC
- U-space provides supporting services:
    - Situational awareness to ATC
    - Communication tools

Applications of Za might be runway and taxiway pavement inspection, FOD detection, lightning inspection, turnaround above aircrafts...

**Zu - Outside of aerodromes**

- Tactical conflict resolution provided by U-space software.
- U-space services help coordinate the UAS traffic providing conflict resolution during flight, from the ground.
- Aircraft Safety Bound created by a “bubble”

It’s possible to have Zu in uncontrolled and controlled airspace depending on the airspace above Zu. If it’s below A,B,C,D or E then, it’s controlled, and tactical conflict resolution service is provided by the U-space Service Provider (USSP ) where all the instructions must be followed.

If the classification is F or G it will be uncontrolled where tactical conflict resolution service provides advisory messages.

A great example of using Zu volume may be a police inspection drone, package deliveries or drones for health emergencies.

Type Y airspace is available from U2 onwards. Type Z airspace is available from U3 onwards

## Architecture

Today, different models have been presented on how the U-space architecture could be developed. Although the ways of coordinating and communicating the different actors participating in the process can differ, they all share a series of principles, based on CORUS Concept of Operations **[5]** so that the behavior of the system is adequate.

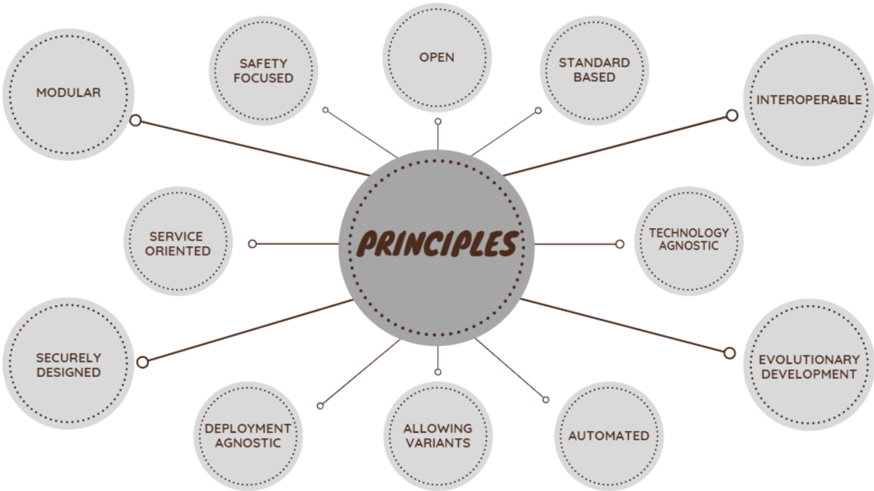


*Figure 6. Architecture principles scheme*

The next figure extracted from the U-space operational stakeholders [5] that are expected to be part of the core business of U-space. Some on this list are direct stakeholders, such as the drone operators, the U-space service providers, and the authorities. Others are ATM-related stakeholders, such as aerodrome operators and ANSPs. Additionally, the notion of U-SWIM (SWIM for U-space) appears, which is intended to be a global information system of the highest quality. and cross-sectional nature between companies, ATM (navigation service providers), database, etc.

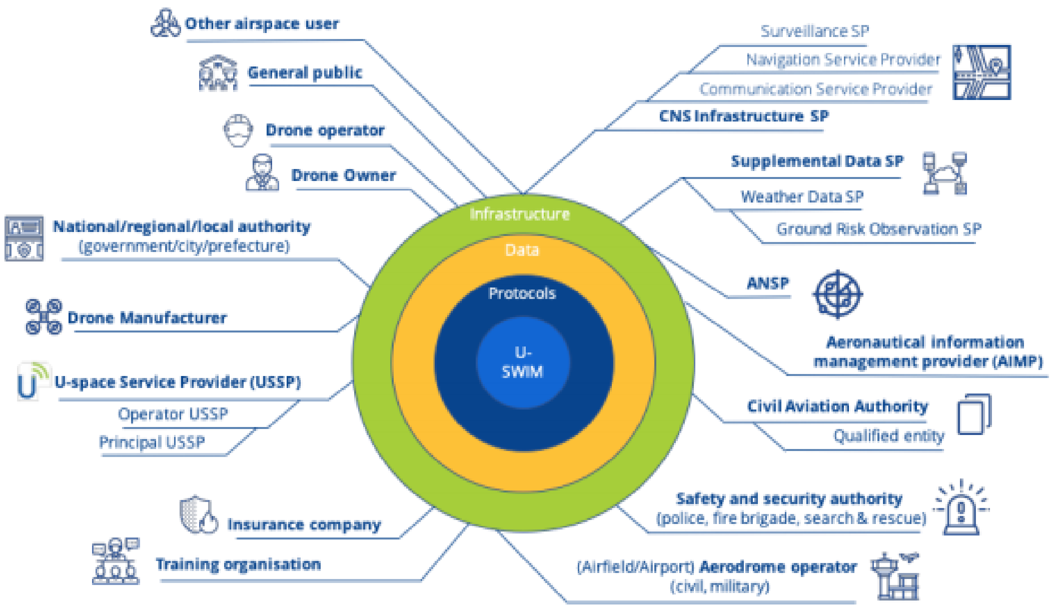


*Figure 7. Stakeholders sketch*

For the moment, this is simply the idea of providing quality information to the right people with the right systems at the right time.

The European ATM architecture (EATMA) framework [9] defines how is possible to create a model of the architecture that provides traceability from performance needs to technical solutions. The CORUS project has focused the elements of this framework to obtain a proper architecture presented organizing them in different layers:

**Capability**

It can be understood as the strategic layer, it refers to what is going to be carried out, thus describing the skills that would be used to deliver specified course of action to the enterprise stakeholders.

- **Airspace Organization and Management**: focused on airspace design and the drone procedure design to ensure clear and unambiguous drone operations and contribute a correct flow between drone operators and ATC.

- **Demand and Capacity Balance**: Dynamic Capacity Management needed for a continuous monitoring of the demand and capacity and thus manage access to the airspace.

- **Airspace User Operations:** focused on Situational Awareness which is the ability to provide traffic information for user situational awareness coming from any kind of monitoring.

- **Conflict Management:** prevention of drone collision during maneuvers or in-flight either by terrain obstacles, other airborne vehicles or infringing geofences, all this always keeping the safe distance to other entities

- **Service Delivering Management**: with a Drone Operational Planning Management the it can manage the planning of drone missions taking into account all relevant information, such as meteorological information, aeronautical information, applicable rules and traffic information.

- **CNS** (Communication, Navigation and Surveillance): facilitate the air-air, air-ground and ground-ground communication, the planning, recording and controlling the movement of an aircraft from one place to another and the provision of ground and air surveillance data from different sources to track and fuse for determining the position of the aircraft.

- **Information Management:** contains the main components to interoperate with ATC, to manage solutions for emergency, provide data to analyze, main ground risks, identify meteorological phenomena, provide restricted areas and so on.

**Operational**

Contains the elements needed to describe the operational concepts [5] and is independent from any physical implementation, the following scheme conceptualizes how some of the actors are related in the operational field and who shares information with whom.

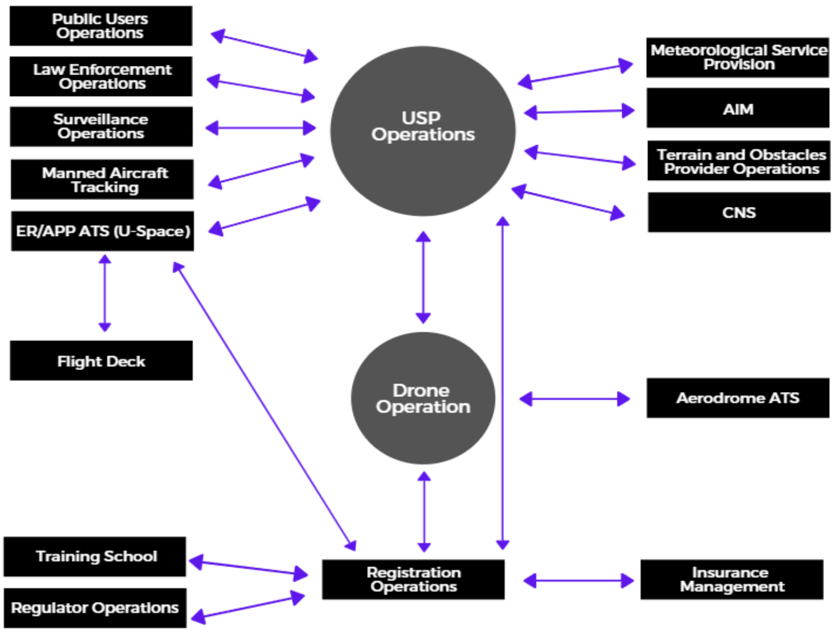


*Figure 8. Operational interactions between different actors.*

**System and Service**

The system layer describes all the human and technical resources of a system, including its internal functional breakdown and its interactions with surrounding systems. These interactions are called services.

All descriptions about roles, technical systems, functional blocks and capacity configuration are developed and explained in the Intermediate ConOps document [5].

They've been grouped in order to manage their complexity:

**U-space services**
Principal and Operator U-space services according to the split of responsibilities in the deployment architecture. They are services strongly linked to U-space domain among USSPs and the end-users.(e-registration, e-identification, tracking, conflict management, interface with ATC,...

**U-space Supporting services**
Infrastructure and Supplemental Data services. These services provide additional data to other services from different sources. They are typical services that are not specific to U-space and can be consumed in other domain as well (e.g. terrain, weather, surveillance, obstacle, cellular coverage).

All these services have been described before in the division of each of the phases of the U-space program, since it is interesting to note what services we currently have, which are being implemented, and which are developing their study.

# 3. UAV Operations

## Regulation

This section will present the current European regulation applicable to all types of drone operations, as well as the requirements, rules and procedures. In a more concise way, the regulations applicable in Spain will also be a point of development, due to the need to know what operations can be carried out legally and how its own regulations apply.

Currently there is no strict regulation focused on U-space operations because the concept is still being developed, but there is a point to start from, since there is regulation for drone operations although these are still far from what the U-space concept is.

The implementation of the regulation helps to establish the market and give rise to new developments so that both citizens and companies can be clear on what to do and what not to do with drones and thus avoid incidents that endanger operations and people as happened in Gatwick in December 2018 in which, due to 2 drones flying over the airport, they had to suspend flights and divert about 40. Minor important incidents have also occurred in Spain where the NAA has verified that in the last five years the Drone incidents at airports throughout Spain have multiplied by four, going from 40 cases in 2015 to 163 in 2019, with a total of 470 over the entire five years [8].

The normative that have been developed has as a starting point the Regulation (EU) 2018/1139 [10] of the European Parliament on 4 July 2018 which determines common rules in the field of civil aviation and establishes a European Union Aviation Safety Agency
The principal objective of this Regulation is to establish and maintain a high uniform level of civil aviation safety in Europe. Within this regulatory publication reference is made to UAVs in the Annex IX, determining essential requirements for unmanned aircraft such as design, production, maintenance and operation.

On June 2019 two new regulations were published in order to standardize the different regulations of the Member States and regulate the civil use of drones regardless of their size or weight. In this way, it will be possible to offer a common regulatory framework that encompasses different operational scenarios, and that adjusts to current technological reality.

From EASA they indicate that the new European regulatory framework applies to all UAS, whether autonomous or remotely piloted, and regardless of their mass or use.
What is noteworthy is that military, search and rescue, police, customs and border control agents, firefighters, coast guards and other security forces and various authorities are exempt.

As we have previously indicated, there are two documents to attend to:

- Commission Delegated Regulation 2019/945 [11], of March 12, 2019, which establishes the requirements for compliance during the design and manufacturing phases, in force since 1st July 2019.

- Commission Implementing Regulation 2019/947 [7], of May 24, 2019, which regulates the use of UAS by drone operators and pilots, whether recreational or professional in force since 1st July 2019 and whose application begins 1st July 2020.

The implementing act is more political and describes the regulation on broader terms and on the 'how'. The delegated act comes closer to real rule making and describes the 'what' of the regulation as laid out in the implementing act.

From the application of Delegated Regulation 2019/945, the requirements and technical specifications that must be incorporated by drones intended for operations under open, specific or certified category (which we will see later) are standardized.

In addition, the systems, applications and accessories that accompany the drone are also included; as well as the safety and navigation information that must be included in the aircraft manuals.

The main requirements established by the standard are two of the basic services offered since the development of U1:

- e-Registration

For the UAS, all drones whose design is subject to certification must be registered. Regarding the operators, all certified and specific category operations must be registered. In open category: drones of more than 250 gr, and those that incorporate cameras or other sensors and are not considered toys.

- e-Identification

An emission system in real time during the flight which will respond to a certain protocol that will include:

1. Operator registration number.
2. UAS or drone serial number.
3. Geographical position and height above the ground.
4. UAS direction and speed.
5. Take-off coordinates.

In addition, the drone must include a manual for the correct installation and configuration of this system. This will serve for the correct identification and monitoring of the operation by the competent authority.

It also introduces a broader concept of geographic areas where drone operations can, express, allow, restrict or exclude. This contributes to control and avoid risks of public security, privacy and data protection, and environmental risks.
In these geographical areas, the Member States of the European Union can:

- Prohibit certain operations or all of them.
- Request specific authorization or require certain conditions.
- Restrict flight to certain types of aircraft.
- Establish specific environmental standards.
- Allow the flight to drones that incorporate certain intelligent systems or specific functionalities.
- Modify the generic requirements to operate in the open category.

The Implementing Regulation 2019/947 [7] is the document to highlight, since it is the one that mainly regulates the use of UAVs, and therefore the most important for pilots and operators. However, some dates of the regulation have been modified by the Commission Implementing Regulation (EU) 2020/746 due the COVID-19 pandemic, delaying almost one year in every implementation of the regulation. Also another modification has been done with the regulation (EU) 2020/639 of 12 May 2020 amending Implementing Regulation (EU) 2019/947 as regards standard scenarios for operations executed in or beyond the visual line of sight, defining some needed terms and limiting in a more accurate way the specifications for the scenarios.

Unmanned aircraft operations will be classified into different risk categories, depending on their weight and the action to be taken and, above all, on what framework they will act on.

Thus, the classification will be as follows: open category for low risk operations; specific category for medium risk; and certified category for flights that present a high level of risk.

Also another milestone in the regulation of operations of UAS in Europe was achieved on October 2019 with the publication of the Acceptable Means of Compliance (AMC) and Guidance materials (GM) [12] for the Regulation on UAS operations in the open and specific category. With the publication, EASA will support UAS operators and Member States in complying with the adopted EU regulation. The document includes the description of a risk assessment methodology to evaluate the danger of an UAS operation and to identify mitigation measures to make the operation safe.

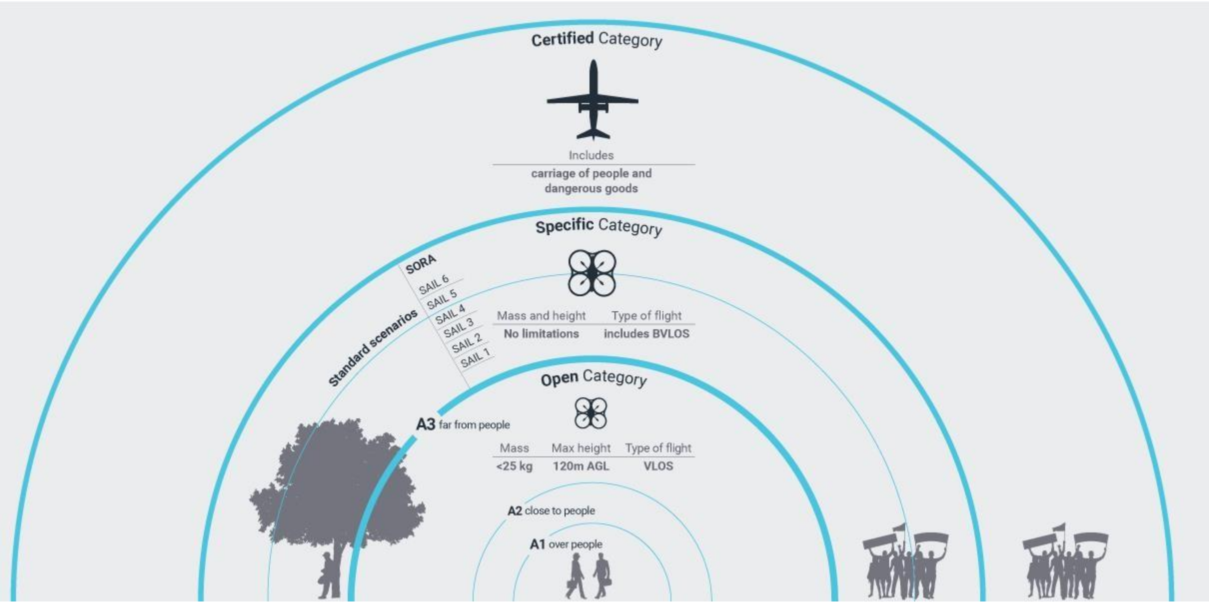


*Figure 9. UAV categories based on Implementing Regulation 2019/947.*

**‘*Open’* category**

These operations will not be subject to any prior authorization or operational declaration of the UAS operator before the operation is performed. It’s a totally defined category

- Low Risk
- MTOM<25kg
- VLOS
- The UAV is kept at a safe distance from people and that it does not fly over concentrations of people
- Cannot fly above 120 m from the closest point on the surface ground, except when flying over an obstacle (15m above)
- Will not transport dangerous goods or drop any materials;

The ‘Open’ category includes 3 sub-categories (A1, A2 and A3), divided into 5 classes of aircraft with different characteristics based on CE marking (C0, C1, C2, C3 and C4, plus self-built drones), where the differentiation is based on weight and imposes certain limits related to the safety of people.

**C0**

- MTOM, including the payment charge, will not exceed 250g; in addition to being controllable by a pilot safely just by following the manufacturer's instructions.
- Maximum speed of 19 m / s;
- Maximum altitude of 120m above the take-off point, or be equipped with an altitude limiter

**C1**

- MTOM, including payload, less than 900g;
- Maximum speed of 19 m / s;
- Maximum altitude of 120m above the take-off point, or be equipped with an altitude limiter adjustable by the remote pilot, in which case, the UAS must be able to send information about its altitude to the remote pilot during the flight.
- e-identification and geo-awareness required

**C2**

- MTOM, including the payload will not exceed 4 kg
- Maximum altitude of 120m above the take-off point, or be equipped with an altitude limiter adjustable by the remote pilot, in which case, the UAS must be able to send information about its altitude to the remote pilot during the flight.
- e-identification and geo-awareness required

**C3**

- MTOM <25 Kg, including payment load;
- Have a maximum achievable height above the take-off point limited to 120m. or be equipped with a system that limits the height above the surface or above the take-off point to a value selectable by the pilot through the remote control; in the latter case, clear information about the height of the UA above the surface or the take-off point during the flight will be provided to the pilot;

- e-identification and geo-awareness required

**C4**

- MTOM <25 Kg, including payment load;
- Being designed and manufactured in order to guarantee a safe flight, it must also not be able to have automatic control modes.

However, this CE marking is not mandatory until at least July 2022 and even then, there will most likely be a transition phase whereby drones produced before will not yet have to be CE certified.

**A1 - Fly over people**

Allows overflight of people outside the operation but overflight of groups of people is prohibited. Applied to drones of less than 250 g, of private construction or of type C0 and C1, which fly over people not involved in the operation, it is established that it is necessary to know the aircraft manual although for type C1, it will be necessary to take an online training course and pass a theoretical exam.

**A2 - Fly close to people**

No flight permission over uninvolved people

Focused on C2 UAS class. The flight is allowed near people outside the operation, provided that a safety distance of 5-30 meters is maintained. For this purpose, it will be necessary to know the drone manual and to have a certificate of competence, obtained through training and theoretical-practical examination.

**A3 - Fly far from people**

No flight permission over uninvolved people. Conducted in an area where the remote pilot reasonably expects that no uninvolved person will be endangered within the range where the unmanned aircraft is flown during the entire time of the UAS operation. They will be carried out at a safe horizontal distance, of a minimum of 150 meters, of residential, commercial areas, industrial or recreational. Established for drones less than 25kg of private construction and type C3 and C4. The requirements for the pilot will be the knowledge of the user’s manual and the completion of an online course with its respective exam.

***'Specific'* category**

This is an UAS operation exceeding the limitations defined in the 'open' category and below the boundaries of the certified

- Increased Risk
- BVLOS/VLOS or altitude >120m
- MTOM > 25 kg
- Urban flights with drones over 4 kg or without CE mark..
- Dropping material
- Flying over crowds of people

The UAS operator shall obtain an Operational Authorization (OA) from the national competent authority of the Member State of registration prior to commencing an operation, except in the following 2 cases:

1. Operations conducted in the framework of authorized model aircraft clubs and associations;
2. UAS operator holds a Light UAS Operator Certificate (LUC) with the appropriate privileges

The main element of the specific category relies on the operator, who has to identify how he want to operate and then carry out a Risk Assessment in accordance to IR947/Article 11, which is the Specific Operational Risk Assessment (SORA)[13].

There are 3 different options available to obtain the OA based on the risk assessment depending on the operation that the operator want to perform.

The first two options are based on AMC's (Acceptable Meanings Compliance) which are the SORA, and a Predefined Risk Assessment (PDRA) [12] , which need prior authorization, after one of the assessments is done, to operate for , and if the UAS operation has lower intrinsic risks, an Operational Declaration may be submitted when the operations comply with the Standard Scenarios (STSs) [14]. Both PDRA and STS are created to avoid repetitive individual approvals identifying these types of ConOps.

**SORA**

This concept was the Joint Authorities for the Rulemaking of Unmanned Systems (JARUS) and It's a multi-stage process of risk assessment aiming at risk analysis of certain unmanned aircraft operations, as well as defining necessary mitigations and robustness level. This methodology provides a logical process to analyze the proposed ConOps and establish an adequate level of confidence that the operation can be conducted with an acceptable level of risk.

It focuses on assigning to a UAS-operation two classes of risk, a ground risk class (GRC) which is the risk of collision of the drone with people, animals or objects on the ground and an air risk class (ARC) which is and air risk that refers to the risk of a collision between the drone and another airspace user. The GRC and ARC form the basis to determine the

Specific Assurance and Integrity Levels (SAIL) for both respectively. The SAIL represent the level of confidence that the UAS operation will stay under control within the boundaries of the intended operation. The SORA allows operators to utilise certain threat barriers and/or mitigating measures to reduce both risk-classes and thereby reducing the SAIL.

There are ten steps supporting the SORA methodology [13]

1. **ConOps description**
   a. flight path
   b. airspace
   c. air and ground density maps
   d. ANSP interface
   e. other information related to the intended use of the UAS

2. **Determination of UAS intrinsic Ground Risk Class (GRC)**
   a. Scaled from 1 to 10
   b. Determined by UAS weight, physical dimensions and intended operation (VLOS/BVLOS with overflown area)

3. **Final GRC Determination**
   Determined considering design aspects which may have a significant effect on the lethality of the drone and three mitigation measures
      i. Strategic mitigations based upon ground risk buffer and overflown population density
      ii. Mitigations intended to reduce the effect of a ground impact.
      iii. Emergency Response plan to address and limit the effect of an operation out of control.

4. **Determination of initial Air Risk Class (ARC)**
   Based on the airspace requested in the ConOps
   a. Atypical vs typical airspace
   b. Altitude
   c. Controlled vs uncontrolled
   d. Airport environment vs non-airport
   e. Urban environment vs rural environment

5. **Application of Strategic Mitigations to Determine final ARC (optional)**
   If an applicant considers that the generalized Initial ARC assigned is too high for the condition in the local Operational Volume has to apply the ARC reduction process but if considers that the generalized Initial ARC assignment is correct for the condition in the local Operational Volume, then that ARC becomes the Residual ARC
   The residual air risk after can be done applying any of the two different strategic mitigation measures
   a. Operational restrictions controlled by UA operators
   b. Operational restrictions controlled by structure of airspace and the associated rules controlled by the relevant authorities.

6. **Tactical Mitigation Performance Requirement (TMPR) and Robustness Levels**
   Applied during the conduct of the operation, and are used to mitigate any residual risk of a mid-air collision that may remain after the strategic mitigations have been applied. Two types of mitigations depending on
    a. VLOS (use human vision to detect aircraft and take action to
    b. remain well clear and avoid collisions from other aircraft)
    c. BVLOS ( a machine is applied to remain well clear and avoid collisions from other aircraft such as DAA, UTM, etc.)

7. **Specific Assurance and Integrity Level (SAIL) determination**
   The SAIL parameter consolidates the ground and air risk analyses and drives the required activities. The SAIL represents the level of confidence that the UAS operation will stay under control.
    a. SAIL I & II: Low risk
    b. SAIL III & IV : Medium risk
    c. SAIL V & VI : High risk

8. **Identification of Operational Safety Objectives (OSO)**
   For the assigned SAIL, the operator is required to show compliance with each of the 24 OSOs, although some may be optional for lower SAILs. Each OSO shall be met with a required Level of robustness High, Medium or Low depending on the SAIL. OSOs cover the following areas:
    a. UAS Technical Issue
    b. Deterioration of external systems
    c. Human Error
    d. Adverse environmental conditions

9. **Adjacent area / airspace considerations**
   This addresses the risk posed by an operational loss of control that would possibly infringe on areas adjacent to the operational volume whether they be on the ground or in the air

10. **Comprehensive Safety Portfolio**
    A comprehensive Safety Portfolio is the SORA safety case submitted to the competent authority and the ANSP prior to final authorization. The Safety Portfolio contains the following information:
    a. Mitigations used to modify the intrinsic GRC
    b. Strategic mitigations for the Initial ARC
    c. Tactical mitigations for the Residual ARC
    d. Adjacent Area/Airspace Considerations
    e. Operational Safety Objectives

The operator should make sure to address any additional requirements not identified by the SORA process (e.g. security, environmental protection, etc.) and identify the relevant stakeholders. After the compliance of all this documentation and information the operator must send it to his NAA which will give or not the authorisation to carry out the operation.

The current SORA application only targets single drone operations; thus it does not take into account multiple drone operations, swarms, and the U-space concept. Programs such as AW-Drones are investigating a series of standards that cover the needs of those already applied as SORA, in order to harmonize regulation to enhance and establish order in operations and the U-space market. The project will make available an Open Repository of "best practices" to support the European Aviation Safety Agency's (EASA) and the European Commission's (EC) rulemaking process for the definition of rules, technical standards and procedures for drones.

**PDRA** (Predefined Risk Assessment)

In a similar way, these predefined risk facilitate the activities of the UAS operator when applying for an operational authorization in the 'specific' category. The provisions and mitigations in the PDRA are described in a rather generic way to provide flexibility to UAS operators and the competent authorities to establish more prescriptive limitations and provisions that are adapted to the particularities of the intended operations. PDRAs only address safety risks; consequently, additional limitations and provisions might need to be included after the consideration of other risks (e.g. security, privacy, etc.)

Actually, it exists one version of PDRA according with the following features:

**PDRA-01**: UA with maximum characteristic dimensions up to 3 m, operated BVLOS of the remote pilot with visual air risk mitigation, over sparsely populated areas and less than 150 m (500 ft) above the overflown surface in uncontrolled airspace

Furthermore, there are some other possible PDRA in development to apply in Temporary flight restriction zone, controlled airspace, some predefined routes over sparsely populated area, etc.

**STS** (Standard Scenarios)

These standard scenarios were proposed in the Implementing Regulation (EU) 2019/947 [7] and developed in the Opinion No 05/2019 [14] of EASA and describe the most common types of drone operations in conjunction with the risk assessment and the mitigation measures. Also describes the mitigation measures, the technical requirements and so on. The operator can either declare himself that he will work compliant to this scenario or that this needs to be checked by a NAA. That choice will be different depending on each standard scenario.
If the mitigation measures are easy to implement, then a declaration by the operator is enough. If these are more demanding an authorization by a NAA is required.

In these STS the authorities have done the SORA for the operators, they gave some specific prescriptive requirements and the operator just must make a declaration and operate. However, STS only works for the scenario it was intended and validated for and thus, is not a "toolbox" from which certain elements can be picked and applied to various and different types of operations. UAS operators will be allowed to start the operation as soon as they have submitted a declaration to the NAA of registration and have received the receipt of confirmation and completeness

It is therefore imperative that the holistic view is kept, where changing one element may have a significant impact on the entire operation, which, in-turn, requires a re-assessment and re-validation of the entire operation.

Two new CE classes, C5 and C6 [14], are established for UAS to be used in the ‘specific’ category and have same technical requirements as class C3 UAS with addition of:

- Health monitor of the Command and Control link
- Provide information on UA speed and height
- Flight Termination system
- Optional geo-awareness

**STS-01 “Urban VLOS”**

Operations in the VLOS over a controlled ground area in a populated environment within Controlled/Uncontrolled airspace at a maximum height of 120 m.

Class C5 is intended to be used within this scenario with features as : <3 m & <25 kg with no fixed wing, Means to reduce the effect of the UA dynamics (i.e parachute) and accessories kit to transform a class C3 UAS.

**STS-02 “Rural BVLOS”**

Operations BVLOS with Visual Observers (VO) over a controlled ground area in a sparsely populated environment, in a Controlled/Uncontrolled airspace with max. flight height of 120m.

Class C5 is intended to be used within this scenario with features as : <3 m & <25 kg; <50 m/s; provide information on UA position; geo-caging; low speed mode selectable up to 5 m/s; automatic modes;

The main mitigation means are provided by the VOs who assist the remote pilot in scanning the airspace for the presence of other airspace users.
Without the assistance of VOs, the range can be up to 1 km. With VOs the range can be extended up to 2 km.

NAAs have time until July 2020 to create STSs applicable to their own country. Those that have been approved prior will remain valid for the next two years until July 2022.
The Regulation establishes the opportunity for member states to confirm national standards to submit to certain conditions the operations of unmanned aircraft for causes that do not fall under the subject of application of these Regulations.

Until then, in Spain , the Royal Decree 1036/2017 that regulates the civil use of drones will continue to apply. In addition, national regulations will also apply in the transitional periods contemplated in the European and in those aspects that are not covered by it.

The Spanish Authorities have developed 8 different STSs [15] according to the regulation in order to establish possible operations until 2022.

- **STSN01** Standard scenario for night flight
- **STSE01** Standard scenario for controlled airspace flight
- **STSA01** Standard scenario for flight in agglomerations of buildings
- **STSA02** Standard scenario for flight in agglomerations of buildings and controlled airspace
- **STSA03** Standard scenario for flight in agglomerations of buildings in atypical airspace
- **STSA04** Standard scenario for flight in agglomerations of buildings, controlled airspace and night flight
- **STSX01** Standard scenario for experimental flights at BVLOS in segregated airspace for aircraft weighing less than 25 kg
- **STSX02** Standard scenario for experimental flights in BVLOS in segregated airspace for aircraft weighing 25 kg

**LUC** (Light UAS Certificate)

This is the most ambitious option, the word “light” doesn’t mean that the UAS has to be light in weight, it refers to a light approval because cover a low-medium risk. A LUC qualified operator can assess the risks themselves and implement their own mitigation measures. Obtaining the LUC will not be an easy matter and cannot be compared to any existing permit in Europe. The operator will have to demonstrate a full functioning safety management system and a good understanding of the SORA risk assessment. This approval has privileges in the operator’s scope, which includes:

- Conduct operations covered by STS without submit a declaration
- Conduct operations covered by PDRA without ask for authorization
- Assess the risk of new operations through SORA and conduct the operation without ask for authorization

The UAS regulations in the ‘open’ and ‘specific’ categories contain some building blocks that enable the development of some of the U-space mandatory services. These are the e-identification capability of the UAS to enable the network e-identification service and the geo-awareness capability of the UAS (within the ‘open’ category) to enable the geo-awareness service in the U-space. In addition, the registration system of the UAS operators required by these regulations enables the necessary access to UAS operator information by the USSP and supports the network e-identification services. The establishment of the geographical zones by Member States also provides essential data for the functioning of the U-space.

### ***'Certified'*** **Category**

When the aviation risks rise to a level similar to manned aviation the operation would be positioned in the category of certified operations. These operations and the aircraft involved would be treated in the classic aviation manner

A UAS operation belongs to the 'certified' category also when, based on the risk assessment, the competent authority considers that the risk cannot be mitigated adequately without

- Certification of the airworthiness of the UAS
- Certification of the UAS operator
- Licensing of the remote pilot, unless the UAS is fully autonomous.

UAS operations are always considered to be in the 'certified' category when they are:

- conducted over assemblies of people with a UA with characteristic dimensions ≥ 3m;
- involve the transport of people
- involve the carriage of dangerous goods that may result in a high risk for third parties in the event of an accident.

This type of category is what U-space is mainly intended to operate, but it is not implemented yet, is being developed by EASA, but they still not clearly defined how the final shape will be besides they have some principles to start shaping this certified category.

They have established the first Notice Proposed Amendment (NPA#1) [16], not developed because is planned for Q4 of 2020, that cover three main types of operation:

- Operation type #1: IFR Operation of certified drones, only for cargo, in Airspace classes A-C taking-off and landing at aerodromes under EASA's scope.

- Operation type #2: UAS operation in a congested or non-congested area using predefined routes in volume of airspaces where U-space Services are provided and will include automated operations carrying passengers, or cargo.

- Operation type #3: Operations as in type #2 conducted with manned VTOL, also in airspace where U-space is not available

All urban operations will require prior authorization and tracking. BVLOS operations will require a detect-and-avoid (DAA) system that not only avoids collision with other airspace users but also with obstacles.

Since these operations are assessed as manned aviation operations, many current European regulations will be affected and thus it has to be modified, such as: Airworthiness, Flight Standards, ANS common requirements, ATM/ANS safety oversight and the Standardized European Rules of the Air (SERA).

This proposal will be very extensive due to the need to change highly standardized rules, the study of how this can affect commercial aviation, and especially how these three types of operations can be carried out safely. Due to the time it will take to develop it, an evaluation will be carried out by EASA through different comments and contributions from entities and collaborative organizations, also from industries, in order to make some changes and finally harmonize the creation of the regulation with the current one and the operations of commercial aviation.

The final proposal to the European Commission is expected by the middle of 2022. After this proposal the EC will start the discussion with the member states and since that moment will not be more than a year until it is approved, so at the middle of 2023 is probably when certified operations will be allowed with all the regulation in order although they haven't fixed these dates as a published deadlines.

Also, EASA has published an important document, Opinion No 01/2020 [17], released on March 2020, which presents a basis for future legislation closely linked to the two existing regulations on drones. In this sense, it lays down the first building block for the establishment of the U-space in Europe. The initial scope is low level airspace, densely-populated urban airspace and locations close to airports. The opinion proposes a regulatory framework that will allow services such as drone deliveries or air taxis to co-exist with all the other activities in urban environments by complementing the existing ATM environment of manned aviation and will evolve along with the growing density and complexity of the air traffic.

*"The proposed high-level regulatory framework intends to allow immediate implementation of the U-space after the entry into force of the Regulation"*

*"In summary, this is a first regulatory phase that is due to support operations as soon as the regulation is adopted and in the near future. It is focused on the principles of strategic and pre-tactical traffic management techniques (strategic because of the use of airspace management techniques to manage the U-space airspace, and pre-tactical because it is based on sharing information prior to and during flight" (Opinion No 01/2020, 2019, p 9)*

Some of the proposed articles are:

**Designation of U-space airspace:** Defined by Member States

**Common information service :** Only one provider per U-space airspace to ensure that there is one single point of contact, one single point of truth that consolidates all the information necessary for the functioning of the U-space airspace. Is at the heart of the U-space system managing information as airspace restrictions, status of the airspace and available traffic information)

**UAS operators :** submit their flight authorization request form to the USSP and ensure that they are able to comply with the terms and conditions given by the USSP (Based on 'open' and 'specific' requirements)

**U-space service providers (USSP):** Demonstrate its capability of providing at least the four mandatory U-space services (network identification, geo-awareness, traffic information and UAS flight authorization, to provide their services, they have to use the information from the CIS and exchange information such as UAS traffic and flight authorization requests when necessary with ANSPs.

**Services:** proposal of four mandatory services, **Network identification service Geo-awareness service, Flight authorization service, Traffic information service** and some supporting services to provide information to the mandatories, such as **Tracking service, Weather information service or Conformance monitoring service**

**Application, conditions and validity for a CIS provider and USSP certificate**

**Competent authority and tasks:** EASA for CIS and USSP for certificates and exercising oversight and enforcement tasks

**Safety Information and pricing of CIS**

## Operations in Volumes X,Y and Z

“Open” class drone operations are restricted to VLOS and thus there will be regions of type X airspace that are dedicated to ‘Open’ class operations which will be restricted areas for other traffic. ‘Open’ flights are also possible in types Y and Z airspace if all conditions are met.

“Specific” operations can occur in airspace types X, Y and Z. Some type Y or Z airspaces may mandate the use of “Certified” drones for ground risk mitigation or similar reasons.

- Operations will need to mitigate the risk of ‘surprise encounters’ with other aircraft, especially BVLOS, in type X airspace. Responsibility for accidents lies with the BVLOS operator in this case.

- Risk mitigations can include permitting one drone at a time to access a restricted airspace, using the U-space services available in types Y and Z airspaces, etc.

- Operational declaration and position reporting are mandatory in types Y and Z airspace and highly recommended in type X.

**Summary of Regulation**

- **Commission Delegated Regulation (EU) 2019/945** of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems entered into force & became **applicable on 1 July 2019;**

- **Commission Implementing Regulation (EU) 2019/947** of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft entered into force on 1 July 2019 & will become **applicable on 31 December 2020**

- **Commission Implementing Regulation (EU) 2020/639** of 12 May 2020 amending Implementing Regulation (EU) 2019/947 as regards standard scenarios for operations executed in or beyond the visual line of sight

- **Commission Implementing Regulation (EU) 2020/746** of 4 June 2020 amending Implementing Regulation (EU) 2019/947 as regards postponing dates of application of certain measures in the context of the COVID-19 pandemic. *Modifies the start of the application of some regulation dates.*

- **Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Commission Implementing Regulation (EU) 2019/947** October 2019.

- **Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Part-UAS** – Issue 1 October 2019

- **Opinion No 05/2019 – Standard scenarios for UAS operations in the 'specific' category – Nov 2019**

  Introduction of class C5 and C6 UAS;
  Adoption of standard scenarios

- **Opinion No 01/2020 - High-level regulatory framework for the U-space**

**Timeline**

December 31, **2020**

- Start date of application (partial) of the Regulation EU 2019/947 [7]
- Registry of operators (national registry system + repository EASA)
- Operations in the 'Specific' category may be conducted after the authorisation given by the National Aviation Authority
- Drone users can start operating in limited "Open" category

July 1, **2022**

- National regulation is no longer applicable
- Conversion of the authorizations or declarations of operators, and pilot competency certificates issued based on standards national
- Definition and publication of geographical areas for UAS by of Member States

July 1, **2023**

- Only CE marked drones can be put up for sale (UAS without CE marking, purchased before this date, can still be operated in subcategory A1 and A3)
- Authorizations to clubs and associations of model airplanes


*Figure 10. Regulation timeline by EASA.*

## Forecast

In order to determine a correct estimation of the number of operations that can be carried out in the European U-space, this section summarizes the main figures for Europe, the impact for the Spanish sector and therefore the impact it will have on the Barcelona's region. This study it's made as reference the European Drones Outlook Study [18] , which analyzes the main future applications of drones and foresees great growth potential for the European sector. In addition, for the Spanish sector it has been based on a Strategic Plan for the drone sector [19] published by the Spanish government.

The operations estimation data will determine some features of the future U-space region evaluated, to be able to simulate the stage in the Barcelona region more precisely. The output of the estimation data should be the annual flights of small, medium and large UAV the number of UAV which will be available and the distribution of different uses of UAV such as those exemplified in possible applications.

The year 2035 has been taken as a reference since at that time automation in the U-space network is expected to be complete or almost complete, allowing the scenario in which UAVs fly autonomously through different skyways to optimize their trajectory and in this way ensure safe and well-distributed missions throughout the city.

To present this section, the potential applications of UAVs are described, as well as the expected demand for 2035 in the European and Spanish sectors. From these data, and through the study carried out in the Barcelona area, the possible number of operations with UAVs in this region can be estimated.

## Applications

Due to the research, development, and investments involved in the construction of this new concept about how drones are going to be managed, the application of UAS is increasingly introduced to the air market, whether evolving existing forms of work or creating new ones and consequently making some disappear.

It is expected that the overwhelming majority of commercial UAS will fall into the micro and small UAS categories. Most of these vehicles will be low-cost and dedicated to specific new and emerging tactical market applications.[18]

The types of operations that can be performed with UAVs are multiple, and may vary significantly in time, altitude and degree of risk for the population. That's why it's important to really know in which areas could this type of operations be carried out; how many operations are going to be handled at the national and European level and how all these are or will be regulated.

Below are the applications of UAVs in different sectors of the economy, their main functions, operational needs and their future estimates in terms of the number of vehicles and number of operations based on SESAR community studies and FAA publications.

### Infrastructure

Today, most such work is performed manually, based on in-person inspections, a slow and costly process that yields incomplete, poor-quality results. In some cases, rope access, scaffolding and elevated platforms are necessary, combined with the need to turn off the installation for the duration of the maintenance.

By allowing BVLOS operation, drone pilots will be permitted to remotely man their drones in secluded areas from a digital screen. Drones will be able to cover more ground in shorter times, and the entire operation will be overseen from a distance, keeping inspectors out of harm's way.

### Energy

Unmanned aircraft are especially suitable for carrying out inspection tasks of production infrastructures and power distribution since they can inspect inspections continuously, remotely controlled and thus improving the efficiency in the operation and security conditions of the same. Drones are likely to be located at most sites permitting more frequent maintenance cycles and better responsiveness to unforeseen events.

The fleet is expected to be composed of VLOS for local site inspections and BVLOS fixed wing drones flying near 150 metres of altitude for long range inspections with some certified drones operating between 300 - 3000 m [18].

Most of inspection drones will fall into the 'specific' category under the EASA framework, whereas the electricity production drones may be considered as 'certified' given they will exceed 150 m in altitude.

The main tasks will be the inspection of energy distribution networks, places of energy production like detection of as well as the production of clean energy thanks to the force of the wind having drones tied at high altitudes. Their estimation is nearly 10 000 by 2035 for Europe and 1300 for Spain. [19]

### Construction and maintenance

Drones also play a fundamental role in taking the places where an existing structure is to be built or remodeled. Additionally, to be able to take photos of specific places that allow us to see more specific details about strategic places that will be used in construction for a specific purpose. While ground surveying is still a critical part of construction planning and monitoring, the use of drone data has become increasingly important.

In this way, one of the greatest difficulties in the management of construction is overcome: the constant updating of documentation, graphic and photographic, during the progress of the project, and the fast sharing of such data. They can reach places of difficult access, capture details in dangerous places, avoid entering high-risk structures, decrease inspection time in certain areas and take 360-degree shots.

### Deliveries and mobility

This is an application with great potential for development in those cases where delivery time is critical, such as medical supplies, transportation of organs for transplants or defibrillators. Many countries are developing and trying to carry out operations in this area, the last one that has tried it is Germany. Before it was done in Colombia, the Dominican Republic or the United States, with time reductions of up to 80% [18].

Also, its use in the field of industrial production, the transport of parts, tools and spare parts from warehouses to operators or citizens. The UPS company is very close to turning this type of operations into reality, they've received the first full Part 135 Standard certification to operate a drone airline by the U.S. government, testing residential package deliveries using drones launched from a roof of a delivery truck [37].

The niche market for parcel delivery drones is expected to focus on Premium deliveries, which are purchases where you are willing to pay more a change to receive before shipping. In general, drone transport is more efficient in cities of a certain size. There could be also transport applications to remote areas, where there are accessibility problems [40].

Deliveries sector is going to be one of the main players in the VLL airspace since it implies a reduction in transport costs for companies, although this may have a predecessor of an initial investment for the necessary UAS infrastructure, a reduction in delivery times and they help decrease traffic in urban areas. A key enabler for all this growth to happen is the regulations for BVLOS operations and separately for these operations in densely populated areas, but until all the initial and advanced services are established, which could be possible in scenarios of Volume Y and volume Z.

Today, around 10% of the nearly 7 billion annual EU packages appear to be same day premium deliveries applicable drone capabilities and most of these packages are less than 2.5 kg [18], light enough for expected drone delivery. In Europe, the adoption of this type of missions for the delivery of parcels is expected to manage 200 million deliveries around 2035 with 70.000 drones for Europe and 7.000 for Spanish deliveries [19].

In terms of transporting people, several initiatives are currently being addressed that advance the design of prototypes of unmanned aircraft for the transport of passengers within the city, as is the case of CityAirbus which made its first untethered flight in December 2019 in Germany [38] or Volocopter, whose first test flight took place in Singapore in October 2019 [39]. The transport of passengers will constitute one of the great challenges of this technology, which must save significant technological and regulatory barriers. Once the use of this type of platform is consolidated among users, it will be one of the services with the greatest development capacity. Due the complexity of the operations and the necessity of public acceptance, regulations of certified category and so on is expected a demand of 100 UAV [18].

## Security and emergency response

This type of aircraft is beginning to be used as a surveillance method, the improvement in the performance of drones, mainly in terms of autonomy and the possibility of continued night operation, will reinforce them as ideal tools to carry outside work in border areas and perimeters, integrating as one more part of security systems.

Furthermore, their great maneuverability and transport capacity, these platforms will develop ideal systems to assist specialists during the provision of emergency and rescue services, thus reducing the risk for the professionals who provide them.

This type of service requires, as in the conventional method of ambulances or emergencies, a priority above the other services that are being carried out in the airspace at that moment. In an uncongested space like the current one, performing these operations does not require interaction with other UAVs since there is no traffic to deal with. On the other hand, if we propose this service in an urban environment with more operations and heavy traffic so it is important how these types of operations are coordinated with the others. There are different possibilities, but all in order to free up a segment of space or skyway so that you can successfully complete your task.

For surveillance and security is expected a demand of 200.000 UAV by 2035 [18] where most of these units are estimated to be classified under the 'specific' category of the EASA framework given these first response drones are light in weight and expected to operate near or below 150 m, yet fly beyond visual line of sight. The higher altitude surveying drones are likely to fall under the ‘certified’ category, especially given most of the technology is a transfer opportunity out of aerospace & defense. In the Spanish scope are expected 16.000 UAV [19].

## Agriculture

A single drone can monitor hundreds of hectares accurately, evaluating the conditions of the terrain, in order to collect information on hydration, temperature or the growth rate of crops. One of the most important functions attributed to these devices is the premature localization of diseases. In this way pests that spoil part of the crop can be avoided

The operations carried out in this sector will be mainly BVLOS due to the extension of the land to be inspected or fumigated.

- Long range surveying at 150 m which will represent around 90% of the total fleet.
- Long range light payload drones to do precise spraying of chemicals at altitudes below 50 m representing the remaining 10% [18]

This sector is expected to create the demand of approximately 125 000 drones by 2035.Also agriculture chemical spraying and seeding could represent 25 000 light load drones flying at low altitudes. In the Spanish scope, it’s expected to create a demand of 20 000 units. Due to the constant improvement in aircraft performance and the consequent increase in payload, it is estimated that between 2035 and 2050 there will be a decrease of 3-5% of operations in this sector [19]

## Media and Entertainment

One of the most popular fields for drone-powered solutions is in the media & entertainment industry. In the media industry, drones are becoming popular among production companies for filming shots that require action sequences, literal birds-eye views, dramatic panoramas or 360-degree views of subjects. This modern drone technology is the gateway to developing media business or career to take it to the next level. Drone aerial photography is a simple & cost effective way for photography or cinematography businesses. The number of drones could reach 30 000 operating within VLOS [18].

In summary, there may be over 400.000 professional units of UAVs flying above Europe with a foreseeable economic impact in 2035 of more than € 10 billion [18] due the rapid current growth in operations within VLOS for uses in infrastructures, facilities inspection and entertainment and the growth potential until 2035 will come fundamentally motivated by operations BVLOS in agriculture, deliveries, security and emergency response. The estimated impacts in terms of number of fleet, economic and employment impact resulting from the aggregate analysis indicate that the fleet of drones for professional use in Spain could be 54.000 UAVs [19].

Considering that Spain has 12% of the European population, the accounts that come out applying these percentage to the number of UAVs are consistent, with a result of about 48,000 units. If we consider the relationship that Barcelona has with Spain in terms of population, GDP [20], deliveries [21] and UAV units [19] we can estimate a range of UAVs as well as operations that can be performed.

| Input | Spain | Barcelona | Relation | Impact level |
|---|---|---|---|---|
| Population | 47 M | 1,6 M | 3,5 % | 15% |
| GDP | 1.245.000 M | 130.000 M | 10,5 % | 25% |
| Deliveries | 196,5 M | 13,8 M | 7 % | 30% |
| UAVs | 4394 | 449 | 10,2 % | 30% |

*Table 1. % Relation Spain-Barcelona.*

If we take the values and calculate their average, we get a total of 8%, which we will use as a lower bound, which results in 4.300 units. Since it is one of the most important powers in the country although it represents very little surface of it, we take as upper bound a slightly higher percentage of 13% which represents 7.000 units. Determining an average value, could be establish over 5.500 UAVs in Barcelona.

With all this number of units, it is likely that 20% of these, 1.100 units, between deliveries, surveillance and data collection, want to be used routinely and with pre-established routes, the so-called 'corridors'. Considering the possibility that they could be operating in a range of 12-16 hours; several operations might be established between 150 – 250 flights/hour.

To strengthen this data and to know another possible version of the impact on the city of Barcelona it has been proceeded to use the Altiscope tool, which aims to estimate UAV volumes for a given country or area. It has 123 inputs in order to cover the main uses of UAVs, considering parameters such as:

- Population
- Urban, agriculture and forest areas
- UAV % potential of deliveries
- Kg per UAV delivery
- Annual trips per capita
- Km of highways, bridges and railways
- Annual infrastructure construction
- Annual emergency response events

This tool works by computing in an Excel environment the influence that has the general parameters of the city, and some parameters added by myself taking into account the projection of the U-space concept, the actual capability of the city in terms of mobility, the possibility of recreational uses of maximum 1% of the population, the infrastructure needed to develop concepts such as UAM, and the most influential factor and deterministic, the commercial uses and the % of capacity that UAVs may have on the sector.

The following figures contain the data obtained from the results of the Altiscope Tool [31]:

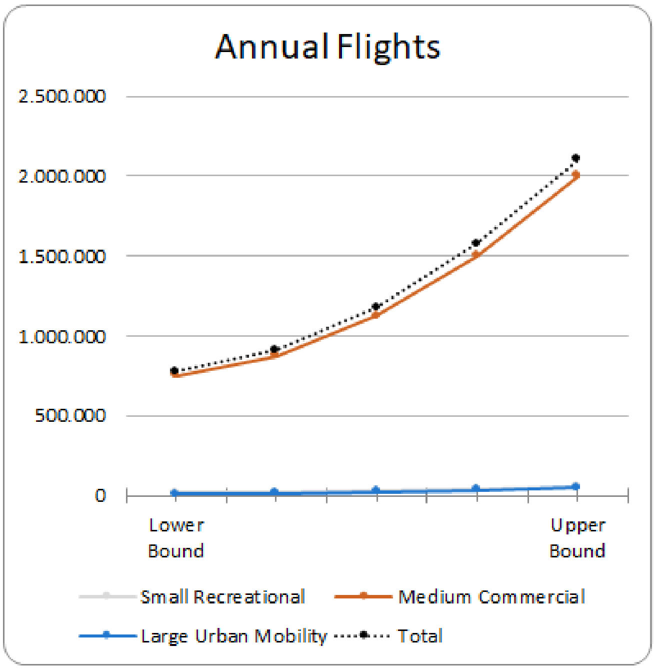


*Figure 11. Forecast of annual flights for 2035*

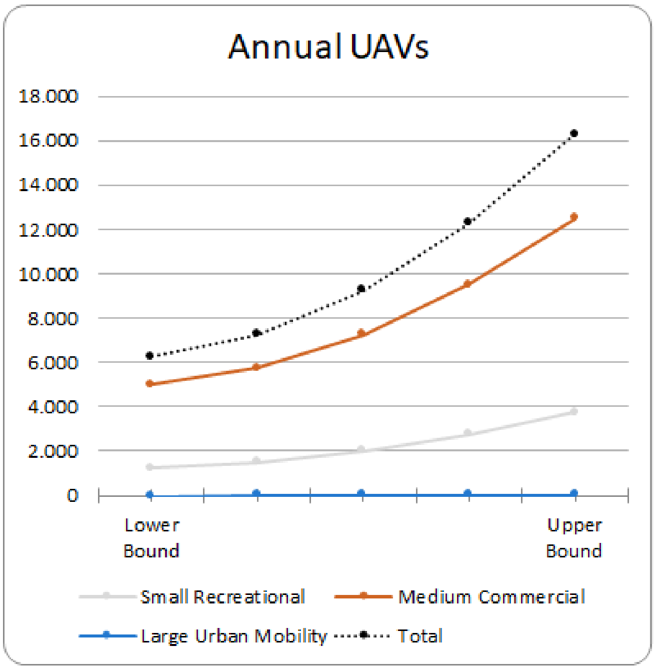


*Figure 12. Forecast of annual UAVs for 2035*

| Annual Flights | Small Recreational | Medium Commercial | Large Urban Mobility | Total |
|---|---|---|---|---|
| Lower Bound | 17.500 | 750.000 | 10.000 | 777.500 |
| | 21.250 | 875.000 | 14.000 | 910.250 |
| | 28.750 | 1.125.000 | 22.000 | 1.175.750 |
| | 40.000 | 1.500.000 | 34.000 | 1.574.000 |
| Upper Bound | 55.000 | 2.000.000 | 50.000 | 2.105.000 |

| Annual UAVs | Small Recreational | Medium Commercial | Large Urban Mobility | Total |
|---|---|---|---|---|
| Lower Bound | 1.250 | 5.000 | 8 | 6.258 |
| | 1.500 | 5.750 | 10 | 7.260 |
| | 2.000 | 7.250 | 16 | 9.266 |
| | 2.750 | 9.500 | 24 | 12.274 |
| Upper Bound | 3.750 | 12.500 | 35 | 16.285 |

*Table 2. Lower and upper bound of annual flights and UAVs for Barcelona's region*

It is observed how the highest amount of drones can sustain in medium commercial for goods transport, inspection and construction activities, while the smallest amount resides in UAVs for urban mobility due to the need of infrastructure that needs to be built for this new concept, and the small recreational ones that are also a minority but influence the amount of operations.

Calculating the possible daily flights, considering that the same missions will be executed every day, and 12-16 working hours per day, the following numbers arise:
For an estimate of 780,000 flights per year, between 130-180 flights could be feasible in one hour. In the other hand, for 2.100.000 annual flights, between 350- 450 could be performed in one hour.

This implies that with high probabilities could more than 100 operations per hour and the average could be set at 200/250 operations per hour.

## Public Acceptance

A key factor for the implementation of the U-space concept, the development in the mentioned applications and the involvement of the technology in it is the acceptance and perception of the public and society in terms of benefits, risks, threats and fears.

If we look at the main dimensions of responsible innovation (anticipation, reflexivity, inclusion and responsiveness) there are different methods to promote the U-space project and everything around it so that in one way or another enough links are built for people to trust the technology and see its potentially safe, sustainable, efficient and profitable use. For it to work, the main actors must collaborate and communicate, for regulation, promotion and testing all aspects before an implementation or launch to the market.

Diverse and inclusive, involving from the early stages a wide range of actors and audiences in the practice of research and innovation, deliberation and decision making in order to obtain more useful and higher quality knowledge, which takes into account the expectations and interests of the audiences affected by the research or innovation.

Anticipatory and reflective, predicting impacts and promoting reflection to better understand how research and innovation shape the future.

Open and transparent, communicating in a balanced and meaningful way the methods, results, conclusions and implications to enable public scrutiny and dialogue.

Responsiveness and adaptability to change, being able to modify modes of thinking and behavior, encompassing organizational structures, in response to changing circumstances, knowledge and perspectives

Some of the external variables that are based on social acceptance are:

- Perceived Benefit
- Perceived Risk
- Perceived Control
- Perceived Usefulness
- Perceived Ease of Use

To visualize in a more effective way these concepts, a survey of the public perception about the implication of drones in their cities it's been made since the U-space concept is not yet known and could cause some confusion, however, most of the population knows that it is a drone and has even seen one, so I spread the survey in the Barcelona area to evaluate certain aspects.

**200 people in different age groups have participated**

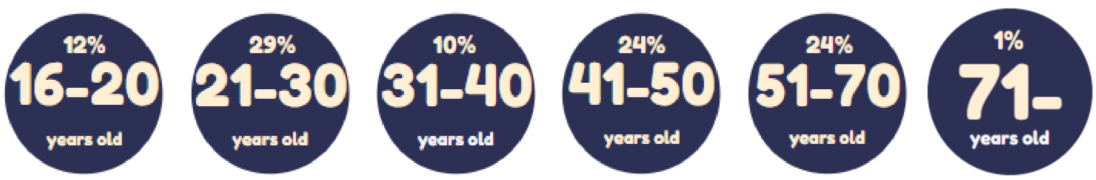


*Figure 13. Age groups, survey*

To get a general perception, they have been asked openly about the uses and applications they think a UAV may have and the year in which they see drones likely to fly over their city in order to create a map of ideas about the perceived usefulness and ease of use. The most frequent uses and years are the following:

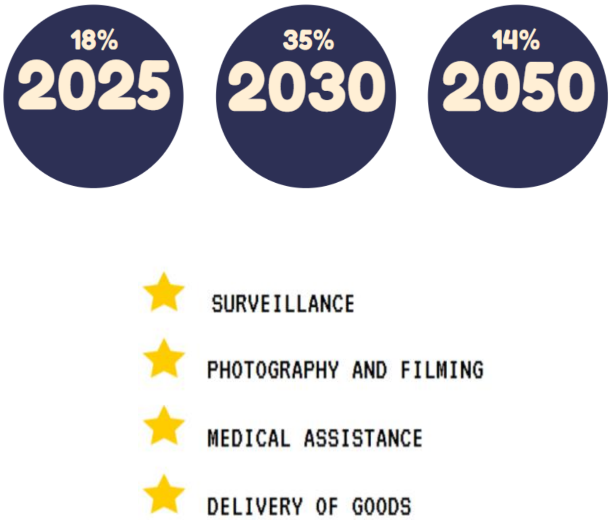


*Figure 14. Frequent UAV uses and years, survey*

Surveillance is the application most highlighted by participants, with 70% of respondents mentioning it, also 50% of respondents have include delivery of goods as a potential use of drones, since the 25% of participants think about photography, filming and medical assistance.

The following 3 questions were posed to make them think if they would be willing to use this technology, and in this way to be able to observe the degree of acceptance based on the information from which the participants start.

**A) Would you be willing to travel in an unmanned aerial vehicle?**

In the youngest sectors, up to the age of 30, a proportion of 50-50 is observed between a maybe and a yes that would travel, while the other age sectors over 70% have marked the possibly, predominating more the no than the yes, making the UAM more feasible than expected, specially in the 31-50 range age.

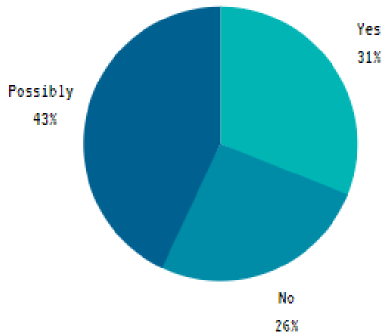


*Figure 15. UAV travel distribution, survey*

**B) Would you accept a delivery of parcels/food/ medicine by drone?**

90% of those surveyed do not deny being able to receive an asset via UAV, as this may be the question in which the associated benefit of the technology is most visible.

This is the response with the highest acceptance of the survey in all age ranges, so the implementation of a service of this style could boost the acceptance of the use of UAVs in other areas, starting with this one.

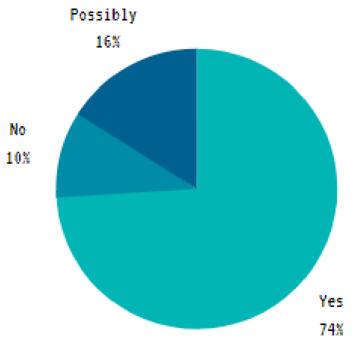


*Figure 16. UAV deliveries acceptance distribution, survey*

**C) Would you be willing to purchase a drone for recreational flying and/or use it for personal goods transportation purposes?**

A great weight of the No comes from the higher age range, from 51 years the percentage of those who would acquire a drone is less than 15%, compared to almost 90% of young people between 16-30 years who doubt or if they would acquire it, leaving the range between 31 and 50 those who doubt more.

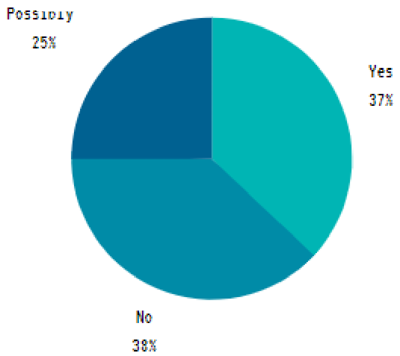


*Figure 17. UAV recreational/personal usage distribution, survey.*

As risk perception is a key factor in the acceptance of this technology, they are asked to rate on a scale the following three issues:

**On a scale of 1 to 5, where 1 is unsafe and 5 is very safe, do you find it safe for a drone to fly over your city?**

The distribution of responses is balanced, with a predominance of 3, which would correspond to " quite safe ", although if we compare the extremes there are more participants who find it unsafe than very safe. The question gives rein to people's imagination when thinking about how they could fly over their house or city, so many are in the middle of the question, although it is a positive point that only about 15% find it unsafe.

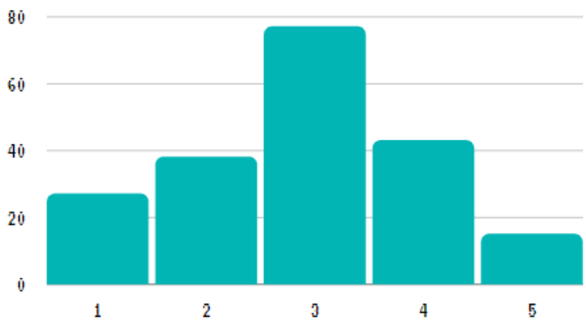


*Figure 18. Safety perception of UAV, survey*

**On a scale of 1 to 5, where 1 is less risky and 5 more risky, do you think it's more or less risky than flying commercial planes?**

The answers in this case make clear the perception in comparison to the traditional flights, which have been established for decades, so that more than 70% of the respondents opt for more risk, which in contrast to the previous question, it is stated that even if they are moderately safe, the risk against an airplane is much higher.

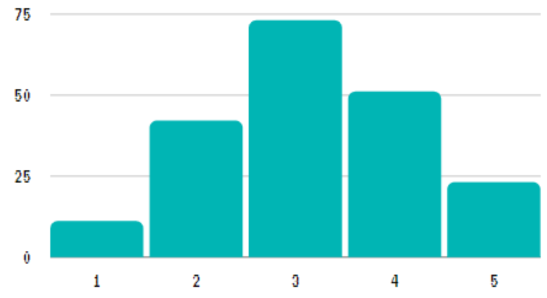


*Figure 19. Risk perception of UAV, survey*

**Which issue do you reject or fear most about drones?**

The highest risk factors found are drones misused by criminals or terrorists, and drones misused with respect to privacy by filming and monitoring everything or respect to the captured data. It is surprising to note that a collision between drones is not one of the main concerns, the possibilities being much greater due to the hypothetical amount expected, as opposed to other major fears or threats such as those mentioned.

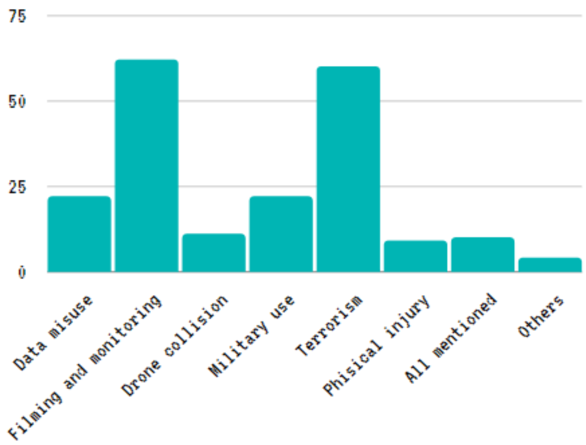


*Figure 20. Fear perception of UAV, survey*

Finally, in order to determine the perceived benefit and threat of drones, 2 opinion questions have been offered:

**Do you think the use of the drones would benefit society?**

Only 10% say that it would not benefit society, so the figure is quite positive, with the ratio being almost 50-50 between probably and yes with a balanced distribution across all age ranges since despite the risk it poses and the threats it rejects, there is a growing view of the UAV field.

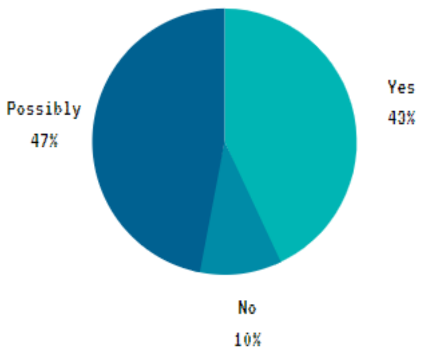


*Figure 21. Benefit perception of UAV, survey*

**Do you consider drones as a threat?**

Regarding this question, almost 15% say yes, while almost half doubt with a probably, which may be due to physical and material risk factors, human resources in terms of work, deprivation of privacy or control or simply ignorance.

Younger people are more confident and more accepting about the technology and services that can be implemented with UAVs, the range between 31-50 is more doubtful in every way, so providing information, having feedback and making them visualize the image clearly would help move them towards a more confident side.

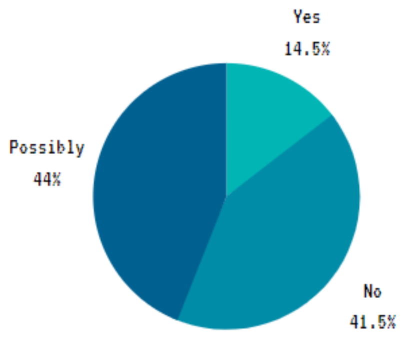


*Figure 22. Threat perception of UAV, survey*

From the age of 51 they are very skeptical, as many, are unaware of applications that can be given to UAVs other than filming and surveillance, and since when the concept of U-space is implemented it will be the older population, their needs must be respected and addressed.

The information received from the population regarding innovations and research of this nature is of vital importance when developing these concepts. Consultation, dialogue and public participation are needed to assess and take into consideration all aspects of public concern, informing them properly, in a transparent and open manner through the technology available today. On part of the different stakeholders it must be built bridges between people, business, policy and research in order to make the perceived risk lower, and the benefit and usefulness higher, potential problems need thinking about together with competitors, retailers and other potentially other industries.

Many people reject the use of drones simply because of the cameras, although not all drones carry them, others because of the freedom they think they can have and the ease with which an illegal act could be committed, so a number of issues need to be raised before and during the implementation of the services, as an iterative process, in order to ensure that the direction taken by the U-space concept is by and for everyone, concepts like:

- What do we do if some people don't support or agree with our assessment of benefit, risk and impact and our understanding of our responsibility and responses?

- How can we understand the potential social, ethical, environmental, cultural & economic risks, impacts and influences of our research or innovation?

- Who will it advantage or disadvantage?

- What can we do ourselves to mitigate negative impacts?

- Who do we need to involve, and how, to get a clear picture?

# 4. U-space configurations design

In this section it is intended firstly to identify limitations of the current airspace configuration regarding UAVs and restrictions in the city in order to understand the environment to be implemented. As a second part we study the possibilities of routes, networks and ways of flying that can be adopted by UAVs within the selected region as well as the characteristics of each of the different ways to perform them and an assessment of which are the candidates to apply them in the city. Finally, the selected configurations will be presented as possible U-space scenarios, which will serve later to perform a series of simulations to analyze factors such as capacity, security or flexibility of the configuration and compare them, thus establishing a framework of which could be more effective and compatible with the desired characteristics.

## Barcelona’s Airspace

Barcelona's main problem in terms of UAV application is the proximity to the airport, since the whole city is contemplated within the CTR and CTR Area 2 volumes which are class D/E [22].

**Class D**. IFR and VFR flights are allowed, and all flights are provided with air traffic control service. IFR flights are separated from other IFR flights, receive traffic information regarding VFR flights and traffic avoidance advice on request. VFR flights receive traffic information regarding all other flights and traffic avoidance advice on request. Continuous air-ground voice communications are required for all flights.

**Class E**. IFR and VFR flights are allowed. IFR flights are provided with air traffic control services and are separated from other IFR flights. All flights receive traffic information, as far as is practical. Continuous air-ground voice communications are required for IFR flights

Nowadays simple drone operations are not feasible within this space due to these restrictions despite the implementation of the new regulation and scenarios published by the NAA. If we add the proximity to the airport to the airspace congestion and the large number of take-offs and landings at the airport, the use of drones without control by the authorities makes these missions a high risk for commercial aviation. Below are various graphs showing the areas of the airspace that can be seen within the city of Barcelona.

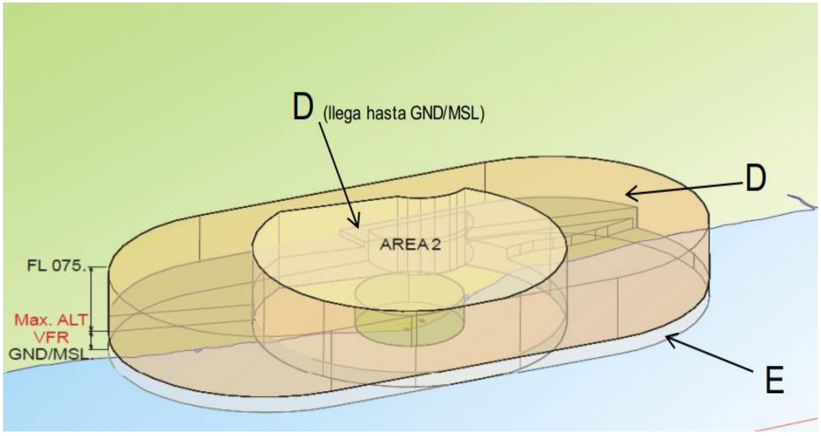


*Figure 23. Barcelona’s CTR limit and class [23]*

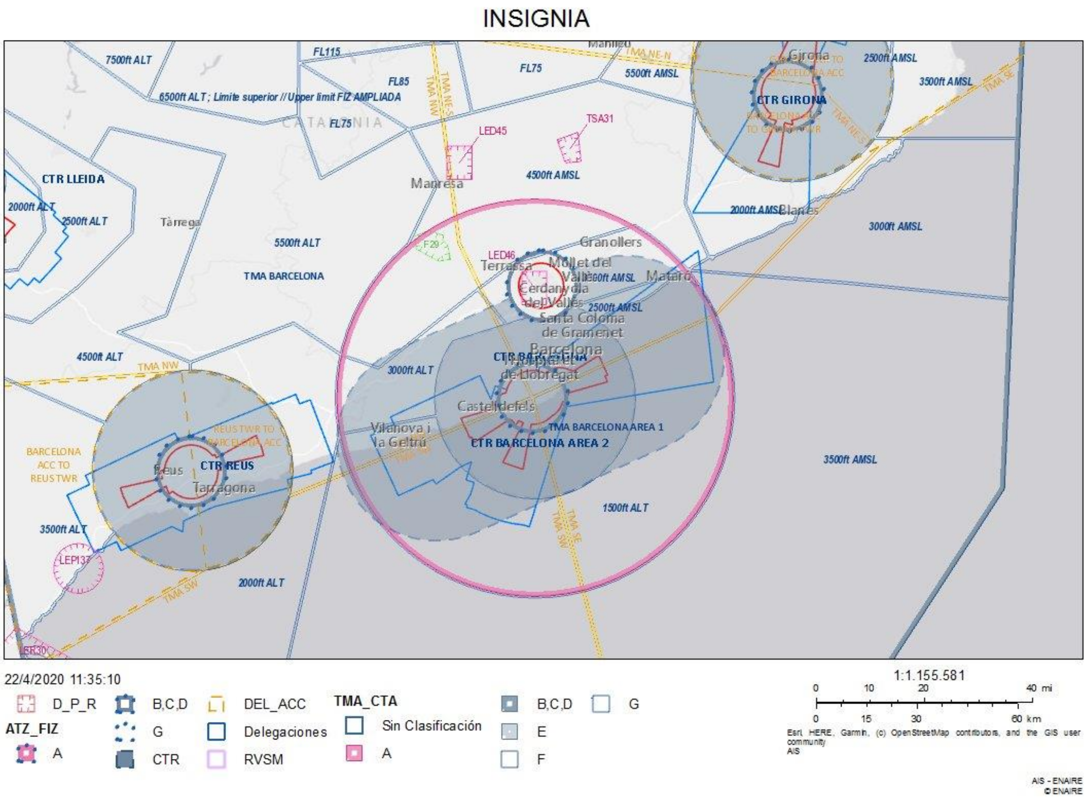


*Figure 24.Barcelona's Airspace by Insignia [25]*

In addition to the limitations by the CTR, it exists the ATZ main circumference inside CTR's region with its center in the aerodrome reference point (ARP). The following table shows the limits and classification of airspace in the figure above.

| Denominación y límites laterales<br>Designation and lateral limits | Límites verticales<br>Vertical limits | Clase de espacio aéreo<br>Airspace class | Unidad responsable<br>Idioma<br>Unit<br>Language | Altitud de transición<br>Transition altitude |
|---|---|---|---|---|
| BARCELONA CTR<br>Espacio aéreo limitado por dos semicircunferencias de 12 NM de radio unidas por sus tangentes comunes, centradas en los puntos TEBLA (412252N 0021930E) y ASTEK (411232N 0014919E) excepto el ATZ de Sabadell. / Airspace limited by two semicircumferences of 12 NM radius joined by its common tangents, centred on points TEBLA (412252N 0021930E) and ASTEK (411232N 0014919E) except Sabadell ATZ. | FL 75<br>MAX ALT<br>VFR SECTOR<br><br>MAX ALT<br>VFR SECTOR<br>SFC | D (3)<br><br><br><br>E | Barcelona APP<br>ES/EN | 1850 m/6000 ft |
| Área 2:<br>Área definida por 412846N 0021100E, arco de circunferencia de 12 NM de radio centrada en 411743N 0020507E hasta 412433N 0015203E, 412720N 0020352E, 412846N 0021100E, excluyendo el ATZ de Sabadell. / Area defined by 412846N 0021100E, arc of circumference of 12 NM radius centred on 411743N 0020507E to 412433N 0015203E, 412720N 0020352E, 412846N 0021100E, except Sabadell ATZ.<br>Ver/See ENR 6.5. | FL 75<br>SFC | D (3) | | |
| BARCELONA ATZ<br>Círculo de 8 km de radio centrado en ARP<br>Circle radius 8 km centred on ARP. (1) | 3000 ft HGT (2)<br>SFC | D | Barcelona TWR<br>ES/EN | |

**Observaciones:** (1) O la visibilidad horizontal, lo que resulte inferior.
(2) O hasta la elevación del techo de nubes, lo que resulte más bajo.
(3) No autorizados vuelos VFR. El tráfico con origen/destino a helipuertos y aeródromos autorizados seguirá los procedimientos establecidos.

**Remarks:** (1) Or the ground visibility, whichever is lower.
(2) Or up to the cloud ceiling, whichever is lower.
(3) VFR flights not authorized. Traffic with origin/destination authorized heliports and aerodromes shall follow the standard procedures.

*Figure 25. Vertical limits and designation of airspace [22]*

The height that limits these volumes is approximately 2300 m, so low and high-level operations are affected

Based on these conditions, the need for implementation of U-space as far as manned aviation is concerned is shown. If what happens at thousands of meters high can affect operations, what flies within the city can disrupt the UAV network, and in this case we are talking about helicopters, heliports, and the missions they develop, which can be merely tourists, surveillance or emergency.
There are different applications that allow users with UAVs to plan flights and observe in what conditions, how, and where they can fly and why in the areas surrounding them.

ENAIRE, the company that manages air navigation in Spain and is responsible for the design of air space, has created an application, ENAIRE Drones [28], which presents on a map the air spaces in Spain with the areas where the use of drones is permitted as well as the areas to be avoided, for example, those containing sensitive fauna, air control areas near airports, heliports, aerodromes, military bases or natural parks that require an additional permit to fly this type of aircraft. The information available in ENAIRE Drones comes from the aeronautical publication AIP Spain where ENAIRE publishes all the information related to restricted areas, procedures, maneuvers, and periodic updates that airspace users should be aware of.

The following figure shows the many restrictions that exist to perform a flight within the city of Barcelona, which can only be performed with an authorization from AESA and its corresponding coordination with the airport authorities. All the areas with limitations and restrictions are shown in red where the main ones are ATZ and CTR, and the smaller ones correspond to all the heliports that exist in the city.

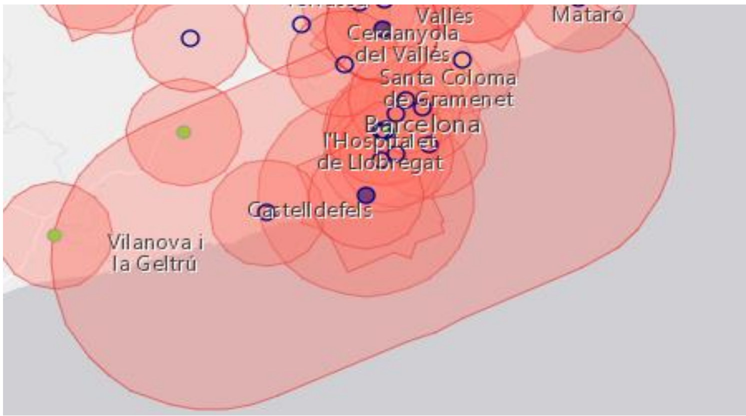

*Figure 26. Barcelona's Airspace with ENAIRE Drones App [28]*

With ENAIRE application, it is quite chaotic to visualize the airspace of Barcelona because of the interface that it has, as there is many restrictions within this airspace range, so the application of AirMap [29], which has the same goal than ENAIRE Drones, has been used to visualize the same conditions to clarify all limits of circumferences.

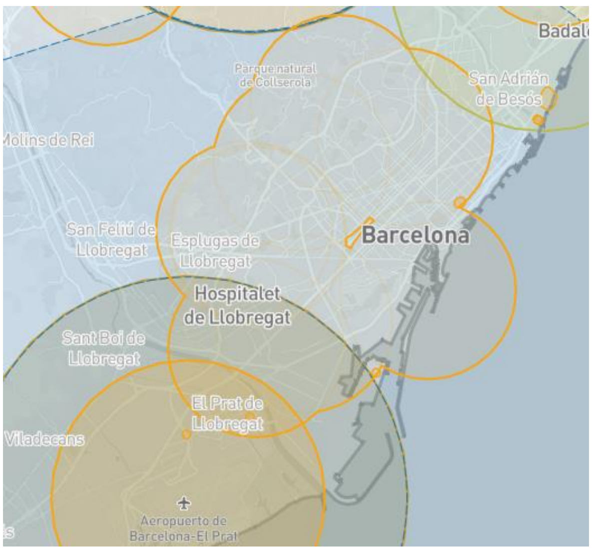

*Figure 27. Barcelona's Airspace with AirMap App[29]*

In addition to the restrictions caused by the airport barriers, there are numerous heliport safety areas with a large radius that limit operations and thus a coordination with the airport owner is necessary. The location of these heliports are shown in the following figure.

**LEDH** - Vall d'Hebron University Hospital
**LEFR** - Fira M2
**LEHB** - Bellvitge University Hospital
**LEJC** - Rey Juan Carlos I Hotel
**LEJD** - St Joan de Déu Hospital
**LEPB** - Barcelona Port Authority
**LERA** - R.A.C.C
**LESP** - St Pau Hospital
**LETK** - Teknon Hospital Heliport

The main concern of helicopter operations is the freedom they have, to fly without the need to specify a specific flight plan and the number of conflicts that can cause a drone to fly BVLOS or VLOS near a heliport.


*Figure 28. Barcelona's Heliports [29].*

With the implementation of U-space, solutions to this problem should be proposed either by including them in the same communications network, making a flight plan mandatory, or creating specific volumes for them, always considering the priorities of security and/or emergency operations.

There is an extra component that can affect the missions, which is the radiosonde performed for the Radiosonde Weather Station, where a balloon is launched to capture information reaching heights of 25.000 m, with an ascent speed of aproximately 330m/min. [22]

Due to the structure of the air volumes and the characteristics of its location, the implementation of U-space in the urban environment of Barcelona must have as a priority to consolidate a network that does not compromise the traditional operations, thus services as the procedural and collaborative interface with ATC, dynamic capacity management, risk analysis and operational plan optimization and processing will be crucial to be able to comprehend all the possible activities in a small space of km2 without obstructing or compromising the other activities

## Routing

We are at a similar place with drones as we were at the start of the use of cars at the beginning of the 20th century, their use is becoming increasingly common, so the next step is to create the "road" network that can ensure safety and flexibility as well as meet the needs of users. There are different ways in which UAVs can develop their operations, and each one determines a different flexibility, capacity, and safety in the area they operate.

As described in Airbus' Altiscope project [30], there are 4 main ways of flying UAV and, depending on mission objective there will be one that is best suited to the operation, however, the best way to harmonize operations is to define a single way of operating, to facilitate flight management, distribute volumes in space and distribute the possibility of collision between aircraft.

1. **Basic Flight**
   This way of flying can be related to some of the open category operations, where there is no coordination between aircraft and each one is responsible for its separation. An example of a mission would be the review of a field or vegetation area.
   The demand for activities that require total control of the UAV without the need to fly in a wide range of space or transport goods in small urban areas such as checking building facades, construction activities or firefighting makes this form of flying feasible. By not having to present any flight plan there is the freedom to fly at any time without the need for control but with the disadvantage that not all the necessary safety is not provided.

2. **Corridors**
   Corridors are volumes of space, either vertically or horizontally, that help manage large traffic demands and avoid conflicts, although depending on whether they are unidirectional or bidirectional there will be the possibility of two UAVs crossing each other, so it must provide a enough safety distance. The most relevant feature of these types of structures are the networks that can be formed by joining several corridors, making them cross each other, in order to have a greater range throughout the territory to be addressed. It should be noted that in order to enter or change any volume of the corridors must be authorized by the competent authority.

   Today there are numerous implementations of corridor structures around the world, either by implementing a single corridor as if it were a highway or by interconnecting them to form more complex networks in urban environments. The following are some examples.

   *"In February 2016, Airbus Helicopters signed an agreement with the Civil Aviation Authority of Singapore for "Project Skyways" to experiment with and develop the regulations, technologies, and operational requirements to safely operate a drone parcel delivery service in urban environments"... "The Skyways UAS over the NUS campus aims to provide efficient delivery of small parcels to students and faculties using a "system-of-system" of drones, ground control systems, air navigation systems, operational procedures, and maintenance procedures that embodies aviation safety at the core of its design"*

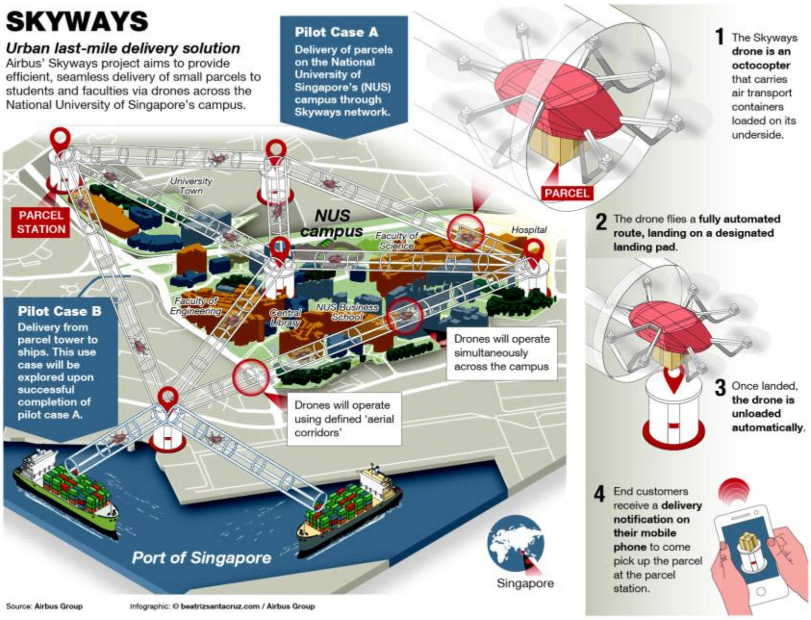


*Figure 29. SKYWAYS project by Airbus [24]*

In addition to this project, researchers at Nanyang Technological University, Singapore (NTU Singapore) [32] are studying ways to allow hundreds of UAVs to fly efficiently and safely at any one time.

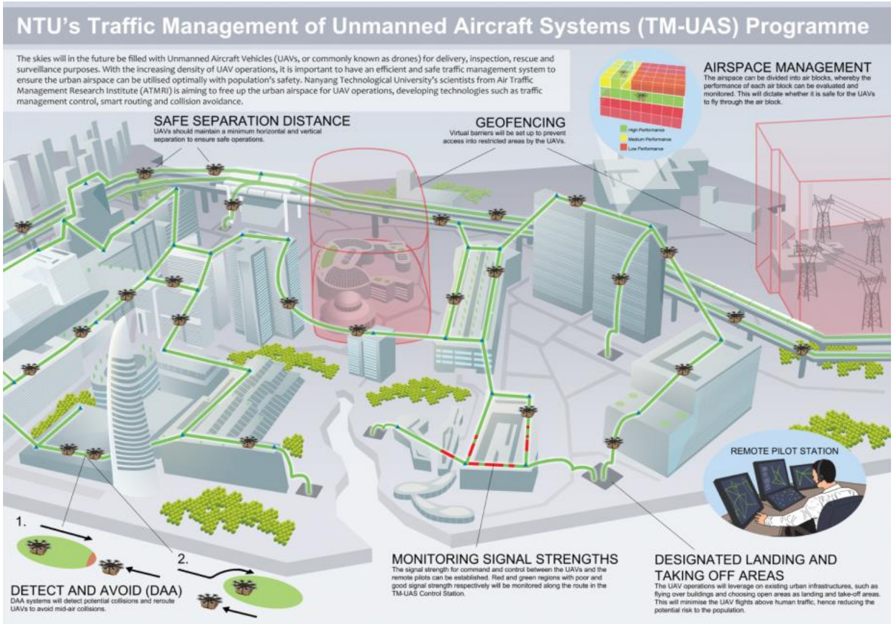


*Figure 30. NTU Management of UAS Programme.*

3. **Fixed Routes**

   Another way to manage UAV traffic is by determining fixed routes for certain operations such as travel between the airport and a point in the city by an eVTOL or other routine routes such as surveillance or inspection. It provides a high degree of security which can also be used for operations within the airport, such as turnaround, runway inspections, or used to manage different warehouses. If we combine this method with corridors, we can create fixed routes that take advantage of the network structures created by optimizing routes, thus increasing the security of the route but affecting its optimization, since the direct route from A to B will always be faster although it may not be feasible due to the environment where it is located

4. **Free Route**

   The free-route is the most autonomous way to manage UAV missions, since they could fly any possible route, under the conditions of the U-space manager, who may or may not approve your flight plan. It can offer a high degree of freedom by taking advantage of the connectivity of the U-space network and the ability to manage conflicts. In order to develop this system correctly, it is always necessary to have a sufficiently precise technology to locate each drone without interference, since a simple failure could cause an accident. Collision detection, AAD or SAA, geofencing, and signal monitoring must be perfectly implemented before this method can be performed.

Although the use of UAVs hardly exists in cities, predictions point to high numbers within a few years, so it is necessary to be aware of the capacity of each environment and the management of missions, so having fixed routes for all drones is not feasible, as well as basic flights should be limited to all activities that need to be performed in this way. It could also be a problem with the implementation of corridors, the city will be congested by a high amount of operations at a time or an excessive number of drones.

The implementation of corridors would raise many debates regarding access to them, although U-space aims to allow access to all users, always with regulation ahead, what will happen if users/companies coincide when using them in the same time window? How would the missions be prioritized? Will there be slots for UAV?  Will you have to pay for using them partially/fully? There is also the option that routes can be booked within the corridors so that the operator/s who implement their services first will perhaps have more rights than other users, so the demand of all users must be taken into account when developing the corridor structure.

One of the ways that are proposed in terms of configurations is the mixture of corridors and free-routing, connecting the city as a network, forming several polygons with the corridors, within which free-routing is allowed, which offers a high flexibility in terms of mobility, although the possibility of free-routing throughout the city should also be considered.

Having discussed the different forms of flight or possible route configurations, two scenarios are established for discussion:

## Configuration 1 - Corridors mixed with Free-Routing

It is a model that has multiple corridors, specifically X, which form a polygon in the area of Barcelona, where within the same, are divided into different polygons in an attempt to imitate the districts or neighborhoods that exist in the city. The start/end of the missions will be located at the vertices of the polygons, where two or more corridors converge. The UAV shall flow in both directions of the corridors, so the first conflict to deal with will be the intersection between two or more UAVs within a corridor.

Besides the configuration of corridors, since it limits the operations, Free-Routing is also added within the polygons that delimit the districts, so if the operation needs to move through the whole city it will not be able to fly any course, but it will have to enter a corridor through an entry point, the union of two corridors, exit through a point with the same conditions, and within the range of the polygon, it will be able to perform Free-Routing.

The configuration is subject to different parameters such as the separation, both horizontal and vertical of the UAVs, as well as the width of the corridors, which must always be greater than the horizontal separation, and how and when they enter the corridors or can perform the mission based on the times that the strategic deconfliction service calculates, which will be explained in more detail in the simulation section.

This model requires most of the initial services and some of the advanced such as pre-flight services including electronic registration, electronic identification, planning and flight approval; as well as in-flight services such as geofencing, flight tracking, dynamic airspace information and automatic technologies to detect and avoid obstacles in order to manage all UAV in a scenario with a great potential for congestion. One of the most important points in this configuration is in the entry and exit management of the corridors since if the UAVs are capable with a strong DAA or SAA system, the bottleneck would be in those points, which may increase in number if the network is modified in the future, using them as HUBs for logistics enterprises or other services. It is also necessary to take into account the diversity of UAVs that will be available in the future so that not all vehicles will respond equally to the different reaction stimuli due to the computational capacity, speed and size of the vehicle, thus raising a question as to the speed limit or minimum speed standard in the corridors.


*Figure 31. Corridors configuration*

## Configuration 2 - Free-Routing

This configuration allows free routing throughout the city, allowing UAVs to perform missions more freely but with greater associated risk, as they do not follow rigid structures while flying, making it a somewhat unpredictable model but with greater flexibility. An important issue to deal with this model is the management of small areas of the city where large numbers of drones can be concentrated, where the possibility of a collision increases drastically. The degree of automation of this model is the highest, so most of the advanced services and all the initial ones are necessary, since it does not have free-routing limitations as in the previous model, which were based within the polygons designated by the corridors, a failure in the trajectory could cause conflicts with manned aircraft, invasion of space...

This configuration also raises a number of questions, in terms of security and ethics of operations. When compared to the corridor configuration, it can be said that it is somewhat determined to the control of the corridors and therefore that the traffic, the end of the missions and the number of UAVs can remain controlled, even if in a certain way it is not.

On the contrary, developing free-routing completely means that the presence of any drone in any part of the city would not be questioned, it would damage all the biodiversity of birds that exists and the creation of congestion is more difficult to avoid and the risk of collision much higher. In any case, as a pretext, it is the most effective way, at first sight, to manage a high density of UAVs.

Raising this problem in a multi-dimensional way, we can observe the complexity of both scenarios, with a high level of operational complexity, population density, and a significative safety impact, which are expected to be implemented in a phase of early expansion or maturity of the U-space concept, which is characterized by a high density of flights, the creation of hubs, reduction of necessary infrastructure and reduction of ATC workload (*see Figure 19).*

To understand the impact of these configurations on safety, the aim is to summarize the main hazards and threats to be considered when applying the concept of U-space and both scenarios. There are obvious determinants of the impact of the configuration on safety such as the density of the scenario, the more vehicles there are, the greater the probability of collision between two or more UAVs, also the speed of the UAVs, or the separation between them. Measures and action plans are needed to mitigate potential hazards such as:

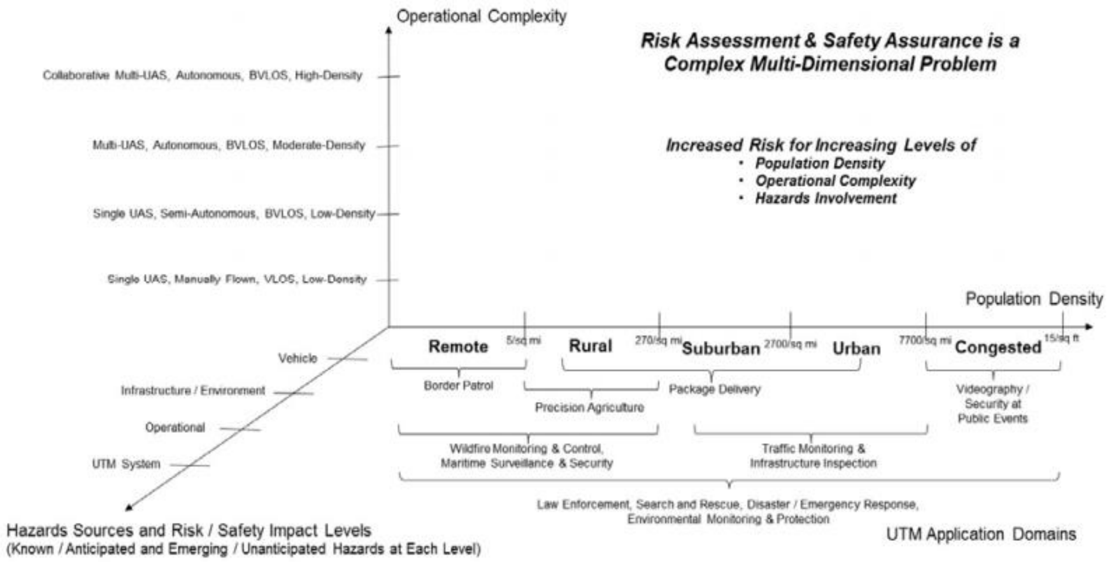


*Figure 32. 3-D Risk Axis* [27]

- Loss of electrical power to control systems
- Loss of control
- Loss of separation
- Failure of GPS or routing.
- Vehicle fly-away
- C2 link lost
- UAM route conflicts with existing air traffic
- Buildings, power lines, airborne vehicles
- Dispatch understaffed, flight planning delayed
- Loss or degradation of ground control station capability
- Lack of vertiport availability

- Human interference with vehicle operations
- Collision between UAVs
- Collision with terrain or water
- Collision with obstacle (building, natural obstacle, man-made)
- Unsafe proximity to people/property
- Cybersecurity-related risks

Some of these incidents can be categorized according to a predecessor failure by identifying different categories of errors or drivers for an incident helping mitigate those errors and strengthen system decision-making based on all recorded event/problem/accident inputs [26]

**System & Components Failure/Malfunction :** Control System Operational Error (e.g., response to sensor errors), Propulsion System Failure / Malfunction, Navigation System Failure / Malfunction Loss of Control / Communication Link

**Vehicle damage:** Improper Maintenance / Manufacturing or Airframe Structural Damage

**Remote Pilot / Flight Crew Error:** Pilot / Flight Crew Decision Error, Operation In / Near Restricted Airspace, Loss of Attitude State Awareness / Spatial Disorientation, Aggressive Maneuver, Inadequate Crew Resource Monitoring / Management

**Ground Control Station (GCS) Failure / Inadequacy:** Lost Communications / Control Link, GCS Power / Electrical System

**Weather & Atmospheric Conditions, Vehicle Upset Conditions, Other External Threat,**

# 5. Simulation

From the two exposed configurations, in this section of the investigation the use of a synthetic traffic simulator is implemented which generates scenarios with a certain volume of concrete UAV missions that are processed and computed as if an interaction between the U-space mission planning service and a strategic conflict service was involved.

The U-space simulator, DronAs, developed by Aslogic [41] (UAB spin-off), has been used to carry out this work. This simulator was developed within the framework of the CEF-SESAR project (https://www.sesarju.eu/U-space) EuroDRONE [35] , in which activities were developed to demonstrate U-space services across the bay of Mesolongi, Greece. This solution was subsequently equipped with new functionalities, such as the creation of scenarios, and is currently operational at the Rozas Airport Research Centre (CIAR) in Castro de Rei (Lugo).

The simulator allows the creation of traffic of different densities, setting the configuration of the airspace through a customizable HJSON, with the ability to generate free routing zones or corridor-based scenarios.

Once the probability of a mission starting or ending in each region is defined, the solution generates random scenarios (start/end time and location within the defined region) according to the airspace restrictions set.

On the other hand, the solution has integrated a U-space strategic deconflicting service (based on another SESAR project, PARTAKE https://www.sesarju.eu/projects/partake ) that allows the detection of potential conflicts during the planning phase, and its mitigation, thanks to a modification of the mission start time (see in Traffic Synthetic Generator section ). In addition, the spatial parameters (minimum vertical and horizontal separation) and temporal parameters (minimum time of submission and confirmation, among others) of this strategic service can be parameterized, allowing the analysis of the impact on safety and airspace capacity of different values. The software exposed will be the basis of the simulations presented below:

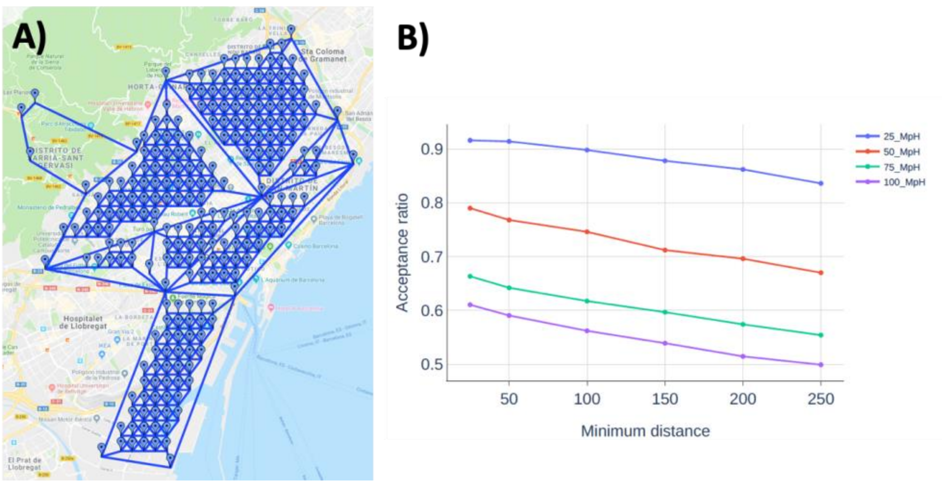


*Figure 33. A) Example of a scenario created in DronAs representing a future configuration of the U-space over the city of Barcelona B) Example of a study of the impact of horizontal separation on the number of missions accepted by the strategic service.*

The simulations were performed through a DronAs API in which through a call the configuration to be simulated is defined (via a HJSON) together with the spatial and temporal parameters of the strategic deconflicting service. As a result of the simulation they are returned:

- acceptance key figures of the created scenarios

- mean shift applied at the beginning of the missions

- scenario display file with the missions (waypoints and timestamps) of the generated and accepted missions.

## Traffic Synthetic Generator

This tool is intended to perform a number of simulations in both scenarios, the configuration of corridors and the configuration of free routing throughout the city, in order to define the parameters that best fit each scenario and how it would affect vary them in a certain range. The parameters for each configuration will be different because of the way the UAVs flow within the city, so a comparison between both will be necessary to visualize which one accepts more capacity in terms of missions/h, the one that becomes more flexible in terms of the amount of missions accepted and finally what is the safety level of the configuration, given by the number of conflicts between UAVs.

The application starts during the planning of the different missions, detecting among all the "requests", which suppose or can generate a conflict by the interaction of the trajectory with other missions. The way it resolves these conflicts is by shifting the start time of the missions, making the trajectories between the possible conflicts disappear or be minimal; this is done from three time windows that are established when managing these missions.

- **Submission window time:** Establishes when the mission must be submitted, if it is set at 300 s, it means that 5 minutes before the mission begins the request must be submitted.

- **Launch window time:** It is a time window indicated to be able to change the take-off time of the mission in case of conflicts, in the case of a 600 s launch window, it is indicated that in a margin of 10 min the take-off time could be shifted

- **Confirmation window time:** The time before the beginning of the mission where the regulated take-off time is notified, within the previously indicated launch window

The process would be summarized in brief steps, starting with the request of the mission planner, doing it according to the submission window, the strategic service studies the possible conflicts and its way to mitigate them through the launch window provided. If it is possible to resolve the conflict by moving the start of the mission within this window, the mission will be accepted, otherwise it will be denied. As soon as it is accepted, the confirmation is sent according to the confirmation time, with the exact take-off time inside the launch window.

The tool also receives different inputs selected based on how you want to manage the mission admission process.

- **Scenario:** Corridors configuration or free routing configuration
- **Duration of the simulation:** 30 min, 1 h, 2 h, …
- **Density:** Number of missions per hour (50 M/h, 100 M/h, …)
- **Time tolerance:** Is the time the mission can start before or after the take-off time, i.e. if the confirmation time is at 15.00h, a tolerance of 120 seconds allows to start from 14.59h to 15.01h
- **Minimum horizontal separation:** Separation minima between UAV in the horizontal axis.
- **Minimum vertical separation:** Separation minima between UAV in the vertical axis.

**Outputs**

- **Acceptance ratio:** Gives a value between 0 and 1 for the accepted missions.
- **Mean time shift :** Is the average time of the missions that have been suffered a change in the take-off time.
- **Submitted missions:** related to density and simulation time
- **Accepted missions number**
- **Rejected missions number**
- **Number of conflicts with missions**

The goal of the simulations is to be able to resolve issues such as the following:

- What parameters have the greatest impact on flexibility and capacity in the evaluated scenario?
- What is the configuration that supports the highest system capacity?
- What impacts most on flexibility, UAV separation or time window modification?
- The difference in flexibility between corridors and free routing

To determine all the above-mentioned outputs:

A. 10 simulations will be carried out for each batch of parameters in the evaluated scenario, obtaining the average of these.
B. The density of the scenarios will be evaluated with 50M/h, 100M/h, 200M/h and 300M/h.
C. The duration of the simulations has been set at 1h.
D. The speed of the UAVs has been set at 20m/s.
E. A minimum vertical and horizontal separation of 10m has been set.
F. The launch window consists of 600s.
G. The submission window is 600s.
H. The confirmation window is 300s.
I. A tolerance time of 120s has been set.

# Simulation results and analysis

The first parameters evaluated were the minimum separation distances, on the vertical and horizontal axis. The distances evaluated were 5,10,50,100 and 200 meters
With the following graph, it can be seen how according to the minimum horizontal distance increases the acceptance ratio decreases in all evolutions of the distances, being 4% the minimum decrease present in the scenarios with densities 50M/h and 300 M/h, while in 100 M/h and 200M/h decreases by 6% and 7% respectively. With the smallest separation, 5 m, a ratio of 0.89 for 50M/h has been achieved compared to 0.34 for 300M/h.
As the separation increases, it decreases between 1-3% at every new time evaluated.

**Corridors**

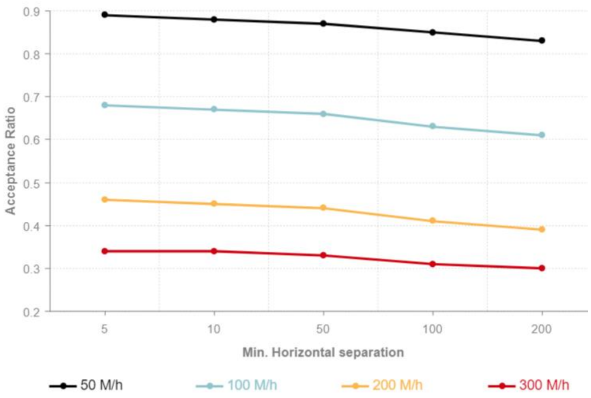


*Figure 34. Acceptance ratio /Min. Horizontal separation: corridors configuration*

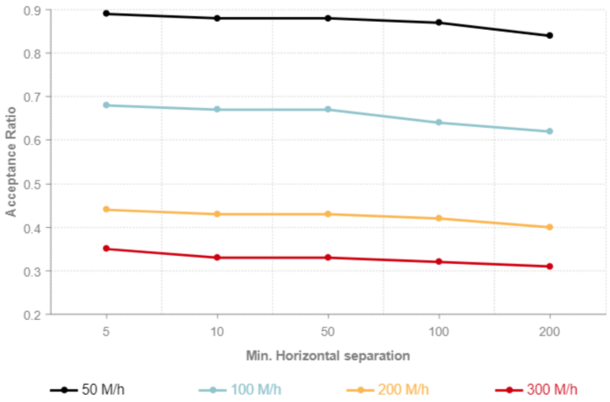


*Figure 35. Acceptance ratio/Min. Vertical separation: corridors configuration*

On the other hand, if we look at the minimum vertical separation, the results are almost identical, with the same decrease in the acceptance ratio in the evolution of the distances evaluated, with a minimum of 4% and a maximum of 7%. In both figures, a ratio of 20% can be seen between the densities of 50-100 and 100-200 and 200 and a ratio of 10% between 200-300. In both simulations it is noted that the capacity of the system for low densities is much higher than for high densities, reaching almost 50% difference.

The impact using free routing configuration tends to lower values if separation minima is increased. In 5-10 meters range the average of the evolution of the separations results differ by 1% or 2%, while in 200 m the ratio acceptance reduction is noted decreasing a maximum of 14% in 100M/h scenario of both separations. The highest reduction within two separation values are found between 50-100 meters in 100M/h and 200 M/h; 6% and 5% respectively.

## Free Routing

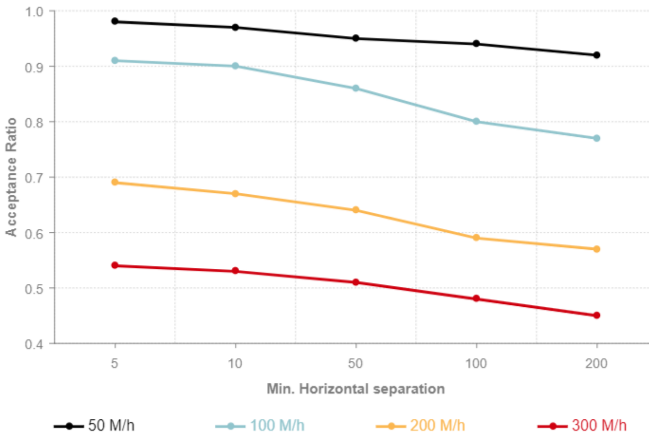


Figure 36. Acceptance ratio /Min. horizontal separation: free routing configuration

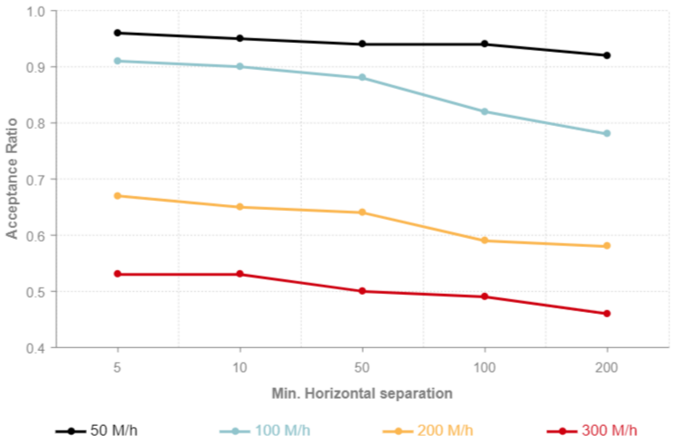


Figure 37. Acceptance ratio /Min. vertical separation: free routing configuration

*With the next simulations a min. separation it's been set at 10 m.*

With the modification of the submission window (see Figure 37) an increase in capacity and flexibility is observed, evaluating time windows of 300,600,900,1200 and 2400 seconds. With a low density in corridors scenario, such as 50M/h with 300s of window 85% of accepted missions has been achieved, increasing by 9% at 2400s.With 100M/h from 0.63 it increases to 0.73, the same as with 200M/h which increases by 10% increasing the window time. While a high density like 300M/h increases only 5% from 0.33 to 0.38.

Because this window serves to indicate the time when the mission request occurs, in advance of the take-off time, the flexibility of the system can be increased by lengthening the window, in high densities the ratio is acceptable but in high densities the requests can be saturated and it may not be sufficient to increase the acceptance rate at the acceptable level.

With free routing the results are similar, increasing up to 7% and 8% although with some decreasing point of 1% at 20 and 40 min. Conflicts are also reduced as long as submission time is increased, with significative difference of 12% between 300s and 900s making the configuration safer and with higher capacity.

## Corridors

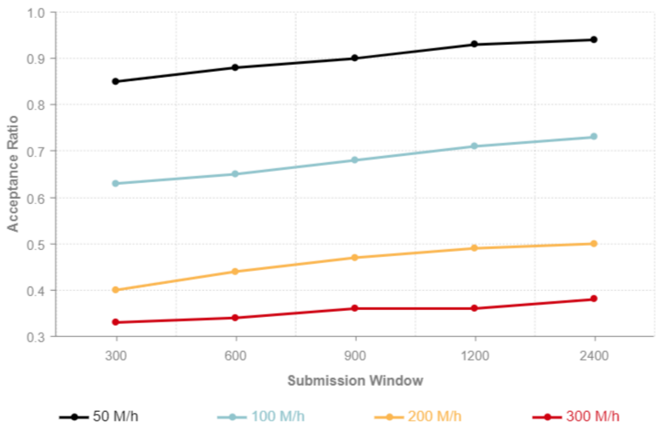


Figure 38. Acceptance ratio/submission window interval time: corridors configuration

## Free Routing

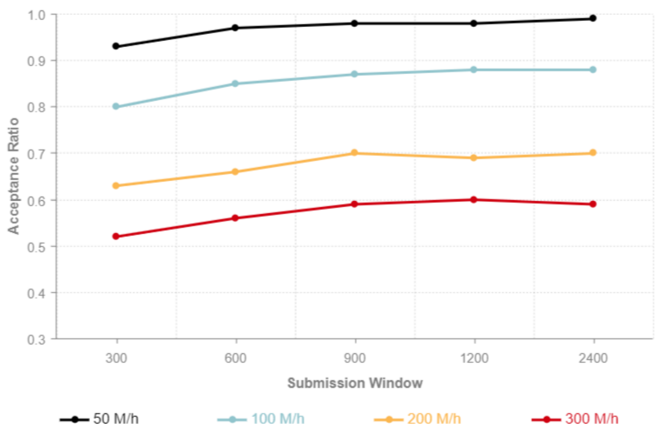


Figure 39. Acceptance ratio/submission window interval time: free routing configuration

Increasing the confirmation window interval from 5 min to 40 min has decreased 6% the acceptance ratio of 100 M/h and 4% for 200-300 M/h. The optimal results are fixed on the lower values for this interval, meaning that the accepted and scheduled missions with a take-off time fixed can impact in future requests. Adding time to the confirmation interval increases the number of conflicts an average of 15%.

**Corridors**

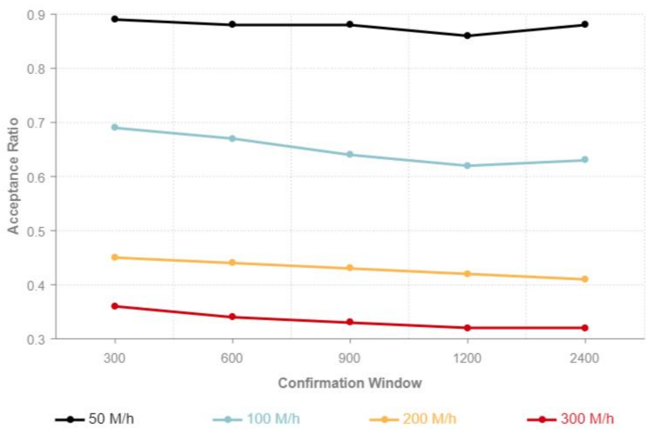


*Figure 40. Acceptance ratio/confirmation window window interval time: corridors configuration*

**Free Routing**

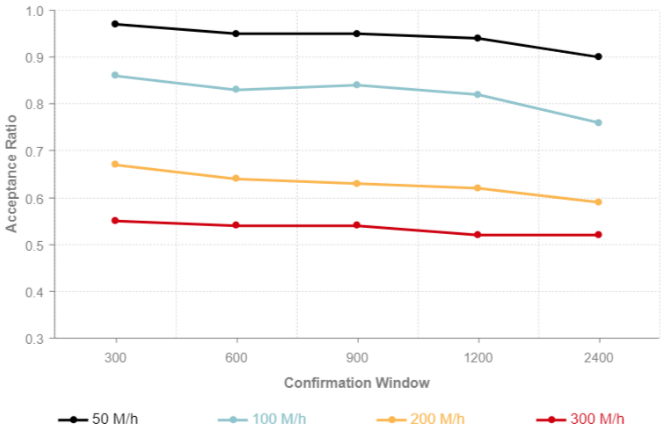


*Figure 41. Acceptance ratio/confirmation window interval time: free routing configuration*

Modifying the launch window from 5min to 40 min gives the higher ratio acceptance values in both configurations, starting with corridors improving 26% the 100M/h scenario with 0.81 ratio acceptance at 40min. Although for 50 and 200 it improves 22% and 25% respectively, for 300M/h it increases from 0.29 to 0.46, accepting less than 50% of requested missions.

On the other hand, with free routing configuration, more than 50% of requested missions with 300M/h density are accepted from 10 min of time interval with a maximum ratio of 0.7 for 40 min. Additionally both 50 and 100 M/h have reached the 100% of accepted missions at 40min.
The launch window time can increase the capacity of the system notably, being the U-space manager more flexible when shifting the take-off time of the mission.

**Corridors**

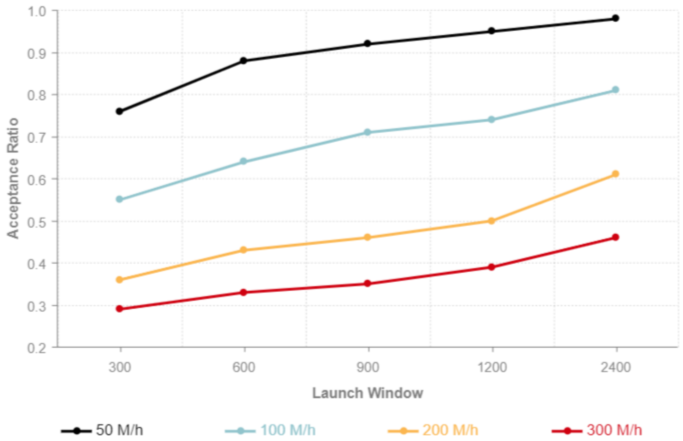


*Figure 42. Acceptance ratio/launch window interval time: corridors configuration*

**Free Routing**

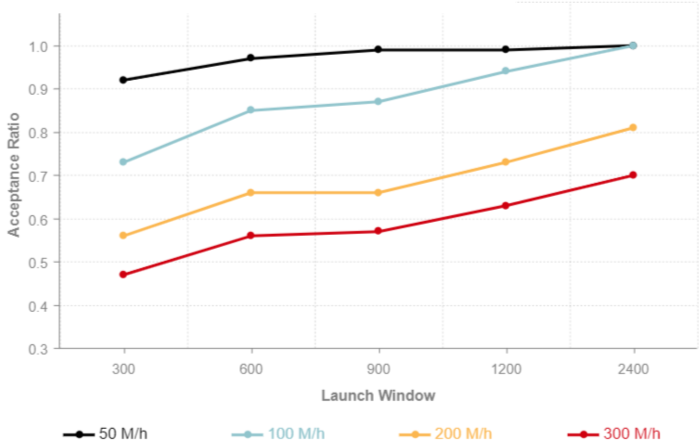


*Figure 43. Acceptance ratio/ launch window interval time: free routing configuration*

Looking at the modified parameters for performing the operations, it can be seen that the one that causes the greatest impact on the acceptance ratios is the launch window, since the increase in this window means a higher level of occupation of the scenario as well as a greater response capacity for defining the start of the mission. For the submission window, the same trend is observed with slightly lower values, so the impact is medium, increasing user restrictions and occupation levels. On the other hand, the confirmation window creates the opposite impact, reducing the accepted missions as the confirmation time increases, so it is a key factor for the mission planners to reduce this time window as much as possible, facilitating when possible the takeoff time, but having a greater range of time to previously modify it to avoid conflicts thanks to the launch window.

If we look at the conflicts that exist, as the density of the missions increases, they also increase, being the highest conflict values when the launch window is 600s than when we set it at 1200s.In the corridor configuration (see Figure 43) the conflict percentage for 50M/h is 2-4% in both launch windows time, but each time the density is increased the percentage rises significantly, reaching 25% of conflicts for 200M/h in both windows and 40% setting the window at 1200s. By changing the configuration, (see Figure 44) there is a drastic reduction in the number of conflicts at high densities, reaching only a maximum of 58 conflicts in the 500 missions per hour with a 600s time window. However, the acceptance ratio is only 0.51, so almost half of the operations have been denied because they could not be moved within the launch window.

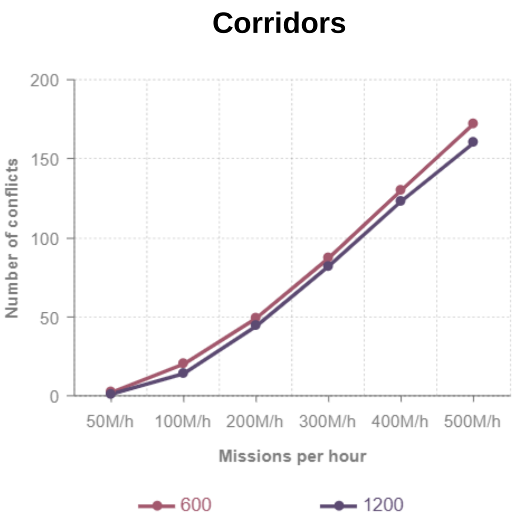


*Figure 44. Number of conflicts/missions per hour: corridors configuration*

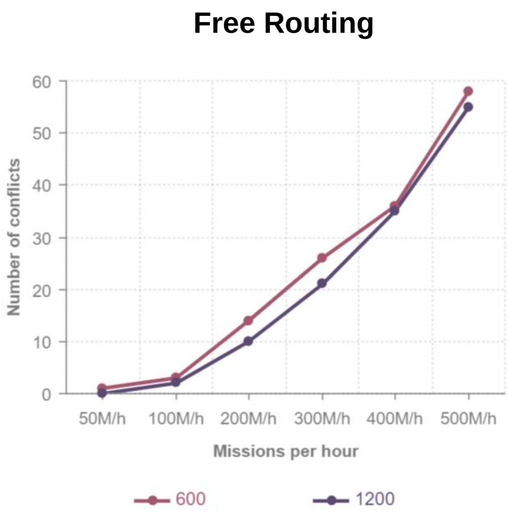


*Figure 45. Number of conflicts/missions per hour: free routing configuration*

Comparing the densities up to 500M/h It can be seen how with the current means a scenario with such a magnitude of UAV/h request becomes unsustainable, creating an unacceptably high percentage of conflicts and accepting only half of the missions. Regarding the shifted time in the corridors scenario the take-off time is modified an average of 2-3 minutes in both launch windows whilst in free routing configuration for a 600s window it is placed at 3.5 min whilst in the 1200s window it is shifted an average of 7 minutes.

It has been noticed how the minimum separation distance also makes the acceptance ratios decrease, diminishing the system's capacity since it is not possible to manage a greater number of UAVs flying at the same time due to the limitation that it implies.

Although the shorter distance means more capacity, less conflicts and a higher percentage of accepted missions, is the U-space system prepared to be able to maintain a safety distance of 5 meters? Since such a small separation could be affected without a tactical conflict resolution service. If so, should limitations apply depending on the size of the UAV, its characteristics and its type of mission?

In view of the results obtained, in which in the scenarios of higher density, 200M/h and 300M/h need higher time windows and the scenarios with lower density, 50M/h and 100M/h present a higher capacity in lower time windows and reach their maximums with the highest windows, it is necessary to define what is the acceptable value to decide that in a scenario the parameters are adequate. A percentage from 60% could be a possible indicator that the scenario can be correctly managed with some increase or decrease of the window. Thanks to the flexibility that the strategic tool provides, the parameters could be adapted according to the density/h that exists since it does not make sense to delay the process of the operation with a density of 25 or 50M/h if in smaller time windows all or almost all the missions can be managed.

For an efficient management of the corridors, a maximum capacity per corridor could be established for each configuration of the time parameters, in this way saturation of the scenario could be avoided. Even so, the free routing option tends to be more effective in terms of conflict management and system flexibility even if it means a higher displacement from the beginning of the missions.

# 6. Conclusions

Having synthesized most of the official information published, it has been possible to give a complete overview of the U-space concept, which is a pillar in the adaptation and regulation of the use, management, and restrictions of airspace as well as the basis for a new type of business and a potential industry. There is a wide range of uses where the use of UAVs would provide clear benefits and save large operational costs, although the cost of airspace use has not been determined yet. Increasingly, drone operations will be observed in urban areas following established phases to establish U-space safely and efficiently. The current legislation limits in many ranges the initiative by companies to participate in UAV-based services, as well as the motivation by urban areas to standardize their use.

If the concept can be developed within the established timeframe, there are many possibilities for trade-related missions within the city of Barcelona, as well as for surveillance, maintenance, and passenger transport tasks. Up to 200 operations per hour could be selected for the management of missions, with free routing being the best option in terms of flexibility, capacity, and security. The management of the different time windows when processing the mission are key to be able to adjust the impact they have on the system.

The configurations that are designed must be sustainable over time and in accordance with current and future expectations, as this is a determining factor in the flexibility, capacity and security of the system. Therefore, if a high demand for missions cannot be assumed due to the configuration, it will be necessary to adapt it to new requirements. Configurations with different levels of layers based with corridors/tubes or creating demand through predefined routes through small slots may be other options.

The free routing concept allows higher traffic densities by reducing traffic flow constraints, in contrast with corridors that need a well-defined and structured approach to handle high traffic densities. With free routing, the separation responsibility is delegated to each UAV employing conflict detection and resolution automation. As a result, traffic is more spread out over the airspace with free routing, since with the configuration of corridors multiple conflicts are generated with the simple process of crossing two corridors, so it can generate limitations when managing entry/exit at strategic points in the configuration and bottlenecks when crossing different corridors, thus using free routing can reduce the number of potential conflicts, thereby increasing both capacity, safety and also the flexibility of the scenarios with higher acceptance values although it is achieved by shifting the missions a longer range of time. If the necessary services were in place, I would choose free routing for the freedom and efficiency in operations that it would provide in a region such as Barcelona, due the territory, forecast and advantages of the configuration mentioned above. To be able to apply this configuration it is necessary to first deal with the acceptance of the population which is vital to be able to mature the use of the VLL airspace; change the paradigm and adapt the regulatory framework to allow commercial operations to be carried out coexisting with manned aviation as well as above crowds and loading parcels, among other properties.

The use of UAVs in urban ecosystems is very limited due to the little control that we have over them, being still a risk to fly near airports due to the lack of communications with ATC and the lack of interconnectivity of the fleet of vehicles that fly over the city. If the last phase of U-space is implemented in 2030, there is a high probability that there will be around 1M flights per year in Barcelona.

The potential social benefits of this technology have been observed, helping to reduce exposure of workers to dangerous situations and reducing time and workload, as well as obtaining real-time information and being able to react to certain events in terms of medical services or surveillance. Furthermore, indirect effects such as the reduction of carbon emissions are positive thanks to the future implementation in the fields of goods transport and construction, although there is very little awareness of this, so it is necessary to inform and involve the population more and make the process more participatory, educational and responsible.

Some of the challenges based on research are:

- The development of an appropriate system for cities adjacent to airports

- The provision of essential services for automated BVLOS operations that reduce or eliminate human interaction routines.
- Adapting regulation to the needs of all operators.

- Increasing popular acceptance of UAVs

- Define the acceptance values of percentages of missions accepted and the number of conflicts detected.

- Establish the adaptation of time parameters based on the density of missions.

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