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1.0	28.06.2020	Ricardo Reis (EMBRT)	Final Version

Table of contents

Executive summary

This report provides a high level integrated and coherent understanding of the ADACORSA project. As such, it establishes the baseline framework and reference information needed to support the formal development of ADACORSA requirements, performance metrics and solutions. It will be followed by two companion documents: D1.2, detailing ADACORSA high level use cases and requirements; and D1.3, supply chain requirements.

In specific, this report provides:

- ADACORSA overarching vision and derived specific goals. Namely, how these articulate with the different mission declaration of its supply chains.

- High-level operational capabilities addressed by ADACORSA to enable its vision statement, derived using the systems engineering approach.

- The context frame, regarding its target sector – drones – where the scope of focus of ADACORSA lies. This will support the project development as a tool to further identify and detail the different internal and external interfaces needed to ensure the results integration among partners and potential future suppliers, clients, and users.

- Reference of the external context regarding drone operations, market, technology, and regulatory landscape to support the understanding and future requirements development. This will be a time referenced description as this is a highly dynamic emerging market, where not only technology is being developed, tested, and deployed, but also for which rules, concepts of operations, business models and societal acceptance and adherence are in their infancy.

Recognizing the accelerated pace of change in the drone domain, a revision of this report and its companion reports is planned before the beginning of activities related to verification and validation in WP6. This revision will be included in D1.4 annexes.

Key Findings:

- A huge societal and market potential is emerging in drone enabled services and business.
- There is on-going effort to accelerate this type of application by developing regulatory frameworks. In Europe, these fall under the U-space concept being pushed under SESAR. International cooperation for harmonization also exists. The regulatory context is not defined yet.
- Key capabilities need to be developed to make mass usage of drones for services and business need to be developed by European entities, to ensure a relevant capture of this market potential. ADACORSA address many of these capabilities within its Supply Chains.
- To align the contributions of the different layers of supply chains into a coherent value chain, addressing drone applications, a holistic understanding and framework is needed. This can be provided by a systems engineering approach.

Publishable summary

This document provides a high-level understating of operational, market and technological context for the development of drone related technologies in ADACORSA project.

The document gives ADACORSA and ADACORSA supply chains vision of purpose, the scope and limitations of the project (out-of-scope).

A detailed top-down description of the operational capabilities addressed by ADACORSA developments is described: SAFE and EFFICIENT BVLOS operations in U-SPACE.

A general market, technology, and regulatory state-of-art for the applications of forestry, smart construction, and logistics, as well for the specific technological themes for each supply chain was addressed.

Non publishable information

Not Apply.

Introduction & Scope

Purpose and target group

This document aims at providing a high-level understating of operational, market and technological context for the development of drone related technologies in ADACORSA project.

The target group are the project partners and those that need to understand how ADACORSA interacts with external context, namely regarding market, technology, and regulation, namely regarding the on-going developments in U-space pursued by SESAR.

Contributions of partners

Explain which partner were involved and their activities in their various sections

TABLE 1: CONTRIBUTIONS

Chapter	Partner	Contribution
1	ALL	Vision statements
2	EMBRT	High-level capabilities analysis
3	ALL	Assumptions on external context with impact on ADACORSA
4	ALL	Out-of-scope items
5	ALL	Market state-of-the-art concerning each Supply Chain.
6.1	ALL	Technology state-of-the-art concerning each Supply Chain
6.2	EMBRT, SYRPHUS, SC6	Legal context and regulations, U-space integration

	partners, SC9 partners	
7	EMBRT	Conclusions

To make this document, EMBRT, as work package and task leader, provided a master architecture and assigned the contributions to the different sections to the supply chain (SC) leaders. The document was structured aligned with a systems engineering approach and to work in complementary fashion to D1.2 (use cases and high-level requirements) and D.13 (supply chain systems and sub-systems requirements).

The different supply chains made their contributions into separate documents, mirroring the master structure. This distribution follows Table 1.

All general sections were made available for revision by the SCs.

Each SC contributed specifically to the sections indicated in the document for Market and state-of-the-art for technology and regulations.

SC9 participated more heavily in general market, economic and social aspects.

SC10 participated more heavily in the legal landscape and regulations (with significant contributions from SC6 and EMBRT).

EMBRT contributed more heavily to the vision, high level capabilities, U-space and BVLOS.

EMBRT did the editing and integration of the document and coordinated the final revision.

IFAG supported final revision and integration as project leader.

Metisbaltic did the final editing revision for reading, typos, and formatting.

Relation to other activities in the project

Explain relations to other activities in the project:

- Inputs: All supply chains provided a separated document with Supply Chain Market, Technology state-of-art and applicable regulations.
- Outputs: D 1.1 will provide inputs to D1.2 and D1.3 and revision. It should inform other WP of external context and support exploitation plan.

1 Vision Statement

The fast pace of technological evolution has increased the access of civil society to ever more sophisticated equipment. Electronics and electrical machines miniaturization, among other factors, coupled with unit cost decrease, opened the path for new business and applications that leverage on capabilities only available a couple of decades ago in the realm of military and other state- related actors.

ADACORSA is focused on “drones”, a layman term for the smaller craft of what is more correctly defined as **UAS** – **Unmanned Air Systems** by ICAO definition – or if a more gender-neutral approach were to be adopted[1], **Uncrewed Air Systems**. These imbue the promise of affordable and easy access to space third dimension for a host of low airspace applications of societal interest: from logistics of commercial packages to medical assistance, from personal photography to land mapping and surveying, from the orchestration of ever more automated machines in construction to inspection and asset management in contexts of difficult or perilous human access, to name a few.

ADACORSA builds on the realization of this huge societal and market opportunity, which has meanwhile accelerated and brought into prominence due to COVID-19 [1].

To enable this promise to come to fruition, several components must converge, namely reliable and low-cost technological solutions, and a regulatory and organizational framework must be in place. Of all the operations modes, the capability of flying **Beyond Visual Line of Sight (BVLOS)** is of critical importance. Without it, drone services would be constrained to the range of the drone pilot eyes and, consequently, business applications limited to specific niche markets.

The seamless integration of drones into the airspace in Europe is being handled by U-space in the SESAR programme [2]. A four-level roadmap has been set for this, with increasing levels of services available and, a host of projects address the CONOPS of U-space operations [3] and demonstration of associated capabilities and services [4]. In the same vein, Federal Aviation Administration (FAA) in the USA is leading an **Unmanned Traffic Management (UTM)** effort, under its NextGEN programme [5]. A joint effort between SESAR, FAA, and EUROCONTROL exists to harmonize efforts in both developments [6].

In this landscape, ADACORSA aims to supply differential technologies in value and cost to enable drone driven – or enabled – business applications and services (see section 5). This aligns with ECSEL main purpose of Europe leadership in electronics and systems, and ADACORSA partners' ambition to capture a stake in this important and emerging domain.

ADACORSA partners encoded this into a joint, shared vision for the project, expressed as **“Provide European technology to render drones as a safe and efficient component of the mobility mix, with differentiated, safe and reliable capabilities in extended beyond visual line of sight (BVLOS) operations”** (Figure 1).

[1] Although attempts in the past were made regarding gender neutrality, they have not been adopted by the general industry so far.

FIGURE 1 ADACORSA VISION STATEMENT

ADACORSA's vision statement is a pull driver for ADACORSA partners. By having a common shared purpose, they are then able to coalesce, organize and integrate their own goals and contributions towards it. Namely, to make the vision come to fruition, a set of specific high-level capabilities was defined, aligned with the core operational capabilities defined for U-space to come to fruition, as expressed in its roadmap [2]. This provides a structure promoting a degree of self-organization and clarity for cooperation among partners. Section 2. details the high-level operational capabilities addressed by ADACORSA and how they relate with U-space.

ADACORSA "Supply Chains" (SC) mimic the value networks that will deliver products and services into the market. In this way, ADACORSA maximizes the potential for future market uptake, exploiting the synergy of mutual understanding between partners along with an organizational structure very aligned with market uptake and deployment (see Figure 2).

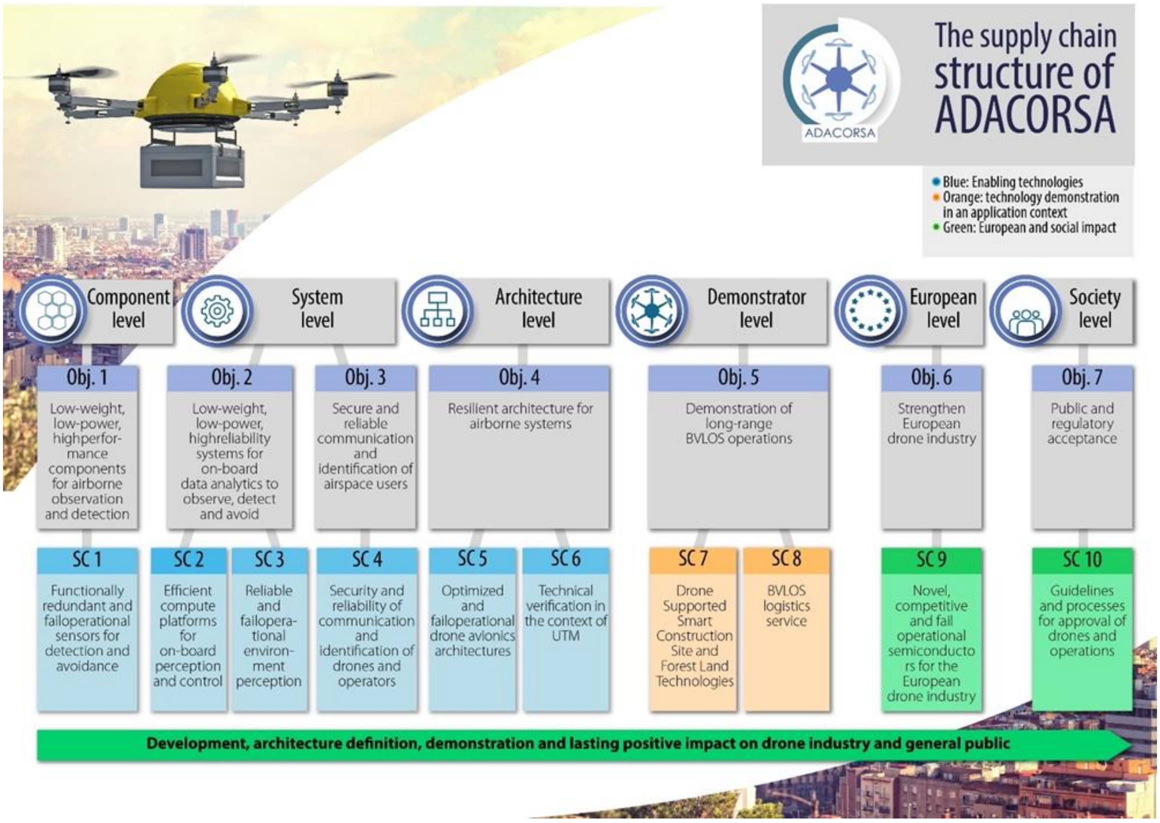


FIGURE 2 ADACORSA SCs OBJECTIVES AND FOCUS

To further stress this market- driven approach, each SC also produced its own vision statement, as follows:

SC 1 Vision : Develop sensors based on automotive technology that is functionally safe, fail-operational, low cost, weight, size, and power, and which scan the drone environment in sufficient detail for detection and avoidance as well as automated take-off and landing, including automated landing as a risk-mitigating measure in the case of emergency or failure.

SC 2 Vision : Enable energy-efficient, lightweight, reliable compute architectures and analytics for the perception of drones.

a. Design architectures that facilitates interpretation of raw data from various sensors
b. Develop algorithms for building 3D maps of an area with a valid coordinate system
c. Guarantee collected data integrity thanks to cryptographic blockchain

SC 3 Vision : Develop algorithms for fail-safe operation of drones, using data fusion technologies, and ensuring a reliable and safe environment perception based on redundant information from different sensors.

SC 4 Vision : Develop reliable and secure identification and communication of drones to enable safe and ubiquitous BVLOS future air mobility for BVLOS scenarios enabled by

SC 5 Vision : Increase safety, availability, and performance of drone avionics systems by designing fail-operational architectures that support diverse, redundant computational approaches and the use of miscellaneous networking solutions

SC 6 Vision : The ambition of this supply chain consists of integrating components in the context of UTM through modelling, simulation, and verification to enable safe and affordable integration of unmanned, highly automated air vehicles into very low-level (VLL) airspace at high vehicle densities and in BVLOS operation scenarios with the future prospect for integration into higher airspace, to enable a multitude of prospective missions ranging from drone inspection to air taxi operations.

SC 7 Vision : Provide components and systems to enable long-range and BVLOS drone operations at reduced cost and at a lower complexity for end-users.

SC 8 Vision : Achieve reliable, secure, and safe logistic services with unmanned and remotely piloted systems and prepare for automated operations in BVLOS conditions.

SC 9 Vision : The vision of SC9 is to design and deliver a roadmap towards the adoption of ADACORSA achievements from the EU market by combining:

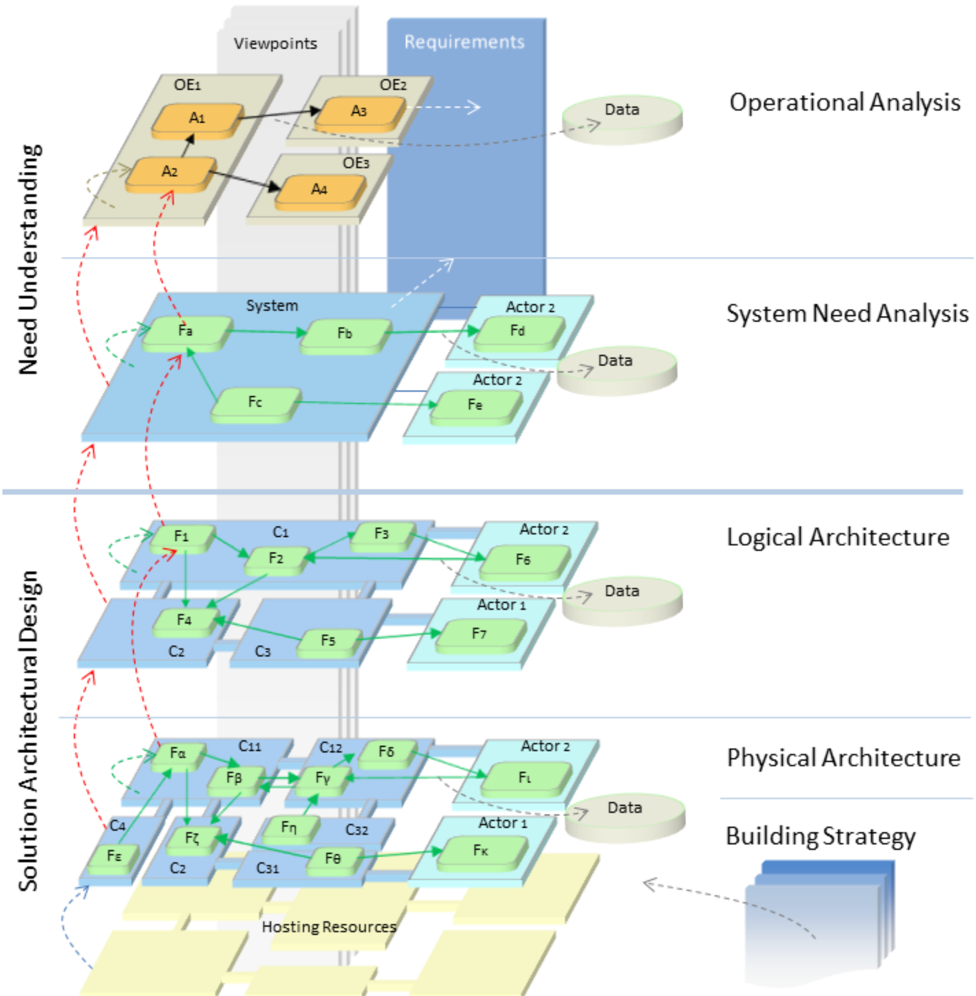
a. a thorough analysis of public acceptance for drones
b. a detailed technical analysis of ADACORSA technical improvements and
c. a detailed market analysis of the EU drone industry

SC 10 Vision : The vision consists of drones that fly their missions with maximum efficiency, considering the needs of its mission objectives, regulations, and the public in mixed traffic within and especially beyond visual line of sight.

In the following section, a more detailed overview of how ADACORSA relates with U-space key services and operational capabilities is given.

2 High Level Operational Capabilities

ADACORSA project will adopt the systems engineering Arcadia Methodology [7] to propose and develop its system solutions (see Figure 3). Arcadia aligns with the V model, also adopted as a reference by ADACORSA. This section focuses on the first layer of such methodology, operational analysis, promoting an understanding of the stakeholder's perspectives, desires, and needs and mapping them into operational capabilities.



Voirin J.-L., *Model-based System and Architecture Engineering with the Arcadia Method*, © ISTE Press, London & Elsevier, Oxford, 2017.

FIGURE 3: ARCADIA METHODOLOGY, FROM [7].

The first aspect contained in the project vision is the meaning of system safety. Although subjective and controversial, the perception of the safety of unmanned aerial systems (UAS), or drones, can be related in general to three main aspects:

- the possibility of drones falling and injuring people on the ground;
- the possibility of drone crashes causing damage to material property on the ground, and
- the possibility of drones causing accidents with other air vehicles in the air.

Thus, a drone system to be considered safe needs to guarantee that the probability of any event of this nature occurring is the minimum possible.

Specific drone applications may also contain aspects associated with the safety of the people and goods involved. In the case of goods deliveries, a typical accident situation occurs when the customer receiving the goods approaches the drone and picks up the goods. This specific problem, although very important, will not be addressed here in the project.

Likewise, the drone operator has a very significant chance of suffering an accident, due to its proximity in handling the system that requires special attention. On the other hand, the operator is responsible for observing and avoiding any possibility of collision against obstacles or between vehicles in the air. Thus, as the drone moves away from the operator, the possibility of a collision event increases. In the case of flights beyond the operator's line of sight, instead of "See & Avoid", technological solutions to detect and avoid collision are required. These are critical situations for which the ADACORSA project must propose and develop solutions to reduce the chances and risks of collisions.

Following the Arcadia Methodology, the designing of a system shall start by identifying the desirable abilities that the system must show off during its operation, named "operational capabilities". So, from the safety point of view, the ADACORSA solutions must include the following operational capabilities, to be considered as a "safe" system:

- Do not harm people and assets on the ground
- Do not damage aerial vehicles
- Ability to operate beyond visual line of sight (BVLOS)

The diagram below indicates the connections between the desired "safe" characteristic and the "operational capacities", as required to ADACORSA solutions:

FIGURE 4 SAFE OPERATIONAL CAPABILITIES

The next step in the methodology seeks to establish the "operational capabilities" and "functions" that the system must have so that during its operation, the system presents the operational abilities defined in the initial step.

Proceeding in this manner, the following “system capabilities” and “system functions” were identified:

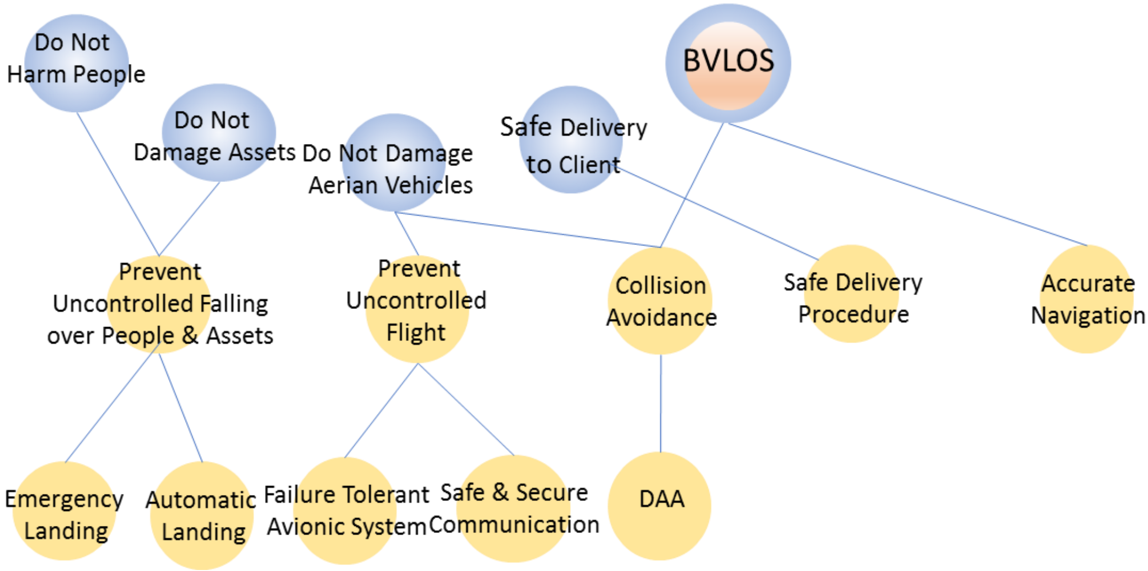


FIGURE 5 SAFE SYSTEM CAPABILITIES & SYSTEM FUNCTIONS

The upper layer in this diagram represents the “operational capabilities”, in the middle layer are the “system capabilities”, while the bottom layer presents “systems functions”. It shall be noted that the ADACORSA project will not develop solutions for all the system capabilities listed above. ADACORSA solutions will be focused mainly on the following system capabilities and functions:

- Prevent Uncontrolled Flight
  - Failure Tolerant Avionic System
  - Safe & Secure Communication

- Collision Avoidance
  - Detect and Avoid System (DAA)

- Beyond of Visual Line of Sight (BVLOS)
  - Detect and Avoid System (DAA)
  - Accurate Navigation System

The second aspect contained in the project vision, “efficient”, refers to the ability of the system to provide services, or products, within the costs, time, and quality expected by the client and service provider.

Also, in this case, slightly different approaches are possible when identifying and expressing the operational capabilities of the system related to efficiency. Here, the capture of the operational capabilities was obtained over a delivery logistic service scenario inside an urban environment. This kind of scenario, due to its typical complexity, can represent and encompass many other scenarios for different drone applications. The identified “operational capabilities” are presented below:

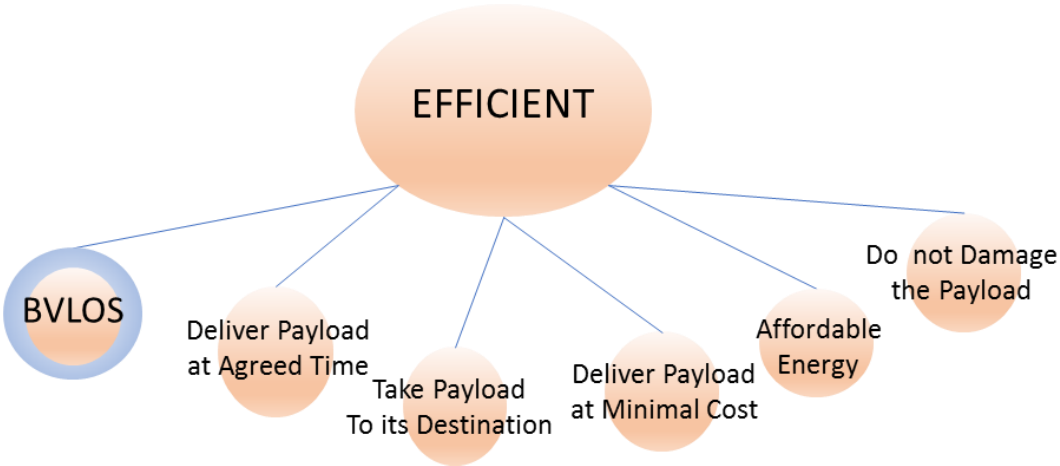


FIGURE 6 EFFICIENT OPERATIONAL CAPABILITIES

Some comments are presented in the following to justify the identification of this assembly of operational capabilities as “efficient”.

First, the aspects related to costs, time, and quality are explicitly presented on the diagram. The delivery to the correct destination is particulary important aspect in terms of a system capacity, and, possibly, could be classified as an “effective” capacity also.

Another remarkably interesting capability refers to the ability to operate BVLOS, meaning the operational ability that allows the system to overtake the limitation of delivering goods beyond the visual line of sight of the operator. Here, in the “efficiency” interpretation, this operational capability overlaps with the BVLOS ability from the “safety” point of view.

The affordable energy capability is related to the drone’s weight and its operational performance.

As before, the next step in the Arcadia Methodology seeks to establish the capabilities and functions that the system must have so that during its operation, the system presents the operational abilities defined above.

The diagram below presents the “operational capabilities”, on the upper layer, and the identified “system capabilities”, in the middle layer, and “system functions”, in the bottom layer:

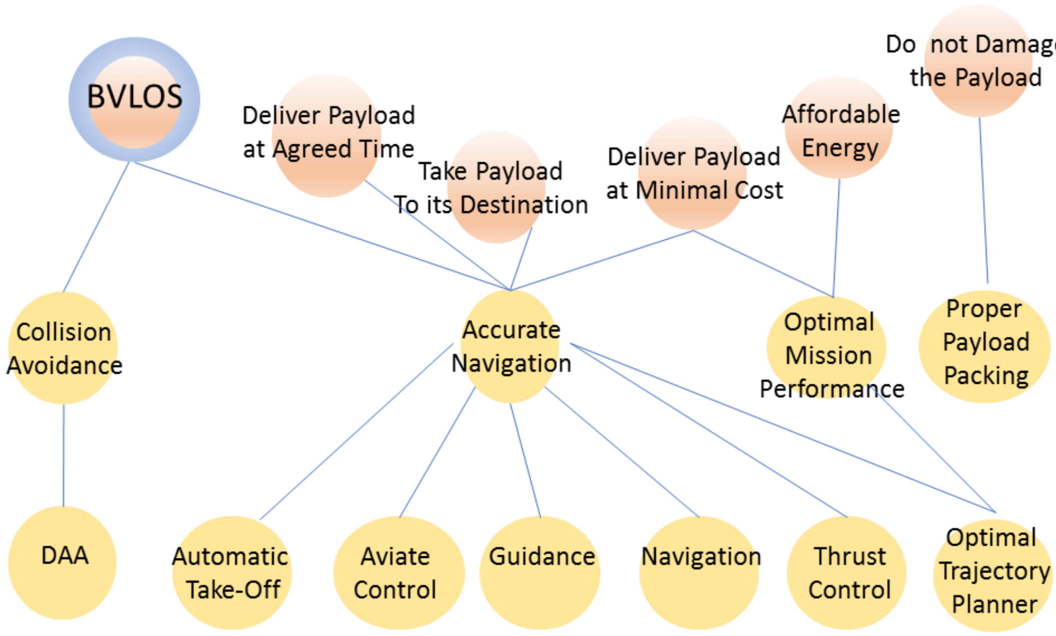


FIGURE 7 EFFICIENT SYSTEM CAPABILITIES & SYSTEM FUNCTIONS

The "Proper payload packing" system capacity will not be developed in the project, neither the "automatic take-off" system function. ADACORSA solutions will be focused mainly on the following system capabilities and functions:

- Collision Avoidance
    - Detect and Avoid System
- Accurate Navigation
    - Aviate control
    - Guidance
    - Navigation
    - Thrust Control
- Optimal Mission Performance
    - Trajectory Planner

The safe and efficient aspects of the ADACORSA solutions represent definitively the ambitions of the project. They are not, however, comprehensive regarding the full vision scope. Another dimension must be added, regarding compliance with regulations that allow the *right to play* in the intended environment. For ADACORSA, in the first instance aiming at the drone operations market in Europe, this means targeting U-space compliance. U-space describes a series of different services and procedures that enable safe operation of drones in Very Low Level (VLL) (usually meaning below 150m of altitude above ground level). A more detailed look into U-space is provided in section 6.1.1. For the moment suffice to say that for this reason, a third aspect needs to be included to support the project's vision: the system's compliance with existing (and, where possible, in development) U-SPACE regulation.

The document "European ATM Master Plan: Roadmap for the safe integration of drones into all classes of airspace" [2], has defined the service "capabilities" required for the operations of drones in U-space. This document sets the creation of U-space in four stages (U1 to U4) so that, "… as the range of mission types expands, and U-space services are deployed and enhanced, drones of all types, and the supporting ground infrastructure, will need to have capabilities that evolve accordingly.” Table 2 maps the “drone capabilities” expected to enable U-space services.

TABLE 2: U-SPACE DRONE CAPABILITIES FOR AIRBORNE COMPONENT FROM [2]

Capability	Description
e-identification	Ability to identify the drone and its operator in the U-space system
Geo-fencing	Ability to comply with geographical, altitude and time restrictions defined by the geo-fencing service. This capability covers the technology, processing, and any required communication links, as well as management and use of geo-fencing information used in the provision of this service.
Security	Ability to protect vehicle and data (interaction with other vehicles and infrastructure) against attacks on information technology and communications systems.
Telemetry	Ability to transmit measurement data from the drone-to-drone operator and/or service provider to meet the demands of relevant services.
Tracking	Ability of the drone to provide flight parameters including at least its position and height.
Vehicle to Vehicle communication (V2V)	Ability for drones to communicate information to each other. The nature of the information exchanged, and its performance requirements, will depend on the application.
Vehicle to Infrastructure communication (V2I)	Ability for drones to share information with infrastructure components
Communication, Navigation and Surveillance	Ability for drones to meet the communication, navigation, and surveillance performance requirements for the specific environment in which they will operate. This capability involves the combination of on-board sensors and equipment (e.g., data link, voice radio relay, transponder, laser, GNSS, cellular etc.) as means of achieving the required performance.
Detect and Avoid	Ability for drones to detect cooperative and non-cooperative conflicting traffic, or other hazards, and take the appropriate action to comply with the applicable rules of flight. This includes the collision avoidance, situational awareness and “remain well clear functionalities, as well as the other hazards described in chapter 10.2.3 of the ICAO RPAS Manual: terrain and obstacles, hazardous meteorological conditions, ground operations and other airborne hazards.
Emergency Recovery	Ability of drones to take account of failure modes, such as command and control (C2) link failure and take measures to ensure the safety of the vehicle, other vehicles and people and property on the ground. This includes identification of possible problems (auto-diagnostic) and all equipment required to manage solutions.
Command and control	Ability of drones to communicate with their ground control station to manage the conduct of the flight, normally via a specific data link.
Operations management	Ability to plan and manage drone missions. This includes access to and use of all aeronautical, meteorological, and other relevant information to plan, notify, and operate a mission.

The service capabilities thus described correlate with "drone capabilities" and are what we have called "operational capabilities" in our analysis in this chapter and are related to operational safety and/or security aspects. As would be expected, some of them coincide with the analysis performed before, which tried to capture and identify the meaning of the “safety” view for ADACORSA solutions.

It is important to notice that the "operational capabilities" required to fly in U-space can be implemented in different ways or solutions. That is, "operational capabilities" can be broken down into "system capabilities" and "system functions" to be implemented exclusively on the drone, or distributed between the drone and the ground infrastructure, or even between multiple drones and the ground.

As an example, the operational capacity "detect", can be implemented in a self-contained manner, when the sensors and identification functions, installed exclusively on board the drone, are used to determine the position of obstacles and / or other vehicles relative to itself. The same operational capacity "detect", can alternatively be implemented in a distributed way, with the drone merging information obtained by the detection system on board, with information of obstacle position and / or other aircraft, received from ground infrastructure, or other vehicles.

Considering the current phase of implementation of the U-space and its required “operational capabilities”, ADACORSA project is taking the opportunity to propose and evaluate innovative distributed "system capabilities" solutions for the following operational capabilities, related to compliance aspects:

- E-identification
- Tracking
- Detect & Avoid

In addition to the regulatory aspects of U-space, the term "compliant" included in the project vision, contains other aspects that will not be addressed in the project. Two of these important aspects concern the drone capabilities related to the structural qualification of the flight platforms and the drone propulsion system. This way, a simplified diagram of the “compliant” operational capability, showing the main system capabilities of interest to ADACORSA project, is displayed below:

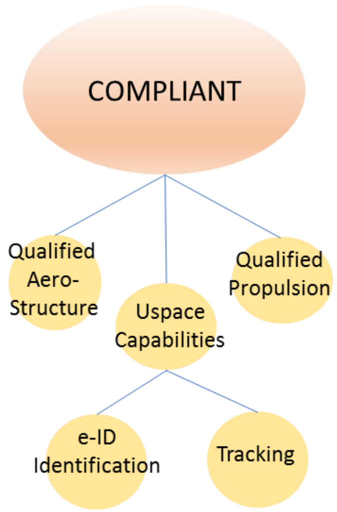


FIGURE 8 COMPLIANT OPERATIONAL CAPABILITIES & SYSTEM CAPABILITIES

Finally, a complete diagram of the "High Level Operational Capabilities" is possible to be assembled, displaying in a graphical view, a first picture of what the ADACORSA solutions shall be and will contain.

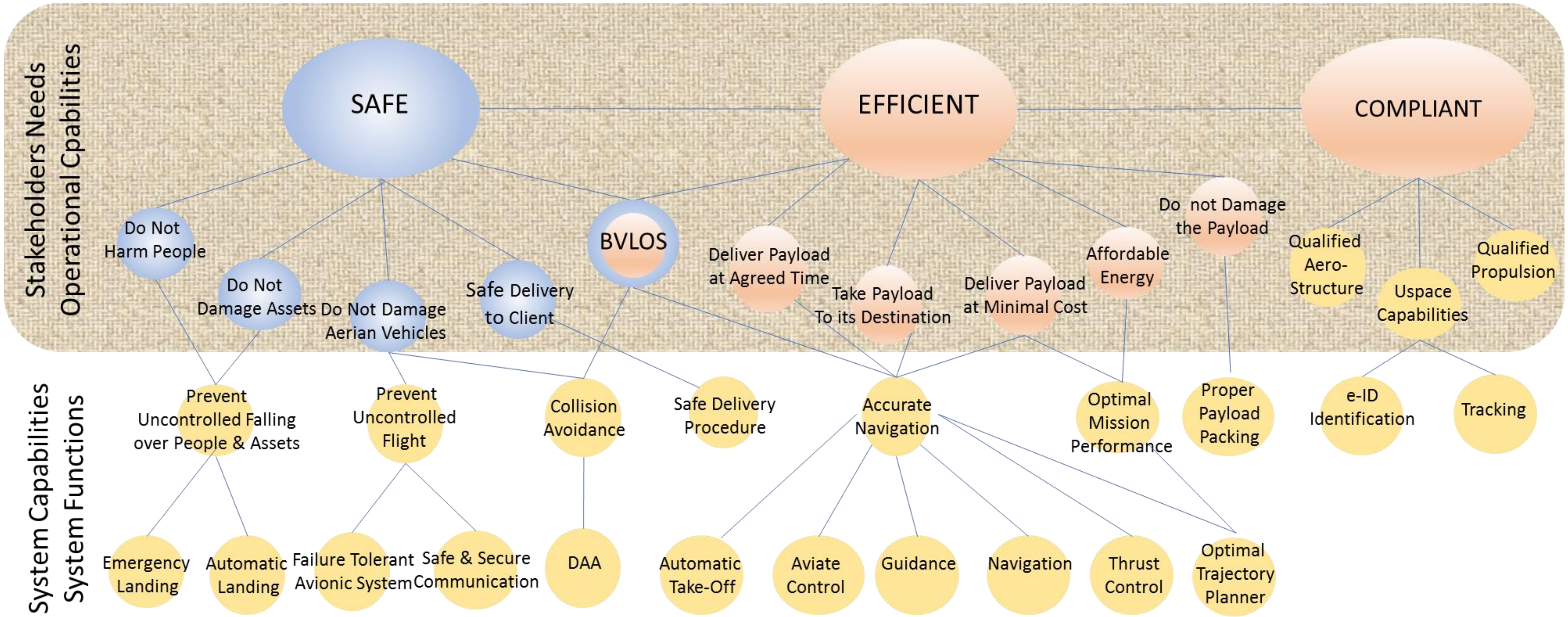


FIGURE 9 ADACORSA OPERATIONAL CAPABILITIES, SYSTEM CAPABILITIES & SYSTEM FUNCTIONS

This project has received funding from the ECSEL Joint Undertaking under grant agreement No. 876019.
This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and the ECSEL member states.

3 Main Project Assumptions

This section captures the main assumptions for ADACORSA[2], namely those regarding aspects of ADACORSA external context that can impact the future exploitation and deployment of its results. The current situation regarding drone operations, application and technologies is changing at a rapid pace.

- ADACORSA assumes SAFETY, EFFICIENCY and BVLOS are key aspects in enabling large scale development of drone-based services
- ADACORSA assumes that drone operations and regulations in EUROPE will be mainly shaped by the U-SPACE developments in SESAR. Due to that, it will refer to CONOPS, reference architectures and other artefacts published by U-SPACE (e.g., from CORUS project)
- The SORA methodology is assumed to provide an enough framework for ADACORSA Safety Operational Analysis tasks
- ADACORSA assumes U-SPACE related capabilities not developed by ADACORSA will be available in the future, according to the European ATM Roadmap / U-SPACE roadmap
- ADACORSA solutions are best indicated for applications that range up to around 100 Km
- ADACORSA solutions are best indicated for drones sizes up to 25 Kg (EASA Class C4)
- ADACORSA solutions are aimed primarily at very low-level airspace (VLL) with U-SPACE services
- ADACORSA solutions will be able to be integrated into other systems and architectures to deliver full solutions for U-SPACE applications
- ADACORSA use-cases will be representative of drone business operations
- ADACORSA guidance on the regulatory process will focus on specific category related with its use cases
- ADACORSA assumes that synergy with adjacent industrial sectors will significantly lower drone technologies cost
- ADACORSA assumes that the state-of-the-art technology available within the automotive sector for automated driving, can be used as starting point for the development of the technical components (hardware, software, competences, and practices) required to operate semi-autonomous drones BVLOS.
- ADACORSA assumes that Detect and Avoid is a required capability to enable BVLOS
- ADACORSA assumes integration of developed technologies post-ADACORSA is achievable due to the use of interface requirements and a common reference architecture

[2] Assumption: future truth that establishes premise for work and decision making today. In fact, it might or might not happen. For management purposes, it should be mainly about the external world issues that can impact project developments and decisions (for instance, regarding future exploitation possibilities for the results).

4 Out of scope

The following section list items that will not be developed or pursued by ADACORSA. This section will provide a clear understanding of ADACORSA boundaries.

- ADACORSA will not develop new CONOPS for U-SPACE (will re-use those developed by CORUS)
- ADACORSA will not address requirements for manned aviation
- ADACORSA will not develop solutions for loading or unloading cargo into drones for logistics purposes
- ADACORSA will not certify solutions or deliver systems ready for commercial use
- ADACORSA will not demonstrate the full integration of the different technologies into a single platform
- ADACORSA will not design, develop, or build a drone as end-product
- ADACORSA will not design, develop, or build drones auto-pilot
- ADACORSA will not develop U-space service solutions
- ADACORSA SC10 will not request approvals for flight operations performed during the project
- ADACORSA will not temper-proof all data acquired by the sensors.
- ADACORSA will not evaluate business models for drone operations.
- ADACORSA will not address the creation of a permissionless full open autonomous system.
- ADACORSA will not design, fabricate, or assemble Very large-scale integration (VLSI) chips or compute board device. Everything beyond a simulated compute platform is out of scope. Integration with other parts of the system will be limited to the simulated interfaces.
- ADACORSA will not address the creation of fully autonomous systems
- ADACORSA will not exploit specialized IP protocols for multipath communication setup
- ADACORSA will not exploit reliability solutions at the physical layer
- ADACORSA SC2 will not pursued detailed SWaP-C (size, weight, power, cost) analysis besides those possible under a simulated environment.

5 Market

5.1 General drone market

Unmanned Aircraft Systems (UAS), commonly referred to as drones[3], were initially restricted to the world of military applications but in the last decade managed to leap in the commercial and civil sector. In the last years, drones are increasingly considered in a wide range of applications such as safety and surveillance, construction and mining, agriculture, logistics, insurance, delivery and many more [8]. Some of their key advantages are that they bring significant economic savings and environmental benefits whilst reducing the risk to human life [9].

According to the Drone Market Report 2020, the global drone market will grow from $22.5 billion in 2020 to over $42.8 billion in 2025 at a CAGR of 13.8% [10]. For Europe, according to the SESAR Drones Outlook Study [11], it is estimated that the European drone market will represent EUR 10 billion annually by 2035 and over EUR 15 billion annually by 2050. Civil missions for government purposes and commercial businesses are expected to generate most of this value based on multi-billion product and service industries. A market of this size will also drive new job creation throughout all Member States, as each will need localized operations, pilots, maintenance contractors and insurers among other specific occupations. In short, over 100 000 direct jobs are expected to be generated by this significant market (based on data by the Organization for Economic Cooperation and Development (OECD)).

For several years, the drones' market had been in the nascent phase, facing a lack of adoption in the commercial sector. Although they were initially viewed as military devices, drones are evolving beyond their origin to become powerful business tools. Drones have already made the leap to the consumer market, and currently, they are being put to work in commercial and civil government applications from firefighting to farming. That is creating a market opportunity that is too large to ignore [12], [11], [13]. Drones got their start as safer, cheaper, and often more capable alternatives to manned military aircraft. Although defence will remain the largest market for the foreseeable future as global competition heats up and technology continues to improve, many market sectors could now integrate drone technology into their operation.

Business use cases for drones have grown significantly over the past few years. Users, as well as the manufacturers, solution providers, operators, and pilots who support these technologies, have been actively engaged in designing, testing, and perfecting solutions for various markets [14]. Those efforts are paying off, with customer engagements reported across an increasing number of industries involving a variety of new and existing applications. More traditional use cases for drones such as business security, surveillance, and monitoring continue to expand, especially in areas where labour costs and crime are on the rise. Emerging markets for drone technologies include agriculture, oil/gas, real estate, government, transportation, entertainment and media, telecommunications, and mining. Adoption in the SMB (Small and Medium-sized Businesses) community is also rising due to the competitive advantages and cost efficiencies of drones. The opportunities for solution providers, operators, and pilots are plentiful, and the only restriction will be the number of applications developers and other inventive professionals can create [14]. Delivery is another opportunity area,

[3] For the origin of the usage of the term drone check [150]

and competition among vendors in that space is driving innovation. Companies like Amazon, Google, Zipline, Flirtey, and Flytrex are rapidly increasing the technological capabilities of drones. The early adopters are also streamlining the delivery processes and forcing communities to redefine, clarify, and in some cases, relax regulatory restrictions. Those actions reduce the cost of entry to the drone delivery market for new developers, solution providers, and operators.

The safety, security, and energy markets are notable examples of drones' ability to enter new, lucrative markets. Drones are increasingly being used to perform tasks that endanger people, including search and rescue activities and surveys of elevated infrastructure. Organizations can easily justify investments in drone technologies if they can reduce or eliminate safety risks for employees and others. Aerial capabilities are also expanding the options for photographers and building inspectors (i.e., zoning officials, contractors, and insurance adjusters), as well as for those who conduct overhead land surveys and mapping.

The key to success in any new market is to satisfy unmet needs. Drones are merely a platform from which organizations can perform a variety of different activities, and one of the initial roles of solution providers, operators, and pilots is to identify and prioritize the opportunities for each of their clients [14]. ADACORSA aims to act as a technology driver for pivotal EU industries and society, fostering the market introduction of highly automated drones and therefore enforcing the European drone industry positioning in this very promising novel market and take advantage of the business and societal opportunities.

The rapid development and growth of drones as remote sensing platforms combined with advances in the miniaturization of instruments and data systems have resulted in increasing uptake of this technology. In such terms, UAVs are unique instruments for collecting data both from the ground and onboard sensors, serving a broad range of applications, such as monitoring, delivery, agriculture, wireless coverage, and military [15]. With recent technological advances, sensors are becoming smaller and more compact than before, while they offer higher data acquisition capabilities and more payload options. These key factors are extending the use of drones in urban environments making remote sensing applications more appealing to the public [16].

Even though unmanned air systems are a major technological breakthrough, there are still several factors that impede their adoption. The greatest challenge to the widespread integration of drones by the society is public acceptance. Concerns over safety of UAS flights over civilian air space, environmental disruption or privacy of sensitive information are emerging key areas that have been identified as controversial, when it comes to public sentiment towards drone use in urbanized environments [17]. Under these circumstances, tight guidelines and the appropriate legislation will ensure safe drone operations as well as limit the risks to people on the ground. A necessary regulatory framework for safety in UAVs operations has been developed by the EASA (European Aviation Safety Agency) issues, addressing [18]. Delivering low-weight, low-power, high-performance components, and high-reliability systems will also make a durable impact on European industry and research in the automotive and aviation sector, specifically in the domain of highly automated vehicles.

ADACORSA aims at changing the current picture by adding novel technology properties for fail-operational, highly automated drones with high robustness and availability based on novel semiconductors for functional integrated actuators, fail-aware sensor systems, and fail-operational control systems at reasonable costs - which are required but currently missing. ADACORSA will contribute address current drawbacks and concerns in terms of safety, reliability, end-user acceptance, and hence make automated drones beyond the line of sight, part of European daily life in several application areas, as mentioned above.

5.2 Applications

ADACORSA targets three main types of applications. From SC7, Forestry and Smart Construction and, from SC8, BVLOS Logistics Services. This section provides an overview of market potential for each.

SC7 Forestry and Smart Construction

In the market segment of agriculture & forestry, UAS are increasingly used. UAS undertake various tasks such as analysing soil and field, planting, crop spraying, crop monitoring, assessing plant health, and irrigation. Their use in agriculture assists in increasing crop yield and helps reduce the number of resources required for effective management of crops. These systems are also used for pesticide spray application, which provides farmers a cost-effective way of harvesting crops. The need to ensure safe operations if UAS is projected to drive the growth of the unmanned traffic management market for agriculture & forestry. According to the Markets & Markets Unmanned Traffic Management (UTM) Market Global Forecast to 2025, the agriculture & forestry end-use segment is projected to grow from USD 117.76 million in 2018 to USD 390.68 million by 2025.

Forestry

Satellite imagery data that comes from satellite programs like Landsat and Sentinel 2 is good for the calculation of different forest indexes (e.g., density or volume), but soon the advent of UAVs opened the road for more applications such as precision agriculture, biodiversity, meteorology, wildlife research, etc. [19]. UAVs in forestry are divided into those that take-off and land horizontally (fixed-wing aircrafts) and those that take-off and land vertically (rotary-wing drones), with the latter covering 57% of case studies. The main applications comprise i) the mapping of forest areas and their biodiversity, ii) precision forestry and forest planning for sustainability (e.g., biomass volume estimation), iii) the mapping of forest canopy gaps, and iv) the measuring of forest canopy height and other attributes [20]. In addition, drones are used for combating deforestation, for preventing forest fires and for detecting and managing forest diseases [21], [22].

In Europe, visible digital RGB imaging is the most adopted technology (40%), followed by multispectral in the VNIR spectral range (35%), MIR and TIR imaging (15%), VNIR hyperspectral imaging (5%), and the lidar (5%) technology [19]. In terms of applications, the majority of the case studies were focused on the estimation of dendrometric parameters (36%), followed by forest health monitoring, and diseases mapping (21%), tree species composition classification (14%), post-fire recovery monitoring and fire measuring (14%), quantification of spatial gaps (7%), and the estimation of post-harvest soil displacement (7%). The total addressable value of UAV solutions is more than 115 billion euros, and among the most promising areas is agriculture [23].

Smart Construction

Since 2006, when the Federal Aviation Administration (FAA) issued the first commercial drone permit, since 2016 when the FAA issued more than 3000 permits to commercial users, the drone industry has reached a $100 billion market opportunity. At the same time, the construction industry accounts for just over $11 billion of that market [24], [25]. The stakeholders of this market comprise:

- Construction companies, which cluster down to construction contractors, building installation companies (e.g., electrical, and plumbing companies), finishing detail companies (e.g., carpenters and painters), demolition and land work companies and specialised construction companies [26].
- Drone companies, which are mostly young and innovative companies, which offer software, hardware, and analytics to drone-as-a-service solutions. Strategic alliances between major construction companies and drone companies comprise the investment of Caterpillar to Airware, and the alliance of John Deere with drone technology start-up Kespry [27].
- Governments, which monitor both sectors and set up various regulations for security and safety, etc.

The use of drone technology in the construction industry can reduce fatal accidents, improve the environment. and yield economic benefits. The application of drone technology to construction projects allowed construction companies to improve several aspects of construction management related to estimating, surveying, site monitoring, quality assurance, safety, and team communication [28], [29]. Drones equipped with laser scanners are used in combination with standard topographic surveys for building 3D models of large areas and for estimating the earthwork volumes that are present on the job site, more precisely and much faster than traditional engineering surveys. Drone monitoring of a construction site provides real-time site conditions that can help prevent serious injuries or accidents. In another line of application, drones combined with infrared thermography sensors can scan a building and create a 3D image of a building envelope to evaluate its energy efficiency and identify defects that may be present. Thus, they allow the quality assurance of a builder's product [30].

The construction industry sets its own technology acceptance models, such as construction safety technology adoption framework (C-STAF), construction technology adoption model (CTAM), CTAM decision path and construction technology adoption process cube (CTAP), which must be taken into consideration from drone companies.

SC8 Logistics

In the market segment logistics, & transportation, UAS are increasingly used for the transportation of passengers and freight. The rising trend of e-commerce has facilitated the use of drones for package delivery. The increasing population worldwide and the rising concentration of people in urban areas have propelled the need for an efficient transportation model. The use of UAS for product delivery serves to be more economical as compared to road transport. UTM systems provide continuous support to georeferenced areas. These systems also provide the much-needed portability to transport & logistics, operators and help in the real-time operation of drones. This has been one of the first areas of commercial exploitation for drones as attested by the first attempt of Amazon Prime in small parcel deliveries with UAVs, back in 2013, as well many other players and projects like those of Matternet, DHL, Google, UPS, etc.

Among others, Switzerland has successfully implemented the delivery of medical supplies and blood for testing using drones instead of land transportation [31]. In September 2017, in Zürich, Mercedes-Benz vans together with US drone systems developed and tested a delivery chain for connecting customers and retailers faster, which combines vans and drones. Wing, an initiative from Alphabet, tested a system to conveniently transport small packages (containing food and beverages, over-the-counter chemist items, and locally made coffee and chocolate) quickly in Canberra, Australia and, Helsinki, Finland [32]. At the same time, Flytrex in partnership with AHA, is testing in Reykjavik, Iceland, the delivery of goods to customers over a wide river that splits the town into two parts. UPS in collaboration with Henry Schein designs a parcel delivery solution for dental and medical practitioners [33], Airbus UTM (Unmanned Traffic Management) partnered with DroneDeploy for the development of commercial drone pilot flights that ensure a safe and efficient operation that follows airspace security regulations [34].

Small-parcel delivery by autonomous or semi-autonomous aerial drones seems to be the most promising market with applications that include merchandise delivery, courier services, food delivery, and humanitarian aid [35]. According to the Markets & Markets Unmanned Traffic Management (UTM) Market Global Forecast to 2025, the logistics & transportation end-use segment is projected to grow from USD 298.65 million in 2018 to USD 1,084.17 million by 2025. Drones are poised to take over the delivery world given that they tackle several critical technology challenges first related to range and payload; efficiency in terms of time; cost and energy; and coordination that respects regulations and ensures safety.

5.3 Market for ADACORSA key technologies

For each SC, a brief outlook of related market items is given in each following subsection.

SC1 Sensors

As mentioned in section 5.1, a steady growth is expected from the commercial UAS market. Identified key trends for this market are autonomous hardware as well as sensor and data fusion [36]. As of today, cameras and radar sensors are already mandatory for assisted automation (L2) in autonomous vehicles while LIDAR will also be required for fully automated vehicles (L4) in the near future [37]. The mandatory market needs of sensors for the limited 2D case of ground-based transportation and logistics underlines the even higher need for sensors for the safe integration of autonomous drones into the 3D air space. The need especially for detect and avoid (DAA) or sense and avoid (SAA) capabilities for collision avoidance on drones becomes quite clear not only to keep the drone from getting damaged but more so to keep the environment from getting harmed. Another market that can potentially be tapped with these new and highly data fused sensors lies within remote sensing and inspection of the example given critical infrastructure [12].

SC2 Computing platforms

Due to their nature, in UAS, SWaP-C issues are more stringent than in larger aerial vehicles. At the same time, their potential usage in highly dynamic airspace, demands several high-level capabilities that are created through heavy use of electronics (sensors, computing) and software for perception, decision, identification, security, communication, etc...

Regarding the computing platforms that give substance to the drone capabilities, several small form factor, low power, and energy-consuming computing platforms from major brands are currently available as platforms in the market. They often include ARM CPU cores and one or several GPU, FPGA, and other [38] specialized accelerators for machine learning and computer vision applications. For example, the nVidia Jetson Nano includes a Quad-cores ARM Cortex CPU and a 128 cores Maxwell architecture [38]. The more recent Jetson Xavier NX's accelerator-based on nVidia Volta architecture including cores optimized for machine learning applications, two deep learning (DLA), one programmable vision (PVA), and one Image Signal Processing (ISP) accelerators. nVidia claims the AGX Xavier module is suitable for visual odometry, sensor fusion, SLAM (Simultaneous Location and Mapping), obstacle detection, and path planning [39]. Although ARM does not commercialize readily available compute platforms, its processors IP range includes general purpose energy efficient (Cortex A78), performance processors (Cortex X1) as well as GPU (Mali) and machine learning NPU (Ethos Neural Processing Unit) and microNPU [40] optimized for inference [41]. Similarly, Intel released a range of SoC for machine learning and computer vision but no readily available board. Recent Intel activities shifted towards specialized accelerators such as the Habana Goya and Gaudi [42] although the 200W TDP suggests their use in data centers rather than in edge devices. For edge devices, Intel Movidius Myriad X [43] VPU (Vision Processing Unit) provides acceleration for edge vision and machine learning inference. CEVA XM6 [44] is another SoC solution for energy efficiency-optimized for computer vision and machine learning applications. Although the chip has been released in 2016, work from CEVA presented in 2019 base their high-performance SLAM on this architecture [45].

SC3 Perception solutions

An overview is given of different market aspects related to perception solutions, namely regarding fail-operational perception algorithms, location and ego-estimation, transponder for DAA, and wireless information sharing.

Fail-operational environment perception algorithms

Mobile robotic automation is one of the fastest-growing international markets, which includes BVLOS drone operation. Applications are spread across a range of verticals including logistics, industrial, agricultural, and maintenance industries, driven by the need to reduce costs for European providers to compete with alternatives in lower labour-cost areas. The total market size for robots for warehousing, agriculture, semi-open space, and public domain, are projected to grow to €58B by 2023, while the BVLOS drone market is expected to be valued at €22B in 2023, according to [24].

The major challenge that impedes the growth of the mobile robotics market is the ability to navigate around the unmapped territory. The software that is envisioned in ADACORSA for Free-Space estimation and Object detection & classification directly contributes to the ability to safely navigate in unmapped territory. The software modules are particularly suitable for

– Drone OEMs that supply platforms to inspection service providers for efficient inspection in ad-hoc, (un)mapped and limited-time opportunities, which are common in industrial facilities

- Navigation technology providers that integrate the ability for drones and other mobile robotics to be used in a BVLOS scenario where collision avoidance is otherwise difficult to achieve
- Large industrial OEMs that supply autonomous vehicles to industrial production facilities (chemical, steel, etc) to be used in outdoor environments that are closed spaces, but where people and incidental objects are encountered
- Logistics and airport autonomous truck manufacturers that route cargo in closed or semi-open spaces. Usage of mobile robotics in these markets will additionally allow for a low-barrier transition to 24/7 operation.

Localisation and ego-motion estimation

The main goal of the ego-motion estimation is to estimate position, velocity, and attitude (orientation) of the ego drone at high update rates. These technologies are essential to utilize drones in outdoor applications that require precise movement for 3D path flying, especially so in restricted airspace. Drone applications that benefit particularly from this technology are spread across three verticals: construction, agriculture, and inspection/maintenance.

Construction drones (market value is expected to reach €40B in 2025) are used for site planning, communication, and progress checking. Future usage includes quality monitoring, for which the drone must be precisely positioned to obtain useful quality data [46].

For agricultural applications, the largest anticipated use-cases consist of disease detection and fertilizer optimization in precision farming scenarios. The utility factor of UAVs increases as the drones can fly closer to crops. Flying precise trajectories will allow the agriculture drones market value to grow from €1B in 2019 to €4.2B in 2024 [24].

Application of drones for maintenance and inspection purposes are diverse in domain and function. The largest domain is the infrastructure inspection sector (valued €40B in 2017 [47]). Like the above drone markets, the utility factor of drones increases as drones can be positioned closer to- and more accurate in relation to the asset. This allows smaller defects to be detected, at an earlier time in the preventive maintenance cycle, saving significant amounts of inspection and repair cost.

Transponder and DAA-system

In the current vision for the development of drone applications, BVLOS operations are an essential capability. Without a pilot on board, the situational awareness needs to be automated using sensors and an (on-board) avoidance waypoint navigation capability. This will lead to the requirement of equipping drones with either a cooperative DAA-system (i.e., in U-space) or even a non-cooperative DAA-system for flight in more remote locations and/or at a higher level (above VLL).

Development of a transponder, compatible with current ATC systems, is a necessity for all future drone operation within a control area (CTA) that extends from ground-level, such as TMA Class D. It extends from ground-level to a height of typically 2500ft, thereby containing all practical forms of commercial drone operation. These areas are mostly centred around commercial and military airports and may contain most of the commercial activity for a given administrative area. With exception of the agricultural drone market (29%), commercial drone applications must rely on transponders to reach their full potential.

Wireless information sharing

Gartner predicts that industrial inspections will represent 30% of the commercial drone market in 2025 [48]. The commercial drone market is dominated by drone providers, which, besides HW, offer complementary specializations by utilizing AI-powered analysis per industry use cases. Examples include, but are not limited to detection of cracks, corrosion, and general outlier detection for periodic maintenance routines and agnostic to materials.

Current state-of-the-art datalinks rely on proprietary modules derived from particular feature subsets of IEEE 802.11ac implementations. To enable transparency and scalability for offering AI-enhanced inspection routines that are performed live rather than post-flight, datalinks must be normalized. By establishing low-latency datalinks, ADACORSA enables data-driven companies and inspection service providers to provide superior inspection routines. Live data analysis will in turn reduce the number of flights needed for close-up asset inspection, reducing periodic maintenance costs for asset owners.

SC4 Communications

Safe and robust communications are an underlying critical feature for enabling the full development of drone operations. This becomes in evidence has several of the services capabilities for the U-space concept mention or are dependent on it. As such, if the market potential for drones related communication technologies strongly correlates with the market dimension of drones, it can well go beyond it these technologies can be further applied for other markets, either in aviation or elsewhere.

Regarding the blockchain-based solution for realizing reliable, secure, and authenticated communication between drones developed in ADACORSA, it will enable SMEs to create reliable solutions for these services. Larger industrials will profit as well. The full market potential is not assessed yet but seems promising as trust – a core feature addressed by blockchain - is a core element of enabling large scale deployment of services in networks of different actors. In the same vein, e-identification, provided by eUICC and eSIM, is part of the first stage of enabling U-space. This means that related technology will be part of almost all drones operating in EU, regardless of size, a considerable market to address. This also applies to future requirements for secure drone-to X communication, as well as in intra-drone subsystems, hardware secure modules (“secure elements”), used to protect integrity and confidentiality of non-temporary cryptographic keys, secure execution environment for cryptographic operations (e.g, to provide a secure storage for logging as used in eUICC/eSIMs) and secure elements integrated with application/communication processors.

SC5 Avionic architectures for drones

The market for avionic architectures mainly overlaps with the general drone outlook market. As drones’ services become regular and massified, instead of flying through exemptions as today, they need to rely on robust and safe architectures, leading to this area of development to mainly overlap with the general expansion of drone usage.

SC6 UTM solutions

FIMS

The Flight Information Management System (FIMS) proposed in ADACORSA will address the UTM market segments agriculture & forestry, logistics & transportation, and surveillance & monitoring. It can thus provide a large host of services regarding the markets already mentioned in section 5. Additionally, some extra overview is given next to the market segment of surveillance and monitoring, not addressed in those sections.

In the market segment surveillance & monitoring, UAS are used for various activities, such as critical infrastructure monitoring, vehicle traffic monitoring, flood monitoring, border surveillance, and perimeter surveillance. These systems provide an enhanced aerial view of the entire geographical area, which makes UAS suitable for environmental monitoring, UTM systems help maintain proper coordination between UAS and general aviation aircraft to avoid a collision. These systems also assist in the monitoring of unmanned aircraft system routes and route planning. According to the Markets & Markets Unmanned Traffic Management (UTM) Market Global Forecast to 2025, the surveillance & monitoring end-use segment is projected to grow from USD 91.82 million in 2018 to USD 377.37 million by 2025.

U-space Simulation

Real-life testing opportunities for drones are widespread and relatively cheap (compared to e.g., aviation), however, several practical, regulatory, and financial hurdles exist which provide a viable case for providing drone simulation as a service. This is especially true within the realm of open UTM traffic, where multiple drones (of varying size and ownership) can interact, pose risks to each other, and compete for the same airspace.

Additionally, drones are becoming more autonomous, with new capabilities for BVLOS missions. Simulation provides the opportunity to provide close to real-life testing, during pre-production, research, and validation of drones' systems. This reduces reliance on real-life testing.

UTM traffic is growing in complexity, going beyond the small camera drones (toys, media, and inspection), into the medium size drones (more sophisticated payloads, (medical) goods delivery) and even large drones. (Larger goods transport, Urban Air Mobility (UAM) / air taxis) Especially in that latter case, the boundary between regular Aerospace and UTM becomes less clear. This heterogeneity calls for smart solutions to the traffic management challenges as regular airspace control doesn't translate easily to drone usage.

DAA

According to the SESAR U-space Blueprint, the progressive deployment of U-space is linked to the increasing availability of blocks of services and enabling technologies. The level of automation of the drones will increase, and advanced forms of interaction with the environment are enabled, including manned and unmanned aircraft. Within the U3 the availability of automated 'detect and avoid' (DAA) functionalities, in addition to more reliable means of communication, will lead to a significant increase of operations in all environments. In the U4 U-space full services, the integrated interfaces with manned aviation, is even more enhanced by a high level of automation, connectivity, and digitalisation for both the drone and the U-space system.

The U-space stages of U3 and U4 will require the on-board DAA-system capabilities mentioned above. However, it should be noted that the usefulness of the DAA-system for BVLOS flight operations extends beyond the U-space environment and is anyway required for airspace integration with both manned and unmanned aircraft.

Simulation of Blockchain services in U-space

For testing hypothesis about blockchain systems, there are two main approaches: using a dedicated test network and using a dedicated simulator. However, all these approaches are specific to certain blockchain technology and do not allow testing of the same application using different blockchain technologies. Moreover, there is no simulation platform that can seamlessly integrate autonomous drones with new capabilities for BVLOS missions and blockchains. This opens the opportunity to fill a market gap, providing close to real-life testing, during research, and validation of autonomous distributed systems, and reduced reliance on real-life testing.

5.4 Economic, social and mission efficiency

Drones are rapidly growing in popularity, as their commercial usage is gaining ground in multiple industries in the last years. While operating in new spaces drone use is expected to have a significant impact on the quality of life, health, social and economic well-being [49]. In this context, several factors should be considered for drones to be competitive against other alternatives and largely adopted by society.

Public acceptance can promote the dissemination of new technologies. Conversely, concerns among citizens about the use of drones in their daily environment could pose potential barriers to the further proliferation of civil drones, especially in urban areas. A lot of obstacles must be overcome to achieve a wide societal approval of drones. Concerns about public nuisance and environmental pollution, restrictions in use, privacy, safety, security, capability, as well as economic and regulatory factors must be taken into consideration. So, it becomes apparent that all these challenges must be addressed by providing an innovative solution for increased reliability and availability, functional safety, cost reduction, energy consumption reduction and improved functionalities.

Until recently, use cases for drones have been closely tied to military and recreational purposes, with little consideration of the way these technologies could be utilized in the business community. The public perception of these devices as toys or weapons, rather than as viable commercial vehicles, limited the market potential to an extent - until recently. Strong global investment and new business use cases are increasing the revenue and profit opportunities for manufacturers, solution providers, distributors, operators, and other drone-related professionals. If we take a close look at the history of the consumer drone market and how drones have been positioned within it, we will notice that products that managed to become widely approved by the public/market were those specifically marketed, easy to operate/fly, high crash tolerant, low propeller risky, and were “ready to fly”.

There are some areas where the drone industry could use improvement to be more competitive against other alternatives. The key point is to prove that drones can fulfil specific existent needs and prove that they deal will them effectively considering the shifting wants and needs of customers. Another driving factor in the acceptance of drones is their cost. A customer to test and consequently approve a product must be able to afford it and be aware of the return on his or her investment. The factors of size and weight should not be omitted as they play a significant role in drones' acceptance by society. Lightweight toy drones are all the rage these days and they sell in high numbers. What is more, as the size and weight of drones increase so does the severity of potential crashes and thus the risk. This puts safety considerations at high priority. Drones that are unsafe will not be acceptable by society. Regulatory issues must be taken under consideration, as an obstacle to be overcome is the continuous changes of government regulation which impose uncertainty in the governing landscape.

Some key business accelerators for drone providers include the expansion of hardware capabilities, an improved regulatory environment, the growth of emerging areas such as AI (artificial intelligence), drone swarms, and autonomous systems, and expansion into new customer segments, including the SMB and international markets. Innovation, governmental rules changes, and new use case opportunities could significantly affect any or all the studied business accelerators in the coming years.

Another major challenge in the drone market is finding, training, and retaining the skilled professionals who can fill various positions in this emerging technology segment. Top industries actively recruiting drone talent include manufacturing, professional/technical services, real estate, and transportation, as well as other information gathering businesses and organizations are projected to continue rising at a steady rate as more organizations realize the benefits of aerial imagery, data collection, and transport. The needs for specialized employees will be greatest for key positions, including software developers, photographers/videographers, hardware engineers, systems engineers, and operators/pilots and must be met.

5.5 Key enablers for societal acceptance: safe drone operations

Security and safety of flight remain critical issues in unmanned aircraft missions. The absence of a clear and mature regulatory framework at the EU inhibits the growth of a truly European market for drone services and aircrafts and limits the potential for employment creation in this sector of the economy [9]. Therefore, across the globe, laws, and regulations are needed to manage drone impacts, particularly in lower airspace [50]. These regulatory measures can significantly increase the requirements of operators to build cultures of safety into their operations. To this end, the EASA (European Aviation Safety Agency) has developed a regulatory framework that defines the technical and operational requirements for drones and provides a framework to safely operate them while addressing privacy, security, and data protection issues [18].

Societal acceptance hinges on safety, security, and privacy in the context of a low-pollution, low-noise, and low-cost device. ADACORSA contributes directly to these metrics, but clear communication and outreach are essential to make sure achievements are appreciated in the wider community.

The major concerns that people have regarding the commercial use of drones are privacy, safety, and security issues. Privacy concerns are connected to drones being equipped with live video cameras which could be used to spy and/or collect personal information. Safety concerns arise from the possibility of malfunctioning, causing accidents and causing damage or harm to people, other aircraft or buildings. Safety also deals with the safe delivery of packages in delivery scenarios. Security concerns in turn are associated with criminal activities like hacking and hijacking drones or using them to aid in crimes.

Security is a prerequisite for safe systems. Reports of hacked automobiles have lowered the trust of the public in networked vehicles, but drones offer the opportunity to build open secure and reliable communication systems in a relatively greenfield environment. Secure communication links and data platforms are essential to ensure that only authorized persons have access to sensitive data while geofencing technology ensures that drones only fly within airspace they can enter.

We live in a risk averse society where there is an increasing awareness and concern towards risk, particularly those associated with new and emerging technologies. In the context of the BVLOS operation, similarly to autonomous driving, the automation must be capable of handling safety-critical situations on its own. A fail-operational safety architecture capable to detect and avoid any emergency must be integrated and implemented. Drones that are unsafe will not be acceptable by society. This is also a reason why safety standards must be in place in every lever and component of a drone platform, such as the power supply unit, a secure and authenticated logical operating environment, a safe and reliable communication system that can be trusted. Lightweight toy drones are all the rage these days and they sell at high numbers. What is more, as the size and weight of drones increase so does the severity of potential crashes and thus the risk. This puts safety considerations at high priority. Drones that are unsafe will not be acceptable by society.

Relevance of drone acceptance

One of the goals of ADACORSA is to contribute to higher public and regulatory acceptance of drone use and accordingly align with new European and world-wide regulation for drones. Some investigations about public concerns with drones as well as attitudes towards drones and preconditions for drone acceptance have been published recently [51], [52], [53], [54], [55], [56]. Some papers are integrating findings into generic models of technology acceptance or models specific to drone acceptance [57], [58], [59], [60]. A persistent finding, which has been replicated repeatedly is that concerns, as well as acceptance, is influenced by the perspective subjects have on drones and the experience, they had with drones so far. Typically, subjects who have been piloting drones have concerns primarily about safety whereas for those who are inexperienced with drones, concerns about privacy are more prominent (e.g. [53]).

Therefore, it is important to consider the unique perspectives of the different stakeholders in the investigation of attitudes towards and acceptance of drones. Furthermore, very few results have been published so far about intercultural differences in drone acceptance and their influencing factors [61]. A gap we intend to close in ADARCORSA by investigating acceptance in the different countries involved in the project using a standardized questionnaire.

6 State-of-the-art-on "Drones"

6.1 Technical:

This section provides an insight into technical state-of-art of U-space, where the drones integrating solutions developed by ADACORSA will fly and BVLOS, a key capability addressed by the project. Its aim is to provide an understanding of the technical challenges on both themes that impact the overall project.

6.1.1 U-space description

To truly unleash the societal and economical benefit of drones, they must be part of the airspace in a standardized, global way. Thus, they must be integrated safely, securely, and efficiently into the current airspace operations. In Europe, this is framed by EASA Opinion No 01/2020 [62], which defines the following high-level goals:

- Preventing conflicts between UAS and manned aviation,
- Expediting and maintaining the orderly flow of UAS traffic,
- Providing information and instructions relevant for safe and efficient UAS operation,
- Notifying appropriate organizations regarding an emergency or abnormal situations with the UAS which may endanger people and goods on the ground or manned aviation,
- Meeting environmental, security, and privacy requirements.

In order to reach these goals, the draft regulatory framework considers the designation of segregated U-space airspace and defines requirements on aircraft operators, U-space providers, as well as U-space services and all the integration with current airspace management entities, rules, and procedures. Namely, U-space is designed to operate alongside "traditional" airspace, such that the Air Navigation Service Providers (ANSP) provide services to manned aircraft, while the novel Unmanned Systems Service Providers (USSP) are responsible to provide services to UAS operators. Risk is controlled by dynamic segregation, managed by ANSPs, such that manned and unmanned traffic don't mix in case of controlled airspace. In case of uncontrolled airspace, safety shall be assured by sharing of position data via Common Information Service (CIS), which are distinct and trusted data management entities that manage U-space airspace but are independent from the USSP.

U-space services will be deployed mainly in Very Low Level (VLL) airspace. VLL is understood to be the airspace below the minimum height for operating under Visual Flight Rules (VFR) [63] (i.e., in Europe, usually up to 150m above ground level). In Europe, the operational development of U-space is being carried within SESAR.

The latest reporting on U-space research [64] describes U-space as:

> *"U-space is a set of services and procedures relying on a high level of digitalization and automation of functions to support safe, efficient and secure access to airspace for large numbers of drones. It provides an enabling framework to support routine drone operations and addresses all types of missions including operations in and around airports. Ultimately, U-space will enable complex drone operations with a high degree of automation to take place in all types of operational environments."*

As such, U-space is not a specific airspace class but an environment where a set of defined services exist, enabling a certain type of drone operations. Some of these services will also have integrated interfaces with ATM/ATC through a Flight Information Management Service (FIMS) layer, enabling the coexistence with manned aviation (to be further discussed in section 6.1.3, on SC6). Their existence is also tied to capabilities and connections between different actors like the Drones themselves, their Operators (i.e., their Ground Stations) and the U-space Systems Service Providers (USSP). Underlying all, a very high level of automation is expected to enable the high numbers of drones in challenging settings, like those of cities and future airspace users, like those arising from the Urban Air Mobility (UAM) and of large Remote Piloted Aircraft Systems (RPAS) ecosystems. According to the European ATM Roadmap [2], U-space capabilities and services will be developed in parallel with the current efforts related to larger RPAS, towards full integration, as expressed by Figure 10.

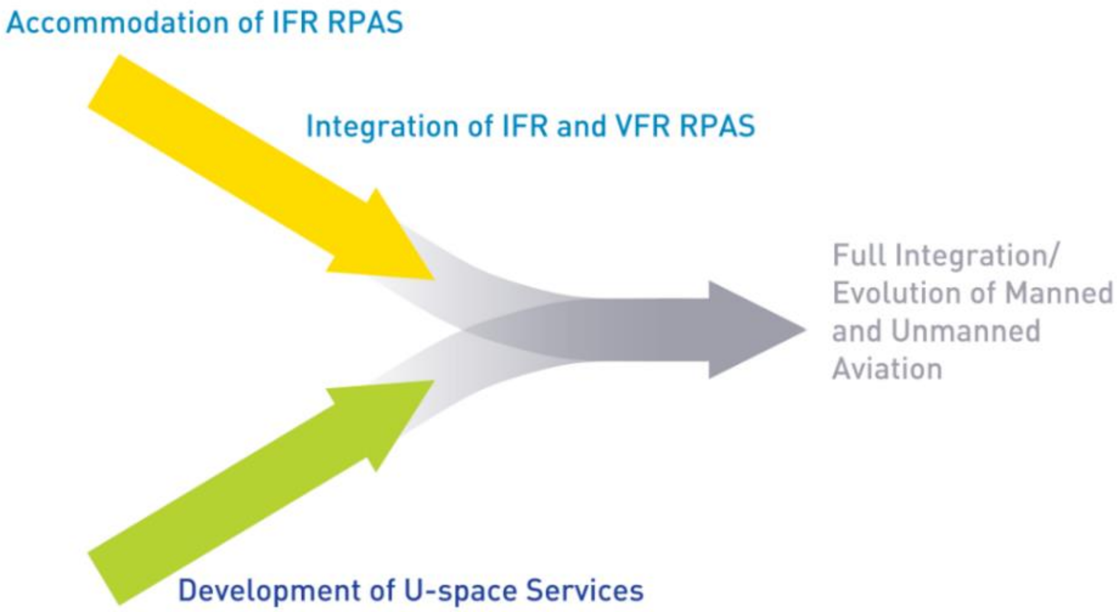


FIGURE 10: EUROPEAN TARGET VISION FOR RPAS AND U-SPACE SERVICE INTEGRATION (FROM [2])

To enable these U-space services and procedures, a roadmap was set [2], layering the availability of these services capabilities in four waves (see Figure 11).

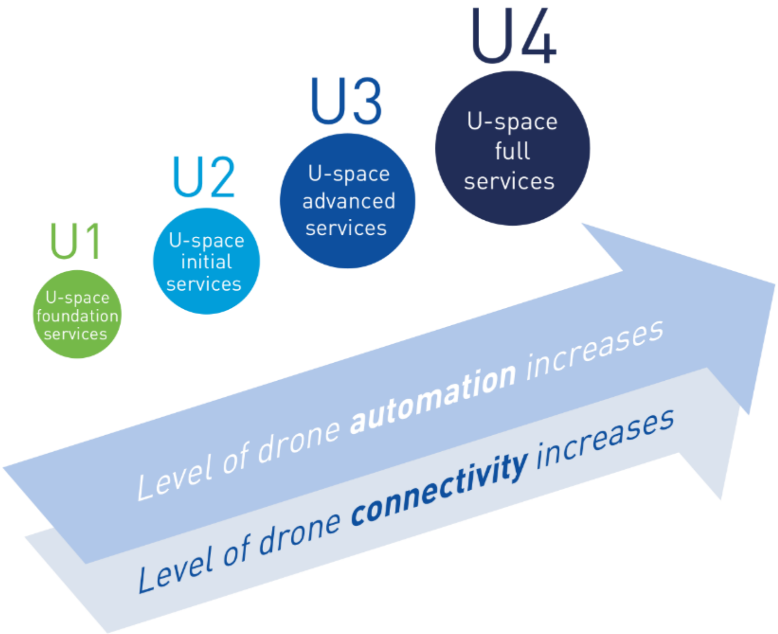


FIGURE 11 U-SPACE INCREMENTAL SERVICE CAPABILITIES

An abridged and adapted description of the four U levels follows, from [2]:

- **U1.** Will provide foundation services (e-registration, e-identification, and pre-tactical geo-fencing). At this level, more BVLOS operations will be possible, but they are still very constrained.
- **U2.** Will have an initial set of services that support the safe management of drone operations and the first level of interface and connection with ATM/ATC and manned aviation. Existing ATM infrastructure will be used but exploitation of technologies from other sectors is foreseen (e.g. long-term evolution - LTE - for data communication). Some operations in controlled airspace will be enabled and some examples of BVLOS operations will become routine (albeit with some constraints).
- **U3.** Expects to bring new technologies, namely automated DAA functionalities and more reliable means of communication to enable a significant increase of operations in all environments and it will reinforce interfaces with ATM/ATC and manned aviation. U3 is where the most significant growth of drone operations is expected to occur, especially in urban areas, with the initiation of new types of operations, such as air urban mobility.
- **U4.** Regards the full integration of drone flights into controlled airspace.

Aggregated with these waves of services, the concept of operations (CONOPS) are being developed within SESAR CORUS project [3] and, several large-scale pilot demonstrations, to hone operational concepts, architectures, technologies and dynamics with all stakeholders. For sake of reading fluidity, Table 4, with U-space expected services is repeated below from section 2.

TABLE 3: U-SPACE DRONE CAPABILITIES FOR AIRBORNE COMPONENT (REPEAT OF TABLE 2)

Capability	**Description**
e-identification	Ability to identify the drone and its operator in the U-space system
Geo-fencing	Ability to comply with geographical, altitude, and time restrictions defined by the geo-fencing service. This capability covers the technology, processing, and any required communication links, as well as management and use of geo-fencing information used in the provision of this service.
Security	Ability to protect vehicle and data (interaction with other vehicles and infrastructure) against attacks on information technology and communications systems.
Telemetry	Ability to transmit measurement data from the drone-to-drone operator and/or service provider to meet the demands of relevant services.
Tracking	Ability of the drone to provide flight parameters including at least its position and height.
Vehicle to Vehicle communication (V2V)	Ability for drones to communicate information to each other. The nature of the information exchanged, and its performance requirements, will depend on the application.
Vehicle to Infrastructure communication (V2I)	Ability for drones to share information with infrastructure components
Communication, Navigation and Surveillance	Ability for drones to meet the communication, navigation and surveillance performance requirements for the specific environment in which they will operate. This capability involves the combination of onboard sensors and equipment (e.g., data link, voice radio relay, transponder, laser, GNSS, cellular etc.) as means of achieving the required performance.
Detect and Avoid	Ability for drones to detect cooperative and non-cooperative conflicting traffic, or other hazards, and take the appropriate action to comply with the applicable rules of flight. This includes the collision avoidance, situational awareness and “remain well clear functionalities, as well as the other hazards described in chapter 10.2.3 of the ICAO RPAS Manual: terrain and obstacles, hazardous meteorological conditions, ground operations and other airborne hazards.
Emergency Recovery	Ability of drones to take account of failure modes, such as command and control (C2) link failure and take measures to ensure the safety of the vehicle, other vehicles and people and property on the ground. This includes the identification of possible problems (auto-diagnostic) and all equipment required to manage solutions.
Command and control	Ability of drones to communicate with their ground control station to manage the conduct of the flight, normally via a specific data link.
Operations management	Ability to plan and manage drone missions. This includes access to and use of all aeronautical, meteorological and other relevant information to plan, notify and operate a mission.

Timewise, the forecasted deployment of each services wave is given in Figure 12.

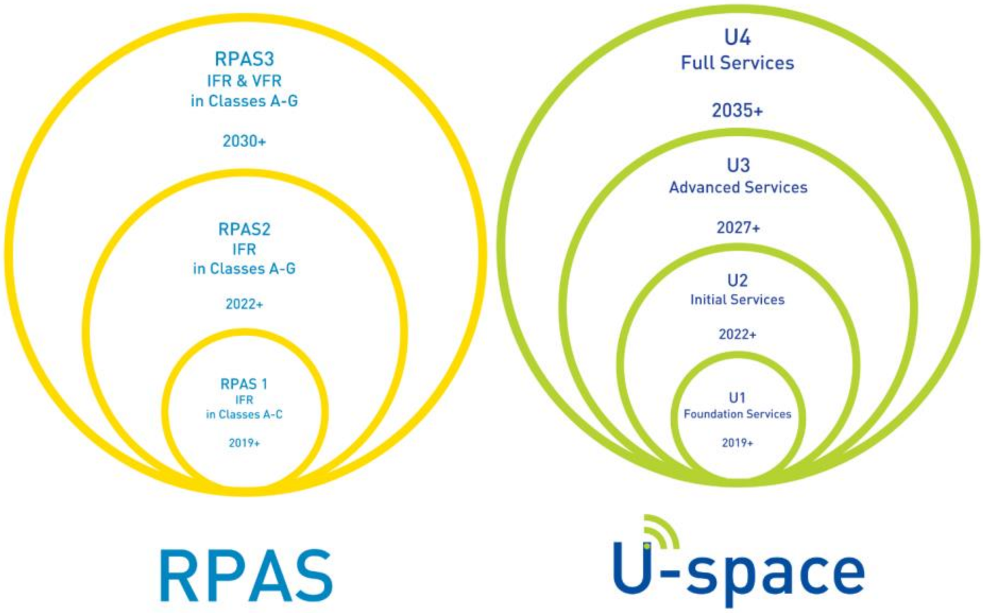


FIGURE 12: U-SPACE AND RPAS DEPLOYMENT FORECAST (FROM [2])

Regarding the CONOPS and integration into the airspace, different types of airspace and operations will demand a different combination of services to ensure global safety. For this, a concept of typical volumes, with growing associated risk, was developed [65]: X, Y and Za and Zu. These volumes are defined according to the services provided, so an operational safety assessment must be realized, like the Specific Operational Risk Assessment (SORA) (also see section 6.2). Volumes Y and Z are of interest to ADACORSA, as they are of higher complexity and allow the exploration of high-value services with drones.

Being of increased associated risk, a key differentiation between the volumes regards the type of available conflict resolution. A brief description of the characteristics of the volume follows, from [3], illustrated from [65].

X: No conflict resolution services are offered. This volume is mainly related to rural areas. It is of relevance, for instance, for the applications related to agriculture, forestry, mining, etc. Even for logistics, reaching out to these regions can already kick-start many specialized markets.

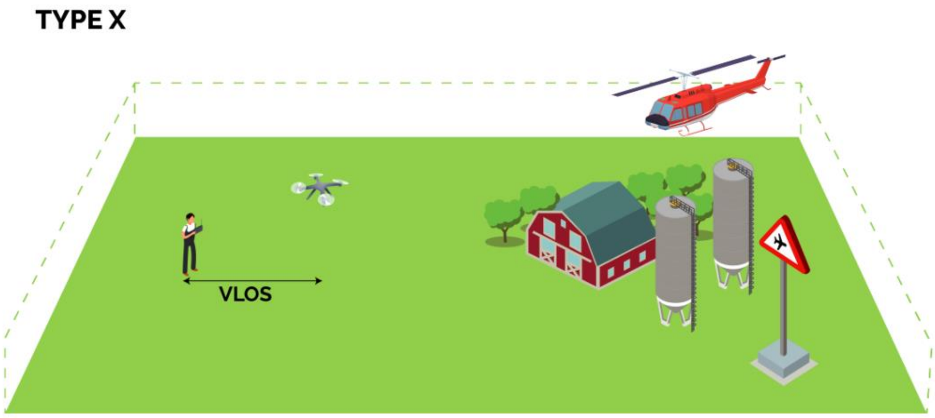


FIGURE 13: X VOLUME, FROM [65]

Y: Only pre-flight conflict resolution is offered (called strategic resolution). Y is to be available in U2, allowing easier VLOS, EVLOS, and BVLOS[4]). These volumes already include urban areas flight and high-density regions but exclude controlled airspace, like the regions enveloping airports, heliports, and the like. With Y volumes, logistic applications can already reach a significant market expression, and well beyond specific applications.

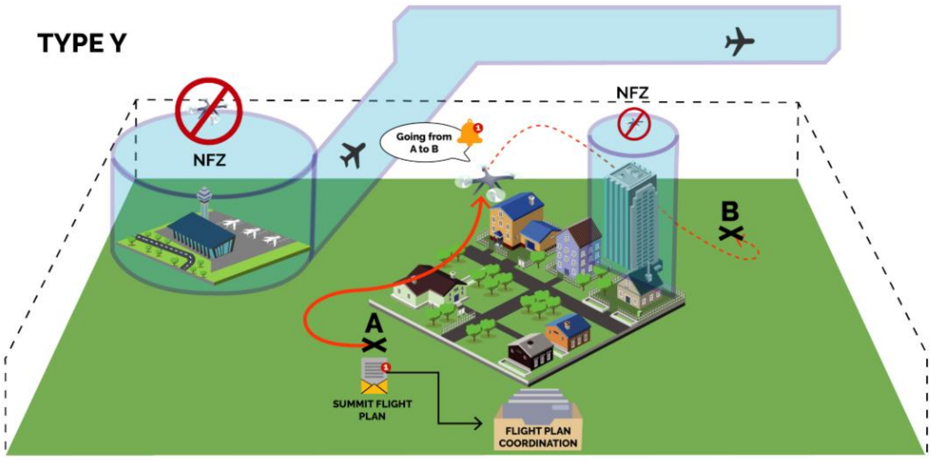


FIGURE 14: Y VOLUME, FROM [65]

Z: Pre-flight conflict resolution and in-flight separation (tactical) are to be offered. Z is further divided into Zu (controlled by UTM) and Za (controlled by ATM). Z volumes will be available in U3 and will allow higher densities of operation than Y and facilitate BVLOS and automatic drone flight. Enabling the interaction with some restricted areas not allowed in the Y and Z volumes will make drone applications start to near their full potential.

[4] Types of operations regarding the ability of the pilot to see the drone and avoid collisions. Visual Line of Sight (VLOS) and Beyond Visual Line of Sight (BVLOS). See next section (6.1.2) for details)

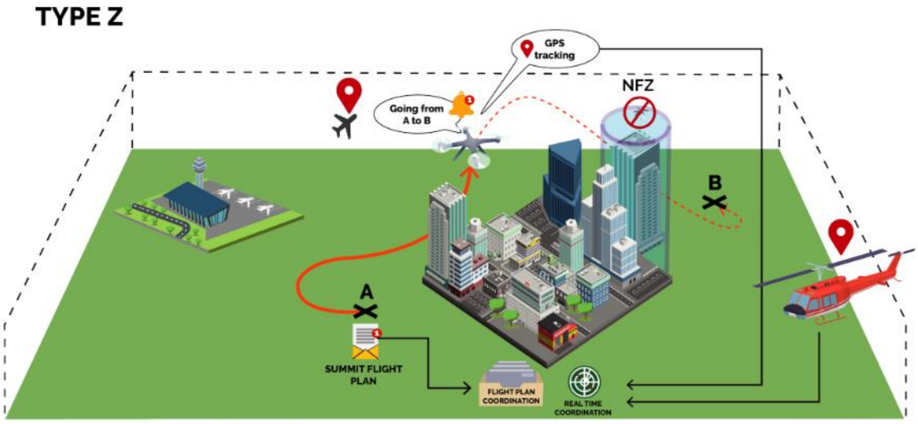


FIGURE 15 Z VOLUME, FROM [65].

Complementing the brief description above, Table 4 gives the current view of the services present in each volume, and their availability in the different U-space phases.

TABLE 4: U-SPACE SERVICES PER VOLUME (FROM [3]).

Service	X	Y	Z
Registration	Mandated	Mandated	Mandated
e-identification	Mandated	Mandated	Mandated
Geo-awareness	Mandated	Mandated	Mandated
Drone Aeronautical Information Publication	Mandated	Mandated	Mandated
Geo-fencing provision	Mandated	Mandated*	Mandated
Incident / accident reporting	Mandated	Mandated	Mandated
Weather information	Mandated	Mandated	Mandated
Position report submission sub-service	Recommended	Mandated*	Mandated
Tracking	Optional	Mandated*	Mandated
Drone operation plan processing	Optional	Mandated	Mandated
Emergency management	Optional*	Mandated*	Mandated
Monitoring	Optional	Mandated*	Mandated
Procedural interface with ATC	Optional+	Mandated+	Mandated
Strategic conflict resolution	No	Mandated	Mandated
Legal recording	Optional+	Mandated*	Mandated
Digital logbook	Optional+	Mandated*	Mandated
Traffic information	Optional	Mandated	Offered
Geospatial information service	Optional	Optional	Mandated*
Population density map	Optional	Optional	Mandated*
Electromagnetic interference information	Optional	Optional	Mandated*
Navigation coverage information	Optional	Optional	Mandated*
Communication coverage information	Optional	Optional	Mandated*
Collaborative interface with ATC	Optional+	Mandated+	Mandated
Dynamic capacity management	No	Mandated*	Mandated
Tactical conflict resolution	No	No	Mandated

U-space Phase	U1	U2	U3

+when needed *where available

From the previous description and sections of this report, the high complexity of the U-space ecosystem can be easily perceived. Figure 16 gives an overview of the many stakeholders involved with U-space, while the architectural view in Figure 17, considers the main nodes and interactions of the U-space components. The reader is further encouraged to read references [3], [66] ,and annexes for more extensive descriptions.

FIGURE 16: MAP OF U-SPACE STAKEHOLDERS (FROM [66])

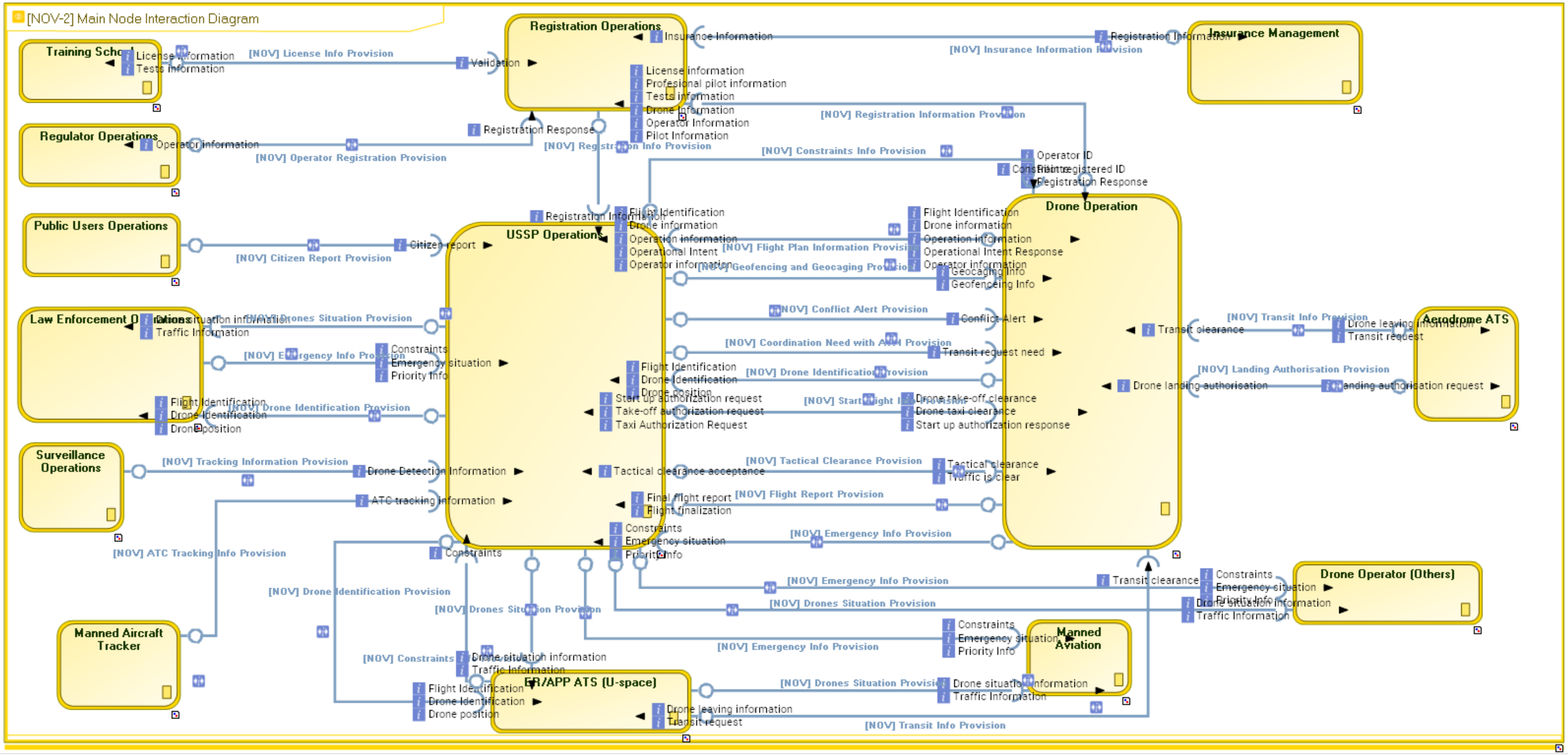


FIGURE 17: U-SPACE MAIN INTERACTION DIAGRAM, FROM [67]

This project has received funding from the ECSEL Joint Undertaking under grant agreement No. 876019.
This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme and the ECSEL member states.

6.1.2 BVLOS flight

ICAO defines Beyond Visual Line of Sight (BVLOS) as “An operation in which the remote pilot or RPA observer does not use visual reference to the remotely piloted aircraft in the conduct of flight” [68].

This type of operation is crucial for the large-scale expansion and economic feasibility of a large range of drone business applications, namely logistics, mapping, and surveying, to name a few. BVLOS enables drones to surpass the limits imposed by the reach and constraints of their operator’s eyes, extending their range and, as such, productivity, and profitability.

The main challenge of enabling BVLOS is the loss of the “see and avoid” capability that exists in Visual Line of Sight (VLOS) operations. Simply, in VLOS the pilot – or an observer, in the context of Extended VLOS (EVLOS) – can see the drone, can see its environment and avoid collision with other air vehicles, the ground or obstacles. The ability to avoid collision is an air safety requirement. If, on one hand, the lack of “see and avoid” could be addressed by operating only in segregated airspace (Strategic Collision Avoidance), this would simultaneously place a high burden in the airspace management and highly limit the types of operations allowed for drones. Another option is creating an equivalent capability to “see and avoid”: “detect and avoid” (DAA).

Detect and Avoid (DAA) is “the capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action”, according to ICAO. DAA can be achieved with different combinations of solutions, provided by a single system or a combination of collaborative systems [69]. Three main functions compose a DAA solution:

- **Detect**: “Identification of potential hazards and notification to the appropriate mission management and navigation systems”. Regarding the airspace, two different types of sub-capabilities are involved here, associated with the type of objects in the trajectory:
    - Cooperative: aircraft or drones that making themselves conspicuous by broadcasting their position, speed, direction, and altitude.
    - Noncooperative: objects not broadcasting their trajectory information, either man made or not.
- **Decide**: “Using the information available, decide on the appropriate mitigating action to take”
- **Avoid**: “Ability to take action in order to maintain safe separation, or to avoid a collision”. Here, two layers can be discerned:
    - Tactical separation: here the collision is avoided by following prescribed and shared procedures, like Rules of the Air, ATC/UTM instructions or UAS-to-UAS rules (this last still to be defined).
    - Tactical Collision Avoidance: an emergency maneuver is made to avoid collision, possibly violating Rules of the Air, ATC/U-SPACE instructions or UAS-to-UAS rules.

Various systems and approaches can thus come into play to create the DAA capability. Four categories of technologies are identified in [69]:

- **Groun-based Infrastructure**, like radar, can provide information regarding aircraft and UAS.
- **Electronic Identification & Conspicuity**, where the identification, position, speed, heading and altitude of aircraft and UAS is available in real-time

This project has received funding from the ECSEL Joint Undertaking under grant agreement No. 876019.
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- **On-board Detect & Avoid Equipment**, which includes functions provided by sensors, computing systems, flight controllers, to detect hazards and evade collisions
- **UTM,** which integrates and disseminates critical data and instructions for airspace users and, interacts with ATM to coordinate UAS in VLL airspace with manned air traffic, for instance.

The specific and appropriated BVLOS enabling solution is thus operation dependent (what, where, and when the operation is done). Today, BVLOS operations are not standardized, each one needing a waiver from the national regulator as a common framing is still being built. The build-up and demonstration of sensors, computer decision systems, communication services are critical for the future standardization and general usage of BVLOS for drone business applications.

6.1.3 Drones Technologies State of the Art

This section focuses on technical state-of-art items specific for each supply chain.

SC1 sWAP and sensors

Currently, there are no radar sensors or sensors per se specifically designed for detect and avoid (DAA) capabilities on drones available. Especially consumer drones heavily rely on on-board cameras and are limited to line of sight (LOS) flight. Traditional radar systems for airborne collision avoidance system (ACAS) from general aviation are too bulky, heavy, and power hungry for commercial drones. Additionally, these systems are only intended for a resolution advisory (RA) instead of an automatic avoidance. State-of-the-art automotive radar sensors on the other hand offer a decent size, weight, and cost perspective but due to their ground-based transportation are of course limited to the 2D case. Another emerging but low-volume radar sensor market is the counter UAS (C-UAS) application where the requirements on the detection of drones would fit the here intended application very well. But these ground-based systems are currently also under development and of course due to their static application have next to no limited power budget. These issues with the current state-of-the-art underlines the need for the planed research and development in this project. For the radar sensors the best approach from the current point of view is to start from current automotive technologies and expand their performance to 3D scenarios needed for BVLOS or autonomous flight.

Sensors with a wide field of view and a high degree of detail on the scenery at the same time are often called microwave imaging, imaging radar or MIMO radars. One of the most prominent applications of these sensors is the standoff detection for weapons or hazardous materials at an airport also called body scanners [70], [71]. The system in [70], [71] employs a massive MIMO architecture with 3008 transmitters and 3008 receivers per panel to achieve the high level of detailed needed for the intended use case. Basically, rendering it unusable for drones due to its size, weight and power consumption.

Another system intended for off-road vehicles possibly driving through burning forests is given in Figure 11. A taken measurement is also shown on the right in Figure 11 with the data fusion from the camera and MIMO radar of the system [72].

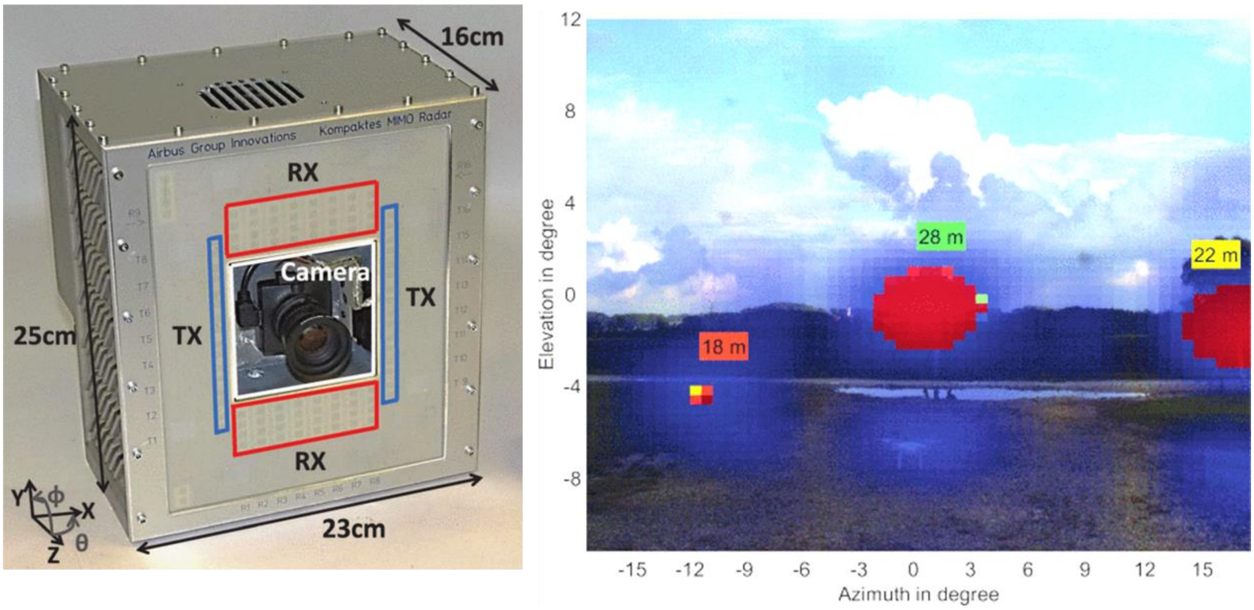

Figure 11: 16x16 MIMO Radar with Camera (left) and data fusion from MIMO radar and camera

While the performance of the system regarding range, a field of view and resolution would be quite suitable for the scope of this project the size, weight and probably power consumption are not. The size and weight are mainly given by the chosen frequency range of 16 to 17 GHz and the resulting antennas and array pattern.

Another very promising state-of-the-art radar with a measurement result is given in Figure 12. The realization of the radar with 24 transmitters and 24 receivers is quite compact due to the used millimeter frequency of 120 GHz [73].

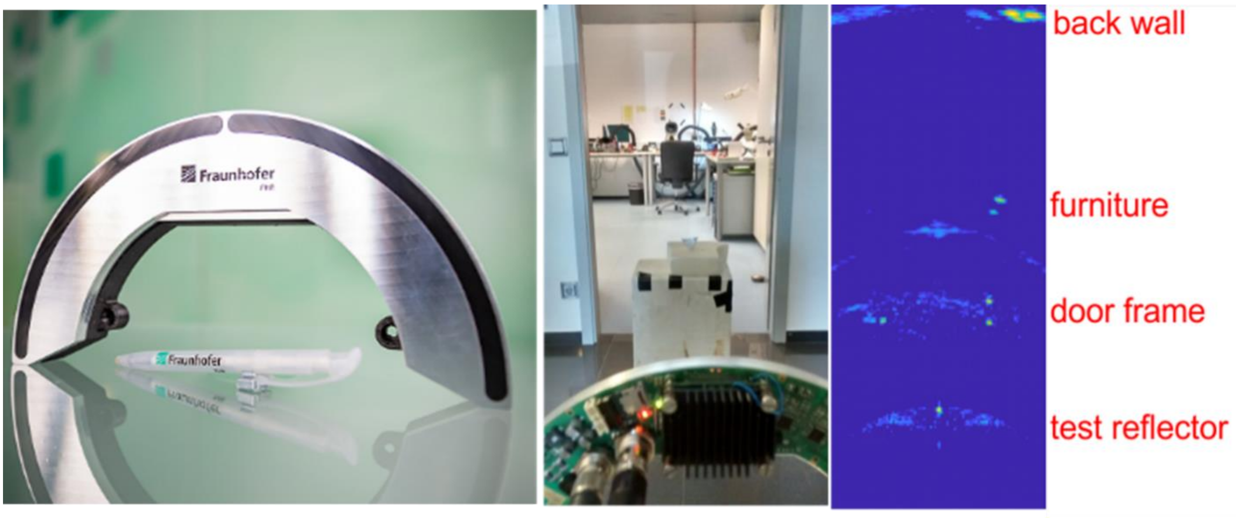

Figure 12: A compact 3D FMCW 24x24 MIMO radar (left) and taken in door measurement (right)

The spatial resolution and angular resolution of the system more than suits the required capabilities. As this demonstrator was intended for in-door inspection of for example given burning buildings the maximum range was not that critical. Also, the complexity of the semicircular 24x24 antenna pattern can be reduced in favour of power consumption, needed processing power, and manufacturability.

SC2 SWaP and compute efficient platforms

Vendors of most compute platforms introduced in section 5.3 SC2claim high performance and low power but do not provide accurate information. For specialized AI acceleration or deep learning processors these platforms are too general and will not give the performance to power ratio that is needed in the ADACORSA project.

TABLE 5: GENERAL COMPARISION BETWEEN DLP, FPGA AND GPUS [74]

	Target	Performance	Energy Efficiency	Flexibility
DLPs	deep learning	high	high	domain-specific
FPGAs	all	low	moderate	general
GPUs	matrix computation	moderate	low	matrix applications

Moreover, most computing platforms are not readily available for use; rather, they are processing solutions board or System on a Chip (SoC) that designers can use when developing such board. The exception is the nVidia Jetson boards series [39]. They feature a small form factor ranging from 69x45mm to 100x87mm and power dissipation between 5 and 30W. The Jetson family is using a GPUs from NVIDIA for acceleration tasks with up to 64 Tensor cores and support for NVLDA deep learning accelerator for machine learning tasks. Even if the Jetson Xavier series is powerful, it still relies on GPU acceleration and thus the energy efficiency is not optimal for applications in ADACORSA where power consumption is an especially important parameter to optimize. It will be essential to co-design the acceleration part of the hardware and the algorithms and machine learning models that is going to be used [75]. Co-designing will give you less flexibility but high performance to a low energy cost which is needed in power constraint devices such as a drone.

SC3 Environment perception

One main requirement for intelligent vehicles is that they need to be able to perceive and understand their surroundings in real-time [76]. The capability to Detect and Avoid (DAA) is crucial for enabling BVLOS operations, as the pilot is no longer able to provide See and Avoid capability (see section 6.1.1). A summary follows two major themes regarding DAA: 1) the capture of signals about the environment and, 2) the processing of such signals to provide an understanding of the said environment.

Currently, DAA systems are still under development and a complete certified redundant sensor system is not (commercially) available in the market. Only for the Medium Altitude Large Endurance (MALE) and High-Altitude Large Endurance (HALE) drones in the military market a few experimental systems are being used. The state-of-the-art for small commercial drones is limited to detection of large obstacles at low speed without any form of safety qualification or certification. On an experimental level, a number of manufacturers and research establishments are working on sensors using different technologies, such as optical, LiDAR, radar, acoustic, next to the more conventional aerospace domain option like the cooperative sensors, using transponder signals (Mode-S, ADS-B).

The optical sensors technology is hindered by the limited optical sensor resolution and the required high volume of data to be processed, requiring larger computing power (high weight and power consumption). The radar sensor technology is hindered by the high computing power, absorbed power, and antenna size to achieve the necessary resolution and range for the detection of drones and aircraft at sufficient distances. The LiDAR sensor technology is hindered by high-power consumption and the size of the sensor to achieve the necessary resolution/range combination and required computing power to process the signals. The acoustic technology is hindered by the difficulty of sound classification and the disturbances of other noise present at the sensor location. With respect to the more conventional aviation transponder technologies, the main issues are: Mode-S transponders need to be interrogated to provide their signal and do not reveal their location, so require interrogation with localization of the signal source. For both Mode-S and ADS-B transponders, the challenge is the congestion of the allocated frequency band.

Drone positioning by radio location

Main localization techniques are based on Received Signal Strength Indicator (RSSI), Time of Arrival (ToA), Time Difference of Arrival (TDoA) and Angle of Arrival (AoA) measurements. The target location is estimated through signal processing mechanisms, based on the data obtained in the wireless scenario.

RSSI-based techniques are based on power measurements in order to estimate the distance between two nodes. On the other hand, time-based localization techniques rely on measurements of the Time of Flight (ToF) between nodes. If all nodes (target and anchors) are synchronized, the target node can determine the ToA; on the other hand, if only anchors are synchronized, then they can estimate the difference between arrival times of packets received by different anchors (TDoA).

Hence, the distance (or relative distance) between anchors and target can be simply estimated assuming that the signals travels at the speed of light. Obviously, all the above considerations are valid for transmissions over channels with LOS conditions. For NLOS-impaired links these assumptions do not hold since the received power is attenuated due to reflections (longer path) and/or refraction through obstacles.

Commonly used unmanned aerial vehicle (UAV) platforms rely on the use of global navigation satellite system (GNSS) receivers for navigation eventually extended with RTK, to have extreme precise positioning. To enable the autonomous navigation of cooperative UAVs in GNSS-denied environments, other techniques must be explored, to counter the lack of GNSS coverage or, eventually, for indoor localization and navigation. Alternative radio technologies are listed in the following:

WiFi: the WiFi technology exploits the existing Access Points (APs) to perform localization. In this case, several approaches can be applied to estimate the real-time user position, such as: (i) TOA, (ii) AOA, (iii) Hybrid TOA/AOA, (iv) RSSI [77]. However, this solution is well suited for indoor drone positioning, while it has a scarce applicability in outdoor scenarios. A WiFi-variant developed for high relative speed environments with varying network technology topology is IEEE 802.11p, that allows exceptionally low latency ad-hoc information exchange up to a distance of typically 1 km and in an infra-structure setting which does not require access-points. In the automotive domain a set of protocols is defined for various message types, a.o. the Cooperative Awareness Messages that inform about position, speed, heading, etc…, whose values are delivered by other sensors.

UWB: it is a radio technology, which allows fully accurate positioning, and recent studies prove the capability to track users even in challenging scenarios. The main disadvantage of UWB-based solution is that to localize a target. one needs to rely on a specific infrastructure composed of anchors equipped with antennas and chips able to manage the short impulses. Furthermore, the same hardware must be installed on the target. Reliable results have been obtained in indoor drone positioning [78].
An interesting aspect is that drones can determine mutual distances making use of UWB, without the need for additional infrastructure, because the basis of the UWB-based location-positioning is pair-wise ranging which is performed to remarkably high accuracy and with low latency by UWB. However, there reliability of the required communication as a function of the relative speed-difference of the drones and the used ranging protocol shall be investigated.

Bluetooth Low Energy (BLE) anchors: BLE beaconing represents an innovative IoT-oriented technology. Their cost effectiveness together with their easy deployment allows its extensive adoption, in indoor environments. The main drawback in indoor BLE beacon-based navigation systems is represented by the requirement of the knowledge of the beacons' positions at the user side. However, BLE has a good usability in case of patrolling [79].

All radio-based localization technologies are limited by issues related to both physical constraints and hardware. An overview of these problems is reported in the following.

Infrastructure dependency: all the radio technologies are based on anchors (e.g., beacons, access points, base stations) placed in known positions. In some cases, this infrastructure has to be specifically deployed for localization purposes. This preliminary setup could be complex, such as for GNSSs.

Multi-path signals given the presence of surfaces between the base stations and the target in almost every scenario, the receiver captures multiple signals, namely the one which is traveling on a straight line between the transmitter and the receiver, and the ones reflected by the ground, walls, etc. This leads to multipath and, typically, to overestimation of the path length. This is strictly related to the NLOS limitations.
Costs: the infrastructures to be deployed could have high costs, in particular for ad-hoc localization systems such as ones based on UWB technology.

Location using ultrasound and acoustic signals

An alternative to RF-based are 3D UAV ultrasound positionings [80]. Different solutions can be implemented using distance map of surrounding objects or based on the use of a Time-of-Flight camera to obtain an initial estimation for the vehicle height and an encoded Ultrasonic-Local Positioning System (U-LPS) to compute the horizontal vehicle positioning through a 2D multi-ateration procedure [81].

Light-based technologies

There are other technologies that can also be applied for drone positioning. For instance, Visible Light Communications (VLC) is investigated to be used in drones in [82], where challenges as the placement of ground units, data rate, long-range, fast-speed mobility, and energy management were identified. Laser scanner (LIDAR) has also been evaluated in [83], [84] obtaining high accuracies, nevertheless, it is an expensive technology, requires LOS and the position estimations can be degraded at high sun angles and reflections.

Inertial Navigation

Solutions based on inertial sensing, or Inertial Measurement Unit (IMU), can provide several advantages because of their infrastructure independence, flexibility, cost-effectiveness, portability.

The main problem of this method is that it suffers from accumulation of position and angular deviation over the travelled distance (a small error in direction can originate a huge positioning error if a long distance is travelled). Usually, inertial methods are combined with other sensors to achieve a good performance and correct the drift as in [85] with cameras or as in [86] with UWB and an optical flow sensor.

Hybrid Radio/Inertial Approach

Even though the localization in cellular networks is a strategic aspect, hybrid approaches have not been investigated exhaustively, yet. Localization in indoor environments is even a more challenging research field and many other technologies could be integrated in order to increase the positioning accuracy.

More specifically, the data of interest are usually:

- LTE 4G RSS, Reference Signal Received Power (RSRP), and Reference Signal Received Quality (RSRQ), only from the connected cell.
- WiFi RSS, in dBm, from all the available APs.
- BLE anchors RSS, in dBm.
- GPS location fixes and accuracy, only when GPS localization is available.
- UWB communication allows low latency and highly accurate determination of range (mutual distance) between any pair of UWB-nodes.

Algorithms and processing for detection

Albeit the challenges already mentioned for sensors like cameras, radio, radar, and LiDAR, the technology has been evolving to lower its size, power, and heat footprints. They are thus becoming increasingly of interest to aerial applications and high synergy exists for transfer from automotive. While in the case of road vehicles the main functions of environment perception are based on lane and road detection, traffic sign recognition, vehicle tracking and behaviour analysis, and scene understanding, in the case of drones the challenges are much more complicated. However, the main areas still comprise [87] from bottom to top: the detection of scene features, the detection and identification of traffic objects and the understanding of the drone position and situation. The UAV motion planning then follows [88].

Obstacle detection is thus one of the components of such a system, which becomes one of the main components of the navigation systems of UAVs. This complements, the pose estimation, which estimates the position and the attitude of the UAV in two- and three-dimensional representations, and the visual servo subsystem, which cares for the flight stability and following the path [89].

Some methods combine continuous shots of the scene from a camera and Epipolar geometry to estimate the distances of feature points (stable obstacle points) and compute the direction of camera displacement and thus improve navigation precision and detect obstacles in the environment [90]. Other methods try to distinguish between stationary and moving obstacles in roads [91] and in the latter case provide an approximation of the detected obstacle's absolute speed. More recent works tackle the collision avoidance problem either with a fusion of low- cost sensors such as infrared and ultrasonic sensors for redundant 360◦ coverage [92] and several distance thresholds that define the risk level at each direction at any moment, or with laser scanners and other range finders [93], or with stereo vision techniques and image filters [94], [95].

Simultaneous Localization and Mapping (SLAM). The general capability described before complements what is called Simultaneous Localization and Mapping (SLAM), or the challenge of simultaneously estimating a map of the environment and the ego-motion. Over the years methods for doing this based on image data have developed and matured so that it is possible to do this accurately, robustly and in real-time [96], [97]. Recently many methods based on machine learning have also been proposed [98]. The local motion estimate these often incorporate state-of-the-art optical flow estimators [99]. Also, depth cues from single images can be used [100]. For SLAM methods to be scalable and used in perception semantic interpretation of the images and environment is important. Also, such methods have matured in recent years [101]. In addition to images, other types of sensor modalities can also be used in SLAM applications [102].

A similar problem as the SLAM problem is the structure-from-motion problem (SfM), where typically not real-time aspects are considered and the data is assumed in batch form [103]. In both SLAM, and SfM robust initialization is paramount. Such initialization problems can typically be described using multivariate polynomial equations, and solvers for such systems are important building blocks [104], [105]. A subproblem to the SLAM problem is the localization or camera pose estimation problem [106], [107]. Also, for this problem other sensor modalities than images can be considered [108] [13].

SC4 Secure and reliable communication

Reliability

The difference between drone communication and traditional communication and networking includes radio propagation model for drone networks, power consumption and network lifetime, computational limitations due to size and weight constraints, adaptability with respect to mobility, node failure, effects caused by changing environmental conditions, and flight path updates, scalability with minimal performance degradation; and application dependent bandwidth and latency requirements.

Many wireless technologies, such as Zigbee, Wi-Fi, WiMAX, and LTE have been tested for aerial networks, each one mapping a specific requirement (e.g., high data rate communication such as 4/5G for sending large amount of data, sub-GHz protocols for long-range communications). Communication and networking are essential to coordinate multiple drones and achieve autonomous behaviour. The communication technology of choice should be able to support drone-to-ground and drone-to-drone links, considering the data needs to be delivered, keeping in mind the QoS requirements, link diversity and high node mobility in drone networks. Several wireless technologies can be exploited for UAV networks such as IEEE 802.15.4, IEEE 802.11x, 3G/4G/5G, LoRaWAN, and infrared. The application specific requirements pose challenges over the network design and communication constraints varying in traffic type, volume, frequency, delay tolerance, communication range, mobility effects and frequency of topology change, control and coordination requirements among multiple nodes, network density, size and energy limitations.

Currently, for many applications, the communication channel between the controller of the operator and the UAV is implemented as direct connection using WLAN or similar technologies. This leads to a limitation of the operational range due to the line-of-sight condition [109] [110]. Thus, to extend the coverage for BVLOS operations, the mobile network in combination with technologies like LoRaWAN are considered.

Regarding the mobile network, launched as a project in December 2004 [111], according to measurements by [112], the Long Term Evolution network (LTE) reached in 2019 average availability values of up to 80% across 87 countries. Thus, it is reasonable to use the widely deployed LTE network as a communication channel for the data link of the UAV. Although, there are some issues by using the LTE network in terms of UAV communication.

Firstly, the UAVs receive downlink interference from a larger number of cells, because of their high line-of-sight propagation probability. Regarding the downlink on the UAV side, interference leads to higher resource utilization, whereby the spectral efficiency of the network is decreased and the terrestrial UEs are negatively influenced. Secondly, the UAV can be the cause of interference, when uploading data to the E-UTRAN Node B antenna (eNB). This can have a negative impact on all user equipment (UE) perceiving the interference [113].

Another aspect is that, if the eNB antennas are down tilted, aerial UEs flying higher than antenna height, are served by side lobes, which can lead to a use of a faraway base station and thus to pathloss [114]. Furthermore, the coverage probability of the mobile network decreases with rising altitudes of the UAV evoked by the interferences [115]. Hayat et al. found in an experimental evaluation an increase in handovers with rising heights of the UAV due to Reference Signal Received Power (RSRP) drops [116]. Similar results show 3GPP in field trial evaluations, where both the number handover failures and handover successes increase with height [113].

Considering the latency 200ms and 300ms for UAV heights of 50 m and 100 m can be measured. In addition, the latency increases with rising heights [5]. Moreover, as shown in [117] the reliability decreases with height as well, leading to a reliability of 51.7 % in a height of 120 m.

In sum, further enhancements are needed in order to realize a reliable communication channel for UAVs over the LTE network. These enhancements will be developed within the contribution of SC4 in ADACORSA.

With the 5G network many enhancements for UAVs will be enabled, although it is still under development [118], [119]. For example, 5G uses mmWave, resulting in high frequencies and thus higher data rates, because of broader bandwidths [110], [120]. Besides, network slicing will be enabled, whereby multiple logical networks are generated on one physical network [110]. Thus C&C data can be separated from the application data. Nevertheless, the main issue with 5G is, that it is still under development and deployment and thus not available for the general public.

A well-established way to achieve higher overall reliability of communication links (and other functionality for that matter), is to implement redundancy. In aviation this has been a requirement for approval of operations for decades (duplication of radios for IFR operations, triplication for ETOPS, etc.).

The same underlying philosophy of duplication of equipment and functionality is behind *multipath networking*, which also has been used for decades. Traditionally, the objective of many users is to increase link capacity, often implemented as statically configured bonding of available links. Some modern protocols (e.g., MPTCP [RFC8684], SCTP [RFC4960] and the upcoming MP QUIC) have added multipath capabilities that allow dynamically adding and removing links as they become available and reach sufficient QoS (latency, packet loss rate). The most distinguishing features of the three most established implementations are listed in Table 6 below.

TABLE 6: PRINCIPAL FEATURES OF ESTABLISHED MULTIPATH COMMUNICATION FRAMEWORKS

	MPTCP	**SCP**	**MP QUIC**
Based on	TCP	IP	UDP
Channels/Streams per "connection"	1	Multiple	Multiple
NAT friendly	No	No	No
In-order delivery	Yes	Yes	Yes
Out-of-order delivery	No	Yes	No
Encryption	No	No	Yes (TLS)
Protocol facilities outside of data transport	No	No	Yes

The general multipath capability implies distinct functionality in the networking stack (protocol stack and supporting real-time tooling and utilities) to carry out discovery of available links and measure the quality, including early detection of links for which the QoS is decreasing to levels where the overall quality of the link can no longer be provided. Other functionalities that make part of these systems is a module to switch the traffic over the available links, making decisions on the internal routing on a packet-per-packet basis.

To reliably transport arbitrary application data over a multipath connection, the key property of the transport is out-of-order delivery of packets, a feature only SCTP provides. This allows higher-level protocols to deal with packet recovery, without cascading effects causing more congestion. At the same time, the security requirement mandates transport encryption. Only QUIC offers transport encryption with TLS (DTLS), which unfortunately does not itself well to out-of-order delivery of packets or leaving packet recovery to higher level protocols.

Security

UAS have many different applications, both military and civil, e.g., search and rescue missions, terrain monitoring, cargo delivery, establishing of emergency infrastructure and more. Therefore, they are attractive targets for hacking attacks which has been shown recently [121], [122]. Their attack surface is further increased if they are operating autonomously or if they are communicating in public networks, e.g., by building flying ad-hoc networks (FANETs) [123] or by participate on the internet if things. FANETs can be seen as vehicular ad-hoc networks (VANETs) and mobile ad-hoc networks (MANETs) [123] because they have some characteristics in common but differ in some aspects, e. g. node density, distances between nodes, velocity. The basic security objectives can be formulated for FANETs: confidentiality, availability, integrity, authenticity, authorization, anonymity, non-repudiation [123]. These objectives can be achieved by different security techniques, e.g., encryption, authentication, trust management. An important feature of FANETs is that they can operate without any ground station. Most of the proposed security solutions depend on the existence of ground stations [123]. Currently there is rudimentary and unreliable identification of drones and their operators (e.g., address labels, which can be easily tampered). Moreover, the authorities to regulate third party products are missing. Thus, the communication between UAVs, operators and authorities is insecure.

For inter-drone communication, a solution as deployed in the automotive market can be considered, which is tailored towards mobility-situations with very high relative speeds and frequent network topology changes, which achieves very low latency and high reliability; the IEEE 802.11p wireless communication standard. The standard operates in the 5.9 GHz band, and it is also considered to allow UAV’s to use (a channel) in this frequency band. The standard also defines PKI based authentication for diverse types of messages, that in a first view seem also well applicable for UAV’s.

Modern cyber-physical systems (CPS) have been increasingly relying upon wireless communication technologies to provide seamless services via flexible cooperation, enabling true Systems-of-Systems (SoS), and UAV systems are no exception. However, these SoS present several safety challenges, considering they heavily rely on wireless communications to exchange safety-critical information [124], [125]. In UAV systems, handing over control of a drone between control stations, is currently unsafe but is mandatory for BVLOS operations. Safe communication aims to ensure that the data sent from the source is correctly received by the destination endpoint. Wired communication protocols such as CANOpen Safety, openSAFETY and SafeEthernet have been developed to provide high reliability and safe communication for safety related systems. These typically implement a set of techniques or defense mechanisms [126], [113]. Safety certified protocols such as safeEthernet or OPENSafety are designed to meet SIL 3 requirements, by showing that the rate of undetected bit errors areis below the acceptable probability. OpenSafety provides a black channel approach where the safety protocol is implemented in the application layer in the OSI model. The safety layer is added in the payload as an extra layer. The medium used, nodes visited in between, as mentioned, will not matter as long as the packet arrives, and the receiver can verify it according to the safety protocol. In [127], [114] authors present derived mathematical models that can be used to perform safety related calculations on wireless channels concerning the IEC 61508 standard. These principles are used to further add safety functions to the bluetooth stack in [128], [129], [130], [110] reaching SIL 3. The same black-channel approach can and should be followed to provide safe communications in D2X, something that holds true for general cooperative CPS.

In addition to this, the tight interdependency between control and communications in these Drone CPS, requires an analysis of these systems in a multidimensional perspective. The expensive equipment and safety risks involved in testing, demands for comprehensive simulation tools that can as accurate as possible mimic the real-life scenarios, from the flight control/perception perspective, as well as from the communications perspective, to better understand the limitations imposed by the network QoS in such systems. This is particularly important in critical stages such as in control station handover. However, there is a lack of co-simulation tools that can avail such analysis, something we addressed in contributions such as [131], [109] for the automotive domain and we intend to extend in ADACORSA.

SC5 Drone avionic architectures

Drones today represent one of the main vehicles for the development of avionics systems in the aeronautical industry. Electro-electronic RIGs are important for the integration of avionics systems. Likewise, virtual simulators make it possible to explore and extend the operating envelope of the systems. However, drones have brought a new and challenging means of developing avionic systems, which make it possible to raise the maturity of technologies to higher levels than RIGs and virtual simulators, TRL 6/7, with operation in environments and conditions already close to products. In addition, with significantly low costs and, also, very safe when compared, for example, with aircraft flight tests.

In fact, the emergence of drones is contributing to a significant change in the aeronautical industry and, particularly, in the area of embedded electronic systems. Along with them, drones have brought strong technological challenges to avionics systems, as well as great opportunities for new entrants to this market.

The first challenge related to avionic systems refers to the diversity of drones, in terms of sizes and applications. There was a real explosion in terms of application possibilities. In this process, sensors were probably the first components of avionics systems to suffer the impacts of the emergence of drones. New and different requirements have arisen for existing sensors to meet new applications. A similar impact occurred for actuators and processors in general.

The great challenge of avionics systems, in terms of requirements for drones, refers to the reduction of size, weight and power (energy consumption) of the components, also known as "SWaP". Without major scalability difficulties, drones are imposing novel solutions for aviation systems in terms of SWaP, which will certainly migrate to commercial aircraft in the future. This challenge represents one of the pillars of the ADACORSA project, focusing mainly on drone classes up to 25Kg.

On the processor side, new and much more stringent demands have arisen regarding processing capacity, speed and memory. Associated with the development of artificial intelligence technologies, there is a need for the integration of high-performance processors such as GPUs, VPUs and other resources, in addition to thermal energy sinks in avionic systems.

From the point of view of the organizational architecture of the components within the avionic system, it can be seen in small drones, that most solutions do not adopt a very elaborate structure. They are usually dependent on applications and the corresponding sensors, connected with a central processor. It is noted that many seek to optimize costs and simplicity, without specific concern ito other aspects, such as safety.

Redundancy of systems or sub-systems is practically not applied in the avionics of today's drones. This characteristic is probably explained by the lack of an appropriate regulation for vehicle safety and its operation. However, it is certain that implementing regulations for drones will impose new challenges for the avionics system of these vehicles.

A notable and very interesting aspect related to the drone's avionic systems is the sharing of information and technological solutions through communities and NGOs that practice the “Open source” principle of the knowledge established in this subject. A typical case is the Dronecode [132] project sponsored by the Linux Foundation. This type of work has been promoting access to these technologies to communities of practitioners. The result of this effort should be the production of new solutions, more innovation and faster. Another probable result of these open-source projects will be the standardization of the best solutions acquired by the communities.

SC6 UTM integration

This section highlights the aspects regarding UTM integration focused by SC6. Complementary discussion is provided in section 6.1.1.

FIMS

The Flight Information Management System (FIMS) is a service layer that connects Drones, the U-space Service Provider and the Air Traffic Management (see example in Figure 18).

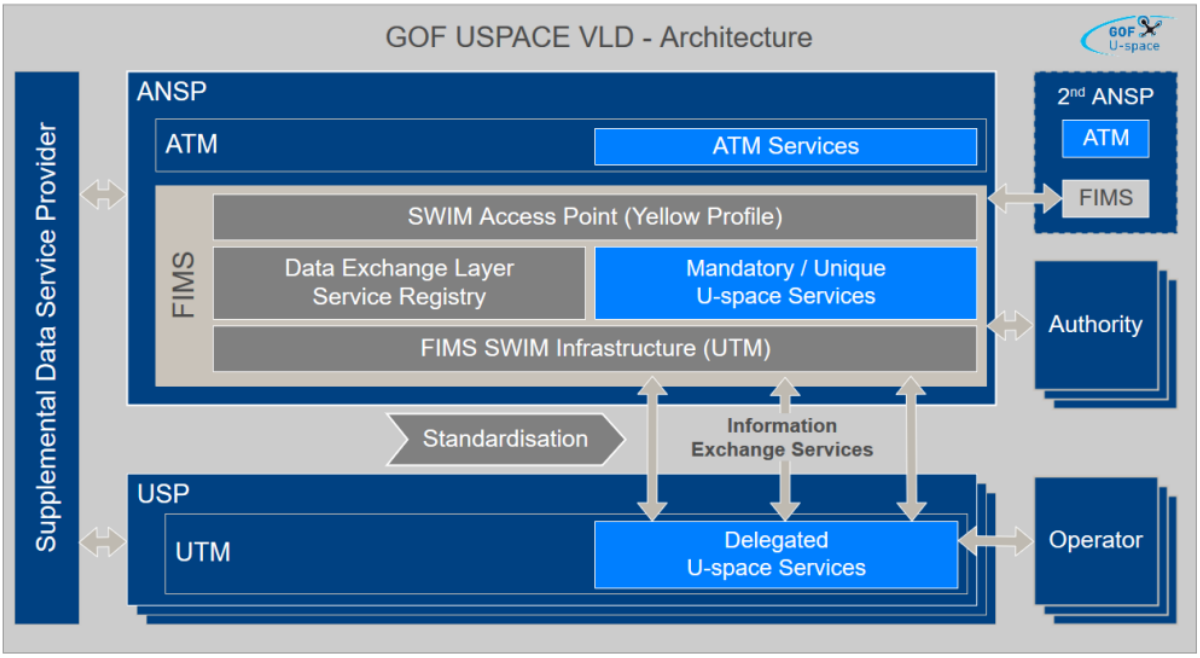

FIGURE 18: GOF U-SPACE HIGH LEVEL DESIGN AND ARCHITECTURE SHOWING FIMS (FROM [133])

For the proposed FIMS in ADACORSA, the following technical concepts have been systematically examined:

- Service oriented Architectures: General Principles
- Service oriented Architectures: Services
- SESAR SWIM (System Wide Information Management): General Concept
- SESAR SWIM Data Models
- SESAR SWIM Services
- SESAR SWIM Technical Infrastructure

The summarization of the applicability analysis of the relevant technical concepts on the global as well as the European level is outlined hereafter.

Global Level

At the global level, the key document is the ICAO 10039 MANUAL ON SYSTEM WIDE INFORMATION MANAGEMENT (SWIM) CONCEPT [134].

The concept for SWIM (System Wide Information Management) is defined as follows:

SWIM consists of standards, infrastructure and governance enabling the management of ATM related information and its exchange between qualified parties via interoperable services.

With respect to the nature of SWIM being a Service-Oriented Architecture (SOA), the definition is as follows:

Service-Oriented Architecture (SOA) is a general concept or paradigm for 'organizing and utilizing distributed capabilities that may be under the control of different owners' (OASIS SOA Reference Model TC). While there is no formally agreed definition of SOA, it is considered that partitioning of functionality into unassociated, self-contained and, therefore, reusable services that can be discovered by potential users is a key feature that discriminates SOA from more traditional architectural paradigms. The SOA paradigm has been used successfully in many industries including manufacturing, banking, health care, and merchandise retailing.

A service orientation is assumed for information exchanges between SWIM stakeholders. That is, an information provider publishes and exposes its services for the use of information consumers; this is done via interconnected registries, which list the services and the specific details for consuming them. One of the benefits of SOA is the promotion of "loose coupling". Loose coupling means that an information provider has a reduced impact on the information consumer. Dependencies are minimized allowing components and services to operate with as little knowledge as possible of other components or services (i.e., a consumer should need to understand only what is absolutely required to invoke a service and no more).

The key concept on the global level is the Global Interoperability Framework (GIF) and is defined comprising the following layers:

a) SWIM-enabled Applications of information providers and information consumers around the globe. Individuals and organizations, such as air traffic managers and airspace users, will interact using applications that interoperate through SWIM.

b) Information Exchange Services defined for each ATM information domain and for cross domain purposes, where opportune, following governance specifications and agreed upon by SWIM stakeholders. SWIM-enabled applications will use information exchange services for interaction.

c) Information Exchange Models using subject-specific standards for sharing information for the above Information Exchange Services. The information exchange models define the syntax and semantics of the data exchanged by applications.

d) SWIM Infrastructure for sharing information. It provides the core services such as interface management, request-reply and publish-subscribe messaging, service security, and enterprise service management; and e) Network Connectivity provides consolidated telecommunications services, including hardware. This infrastructure is a collection of the interconnected network infrastructures of the different stakeholders. These will be private/public Internet Protocol (IP) networks.

European Level

At the European level, the ICAO SWIM Global Interoperability Framework is translated in the following Eurocontrol documents:

(1) EUROCONTROL Specification for SWIM Information Definition (Edition: 1.0 Edition date: 01/12/2017 Reference nr: EUROCONTROL-SPEC-169) [135]

This specification contains requirements for information definitions in the context of Initial System Wide Information Management (iSWIM) in Europe.

Information definitions, the formal descriptions of exchanged information, are produced or reused by operational stakeholders. They act as the means whereby the exchanged information is clearly defined, understood and harmonised between stakeholders. Examples of information definitions are the description of information exchanged by services, standardised information exchange models, data catalogues used to list details on the exchanged information, and information exchanges captured as part of a business process model.

The requirements come in two broad categories: general requirements for information definitions and requirements on how to document semantic correspondence to the ATM Information Reference Model (AIRM).

The general requirements include, for example, the need for an edition and a reference date.

The semantic correspondence requirements facilitate semantic interoperability, which is the ability of computer systems to exchange data with unambiguous, shared meaning. The requirements ensure that information definitions conform to the semantics of the AIRM, the common reference language for iSWIM.

(2) EUROCONTROL Specification for SWIM Technical Infrastructure (TI) Yellow Profile (Edition: 1.1 Edition date: 05 July 2020 Reference nr: EUROCONTROL-SPEC 170) [136]

This specification contains requirements for the implementation of technical infrastructure supporting information exchanges in iSWIM.

It enables technical interoperability by specifying standardised technical interfaces (e.g. protocols) and the capabilities required to enable a reliable, secure and efficient exchange of information.

This specification is modular and provides different implementation options based on mainstream technology, considering a wide range of information exchange needs (e.g. security).

This specification is intended for use by technical experts designing and implementing systems and services.

(3) EUROCONTROL Specification for SWIM Service Description (Edition: 1.0 Edition date: 01/12/2017 Reference nr: EUROCONTROL-SPEC-168) [137]

This specification contains requirements for describing implemented information services within the context of Initial System Wide Information Management (iSWIM). In order for service consumers to make good use of the available information services, it is essential that service descriptions cover the service consumers' needs. Therefore, the requirements focus on the service description that a service provider makes available to service consumers.

More specifically, the requirements prescribe the minimum set of elements to be contained by a service description in order for a service consumer to discover a service, consider using a service, or implement a service consuming client.

The requirements ensure that a service description covers the information needs of business experts, operational experts and technical experts, more particularly in terms of: what a service does, how a service works, how to access a service, and other information for consuming a service.

On-Board Safety Layer

Detecting and correcting mishandling abnormal flight behaviour is a safety layer component needed to enable BVLOS operations. One solution is the On-board Safety Layer for Autonomous Flight. This layer should be able to handle any abnormal flight behaviour jeopardizing an intended mission, eliminating or reducing any risk on the ground or air domains, associated with the mission (operational scenario).

ADACORSA safety layer demonstration will address testing of multi-UAV scenarios, as well as a set of algorithms - the 'safety layer' - which will guarantee vehicle safety with the help of online verification methods, and in the presence of unverified control and planning technology. The safety layer runs in parallel to the standard control and planning software and takes over control only in case the safety of the vehicle could not be verified for a certain time interval. In such a case, a verified emergency maneuvre is performed. The safety layer receives input from sensors aboard the vehicle (either the same sensors used by the standard control and planning software, or extra sensors).

Several enhancements to the state-of-the-art of UAV safety technology are envisioned:

- Efficient occupation prediction algorithms.
- Suitable emergency maneuvres and controllers.
- Traffic rules for densely populated urban airspace.

An important technical risk for the development of such a safety layer is the limited computational power of onboard computers.

Simulation in U-space of ROS UAS

Due to the high level of complexity of the airspace, simulation is a highly desirable tool to develop and test new concepts of airspace management prior to real-life operational tests. The use of Robotic Operating System (ROS) is increasing in the field of drones and simulation tools are expected to provide for ROS-based virtual drones (native ROS or bridged over e.g. MAVLink). Current industry-standard simulation tools for ROS are GAZEBO [138], CoppeliaSim (former v-REP) [139]. There is also some experience of using high-end game engines (Unreal Engine, Unity, etc.) as simulation environments for ROS-based drones.

For the purpose of this demonstration, several enhancements to the state-of-the-art in robotic simulation are envisioned:

- Efficient and effective simulation of multiple drones in the same environment
- Hardware in the loop: The ability to have real drones operate in an environment where other traffic is simulated
- Adverse environment modeling, for example, the smoke, wind, EMI, etc.
- More advanced models about sensors and (RF) environment.

These simulation environments can further be hosted in the cloud, including using web-technology for accessing the environment, allowing easier collaboration, and reducing the complexity of setting up simulations. Because the simulation environment is developed within SC6 of ADACORSA, it can be a good opportunity to integrate Frequentis's FIMS environment into the simulation environment, through exposing its APIs to the (virtual) drones.

An important technical risk for the development of such an environment is the current lack of regulations on mandatory technology within the drones. The implication of that risk is that the simulation environment will need to be quite flexible regarding potential future technology choices.

Simulation-based Evaluation of Blockchain-enabled U-space

As stated in SC4, safe and robust communications are an underlying critical feature for enabling the full deployment of drone operations. This becomes even more stringent as several of the service capabilities for the U-space concept mention or is dependent on it. Especially when we consider in BVLOS operation scenarios with the future prospect for integration into higher airspace, with the goal of enabling a multitude of prospective missions ranging from drone inspection to air taxi operations.

Blockchain technology is considered in this context (i.e., the context of safe and secure and communication infrastructure in ADACORSA) to provide a safe reliable support to "Authentication and Trust Management System". In the literature, blockchain infrastructures are more and more cited as a candidate for supporting Trust Frameworks in particular in the context of Federated Identities (see NIST report on Identity management [140]). Even though this technology is quite young, especially if we consider non-crypto-currency applications, many studies have already been conducted towards their use in domains such as autonomous vehicles VANETS in automotive, underwater drones, and more recently within FANETS applications resulting in Proof-of-Concepts (PoCs) and academic papers.

More largely, the blockchain technology is well suited to support secure interactions between actors within decentralized contexts such as systems of systems like U-Space even if some actors are faulty or malicious. It is thus a promising technology that can provide resilient robust, trustable traceability and accountability support to combine UTM/ATM applications. It may participate to reinforce protection of critical data exchange between actors of the system. As such, it can at reasonable costs, improve **trust** and **robustness** of UTM/ATM control processes.

Several usages of blockchains may benefit to UTM/ATM applications.

- As a distributed ledger service, it can support UTM management system with authorization registration and control.
    - It can deliver proofs of certificate and authorizations, register air plan, operators involved, and can be consulted and/or used both by control authorities, or by actors.
- As an active component, a blockchain using dedicated smart contracts (i.e., immutable deterministic programs deployed onto the blockchains) may perform online monitoring and/or help to respect trajectories.
- Regarding safety and reliability issues, a blockchain may register flight information that can prove that mission profiles used for reliability computation have been respected and/or help replan missions so that the drone stays within its mission scope.

Indeed, the technology is still in its infancy to be directly applied in critical embedded applications without prior serious experimentation and evaluation studies. As a matter of fact, the use of blockchain technology and deployment strategies must satisfy many criteria that must be carefully chosen.

The main issue to tackle within the project is **to help decide of the nature of a blockchain model and protocol**. Main anticipated issues:

- Type of permission block-chain
- Type of consensus protocol (proof-of-work, which is energy consuming, does not seem appropriate in this context)
- Deployment architecture

Many other criteria must be considered to provide a good compromise regarding constraints imposed by the domain:

- Verified properties guaranteed by the protocol used;
- Response-time;
- Interoperability;
- Scalability;
- Easy integration with sensors and sources of information;
- Application development language and environment to help implement dedicated services.

Mastering all these aspects is not trivial and designers need support to help to select appropriate policies, parameters, paradigms and compare different configurations and solutions. In this area, simulation can also be exploited to further advance the understanding and characterization of the performance of such solutions and validate their potential for further tests in an operational environment.

To this end, dedicated tools are needed to provide early evaluation of blockchain based solutions [141]. Some tools are emerging but few of them are directed towards early evaluation as well as qualitative, and adversarial studies and no commercial tool is available yet. Most testbeds are conducting performance evaluation but do not provide tight qualitative support.

CEA is developing such a tool named MAX (Multi-Agent eXperimenter) [140] that permits to explore blockchain based solutions within a simulated environment and helps performing early evaluation in various nominal and adversarial contexts. MAX is a framework build on a multi-agent simulation paradigm. The objective of MAX is to make rapid prototyping of industrial cases and to carry out their feasibility analysis in a realistic manner. It is particularly well suited for modeling open, distributed, and intelligent systems. By recreating the dynamics of the system at an agent level, the impact of actions executed by an algorithm under different scenarios can be tested and analyzed at different granular levels of detail.

MAX provides a modular and layered architecture with an extensive library for simulating various blockchain systems (Figure 19). This library is implemented on top of a Network Model that can be customized to implement different communication paradigms.

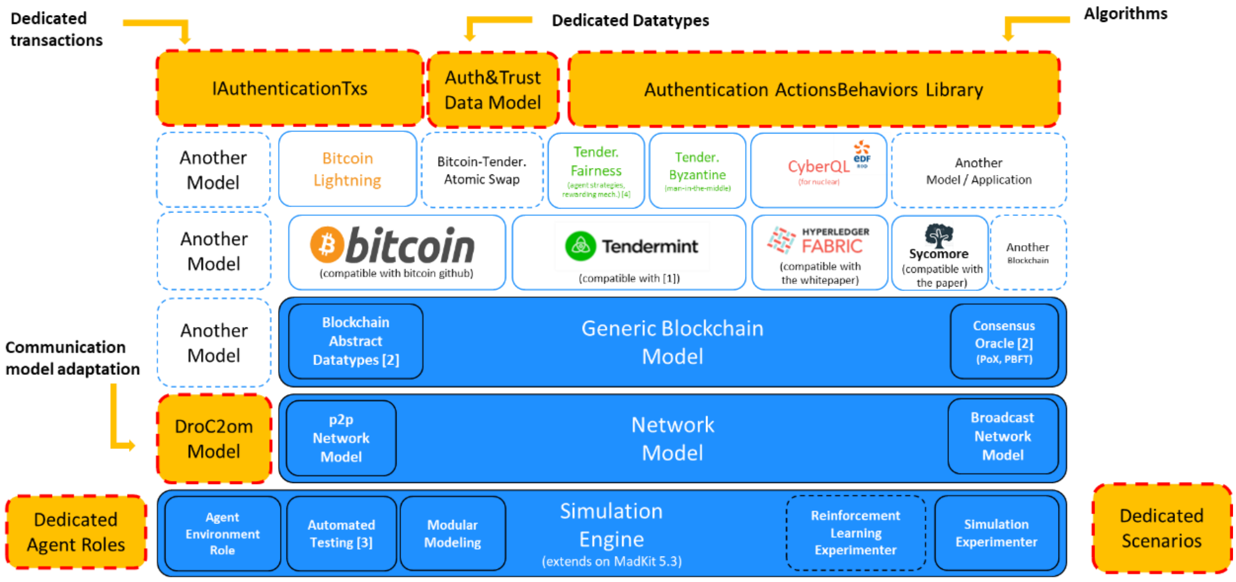

FIGURE 19: THE MAX FRAMEWORK ARCHITECTURE AND DEDICATED BLOCKCHAIN SIMULATION MODULES

A Generic Blockchain Model whose objective is to model generic properties and behaviors of blockchain systems. This abstract model provides generic concepts and data types that are common to blockchain abstraction and used by dedicated components implementing various blockchain models.

Based on this Generic Blockchain Model, it is possible to model any kind of blockchain system. Currently, MAX provides a Bitcoin (high-energy consensus) and a Tendermint (low-energy consensus) blockchain model.

On top of these dedicated blockchain models, it is possible to develop application- specific models as shown in the topmost layer of the architecture (“authentication” example in yellow).

Because the simulation environment is developed within SC6 of ADACORSA, it can be a good opportunity to integrate and/or to provide interoperability with other partners' simulation environments into/with MAX.

Within ADACORSA, CEA will adapt MAX to UTM –U-space domain and extend it to support evaluations of solutions and their robustness towards adversary behaviors. In the first place, the blockchain technology will be used to support new authentication and trust management systems at the communication level (SC4) at a conceptual and simulation level. Demonstrations of the tool will be performed on the SC4 application Use Cases related to "Authentication and Trust Management" but could be extended for other higher- level services. Another promising concept is the use of blockchain technologies to provide a trust and traceability infrastructure for several U-space services, for instance, e-identification and digital logbooks.

Several enhancements to the state-of-the-art in UTM simulation are envisioned:

- Definition of a necessary physical environment for the operations of drones
- Adverse environment modeling, for example, smoke, wind, EMI, etc. and modeling of their effects to the network parameters like delay and reliability.
- Efficient and effective simulation of multiple drones in the same environment,
- More advanced models regarding sensors and (RF) environment.

An important technical risk for the development of such an environment is the current lack of regulations on mandatory technology within the drones. The implication of that risk is that the simulation environment will need to be quite flexible about potential future technology choices.

DAA

DAA is a key component for enabling integration into U-space, either for cooperative, as well for un-cooperative aerial traffic, as mentioned in section 6.1.1.

Currently, U-space is still in the development phase and standards for integration aspects for safe airspace integration and the usage of DAA (technologies) are still under development. While the sensors and other components for the required DAA-system are being developed, verification of those system components is necessary and adds to the smooth development of these systems.

SC7 Technical considerations for enabling the deployment of drones for forestry and smart construction

When it comes to forestry applications, it is important to guarantee that drones and their equipment satisfy several power-constraints, and are supported by flexible local networks with a communication ranging from a few meters to hundreds of meters, so that they can cover long distances and still communicate with the main control. Coverage, battery, and computing constraints apply to all operations, whereas security constraints are less critical, though still [142]. Solutions must also consider finding alternative methods based on vision-based analysis motion control that can handle unknown and complex environments.

When designing drones for the construction sector it is important to equip them with effective vision-based techniques that can perform 3D and 2D model reconstruction, be able to evaluate the infrastructure site and detect and recognize physical obstacles. Safety inspection tasks are also very demanding in vision capabilities, and it is important to develop vision-based methods that can handle images that deteriorate from illumination variation and image viewpoint variation. All the above, require a high computational processing unit of multi-object vision detection methods applied for constructions and infrastructure inspections [143].

SC8 Technical considerations for enabling the deployment of drones for logistics

Drones can serve a wide spectrum of logistic applications: from the very specialized, like organs for medical emergency, medicines, to parts for industrial applications and to the mundane like flowers and pizzas. And these can be further overlayered into where they occur, from inside warehouses, to linking the low population density of rural settings, the fenced space of large industrial spaces to high density urban regions.

This wide context frames the technical considerations regarding the challenges of drone logistic deployment, with each operation stereotype bringing specific considerations. Regardless of this, taking a broader view aiming at mass usage, "daily life normal", of drone logistic services, some major common technical challenges emerge among many of these application scenarios:

- **BVLOS.** By decoupling the range attended by the drone from the visual limitations of the human pilot, BVLOS capability opens the horizons for logistics applications and is thus critical for these types of services. Connected with this comes, unavoidably, **DAA capability**, without which BVLOS is not possible.
- **Frictionless airspace integration**. Being able to quickly initiate and deploy a drone mission, with a few clicks or none at all, is necessary for mass deployment. Current regulations demand dedicated applications per usage, are restricted and specific to each operation, making the operation as a business very specialized. In this area, the USSP will play a major role. Also, this integration focuses on the drone relationship with other drones, their ability to negotiate an efficient route through the airspace. Once again, DAA capability comes into play.
- **Safe** for people, ground property, other aerial vehicles. Drones must be safe and perceived as safe. In that regard, besides safe movement through the airspace among other vehicles, safe also implies what happens when the drone falls into the ground. This demands solutions not only for airspace, but also automation for ensuring flight safety and other regarding minimizing impact damage (parachutes, frangible design, etc)
- **Secure.** The full chain of the drone service must be secure, where cybersecurity is of paramount importance, reflecting from the communication channels, decision, and control systems to the humans involved in the activity. So, besides technical solutions related to cryptography, communication links, etc, training will also play a part to close the security loop.
- **Automation.** Releasing the drone from the shackles of one pilot – one drone paradigm will have a high impact on man hour costs associated with the operation, enabling some services to scale by several orders of magnitude.

- **Cost-efficient**. They must be cost-efficient to operate through their lifecycle. This has implications in the reliability of components, their cost, the ability for the continuous evolution of their software solutions, etc.

6.2 Regulatory

6.2.1 Legal landscape

In 2015 the European Commission ordered EASA to develop a regulatory framework that enables the rapidly increasing number of UAS/RPAS/Drones operating in many commercial and non-commercial areas to be safely integrated into the very low-level (VLL) airspace. EASA developed a three-pillar approach to address the risks on the ground and in the air (see Figure 20). These three pillars are the “open”, “specific” and “certified” category and are described in the EU implementing rules (EU) 2019/947 and (EU) 2019/945 and subsequent documents like certification specifications (CS), acceptable means of compliance (AMC, and guidance material (GM).

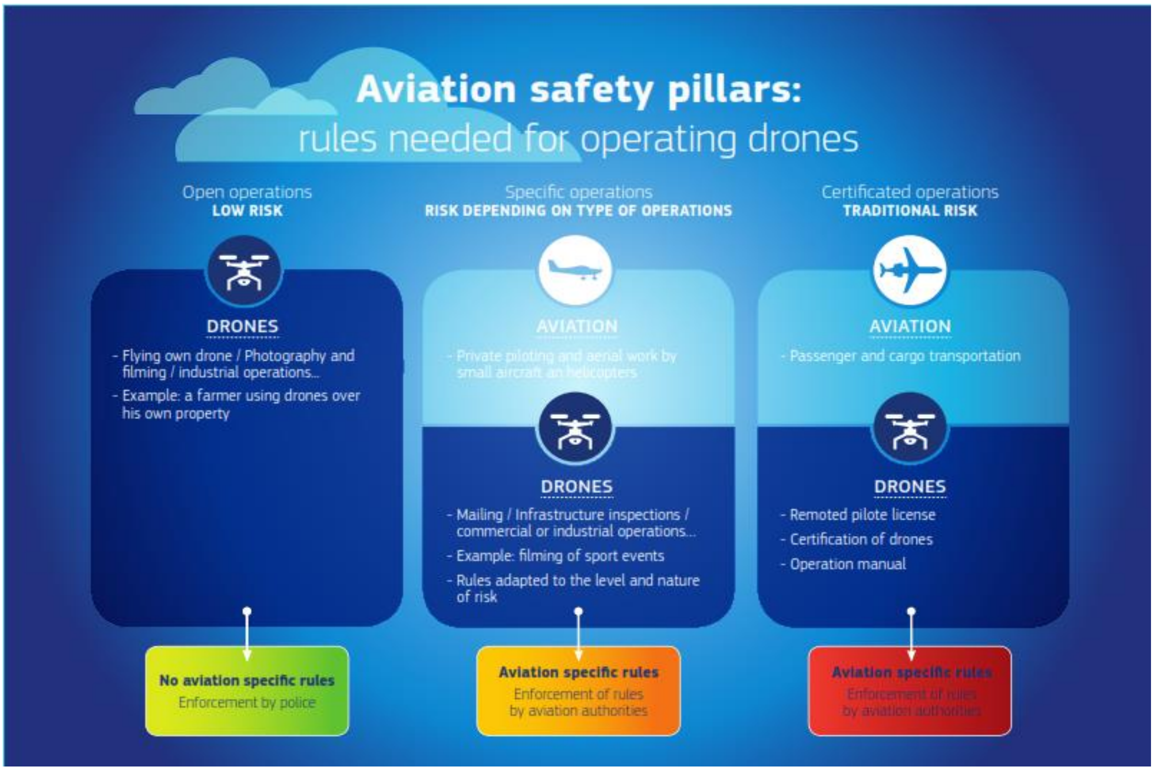

FIGURE 20 AVIATION SAFETY PILLARS (SOURCE: EASA)

Besides the development of the new regulatory framework by EASA, many countries developed their own national regulations for unmanned aircraft operations which are expected to be harmonized and replaced by the same European Rules in the next 1 to 2 years.

The new European regulatory framework has been released in 2018 and is still changing. The Regulation 2018/1139 establishes specific rules for drones in Section VII on “Unmanned Aircraft”, i.e.

Articles 55 to 58, and in Annex IX on “Essential requirements for unmanned aircraft”. In addition, the Regulation mandates EASA to propose technical rules for all sizes of civil drones and standards to the European Commission. This resulted in the classification of drones according to Table 7.

TABLE 7 EASA DRONE CLASS CHARACTERISTICS, FROM [3]

Class	MTOM	Max Speed	Max height	Max noise	eID	Geo aware	Lights	Serial number
C0	250g	19m/s	120m	-	N	N	N	N
C1	900g	19m/s	120m	60db(A)	Y	Y	Y	Y
C2	4kg	-	120m	60db(A)	Y	Y	Y	Y
C3	25kg	-	120m	-	Y	Y	Y	Y
C4	25kg	-	-	-	-	-	-	-

The creation of all the reglementary body regarding drones is thus a very dynamic process, which will live from the above-mentioned relationship to the rulemaking working groups. A recent overview of the legal challenges of drones in the EU space is given in [144].

The UK regulations on recreational and commercial drones [145] generally, align with those being introduced as part of the new EU regulations. The basic safety rules for ‘recreational drones’ (less than 20Kg without its fuel) state that “small, unmanned aircrafts” must not be flown at a height of more than 400 feet or within 1km of an airport or airfield boundary, and the person in control must “maintain direct, unaided visual contact” at all times. For those that weight more than 7Kg it must not be flown in Class A, C, D or E airspace, or within an aerodrome traffic zone during the notified hours of watch of the air traffic control unit. In addition, it may not be flown over or within 150 meters of any congested area, over or within 150 meters of an organized open-air assembly of more than 1,000 persons, or within 50 meters of any person. From 30 November 2019, there will also be requirements for the registration of small, unmanned aircraft operators (of drones with a mass of 250 grams or more) and for the competency of remote pilots to be tested.

As far as it concerns Commercial drones the operating permission is considered on a case-by-case basis by the Civil Aviation Authority (CAA). Small drones can be used for commercial work following the guidance document on Unmanned Aircraft System Operations in UK Airspace. Large drones (20 kg to 150 kg) are not permitted to fly in any non-segregated airspace in the UK, without specific permission from the CAA. Finally, unmanned aircraft weighing more than 150 kg are subject to additional certification requirements as determined by the European Aviation Safety Agency (EASA).

In terms of Traffic Collision Avoidance, all drones operating in non-segregated airspace must be equipped with, and be able to operate, a Secondary Surveillance Radar transponder, since currently small drones cannot be seen by UK traffic management radars.

Concerning privacy, the DPA 1998 is still the predominant legislation covering personal data protection and with the 2015 update, the Information Commissioner’s Office (ICO) updated its code of practice on surveillance cameras and personal information to include the use of drones on the grounds that they have the potential for ‘collateral intrusion’ by recording images of individuals unnecessarily.

Finally, the EU Regulation 785/2004 requires that commercial drone operators purchase third party liability insurance and defines limits for the minimum amount of third party liability insurance required based on the mass of the aircraft on take-off (~€660,000 for drones weighing less than 500kg), whereas drones for leisure use and model aircrafts weighing less than 20kg are not required to have third party liability insurance.

The US Federal Aviation Administration (FAA) presented, in 2016, rules on small drones (under 25 kg) that limit flights to daylight and to the operator's visual line of sight, and address height and operational restrictions, operator certification and aircraft registration. Flights over people and in airport flight paths would be forbidden. International standards to regulate certain aspects of drone operations are currently being considered by ICAO. It set up an Unmanned Aircraft Systems Study Group (UASSG) in 2007, and in 2011 issued its circular Unmanned Aircraft Systems (CIR328). In November 2014, the UASSG was elevated to the status of a Panel and publishes Standards and Recommended Practices (SARPs) on unmanned aircraft. Besides ICAO, several countries are working together within JARUS (Joint Authorities for the Rulemaking of Unmanned Systems), which is a voluntary membership body comprising national civil aviation authorities from EU and non-EU countries and regional organisations.

In Europe, the European UAS Standards Coordination Group (EUSCG) is responsible for the European UAS Standardization Rolling Development Plan (RDP), available in version 5.0 as of 2020-07-23 [146]. The RDP brings together all relevant standardization and regulatory activities and their status and is updated regularly to maintain visibility and awareness of the progress. The RDP lists around 300 standards and regulatory documents from globally relevant standardization and regulatory activities and organizes them in the following categories:

- General
- UAS Traffic Management
- Command, Control and Communication
- Detect and Avoid
- RPAS Automation
- Design & Airworthiness
- Operations
- FCL
- Environment
- Autonomous Operations

Finally, regarding standardization, the EUROCAE WG-105 is tasked to develop the necessary standards to enable the safe integration of UAS, or RPAS when controlled and monitored from a Remote Pilot Station (RPS), into all classes of airspace, with consideration of the emerging European regulatory proportionate risk- based approach, of the related categories of operations (Open, Specific and Certified) and of the industry requirements. The work of WG-105 is organized in six Focus Teams working in a specific area. The current Focus Areas are:

- Focus Area 1: Detect and Avoid
- Focus Area 2: Command, Control and Communication, Spectrum and Security
- Focus Area 3: UAS Traffic Management
- Focus Area 4: Design & Airworthiness Standards

- Focus Area 5: Enhanced RPAS Automation
- Focus Area 6: Specific Operational Risk Assessment

Keeping a close connection with the outcomes - or even participating in these several bodies and working groups – is tantamount to increase the alignment with a fluid regulations environment and improving the likelihood of success and lower rework of developed solutions towards integration.

6.2.2 Legal compliance

As stressed in previous sections, the regulatory landscape regarding drone operations is still in a dynamic flux. It is expected that beyond ADACORSA lifetime the drone business applications like logistics, smart forestry and smart construction become a normal affair, under the same regulatory framework and rules across Europe. Meanwhile, applications are given in specific conditions, subjected to the terms of each country. With this context, compliance to the regulation from the ADACORSA perspective is twofold.

The first and most important is the guidance and process for the work package partners to address the regulatory requirements. The demonstrators should be able to show how the developed solutions fulfil these regulatory requirements. This includes the regulations currently available and possible future requirements to be added to the framework over time.

The second part is to ensure the planned test and demonstration flights are authorized by the local authorities of the countries where these flights will be performed, under the regulations valid at this time. Early enough before the flights will take place the approval process shall be started.

This will be addressed by SC10's work, which provides the guidance and process for the work package partners to address the regulatory requirements. The demonstrators should at the end be able to show how the developed solutions can address these regulatory requirements, including the business case (operational) perspective, under which the solution might be used. This includes the regulations currently available and as possible, future requirements to be added to the framework over time.

6.2.3 Regulatory Methodologies: SORA

A brief highlight is given to the Specific Operation Risk Assessment (SORA) [147]. This method is a process to identify the risks on the ground and in the air. Depending on the resulting risk level operational safety objectives must be implemented and the integrity and robustness demonstrated. It was developed by the Working Group 6 of the international cooperation entity, Joint Authorities for the Rulemaking of Unmanned Systems (JARUS), and then adopted by EASA as an Acceptable Means of Compliance (AMC) towards the requirements in the EU Regulations.

Under EASA regulations, SORA (which refers to the "specific operations" category of drone operations) is the responsibility of EU member states, in that they issue the authorizations for operations in this category. EASA has proposed possible means of compliance (labelled "acceptable means of compliance", (AMC) a term used in certification) to help align the way specific operations can be organized and carried out across Europe, but specific details, or even the overall approach, can be decided by member states as long as it follows the general SORA specifications. SORA can thus be adopted, as referred in [147], to support the activities related to airworthiness requirements. It must be stressed however that SORA itself is evolving to incorporate ever more complex scenarios and should be complemented with other approaches. It gives, however, a very comprehensive way forward in this respect. ADACORSA is concentrating on the "specific" category because most of the use cases for future UAS operations including BVLOS operations will be performed under this pillar. The operational risk evaluation framework articulates different layers to evaluate and lead to minimum deployment risk. Figure 21 shows a representation of the SORA semantic model, dividing between ground and air risk and the different safety layers.

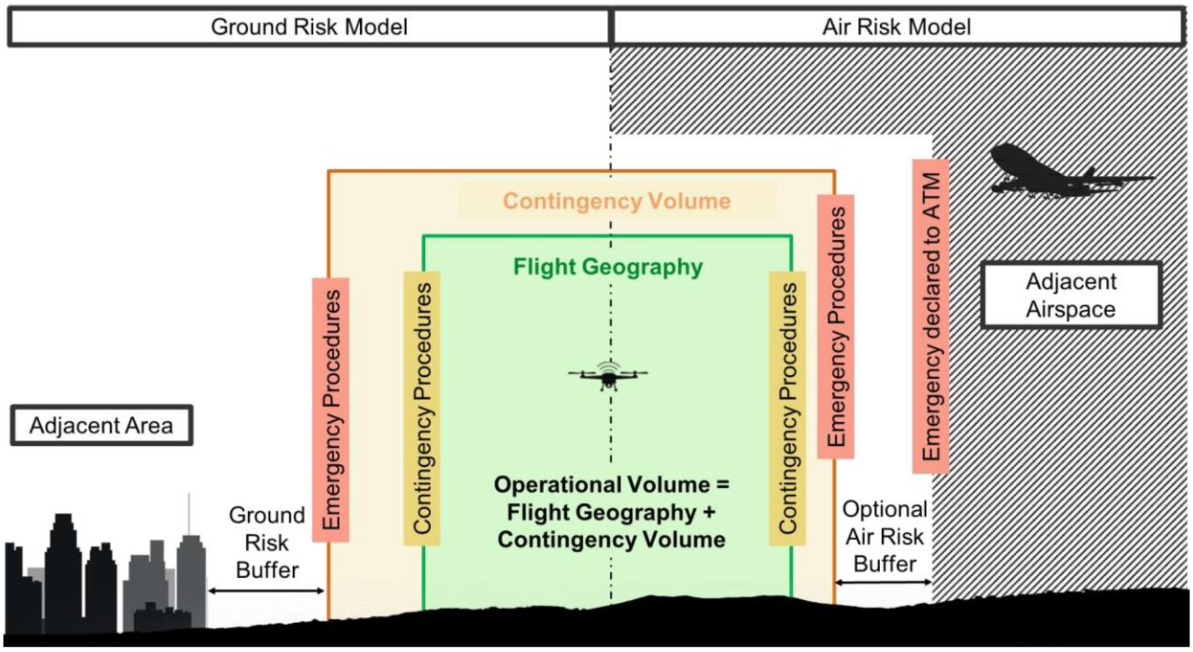

FIGURE 21: SORA SEMANTING MODEL, FROM [147]

SORA provides a compound method that addresses the desired level of robustness according to the risk associated. Robustness then becomes a combination of the level of integrity (safety gain provided by mitigation actions) and assurance (method of proof that the safety claim was achieved.) Robustness is thus categorized as low, medium, and high depending on the combination mix of integrity level and assurance level. The SORA process starts from evaluating the operational description to ascertain, through a standardized categorization, what is the associated Specific Assurance and Integrity Levels (SAIL). From that is set the Operational Safety Objectives (OSO) and then evaluates if the mitigation and OSO are met be the applicant in a satisfactory way. More details can be consulted in [147] and will be further developed by SC10 for guidelines to support systems requirement development.

6.2.4 Environmental

Environmental issues are addressed on two levels.

Operational

Impact on the environment from the product point of view. This means mainly not to use hazardous materials per WEEE or RoHS standards and other EU regulations. This addresses material used during manufacturing and used in the product itself for recycling and waste handling.

Product related

Impact on the environment during operation with UAS using technologies developed by ADACORSA is another aspect to be considered. This may include impacts like noise produced by the UAS or pollution because dangerous goods are transported.

As ADACORSA focuses more on technology demonstration and proof of concepts this aspect both considerations may play a minor role but should somehow reflect in the reports created for the demonstrations.

7 Conclusion

7.1 Contribution to overall picture

This document provides the upper layers of an overall framework reference for the ADACORSA project, namely regarding an understanding of ADACORSA vision and ambitions and how they related to market, societal interest, and key drivers for acceptance, airspace context for drones in Europe with state-of-the-art for technology, and regulations.

This deliverable is related to D1.2, on use cases and high-level requirements, and D1.3, on supply chain requirements.

7.2 Relation to the state-of-the-art and progress beyond it

The document describes the state-of-the-art for drone applications and deployment into the European U-space initiative.

The document is a reference at the point of release due to the fast pace of developments in the area of drone applications and the different ongoing activities in the regulatory sphere. It should be reviewed and updated during the project to ensure its continued alignment with external and internal developments.

7.3 Impacts to other WPs, Tasks and SCs

This document is part of a reference package, with D1.2 and D1.3, for the remaining activities of the project, namely those on WP6, for evaluation, and WP8, for exploitation.

7.4 Contribution to demonstration (what aspects of the work that will be demonstrated

The document informs the design of the demos regarding the key aspects for enabling drone operations in U-space.

7.5 Other conclusions and lessons learned

Some final comments arising from the execution of activities related to this document:

- COVID-19 brought a significant impact on collaboration activities. One of those is the impossibility to make face-to-face meetings, where concentrated and focused work can happen and benefit from live interactions. This is of interest regarding the aspect of integration, be it technologies, services, architecting.
- COVID-19 also accelerated the deployment of drones worldwide as a measure to support society regarding the pandemic. This has reinforced the immense potential drones have and confirmed the validity of ADACORSA the vision.
- A significant effort must be made, using formal and structured processes to support the integration and coherence when integrating full supply chains developing components, systems, architectures, and applications in parallel. The adoption of

systems engineering practices and model-based systems engineering, helps in this aspect, aligning all actors across a shared understandingwhat and how.

- Due to the high fluid environment, in the market, society, technology, this type of document, if not used as a “live” document, with periodic revisions, will become a time capsule at the time of release. Thought about this is encouraged so uncertainty can be managed across the technology management life cycle.
- Due to the maturity level, only high-level market potential was addressed by most SCs. This is expected as detailed or deep market analysis is pursued after a higher degree or certainty on the technology has been achieved.

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9 Acronyms and Abbreviations

ABREVIATION	DESCRIPTION
AIRM	ATM Information Reference Model
AMC	Acceptable Means of Compliance
ANSI	American National Standards Institute
AoA	Angle of Arrival
AP	Access Points
ASTM	American Society for Testing and Material
BLE	Bluetooth Low Energy
BRLOS	Beyond Radio Line of Sight
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CTA	Control Area
CIS	Common Information Service
CONOPS	Concepts of Operations
DAA	Detect and Avoid
GIF	Global Interoperability Framework
GOF	Gulf of Finland SESAR U-space demonstration
EASA	European Union Aviation Safety Agency
ECSEL	Electronic Components and Systems for European Leadership
EUROCAE	European Organisation for Civil Aviation Equipment
EUROCONTROL	European Organisation for the Safety of Air Navigation
eSIM	Embedded Universal Integrated Circuit Card
EUSCG	European UAS Standards Coordination Group
eUICC	Embedded Universal Integrated Circuit Card
EVLOS	Extended Visual Line of Sight
FAA	Federal Aviation Administration
FIMS	Flight Information Management System
HALE	High Altitude Large Endurance
IEEE	Institute of Electrical and Electronics Engineers
IMU	Inertial Measurement Unit
ISO	International Organization for Standardization
iSWIM	Initial System Wide Information Management

JARUS	Joint Authorities for the Rulemaking of Unmanned Systems
LIDAR	Light Detection And Ranging
MALE	Medium Altitude Large Endurance
OECDE	Organization for Economic Cooperation and Development
OSO	Operational Safety Objectives
RDP	Rolling Development Plan
RLOS	Radio Line of Sight
RPAS	Remote Piloted Aircraft Systems
RSSI	Received Signal Strength Indicator
SAA	Sense And Avoid
SAIL	Specific Assurance and Integrity Levels
SARP	Standards and Recommended Practices
SC	Supply Chain
SESAR	Single European Sky ATM Research
SfM	structure-from-motion problem
SLAM	Simultaneous Location and Mapping
SME	Small Medium Entreprise
SOA	Service-Oriented Architecture
SoC	System on a Chip
SORA	Specific Operational Risk Assessment
SWaP	Size, Weight and Power
SWaP-C	Size, Weight, Power and Cost
SWIM	System Wide Information Management
TDoA	Time Difference of Arrival
TMA	Terminal Area
ToA	Time of Arrival
ToF	Time of Flight
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System / Uncrewed Aircraft System
USSP	U-space Service Provider / Unmanned Systems Service Provider
UTM	Unmanned Traffic Management
VFR	Visual Flight Rules
VLC	Visible Light Communications
VLL	Very Low Level

VLSI	Very Large-Scale Integration
VLOS	Visual Line of Sight
WiFi	Wireless Fidelity

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