POLITECNICO DI TORINO

Master's Degree in Aerospace Engineering

Master's Degree Thesis

Civil/military UAS regulatory framework approach: analysis, theoretical comparison and study-case

Supervisors
Prof. Battipede Manuela
Eng. Signorini Andrea
PhD. Piccione Emanuele

Candidate
Nespolo Sofia Maria

A.Y. 2022/2023

Abstract

Unmanned Aircraft Systems (UAS) represent a great opportunity for the future of aviation, offering new services and performing existing ones in a more affordable and effective manner. UAS were initially employed for military purposes, but in recent years, they become increasingly popular in the civil sector. To fully exploit the potential of this market, a regulatory framework is needed not only to guarantee that all unmanned system services are provided in a way that ensures safety, sustainability, privacy, and affordability, but it is also a key issue to attract stakeholders' interest in this emerging technology and encourage economic investments from the industry.

This thesis aims to analyze the existing UAS regulatory framework considering both military and civil approaches, highlighting similarities and differences.

The state of the art of UAS, their evolution and main classifications will first be illustrated. A review of the civil and military regulatory framework will follow, with emphasis on the rules to operate a UAS in the specific category and a detailed description of the SORA process. In addition, this risk assessment will be applied to a real operational scenario, comparing it with the provisions of the applicable military regulations and assessing the effects of these two different approaches (civil and military) on the design and the management of UAS operations.

In conclusion, this study will highlight that despite many efforts made in recent years by regulatory authorities, much progress still needs to be made to achieve a final, harmonized, and comprehensive regulation. Actually, civil and military approaches are quite different, but the trend is to establish a new common methodology to define UAS rules, not only based on the features of the aircraft employed but also on the type of operations, the operational scenario and the related risk, moving towards a progressive and risk-based approach.

Table of Contents

List of Tables

List of Figures

Acronyms

ACO Allied Command Operations

ACT Allied Command Transformation

AltMOC Alternative Means of Compliance

AMC Acceptable Means of Compliance

A-NPA Avanced Notices of Proposed Amendments

ANS Air Navigation Services

ATM Air Traffic Management

BVLOS Beyond Line of Sight

BRVLOS Beyond Radio Line of Sight

CHOD Chiefs of Defence

ConOps Concept of Operations

CS Certification Specification

DAAA Direzione degli Armamenti Aeronautici e per l'Aeronavigabilità

DVR Design Verification Report

EASA European Union Aviation Safety Agency

EC European Commission

ECAC European Civil Aviation Conference

ENAC Ente Nazionale Aviazione Civile

EO Electo-optical

EU European Union

EUROCAE European Organisation for Civil Aviation Equipment

EUROCONTROL European Organisation for the Safety of Air Navigation

FAA Federal Aviation Administration

GM Guidance Material

ICAO International Civil Aviation Organisation

IR Implementing Regulation

JARUS Joint Authorities for Rulemaking on Unmanned Systems

JCGUAS Joint Capability Group Unmanned Aicraft Systems

LT Leadership Team

MOC Means of Compliance

MOE Means of Evidence

MTOW Maximum Take-off Weight

NAA National Aviation Authority

NAC North Atlantic Council

NATO North Atlantic Treaty Organization

NPA Notices of Proposed Amendments

NPG Nuclear Planning Group

NSO NATO Standardization Office

OA Operational Authorization

ONS Office for NATO Standardization

PANS Procedures for Air Navigation Services

PT Plenary Team

RLOS Radio Line of Sight

RMT Rulemaking Task

SAIL Specific Assurance and Integrity Level

SARP Standards and Recommended Practices

SC Special Condition

SDR System Design Responsible

SESAR Single European Sky ATM Research

ST Secretariat

STANAG Standardization Agreement

SUPP Regional Supplementary Procedure

TEC Technical Committe

ToR Terms of Reference

UAM urban Air Mobility

UAS Unmanned Aircraft System

UAV Unmanned Aicraft Vehicle

UGV Unmanned Ground Vehicle

UMV Unmanned Marine Vehicles

USAR UAV System Airworthiness Requirements

VLOS Visual Line of Sight

VTOL Vertical Take-Off and Landing

WG Working Group

Introduction

Unmanned aircraft systems were originally created for military purposes as a safer and cheaper alternative to traditional manned systems, however, due to their potential, the civil market grew rapidly in recent decades. From different points of view, UAS are comparable to manned aircraft, in both cases an aerial platform is employed, and ground stations, qualified personnel and support services are needed to conduct operations. The key difference is that UAS do not have a pilot and crew on board. Therefore, the main advantage is the possibility of using UAS in much more hazardous and severe operational conditions than typical manned vehicle operations. By remotely or autonomously piloted vehicles, it is possible to greatly reduce, or eliminate, the risk to which pilot and aircrew would be subjected during operations. This is especially relevant for military missions, but it can be useful also for civilian ones. Another advantage is UAS flexibility, thanks to the wide variety of products and configurations available on the market, they can be employed in a wide range of operations. In addition, they are typically more maneuverable than manned aircraft due to their size and characteristics and they can be operated for a long time because they do not depend on the physical performance of a single pilot. This characteristic is especially relevant for repetitive observation missions, which are long and monotonous. The cost is another important aspect. The economic effort needs to employ these systems is lower if compared with manned operations. UAS do not employ personnel on board, are less complex, and are smaller in size and weight, so they are expected to require less operating and maintenance costs. For example, fuel costs are reduced by the lower operational weight of unmanned vehicles[136] [64] [78].

Considering all these factors, the industry recognizes UAS as an opportunity to improve its production processes or create new services. Today, when people think about drones, they no longer think only of sophisticated military UAS or small aerial platforms used for recreational purposes, such as aeromodelling or hobbyist tools for capturing images or video making[15]. Popular uses include surveillance operations or in the transport sector, the use of unmanned systems for deliveries, which has already been tested in many countries[21]. Other fields of application are agriculture, monitoring the status of crops, scheduling irrigation or fertilization by optimization processes, delivery of medical supplies or humanitarian aid in a rapid and efficient way in remote regions difficult to reach by traditional vehicles, public safety and security, or UAS can be employed as platforms for communication hubs or for weather and pollution monitoring, or for maintenance of infrastructures, up to the future scenario of new urban mobility in which unmanned aero taxis will be used to transport people, reducing ground traffic and achieving sustainable transportation[21].

As reported in the paper "A Drone Strategy 2.0 for a Smart and Sustainable Unmanned Aircraft Eco-System in Europe" published by EASA in 2022, the drone market in Europe could reach a value of € 14.5 billion by 2030. However, UAS technology is still in development and must fit within the complex scenario of aviation. To do this it is necessary to take into consideration five main factors which are public acceptance, regulation, economic drivers, infrastructure, and technological capabilities. As a new technology in order to be operated, it is necessary to have an adequate support infrastructure network. Typically, smaller systems do not require complex infrastructures, but for more sophisticated UAS multifunctional control units, landing facilities, payload control stations and support infrastructures to allocate personnel are needed[15]. In addition, it is true that UAS can be used in several applications due to their performance and the variety of models available on the market, however, to guarantee such versatility increasingly sophisticated and innovative technologies must be developed. For example, better batteries would allow to conduct longer and extended-range flights for electric propulsion systems; or new features such as autonomous flight or coordination algorithms for UAS fleets can increase operational potential. The technological progress proceeds together with the economic investments by the stakeholders. Economic drivers can determine the future of this market: investors direct funds toward applications of interest or toward sectors that are expected to generate future higher incoming[15].

A further fundamental aspect is public acceptance, which can promote or limit the diffusion of this technology. Today, people still have reservations about the use of unmanned aerial vehicles. According to several studies conducted by the German Aerospace Center from 2018 to 2022, public opinion is divided. Only about 49% of people surveyed are in favor of UAS employment. In addition, investigating the public acceptance towards different types of applications, the population is more likely to accept only certain types of operations, such as catastrophe response, life-saving effort and rescue operations or medicine transportation. The studies further showed that the reservations on the use of unmanned aircraft can be traced back to three main critical issues: UAS employment for criminal purposes, privacy concerns and safety of operations[98].

So, it is necessary to increase people's confidence in this emerging technology, and one

of the main factors that could help in this regard is regulation. Having a regulation framework that defines safety levels, rules and procedures, operational limitations such as dedicated areas or temporal restrictions, and systems requirements, will create a suitable environment for UAS acceptance and diffusion[98]. The need for a regulatory system is not only important for the safety of operations, but it also represents a key issue from an economic point of view[15]. European goal consists of creating a comprehensive and reliable regulatory framework to integrate UAS into the existing aviation system, maximizing social benefits, sustaining public acceptance, safety and economic aspects[62].
The first step toward creating a new regulation was taken in 2002 when Basic Regulation No. 1592/2002 was updated to include in the regulatory system the airworthiness and environmental regulation of unmanned aircraft with a maximum take-off mass of 150 kg or above[132]. Thus, authorities established that unmanned vehicles above that weight limit would be regulated similarly to traditional manned aircraft, based on weight category, instead of lighter vehicles that remained under the responsibility of each Member State, which could regulate them based on their individual needs. Firstly, this subdivision was considered successful, but as the UA market started to increase significantly, it became apparent that this approach was not effective. Manned aviation's requirements were too demanding for heavier vehicles, while the absence of common EU rules for smaller drones would lead to a fragmented system, in which the necessary level of safety would not be guaranteed. So, in 2015 the Riga Declaration on Remotely Piloted Aircraft established that "drones need to be treated as new types of aircraft with proportionate rules based on the risk of each operation"[1]. The Aviation Community requested EASA to issue a simple, performance-based and globally harmonized rules framework to allow individuals and companies to start low-risk operations and to help the private sector to take investment decisions[13]. The tipping point was December 2015, when A-NPA 10/2015 was published. It reflected the principles laid down in the Declaration and included a draft of a proportionate regulatory framework based on UAS operations[40]. The new regulation method applied was a more general approach, not restricted to aircraft features and performances, but based on the concept of risk. Risk is defined as "the combination of the frequency (probability) of an occurrence and its associated level of severity"[2]. In the case of unmanned aerial systems, it depends on the kinetic energy of the UAV, the population density of the overflown environment and the density of airspace traffic, evaluating harm to people, damage to critical infrastructure and mid-air collision with manned vehicles. This

[1]Riga Declaration

[2]JARUS, JARUS guidelines on Specific Operation Risk Assessment (SORA), Chapter 2 "The SORA Process", Section 2.1, Point (a), p.17, 2019

new approach is completely different from the one used in general aviation: traditional parameters for aircraft classification are no longer suitable to represent UAS. So considering the wide range of operations and numerous types of UAS available on the market, EASA proposed three categories to classify UAS, taking into consideration not only the specifics of the aerial platform employed but also the type of operation conducted, the payloads carried, the overflown areas and the airspace travelled. These categories are classified from low to high risk and are called 'open', 'specific', and 'certified', and today they are the basis on which develop proportionate and progressive regulations[44].

In 2019 the Commission Implementing Regulation (EU) 2019/947 was adopted, establishing the rules and procedures for the operation of unmanned aircraft[17]. This Regulation lays down detailed provisions for the operation of unmanned aircraft systems as well as for personnel, including remote pilots and organizations involved, particularly for the open and specific category, while those for the certified category are still under development.

Despite many efforts made in recent years by regulatory authorities, much progress still needs to be made to achieve final and comprehensive regulation that is effective and satisfies all stakeholders. Indeed, today the regulation dedicated to UAS is not yet complete and uniform, many documents are still under development such as rules to operate 'certificate' category UAS, or CS for Type Certificate of unmanned systems[61]. Many regulations already available are often under revision to solve critical issues arise during their implementation to practical applications, or to be adapted to the evolving technology. An example is the Specific Operation Risk Assessment, published by JARUS and assumed as acceptable means of compliance by EASA to evaluate operational risk for UAS employment. Actually, the SORA in force is version 2.0, but SORA 2.5 is pending publication, while JARUS is already working on SORA 3.0[109].

The cause of this complex scenario can be traced to the new method of regulation that EASA has adopted for UAS. This approach and the difficulty of its implementation create uncertainty among industries that, without a comprehensive and well-defined regulation, show concerns about investing in vehicles and systems whose employment will be limited in the future due to new regulations. However, given the difference between UAS and manned aircraft, EASA believes that this new method is the only way to guarantee the proper operability of remotely piloted and autonomous systems, ensuring the safety of people and encouraging market growth.

However, UAS are not employed only in the civil sector. As mentioned, remotely piloted/unmanned aircraft were initially designed for military purposes. The armed forces have been using UAS for decades. However, it can be said that the military regulatory approach is different from the one recently introduced by EASA. It is based on the traditional manned aviation approach, thus based on the weight categories and wing type of the aircraft, fixed wing or rotary wing. The purpose of this thesis is to analyze the civil and military regulatory frameworks and analyze their similarities and differences.

Chapter 1

Introduction to UAS

1.1 What is a UAS? UAV or UAS?

A UAV is an Unmanned Aerial Vehicle, an uncrewed aircraft operating in aerospace. Uncrewed Vehicles can be controlled by a remote pilot or operate autonomously. This group also includes:

- Unmanned Ground Vehicles (UGVs): vehicles that operate on the ground, such as self-driving machines;
- Unmanned Marine Vehicles (UMVs): vehicles that operate in the marine environment and include, for example, Unmanned Underwater Vehicles (UUV) and Unmanned Surface Vehicles (USVs).

UAVs are also commonly known as drones. This term, applied to the aeronautical field, owes its origin to the first radio-controlled aircraft used in 1946, whose noise, emitted during flight operations, was like the typical buzz of the male bee. However, from a technical point of view this term is considered general and ambiguous because it refers to all unmanned and remotely controlled aerial vehicles. According to this definition, cruise missile weapons, ballistic vehicles or projectiles fall under this definition.
In 2008, in the "Unmanned Aerial Vehicle System Roadmap", FAA[1] proposed a new definition for UAVs that can be taken as a reference:

"a powered, aerial vehicle that does not carry a human operator, uses aerodynamics forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or

[1] Federal Aviation Administration

recoverable, and can carry a lethal or non-lethal payload. Ballistic or semi ballistic vehicles, cruise missiles, projectiles are not considered unmanned aerial vehicles"[2]

In these few lines main characteristics of UAVs are highlighted: aerial platforms that have no crew on board, remotely pilotable or with autonomous control, reusable or recoverable. In particular, the last property differentiates them from guided weapons and other munition delivery systems.
However, it should be noted that the abbreviation UAV is not yet used in the same way worldwide. Unmanned Aerial Vehicles are an emerging technology and still under development, so even the related terminology is not yet unambiguous and well defined. Several Nations, Organizations and Agencies prefer to use different acronyms to refer to the aerial platform. For example, the United State Air Force uses RPV (Remotely Piloted Vehicles), a term used for the first time during the Vietnam War, and the UK Armed Forces uses the acronym RPA (Remotely Piloted Aircraft).
In recent years, the new trend is to refer, in addition to the aircraft itself, also to all the elements necessary to perform operations correctly, which therefore include the remote pilot, the Ground Control Station, the command unit and communication links. Regulations use the term UAS which means Unmanned Aircraft System, as FAA and EASA[3] indicate . The definition of UAS provided by ICAO[4] is reported:

"an aircraft and its associated elements which are operated with no pilot on board, which is flown without a pilot-in-command on board and is either remotely and fully controlled from another place (ground, another aircraft, space) or programmed and fully autonomous"[5]

The term UAS refers to the system in its totality which typically includes three elements:

- UAV, Unmanned Aerial Vehicle, intended as an aerial platform;
- An autonomous or human-operated control system which is usually located on the ground. It is indicated as 'Command Unit' (CU), that is "the equipment or system of equipment to control unmanned aircraft remotely which supports the control or the monitoring of the unmanned aircraft during any phase of flight"[6] ;

[2] Office of Secretary of Defense. "Unmanned Aircraft Systems Roadmap 2005-2030", 2005, [130]

[3] European Aviation Safety Agency

[4] International Civil Aviation Organisation (ICAO)

[5] ICAO. Cir 328 AN/190, "Unmanned Aircraft Systems (UAS)", 2011, [88]

[6] EASA, "Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and 2019/945)", Article (2), Point (26), p.22, 2022, [46]

- The (C2) link service, which means “a communication service supplied by a third party, providing command and control between the unmanned aircraft and the CU”[7];

The use of the term UAS emphasizes not only the importance of the aerial platform, but also how ground control, with Control Ground Station, remote pilot or other operators involved and the communication links are essential to the success of the operations. These are a significant part of a system, that must be considered in its entirety. In conclusion, UAV (or other acronyms) and drone (despite an improper term but accepted in common vocabulary) are often used interchangeably, but to underline the importance of the system aspect, UAS is preferred. In this paper the term UAS will be used to refer to the whole system, while acronyms such as UAV, UA or the term drone will be used to indicate aerial platforms.

1.2 UAS Components

A UAS is a set of several elements. As defined by FAA, Unmanned Aircraft Systems include not only the unmanned aircraft but also “all of the associated support equipment, control station, data link, telemetry, communications and navigation equipment, etc., necessary to operate the unmanned aircraft”[8]. Figure 1.1 illustrates the basic components of a UAS.

1.2.1 Unmanned Aircraft

FAA defines UA as “the flying portion of the UAS, flown by a pilot via a ground control system, or autonomously through use of an on-board computer”[9]. The aerial platform consists of the aircraft and the integrated equipment (propulsion, avionics, fuel, navigation, communication system, batteries, on-board computer, etc.), but does not carry human operators. UA can be equipped with lethal (missiles, weapons, bombs) or non-lethal payloads (cameras, sensors). It must be recoverable or reusable. Several UA categories can be defined following criteria such as types of operations they are used for, size, weight, payload, endurance, type of wings, etc. This classification will be analyzed in detail in Chapter 2.

[7] EASA, "Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and 2019/945)", Article (2), Point (27), p.22, 2022, [46]

[8] Illinois State University, University Policies and Procedures, https://policy.illinoisstate.edu/facilities/6-1-40/, 2023, [142]

[9] Western Michigan University, UAS Policy, https://wmich.edu/policies/drones, 2023, [143]

Figure 1.1: Elements of an unmanned aircraft system, (Source: Richard K. Barnhart, "Introduction to Unmanned Aircraft Systems", Chapter 2, p.18, 2012,[9])

1.2.2 Payloads

The payload is the carrying capacity of an aircraft, including cargo, munitions or scientific instruments, and it depends on form the mission purpose. Typical examples of payload are cameras, day and night sensors, radar, electro-optic sensors, communications relay, weapons, cargo, etc. Payloads can be internally or externally. Most of today's payloads are imaging sensors, such as electro-optical (EO) or infrared (IR) sensors, and radar (SAR, ISAR and maritime search radar). Other operations employ ground, surface and maritime moving target indicators, light detection and ranging (LIDAR). Missions to monitor areas subjected to atomic, biological, chemical or nuclear accidents require gas sensors or CBRNE detectors. Some UAS use sensors for mapping an overflown area or scanning and measuring an object. In military operations, laser range finders and designators enable accurate distance and speed measurements for target location. Military UAS employ payloads such as lethal weapons, missiles or bombs. Finally, cargo missions transport goods and furniture to be delivered. For example, UAS can be used to carry medical supplies in areas difficult to reach.

1.2.3 Human Operators

The aircraft is not manned but the system is. Human operators are essential to mission success and to guarantee safe operations, they are a key part of the system. To operate an Unmanned Aerial System, human personnel is essential to prepare and execute the

(a) *Camera for recreative purposes, (Source: https://denmarktimes.dk/denmark-inspects-ships-sniffer-drone-tech/)*

(b) *Weapons for military purposes, (Source: https://www.difesaonline.it/evidenza /approfondimenti/gli-uav-e-la-morte-dal-cielo)*

Figure 1.2: Examples of payloads

mission. For example, human operators have to plan the mission, by conducting pre-flight inspection and flight planning activities, command unmanned aircraft, communicate and manage interactions with Air Traffic Control, supervise operations, and if necessary, manage emergency situations by implementing contingency and emergency procedures.
The personnel involved in operations is generally indicated with 'remote crew' which refers to all people who are actively involved and are essential to conduct operations, during flight activities [10]. A remote crew may consist of one or more people depending on the complexity of the operations. For example, the remote crew needed for simple missions such as UAS flights for recreational purposes consists of only one member. The remote pilot, who commands the aircraft, performs also all activities required to conduct the mission. Instead, more complex missions, such as military ones usually require a multi-crew. Each crew member has one or more specific tasks assigned, for example: the remote pilot in command [11], the visual observer [12], the mission commander [13], etc.

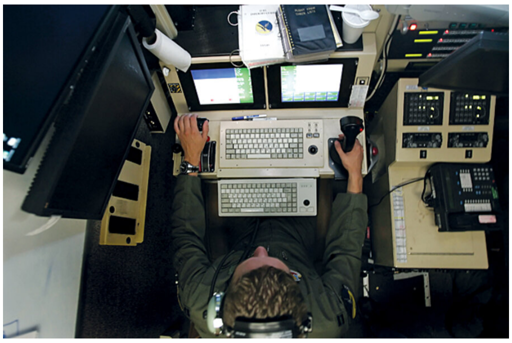
[10]ICAO, Cir 328, Unmanned Aircraft Systems (UAS), Glossary, 2011, [88]

[11]The remote pilot in command has to pilot the airplane remotely or in case of autonomous flight must supervise operations and has to be ready to intervene in case of need and take the control of the aircraft

[12]The visual observer has the responsibility to maintain visual contact of the aircraft and to collaborate and warn the pilot if the UAS is not in a safe area or is not operating properly, scanning the operational airspace for potential hazards

[13]The mission commander can override the preloaded mission plan and sending other commands to change the position or aircraft tasks as necessary, for example he has the authority to make the aircraft

In addition, technologically advanced missions often employ complex payloads, essential to the purpose of the operation. In this case, the remote crew usually also includes one or more members to operate or supervise payload functioning and/or analyzed data provided. For example, an analyst who monitors the data received by on-board sensors, or someone who points a camera on a target. In addition, maintainers also have an important role in the success of the mission.
UAS personnel must be trained and qualified in their particular area of involvement with an increasing level of expertise based on the complexity and risk of operations.



(a) *Remote pilot in command, (Source: https://www.csmonitor.com/USA/Military/2012/0228/Drone-pilots-Why-war-is-also-hard-for-remote-soldiers)*

(b) *UAV inspection before flight, (Source: https://www.wired.com/2013/04/drone-cuts/)*

Figure 1.3: Human operators working on UAS

1.2.4 Command and Control Element

The Command Unit is *"the equipment or system of equipment to control unmanned aircraft remotely as defined in point 32 of Article 3* [14] *of Regulation (EU) 2018/1139 which supports the control or the monitoring of the unmanned aircraft during any phase of flight, with the exception of any infrastructure supporting the command and control (C2) link service"*[15].

land or return it to a point. The mission commander may be the PIC or another operator under the direct control of PIC.

[14]"equipment to control unmanned aircraft remotely' means any instrument, equipment, mechanism, apparatus, appurtenance, software or accessory that is necessary for the safe operation of an unmanned aircraft, which is not a part, and which is not carried on board of that unmanned aircraft;", EASA, (EU) 2018/1139, 2018

[15]EASA, "Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and 2019/945)", Article (2), Point (26), p.22, 2022,[46]

These equipment can be located in a self-contained facility (land- or sea-based, vehicle- or ship-mounted) or can be portable (handheld transmitter). The type and complexity of the command unit depend on the mission requirements. Typically, military UAS require a command unit with multiple workstations and multiple personnel to operate separate systems.

(a) *Vehicle mounted CS, (Source: https://www.analisidifesa.it/2019/12/gli-uas-turchi-bayraktar-tb2-schierati-a-cipro-nord-e-decimati-in-libia/)*

(b) *Ground Control Station, (Source:https://it.quora.com/I-droni-militari-statunitensi-sono-fabbricati-negli-Stati-Uniti-e-come-vengono-trasportati-nei-luoghi-di-spiegamento-ovvero-a-7000-miglia-in-Afghanistan)*

Figure 1.4: Examples of Control Stations

Smaller UAS, for example, commercial UAS, can be operated with a portable GCS, such as a laptop, tablet or other mobile devices with ground control software.

Figure 1.5: Portable Control Station,(Source: https://www.aeroexpo.online/it/prod/worthington-sharpe/product-185931-28625.html)

1.2.5 Communication Data Link

To conduct UAS operations, command and control information must be sent and received both to and from the unmanned aircraft and the command unit. The data link is indicated as 'C2 link service' which means "a communication service supplied by a third party [16], providing command and control between the unmanned aircraft and the CU"[17]. The C2 link service employed depends on the type of operation to be conducted:

- Radio Line of Sight (RLOS);
- Beyond Radio Line of Sight (BRLOS).

Radio Line of Sight refers to operations in which unmanned aircraft are commanded and controlled via direct radio waves. Beyond Radio Line of Sight refers to UAS operations commanded and controlled via satellite communications or using a relay vehicle. For example, civilian operator have access to BRLOS via the Iridium satellite system.

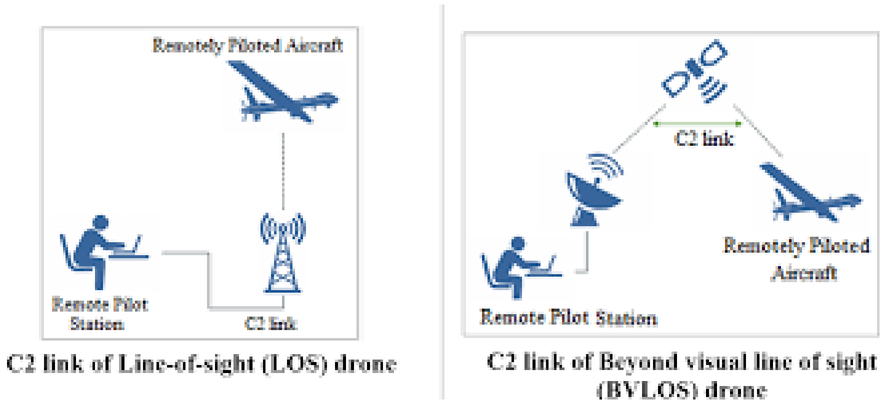


Figure 1.6: C2 links, (Source: https://www.everythingrf.com/community/what-are-c2-links)

[16]A Third Party is someone who "deriving no economic benefit and no control over risk associated with the UAS operation", JARUS. Doc.JAR-DEL-WG6-D.04_I Annex I , "JARUS guidelines on SORA - Annex I - Glossary of Terms", Version 2.0, 2019, [107]

[17]EASA, Easy Access Rules for Unmanned Aircraft Systems, (EU) 2019/947, Article (2), Point (27), p.22, 2022,[46]

1.3 Unmanned Flight History

This section provides a brief overview on UAS flight history. UAS followed the advent of airplanes and assumed several roles during their evolution. First known as "smart bombs" or target drones, unmanned aircraft became reconnaissance systems with a more active role in aerial combats. Today, they can be employed in various type of operations.
To understand the evolution of UAS, it is necessary to look back at their predecessors. The concept of the UAV as aerial platform remotely controlled or capable of following a predefined path can be traced back in 1849 when the Austrian Army used the Ballon Bomben. Lieutenant Franz Von Uchatius had the idea of launching an attack using unmanned balloons loaded with explosives to conquer Venice. Ballon Bomben were small balloons equipped with an archaic carbon timing device and a grease-soaked cotton thread to set off the explosion over the city. During the First World War, in 1917, Henry Philip

Figure 1.7: Ballon Bomben, (Source:https://www.quora.com/What-is-the-purpose-of-painting-military-drones-white)

Folland and Montgomery Low designed the Aerial Target. It was a British aircraft without pilot employed as a target for anti-aircraft systems. In the same years the Americans devised the Kettering Bug, designed by Bion Arnold and Charles Kettering. In order to be launched, it required a four-wheeled cart that ran on a portable and easily mounted rail. This vehicle was employed as "smart bomb": after a predefined flight interval evaluated before departure, a control stopped the power supply to the engine, the wings were detached and the plane crashed the ground with 90 kg of explosives on the desired area.
Between World War I and World War II, Target Drones were the most popular type of UAV. In 1933, Britain used the Queen Bee. It was a modified version of the Tiger

Figure 1.8: Kettering Bug, (Source:https://www.combodrone.it/storia-dei-droni-1849-oggi/)

Moth, a maritime surveillance aircraft. Compared to the models previously employed, the Queen Bee was certainly more advanced. It could take off or land on classic runways or be launched by a catapult system. The control system was very simple: it consisted of a wheel similar to the one of an old analog telephone. Remote pilot should control the vehicle by commands in form of numerical sequences. Queen Bee was crucial to the development of British anti-aircraft forces. About 400 examples were producer over time.

Figure 1.9: Queen Bee, (Source: https://www.researchgate.net/figure/Launch-of-a-DH82-Queen-Bee-mother-of-drones-target-drone-1941_fig1_326050429)

In 1937, the United State Army developed the Curtiss N2C, an aircraft similar to manned vehicles used for military anti-aircraft training. In 1939, the Radioplane OQ-2 manufactured by Radioplane Company, founded by Reginal Denny, flew for the first time. With its follow-on versions, it became the most widely used target drone in US service: over 9,400 Radioplane OQ-2 were built during World War II. Radioplane OQ-2 was a very small airplane for the time (2.56 meters long with a wingspan of 3.7 meters), it could be launched with a catapult and was equipped with a parachute to help with landing in case of a shoot-down.

Figure 1.10: Radioplane OQ-2, (Source:https://www.modelaircraft.org/miniature-aircraft-work)

In addition to target drones, aircraft used as guided missiles were also developed. The U.S. Naval Factory produced the TDN-1, a low-cost remotely controlled assault vehicle capable of carrying loads or armaments up to 900 kg. In Germany, the V-1-DoodleBugs were used in Terror Bombing Campaigns. The V-1 DoodleBugs were capable of carrying about 850 kilograms of explosives to a range of 150 nm. After flying for a predetermined time, they were crashed to the ground.

Figure 1.11: V-1-DoodleBugs, (Source:https://it.wikipedia.org/wiki/V1_(Fieseler_Fi_103))

The Vietnam War gave the U.S. Military Forces a great opportunity to recognize the true potential of UAS employed in aerial combat. UAs were used for reconnaissance purposes. A key role was played by the Fire Bee, which in follow-on versions became the Lighting Bug. It gave a great contribution to the Vietnam War by providing tactical intelligence discovering Vietnamese Forces bases, missile sites and supporting manned aviation. These UAVs were equipped with high-altitude reconnaissance cameras, could fly within 2000 kilometers with an altitude of 16 km and were equipped with a radar anti-detection system. Later this type of vehicle was directly involved in fighting. For instance, a Lighting Bug was used to disperse a cloud of reflective radar materials in the air momentarily blinded enemy radars. Others Lighting Bugs were equipped with attack systems so as to be identified by the enemy aviation as combat aircraft. In this way, they were engaged by enemy aircraft and allowed the real combat aircraft to act undisturbed.

Figure 1.12: Lightening Bug, (Source:https://www.historynet.com/keeping-tabs-on-the-enemy-in-vietnam/viep-181200-killer-tech-05/)

Despite the technological progress in the 1970s-80s that contributed sharing the first unmanned aircrafts for commercial and recreational uses, especially for model airplane enthusiasts, it took some decades to give UAS widespread recognition. A fundamental help to the diffusion of UAS comes from the Military sector, as often happens in Aviation. Thanks to the experience gained during the great conflicts of the 20th century that brought out the potential of this new type of vehicle, Military decided to exploit advantages of this technology by investing in its development.
From different point of view, UAS are comparable to manned aircraft, in both cases an aerial platform is employed, and ground stations, qualified personnel and supporting services are needed to conduct operations. The key difference is that UAS do not have a pilot and crew on board. As a consequence, the main advantage is the possibility to use UAS in much more hazardous and severe operational conditions compared to typical manned vehicles operations. Through the use of remotely or autonomously piloted vehicles, it is possible to greatly reduce, or completely eliminate, the risk to which pilot and aircrew would be subjected during operations. This is especially relevant for military and dangerous civilian missions. For example, Armed Forces often require surveying and overflying high-hazard areas, transporting armaments, or engaging in aerial combat. It is evident how the use of unmanned vehicles can be an advantage: the Army can execute tasks without endangering soldiers. In addition, having no personnel on board also allows to perform more hazardous maneuvers to successfully complete the mission, even considering the possibility of losing the vehicle but without sacrificing lives.

The first employment that established the essential importance of unmanned aircraft in military operations can be traced back to the Lebanon War. The Israeli Air Force employed IAI Malat Scout and Mastiff to destroy anti-aircraft Lebanese systems. Those UAVs had a wingspan of about 15 meters and a length of 8 meters, they could fly at 195 km/h at an altitude of about 6000 meters for 25 hours. In a little more than two hours, the Israeli Army annihilated enemy defenses.

(a) *IAI Malat Scout, (Source:https://www.israeli-weapons.com/weapons/aircraft/uav/scout/Scout.html)*

(b) *Tadiran Mastiff, (Source: https://www.wikidata.org/wiki/Q2893135)*

Figure 1.13: Examples of Israeli UAS

The absence of personnel on board is an important feature also for future civilian employment: UAS can be used to reduce the risk to which operational personnel are subjected to in missions that involve the transport of payload dangerous for human health such as chemical, biological, radiological and nuclear payload, or flying over areas involved in natural or biological disasters or in bad meteorological conditions, such as observational flights over forest fire or research missions in the artic. This and many other beneficial uses that will be discussed in detail in Chapter 2, combined with the technological progress, miniaturization of components, cost reduction, and the interest of the general public led to an expansion of the civilian market since the early 2000s for both commercial and recreational purposes. The most popular architecture for civilian use is the quadcopter configuration, due to its small size and high maneuverability. In 2013, the DJI Phantom became the first mass-market UAS in History and brought small unmanned aircraft into the mainstream.

Figure 1.14: DJI Phantom, (Source:https://www.quadricottero.com/search/label/Phantom)

At the same time as the civil UAS market uptake, military industries carried out the development of new products and their employment. Some examples of the most popular unmanned aircraft systems, designed since the mid-1990s and actually employed or still in development are reported in the following lines.

- MQ-9A Reaper [2]
  Firstly known as Predator B, is a medium-altitude long endurance unmanned aircraft system developed by the General Atomics. It flown for the first time in 2001, and today is largely employed by U.S Air Force, the Royal Air Force, the Italian Air Force, the French Air Force and the Spanish Air Force. The MQ-9A is capable of carrying multiple mission payloads to include EO/IR radar, maritime surveillance radar, laser designators and weapons. It has a maximum take-off weight of 4760 kg, with a payload capacity of 1746 kg. It can operate up to 50000 ft and has an endurance of over 27 hours. This vehicle was developed from MQ-1 Predator that was the primary remotely piloted aircraft used for offensive operations by USAF in Afghanistan from 2001.

Figure 1.15: MQ-9 Reaper (Source:https://www.ga-asi.com/remotely-piloted-aircraft/mq-9a#images-1)

- RQ-4 Global Hawk [82]
  It is a high-altitude remotely piloted aircraft designed by Ryan Aeronautical from 1998. It provides surveillance information by using high-resolution SAR and EO/IR sensors. It is operated by USAF as a high-altitude long endurance (HALE) UAS to support forces in military operations. It was the first unmanned aircraft to cross the Pacific Ocean.

Figure 1.16: Global Hawk (Source: https://metronews.it/2022/02/28/droni-global-hawk-e-caccia-allerta-in-basi-nato-italiane/)

- RQ-14A Dragon Eye
  The Dragon Eye is a small UAS developed by the Naval Research Laboratory and the Marine Corps Warfighting Laboratory and employed by the United States Marine Corps. It is a hand-launched mini UAs designed for reconnaissance and surveillance. It records and transmits data in the form of color or infrared images.

Figure 1.17: (Source: Dragon Eye https://www.militaryfactory.com/aircraft/detail.php?aircraft_id̄912)

- MQ-8B [81] [149]
  The Northrop Grumman MQ-8 Fire Scout is an unmanned autonomous helicopter developed by Northrop Grumman from 2000 and retired in 2022. It was used by the United States Navy. The Fire Scout has been specifically designed to deliver reconnaissance capabilities, enhance situational awareness, offer aerial fire support, and provide precision targeting support for ground, air, and sea forces.

Figure 1.18: MQ-8B (Source: https://it.wikipedia.org/wiki/Northrop_Grumman_MQ-8_Fire_Scout)

- RQ-170 Sentinel [80]
  The RQ-170 Sentinel in an unmanned aircraft system developed by Lockheed Martin from 2007. It is operated by the United States Air Forces and by the CIA. It is a stealth aircraft, developed for reconnaissance purposes. UASF has not released other information.

Figure 1.19: RQ-170 Sentinel

UAS for military purposes are used for surveillance, reconnaissance, combat operations and target acquisition. They can be used in combat scenarios to reduce the risk of military personnel by enabling remote operations, and are more cost-effective because they require less maintenance, fuel and supporting infrastructure. This led more and more nations to invest in this emerging technology. Future generation unmanned aerial systems will be equipped with advanced technologies, such as artificial intelligence, machine learning and advanced sensors. This will lead to the development of increasingly sophisticated UAS with better capabilities such as longer ranges, extended endurance and advanced payloads. An example of project actually under development is the MQ-28 Ghost Bat. Developed by Boeing with a planned introduction date in 2024-2025, it is equipped with integrated sensors to support intelligence, surveillance and reconnaissance. This UAS uses artificial intelligence so can fly independently or in support of crewed aircraft extended mission capability [12].

Figure 1.20: MQ-28 (Source: https://www.aviation-report.com/drone-conosciuto-come-loyal-wingman-prodotto-in-australia-da-boeing-chiamato-mq28a-ghost-bat/, @Commonwealth of Australia, Depertment of Defense)

Another example is the Mojave developed by General Atomics. This UAS is built upon the designs and systems of the MQ-R Reaper and MQ-1C Gray Eagle to be employed in attack and reconnaissance missions. It is equipped with autonomously and machine learning capabilities and it is able to short takeoff and landing without the need for typical paved runways or infrastructure. The development of the Mojave began in 2018, it completed its first flight test in 2021.[1]

Figure 1.21: Mojave (https://www.ga-asi.com/remotely-piloted-aircraft/mojave)

Taranis and nEUROn are two UAS equipped with stealth technology. The nEUROn is a European development programme, which involves France, Italy, Greece, Spain, Sweden and Switzerland. The industrial goal is to give European firms experience designing and building high-end UAVs and related technologies. The first flight took place at the end of 2012. It is a flying wing aircraft equipped with a single-engine. The initial development programme was planned by the French Dassault, now it is a European cooperation project including the Swedish SAAB, the Greek EAB, the Swiss RUAG Aerospace, the Spanish EADS CASA and the Italian Alenia, now Leonardo Aircraft Division[8]. Taranis is a BAE Systems development programme for unmanned combat air vehicles. It is a flying wing aircraft, able to fly intercontinental missions, carrying weapons to attack both aerial and ground targets. Taranis prototype's first flight took place in 2013 and it is expected to enter in service in 2030[137].

(a) : *nEUROn (Source: https://www.ilgiornale.it/news/mondo/test-combattimento-contro-nemici-reali-drone-neuron-1626723.html)*

(b) *Taranis (Source: https://it.wikipedia.org/wiki/BAE_Systems_Taranis)*

Figure 1.22: Examples Sealth UAS

Also, the civilian market is growing rapidly. In the commercial sphere, UAS will be used both for recreational purposes and by industries to conduct operations in a faster and safer manner. For example, UAS can be employed for commercial deliveries, to survey and monitor disaster zones and infrastructures. A further technological application will be the use of unmanned aerial systems in Urban Air Mobility defined by EASA as a "new air transportation system for passengers and cargo in and around densely populated and built environments, made possible by vertical take-off and landing electric aircraft (eVTOL) equipped with new technologies such as enhanced battery technologies and electric propulsion"[18]. According to EASA's studies on the development and public acceptance of UAM, these new transportation systems will initially have pilots on board, and later UAS will be employed. Some examples of aero taxi remotely piloted or completely autonomous are the VoloCity and the Wisk's 6th Generation. The Volocity, developed by Volocopter, is an all-electric aircraft equipped with vertical takeoff and landing capabilities. It is applied for a type certificate. Initial flights will be piloted, and in future, it will be employed as a fully autonomous service.[146]

[18]EASA, Urban Air Mobility, https://www.easa.europa.eu/en/light/topics/urban-air-mobility-uam, 2023

Figure 1.23: Volocity (https://evtol.news/volocopter-volocity/)

Wisk's 6th Generation is an autonomous, passenger-carrying eVTOL air taxi. Developed by Wisk Aero in California, it can transport 4 passengers in a range of 144 km at a cruising speed of 120 knots.[152]

Figure 1.24: Wisk's 6th Gen (https://wisk.aero/news/press-release/generation6/)

In conclusion, due to many areas of application, the wide variety of operations and the increasing interest shown by both the military and civilian sectors, UAS will represent the technology of the future. However, the development of a uniform and consolidated regulation that takes into consideration the public acceptance of this new technology and that guarantees safe operations is necessary and essential to encourage economic investments and fully exploit the potential of unmanned aerial systems.

Chapter 2

UAS Classification

The fast development of UAS technology and the growing interest in this new type of products led to numerous Unmanned Aerial Vehicles being available on the market. Several UAS classification schemes have been propose. Unmanned Aerial Vehicles can be grouped by size, weight, endurance, type of operation, and a lot of other criteria. This section proposes a brief description of UAS main classifications considered useful for this study.

2.1 Type of operations

A first immediate classification is based on the type of operation for which UAS are employed for. UAS can be used to perform many different activities. In recent years, they have proliferated rapidly around the globe in both military and civilian spheres. For example, today over 90 nations and non-state groups operate UAS in military and non-military activities. However in recent years also drones for hobbyists are exploded in popularity. The technological advancement contributed to place on the market UAS with an affordable cost but with high-end capabilities. Therefore, UAS can be grouped into the following categories:

- for recreational purposes;
- for commercial use; and
- for military use.

2.1.1 UAS for recreational purposes

UAS used for recreational purposes represent a large segment of the market. If until a few years ago UAS available on the market were little more than toys that were controlled by joystick and had a short range within the line of sight. Today's UAS are machines that can be used for many purposes. Many COTS are now equipped with GPS and functions that allow them to plan the flight path to fly independently, can operate in extended ranges and due to more powerful batteries have an increased endurance. A typical activity for this category of UAS is photography and video production. For example, the DJI Mini 3 is a compact and ultra-light quadcopter UA equipped with a high-performance camera that makes it suitable for professional daily and night use.[36]

Figure 2.1: DJI Mini 3, (Source: https://www.dji.com/it/mini-3/specs)

DJI Mini 3	
Max Takeoff Weight	248 g
Size (folded)	148x90x62 mm
Size (unfolded)	251x362x72 mm
Endurance	38-51 minutes
Range	18-25 km
Max Horizontal speed	16 km/h

Table 2.1: DJI Mini 3 Technical Data (Source: https://www.dji.com/it/mini-3/specs)

2.1.2 UAS for commercial use

UAS used for commercial operations offer an additional level of sophistication when compared with hobbyist UAS, in addition they are a low-cost alternative to helicopters, although their cost remains prohibitive for individual use. Typically, commercial UAS are larger and have a longer range and endurance, can carry more sophisticated payloads compared to recreational UAS. In the UAS Safety Risk Portfolio and Analysis [64], published by EASA in 2016, are identified three main types of operations conducted by commercial UAS:

Aerial Derivily

Delivery companies such as Amazon Prime Air and DHL are particular interested in this application. The concept behind this usage is to replace most of the deliveries that nowadays are made on the roads with UAS that can reach the point of delivery in less time, avoiding car traffic. In Europe, in 2013 DHL began experimenting short-distance deliveries by employing the Parcelcopter 3.0 , a UAS with a wingspan of 2 meters[76]. While in 2022 Amazon Prime Air started the first trials in California and Texas with the

MK27 model. It is an hexacopter that can carry a payload of about 2.5 kg and that can fly in a radius of 3/5 miles, dropping packages from 3/4 meters high.[5]

(a) *Parcelcopter 3.0, (Source: https://payloadasia.com/tag/blue-dart-express/)*

(b) *Amazon Prime Air, (Source: https://www.bbc.com/news/technology-48536319)*

Figure 2.2: Examples of UAS for Aerial Delivery

An additional example of a successful UAS delivery service, with more than 350,000 completed deliveries across 3 countries, is Wing Aviation LLC. That company developed a drone delivery system and UTM systems. Wing's unmanned aircraft are designed for small package delivery, can take off and land vertically and are powered by electric batteries. These UAS have been successfully employed in Australia, as part of a pilot program, since 2018, collecting more than 100,000 successful fights. In April 2019, Wing became the first drone delivery company to receive an Air operator's certificate from the FAA the company, in 2023 announced a partnership with Walmart extended its service in the Dallas-Fort Worth Metroplex (U.S) to more than 60.000 people.[151]

Figure 2.3: Wing's UA, (Source: https://www.bbc.com/news/technology-64891005 @Wing)

Aerial Surveillance and Survey

Aerial surveillance and survey are the most common use for UAS in the civil sphere. For example, this type of operation includes monitoring of areas subject to environmental disasters and critical infrastructures. UAS allow to reduce considerably the necessary time to carry out operations, improving performance and also reducing the risk that involved personnel is subjected to carry out these tasks. For example, UAS can be used for forest fire monitoring and prevention, or to make on-site inspections in areas damaged by earthquakes, floods, hurricanes or intervene in contaminated zones, to identify areas at risk and to manage the rescue in a more effective way. The UAS are also widely used to protect critical infrastructures, such as monitoring oil and gas pipelines, protecting maritime transportations, monitoring railways or observing traffic flows. DJI Inspire 1 is indicated by EASA as a typical UAS employed in this type of application [37]. The DJI Inspire 3 is a quadcopter now available on the market [38].

Figure 2.4: DJI Inspire 3, (Source: https://www.dji.com/it/inspire-3/specs)

DJI Inspire 3	
MTOW	4.3 kg
Size (unfolded)	176x709.8x500.5 mm
Endurance	25 min
Max Altitude	3800 m
Max Horizontal speed	94 km/h

Table 2.2: DJI Inspire 3 Techical Data (Source: https://www.dji.com/it/inspire-3/specs)

Other activities

UAS are used in numerous other fields of application, such as:

- Agriculture
  UAS can be used to fly over hectares of cultivated fields to monitor the status of crops, programming irrigation or fertilization where necessary. This type of application allows to optimize the maintenance process, and cover large portions of territory in a shorter time. For example, in 2010 in Japan 30% of rice fields were irrigated by the use of RMAX UAS;

- Internet Connection
  UAS can be used to expand internet connection. For several years, companies like Google and Facebook planned to employ unmanned aircaft to improve internet coverage around the world, even in areas difficult to reach with traditional infrastructure;

- Delivery of medical supplies or humanitarian aid in a rapid and efficient way in urban and suburban areas, as well as in remote regions difficult to reach by traditional vehicles;
- Meteorology
  UAS can be used to monitor extreme weather events such as hurricanes and typhoons, but also to observe volcanic eruptions more closely;
- Filming for cinema or events
- Monitoring of cattle and wildlife
  UAS may be used to monitor the periodic migratory movements of groups of wild animals, monitoring their health status, population and other parameters.

2.1.3 UAS for military use

Firstly, UAV technology has been developed for military purposes. The advantage of using drones is to carry out large-scale operations at significantly lower costs. In addition, being able to operate an aircraft without personnel on board also reduces the lives at risk during these types of missions. Military drones are highly sophisticated vehicles that require military support infrastructure, as well as highly specialized remote personnel able to manage the mission. This application usually requires more advanced technology and more autonomy of flight. Military-type unmanned aircraft are used principally for surveillance and identification operations and for combat missions. First-type of operations use UAS of small and medium sizes. They can employ high-definition cameras, night-vision infrared cameras or electro/optical sensors, and collect data that can be transmitted in real-time to the Control Station. Larger sizes UAS are usually employed in combat operations. They have a higher payload capability to carry weapons, sophisticated sensors, increased range and endurance.
The following is a list of the main uses for military purposes:

- Reconnaissance and surveillance: They are used to gather information about an area or target, or to monitor them for a long time. Thanks to the equipment with high resolution cameras and a high flight autonomy, it is possible to monitor objectives of interest for a long time at a distance, having data available in real time and without involving soldiers;
- Dangerous rules: are operations involving the surveillance of highly protected and dangerous areas, where the use of vehicles with crew may not represent the optimal choice. The loss of UAS in such areas is definitely less expensive than an aircraft with

people on board. Moreover, since these are very dangerous areas, the use of unmanned systems allows not to involve people on the field in highly stressful operations that could compromise the mission success. Stealth UAS are usually used in this kind of operations since they are difficult to detect by radar and therefore have greater range of action remaining covered by enemy anti-aircraft fire;

- Dirty Rules: are applications that require intervention in areas subjected to nuclear contamination or exposed to chemicals, thus avoiding putting human lives at risk;

- Dull Rules: are typically long, monotonous and repetitive operations that can lead to a drop in attention by the staff involved, resulting in non-compliance with mission objectives. The use of USs with ground data transmission capability allows to perform the mission with better performance excluding human limits;

- Law enforcement: UAS can be used by law enforcement to carry out air surveillance and ensure public order. For example, they can be used for automotive traffic surveillance;

- Fight against terrorism;

- Military training: one of the oldest uses of UAS is to use them as targets for training military pilots;

- Border Territorial Security: Similar to the application by law enforcement, it involves the use of UAS for border monitoring and surveillance. For example, the United States began working with Mexico in 2011 to monitor illegal immigration and drug trafficking;

- Research and development;

- Combat operations.

An example of a small-scale military UAS is the Raven AeroVironment RQ-11 Model, designed for rapid deployment and high mobility. Raven is used to provide day-and-night situational awareness, and provides real-time video or infrared images to ground control. [4]

Figure 2.5: Raven B RQ-11
(Source: https://www.al.com/news
/2016/03/pentagon_admits_using
_drones_t.html)

RAVEN B RQ-11	
Max Takeoff Weight	2.2 kg
Length	0.9 m
Wingspan	1.4 m
Endurance	60-90 minutes
Range	10 km
Ceiling	30-152 m
Cruise speed	32 km/h

Table 2.3: Raven B RQ-11 Techical Data
(Source: https://www.avinc.com/
images/uploads/product_docs/
Raven_Datasheet_05_220825.pdf)

Another example of military UAS for surveillance and reconnaissance is the Black Hornet 3 Nano. It is used by the armed forces of the USA, France, UK, Germany and many other countries. It is easily transportable by soldiers and is equipped with a camera that allows you to monitor the affected area remotely. The unamend system is controlled through a monitor and has the possibility of scheduled flight towards a goal. [148]

Figure 2.6: Black Hornet 3, (Source:
https://www.dronezine.it/15782
/black-hornet/)

Black Hornet 3	
Max Takeoff Weight	33 g
Length	16 mm
Rotor diameter	12.3 mm
Endurance	25 minutes
Range	2 km
Cruise speed	32 km/h

Table 2.4: Black Hornet 3 Technical Data
(Source:https://www.equipnor.com
/media/2934/black-hornet-prs-brochure
-web.pdf)

AWHero is a 200 kg class rotary UAS developed by Leonardo for Intelligence, Surveillance, Target Acquisition and Reconnaissance purposes. It is employed alongside Leonardo's helicopters, to provide operational superiority in complex tasks and maximum mission availability. It has two modular payload bays that allow Maritime RADAR, EO/IR, LIDAR, hyperspectral camera, communications relay and AIS, which combinations can be configured to adapt the aerial platform in a broad range of roles and tasks. AWHero is the only Military Certified UAS in its class, based on STANAG 4702. [83]

Figure 2.7: AWHero (Source:https://www.varesenews.it/2023/06/leonardo-presenta-lawhero-lelicottero-drone-che-opera-dalle-navi-militari/1634597/)

AW Hero	
Max Takeoff Weight	200 kg
Rotor diameter	4 m
Endurance	6 hours
Payload Capacity	Nose: up to 20 kg
Belly: up to 40 kg	

Table 2.5: AWHero Technical Data (Source: https://unmanned.leonardo.com/it/products/awhero)

The General Atomics Avenger (formerly Predator C), developed for the United States Armed Forces, is an example of UAS that can be employed both for intelligence, surveillance and reconnaissance missions, and for combat operations.[3]

Figure 2.8: Predator C-Avenger (Source: https://www.nytimes.com/2017/11/16/us/politics/north-korea-missile-defense-cyber-drones.html)

Predator C Avenger	
Max Takeoff Weight	8250 kg
Payload Capacity	1500-2900 kg
Length	14 mm
Wingspan	20 m
Endurance	20 hrs
Range	10 km
Cruise speed	32 km/h
Max Altitude	15240 m
Max Air Speed	400 KTAS

Table 2.6: Predator C Avenger Technical Data (Source: https://www.ga-asi.com/remotely-piloted-aircraft/predator-c-avenger)

UAS employed in theatre of war can be equipped with stealth technology. These aircraft are designed to minimize their presence on enemy radar and with barely detectable communications. Currently, only the United States is known for possessing and operating stealth drones. One example is the Lockheed Martin RQ-170 Sentinel, an American high-altitude long-endurance UAS. The RQ-170 Directly supports combatant commander needs for intelligence, surveillance and reconnaissance to locate targets. [80]

Figure 2.9: RQ-170 Sentinel, (Source: https://www.19fortyfive.com /2022/06/rq-170-sentinel-the -u-s-militarys-top-secret-stealth-drone/)

RQ-170 Sentinel	
Lenght	4.5 m (estimated)
Wingspan	20-26 m (estimated)
Max Altitude	15000 m (estimated)

Table 2.7: RQ-170 Sentinel, (Source:[80])

2.2 Classification by Performance Characteristics

UAS often vary widely in their configurations depending on the platform and mission. UAVs can be classified based on performance characteristics, such as weight, endurance, speed, maximum altitude, etc. This method of grouping UAVs can be useful for potential customers in selecting a vehicle that better suits their needs. However, such classifications are not homogenous and internationally shared. UAS are an emerging technology: its rapid development in the last decades, the introduction of innovative solutions and the wide variety of models available on the market contribute to the creation of a fragmented scenario in which is difficult to put order. In addition, the absence of a uniform and well-defined regulatory framework to refer to contributes to this.
In the following section some significant classifications based on UAV design characteristics, and traced among the many available in literature, will be proposed.

2.2.1 Classification by weight

Weight holds significant importance in the field of aeronautics when it comes to aerial platforms. Both EASA and NATO classification, which will be explained in detail in following sections, consider weight as the primary parameter for categorizing UAVs into classes. Today, numerous weight-based classification are available in literature. For example, a first classification introduced is the Brooke-Holland classification proposed in “Overview of military drones used by the UK armed forces”[1]. UAVs are divided into three

[1]Louisa Brooke-Holland UK Parliament. "Overview of military drones used by the UK Armed Forces", September 2015, [133]

classes, in addition Class I is further divided into four subcategories.

MTOW	Common Taxonomy	Category
<200g	NANO	Class I (a)
200 g to 2 kg	MICRO	Class I (b)
2 kg to 20 kg	MINI	Class I (c)
20 kg to 150 kg	SMALL	Class I (d)
>150 kg	TACTICAL	Class II
>600 kg	MALE/HALE/Strike	Class III

Table 2.8: Brooke-Holland Classification (Source: Overview of military drones used by the UK armed forces [133])

Arjomandi in "Classification Of Unmanned Aerial Vehicles"[2] classified as:

MTOW	Category
>2000 kg	Super Heavy
200 kg to 2000 kg	Heavy
50 kg to 200 kg	Medium
5 kg to 50 kg	Light
<5 kg	Micro

Table 2.9: Arjomandi Classification (Source: Classification Of Unmanned Aerial Vehicles [6])

2.2.2 Classification by Endurance and Range

Another method of classification for UAS is based on endurance and range. This parameter is important for missions requiring long-time operations or when they need to reach points far from the launch site. A possible classification defines:

Endurance	Range	Category
>24 hrs	1500 km	High Endurance
5-24 hrs	100-1500 km	Medium Endurance
<5 hrs	100 km	Low Endurance

Table 2.10: Classification based on range and endurance (Source: Hassanalian Mostafa and Abdelkefi Abdessattar. "Classifications, applications, and design challenges of drones: A review", Elsevier, 2017, [118])

[2]Maziar Arjomandi, Shane Agostino, Matthew Mammone, Matthieu Nelson, and Tong Zhou. "Classification of unmanned aerial vehicles". Report for Mechanical Engineering class, University of Adelaide, Adelaide, Australia, pages 1–48, 2007, [6]

Another possible categorization proposed in the "Handbook of unmanned aerial vehicles"[3] for existing systems in 2006 is:

Endurance	**Range**	**Weight**	**Category**
1 h	<10 km	<5 kg	Micro
<2 hrs	<10 km	<20 kg	Mini
2 hrs-4 hrs	10 km to 30 km	25 kg to 150 kg	Close Range
3 hrs-6 hrs	30 km to 70 km	50 kg to 250 kg	Short Range
6 hrs-10 hrs	70 km to 200 km	150 kg to 500 kg	Medium Range
10 hrs-24 hrs	500 km	1000 kg to 2500 kg	Medium Altitude Long Endurance
24 hrs-48 hrs	500 km	2500 kg to 5000 kg	High Altitude Long Endurance

Table 2.11: UAS Classification (Source: Handbook of Unmanned Aerial Vehicles, George J. Vachtsevanos, Kimon P. Valavanis, 2014 [145])

2.2.3 Classification by type of wings

UAS can be divided in three categories based on the configuration [153]:

- Fixed-Wing UAS
  These vehicles resembled traditional aircraft. This type of wing is preferably used for long-range missions, and typically accommodate heavier payloads then multi-rotors UAS. They can be classified into four subcategories:

  - Normal;
  - Swept back;
  - Swept forward;
  - Delta.

  They need a runway or a system as a catapult to take off.

- Rotary-Wing UAS
  Rotary-wing UAS can be further divided into single-rotor vehicles and multi-rotor vehicles. Single-rotor UAS use the main rotor for attitude control and a tail rotor directional control. Multi-rotor UAS can be subdivided in

[3] Kimon P Valavanis and George J Vachtsevanos. Handbook of unmanned aerial vehicles, volume 1. Springer, 2015 [145]

- Birotor;
- Trirotor;
- Quadrotor;
- Hexarotor;
- Octocopter.

Multi-rotor UAS allow complex and flexible maneuvers but typically are used to carry light payolas.

- Hybrid UAS
  Hybrid UAS combines feature of the two previous categories. An example of UAS falling under this class are VTOL (Vertical and Horizontal Takeoff & Landing) vehicles.

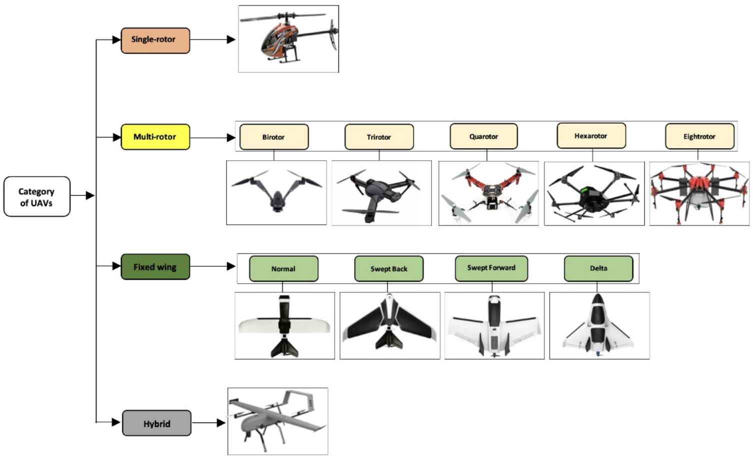


Figure 2.10: UAVs classification on type of wings (Source: https://encyclopedia.pub/entry/43656)

As evident from the figure above, the parameters used for the different classifications are correlated. Numerous diagrams that group UAS based on two or more characteristics can be indeed found in literature. For example: Weibel and Hansman employ the graph represented in Figure 2.11, to classify UAS by maximum takeoff mass and maximum altitude [147]. As shown, Micro UAS are usually used for low-altitude operations, while Mini UAS can fly up to medium altitude, while heavier UAS can be employed in high-altitude operations.

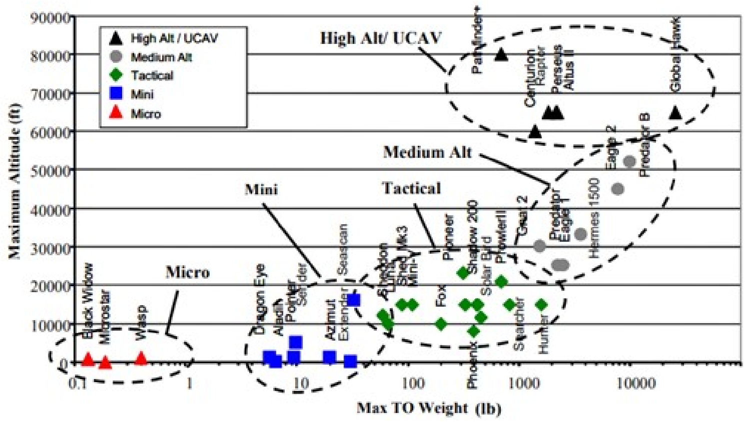


Figure 2.11: UAV Classification (Source: Safety Considerations for Operation of Different Classes of UAVs in the NAS Roland E. Weibel and R. John Hansman, Massachusetts Institute of Technology, Cambridge, MA 02139 [147])

The Brandenburg Institute for Society and Security is proposed the following classification in the Policy Paper "Unmanned Aircraft Systems for Civilian Missions"[136]:

Category	**Range (km)**	**Flying Altitude (m)**	**Endurance (h)**	**MWTO (kg)**
Micro& Mini UAV (MUAV)	10	300	2	30
MediumAltitude Long Endurance (MALE)	500	15000	24-48	1500-7000
HighAltitude Long Endurance (HALE)	2000	20000	24-48	4500-15000
VerticalTake-Off and Landing UAV (VTOL UAV)	x-204	x-6100	0.18-8	0.019-1400

Table 2.12: Possibile Classification of UAS (Source: Unmanned Aircraft Systems for Civilian Missions, Policy Paper, BIGS, 2012 [136])

MUAVs includes Micro e Mini UAVs. They have a maximum takeoff weight of 30 kg a short range autonomy and a minimal altitude of about 300 meters, their endurance is less than 2 hours.
MALE are Medium Altitude Long Endurance Systems and HALE refers to are High Altitude Long Endurance Systems. As suggested by their names they have a significant

longer endurance, exceeding 24 hours. MALE UAVs can fly for more than 500 km and can reach an altitude up to 15000 meters, whereas HALE UAVs can achieve flight distances exceeding 2000 km and altitude up to 20000 meters. These platforms are characterized by a higher WMTO, and consequently can carry larger payload.
Vertical Take-Off and Landing (VTOL) UAVs represent a configuration that combines elements of fixed and rotary wing UAVs. They have characteristics that vary over a very wide range, for example VTOL vehicles can vary in size, can fall under MUAV or MALE class.

2.3 Military UAS Classification

UAS military classification is based on the NATO classification guideline, which is a useful basis for establishing a common terminology framework. A common reference for grouping UAS can help to define standards such as requirements for equipment, airworthiness and training requirements and allows the Services to organize, train, equip and standardize UAS for optimum employment.
As indicated in the JAPCC's book published in January 2021 titled "A Comprehensive Approach to Countering Unmanned Aircraft System"[4], NATO UAS classification is based on two main parameters: the UA maximum take-off weight and the Normal Operating Altitude. Weight is used as the first criterion to divide UAS into three classes [14]:

- Class I: less than 150 kg;
- Class II: between 150 kg and 600 kg;
- Class III: more than 600 kg.

2.3.1 Class I

Class I is further divided into three subcategories:

Micro UAS

UAS with a kinetic energy less then 66J. They can flight up to an altitude of 200 ft AGL, in a radius of 5 km. An example of this type of UAS is the "Black Widow", a small

[4]https://www.japcc.org/books/a-comprehensive-approach-to-countering-unmanned-aircraft-systems/

fixed wing vehicle, designed in a circular platform, developed as part of DARPA's MAV program.[144]

Figure 2.12: Black Widow (Source: https://defense-update.com/20040604_black-widdow.html)

Black Widow	
Max Takeoff Weight	50 g
Wingspan	6 inches
Endurance	30 minutes
Max horizontal speed	20 m/s
Ceiling	769 ft

Table 2.13: : Black Widow Technical Data (Source: https://defense-update.com /20040604_black-widdow.html)

Mini UAS

Unmanned vehicles weighing less than 15 kg. Mini UAS can be launched by hand or with a launch system. They flight at an altitude up to 3000 ft, in a radius of 25 km. An example of this type of vehicle is the Skylark I – LEX produced by Elbit Systems. It is used in various NATO countries for intelligence, surveillance and monitoring missions.[138]

Figure 2.13: Skylark (Source: https://it.topwar.ru/10503-bpla-skylark-i-le-poluchil-razreshenie-na-polety-v-nebe-francii.html)

Skylark	
MTOW	7.5 kg
Max Payload Weight	1.2 kg
Length	2.2 m
Wingspan	2.4 m
Endurance	3 hours
Range	40 km
Ceiling	4600 m

Table 2.14: Skylark Technical Data (Source: https://elbitsystems.com/products/ uas/skylark-i-lex/)

Small UAS

Unmanned vehicles weighing more then 15 kg and less then 150 kg. Small UAS employ a launch system and flight at an altitude up to 5000 ft. They operate in a medium radius of 50 km. An example of this type of vehicle is the Scan Eagle. It is a small, long-endurance, low altitude fixed wing UAS built by INSITU (a Boeing Company), and used by United States Navy and Marine Corps for surveillance and reconnaissance missions.[99]

Figure 2.14: Scan Eagle (Source: https://it.wikipedia.org /wiki/Boeing_ScanEagle)

Scan Eagle	
MTOW	26.5 kg
Max Payload Weight	5 kg
Length	1.71 m
Wingspan	3.1 m
Endurance	18 hrs
Ceiling	5950 m
Max horizontal speed	80 knots

Table 2.15: Scan Eagle Technical Data (Source:https://www.insitu.com /products/scaneagle)

2.3.2 Class II

Class II is the NATO weight class from 150 kg to 600 kg, for medium size and tactical systems. Usually operate at altitudes less than 18.000 ft AGL in a range of 200 km (LOS), often use a catapult-launch system. Class II unmanned aircraft are typically employed within tactical formations and usually have a small logistics footprint.

An example of Class II UAS is the Sperwer developed by SAGEM. This UAS use a rail to be launched and is employed for reconnaissance purposes. The Sperwer has a maximum takeoff weight of 320 kg. It can fly at an altitude of over 16.000 ft for 5 hours.[7]

Figure 2.15: Sperwer B (Source: https://en.wikipedia.org /wiki/SAGEM_Sperwer)

Sperwer	
MTOW	7.5 kg
Max Payload Weight	320 kg
Length	3.50 m
Wingspan	6 m
Endurance	5 hours
Maximum speed	120 km/h
Ceiling	16.000 m

Table 2.16: Sperwer Technical Data (Source: https://avia-pro.it/blog/sagem-sperwer-le-tehnicheskie-harakteristiki-foto)

Another Class II's UAS is the Watchkeeper, developed by Thales in the UK. It is employed in intelligence and reconnaissance missions, providing real-time situational awareness on the ground. It has a maximum take-off weight of 485 kg, and can fly at an altitude of 16.000 ft for 14 hours.[139]

Figure 2.16: Watchkeeper (Source: https://www.avionews.it/item/1162882-aerei-a-pilotaggio-remoto-il-drone-watchkeeper-prende-servizio-in-afganistan.html)

Watchkeeper	
MTOW	7.5 kg
Max Payload Weight	485 kg
Length	6.50 m
Wingspan	10.9 m
Endurance	14 hours
Maximum speed	77 kts
Ceiling	16.000 ft

Table 2.17: Watchkeeper Technical Data (Source: https://www.army.mod.uk/news-and-events/news/2020/08/watchkeeper/)

2.3.3 Class III

Class III includes UAS weighing more than 600 kg. These unmanned aircraft are typically large and complex systems that can operate in a range of hundreds of kilometers, with endurance exceeding 24 hours. These unmanned platforms are essentially comparable in size to manned aircraft.
The third class is further divided according to the altitude of use, into:

- Strike/Combat drones;

- HALE
  High Altitude Long Endurance Systems which can reach an altitude up to 20000 meters.
  An example is the Global Hawk operated by the United States Air Force for day or night intelligence, surveillance, and reconnaissance to support combatant forces.[82]

Figure 2.17: Global Hawk (Source:https://news.laran.it/2019/11/arrivato-a-sigonella-il-primo-global-hawk-del-nato-ags/)

Global Hawk	
MTOW	14628 kg
Max Payload Weight	1360 kg
Wingspan	39.8 m
Lenght	14.5 m
Endurance	34 hrs
Ceiling	18288 m
Max horizontal speed	310 kts

Table 2.18: Global Hawk Technical Data (Source: https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104516/rq-4-global-hawk/)

- MALE
  Medium Altitude Long Endurance Systems are UAS that can reach an altitude up to 15000 meters.
  An example is the Heron, an unmanned aerial system used for strategic and tactical missions. It is provided with a multi-mission system composed of up to six diverse mission payloads simultaneously allowing intelligence, surveillance, target acquisition and reconnaissance purposes over land and sea.[85]

Figure 2.18: Heron (Source: https://gagadget.com/it/296535-lindia-utilizzera-i-droni-da-ricognizione-israeliani-heron-mk-ii-per-monitorare-il-confine-con-il-pakistan-e-la-cina/)

Heron	
MTOW	1270 kg
Max Payload Weight	470 kg
Wingspan	16.6 m
Lenght	8.5 m
Endurance	45 hrs
Ceiling	35000 ft
Range	>250 km (LOS) >1000 km (BVLOS)

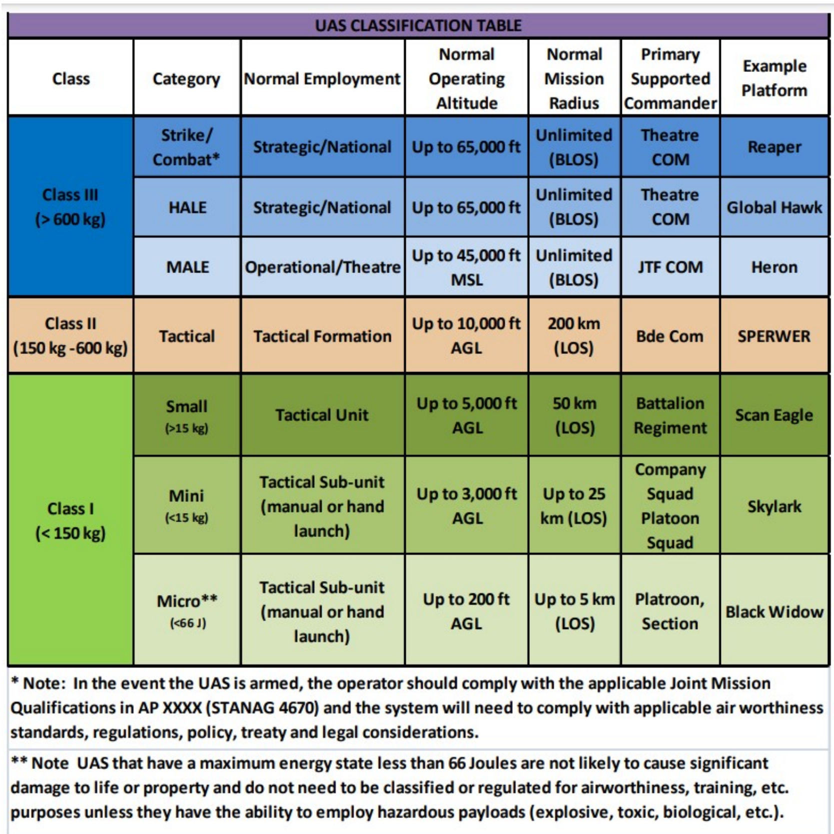
Table 2.19: Heron Technical Data (Source: https://www.iai.co.il/p/heron)

Another example is the Falco Xplorer, developed by Leonardo. This UAS is designed to conduct surveillance, intelligence, and reconnaissance missions. It has a maximum takeoff weight of 1300 kg and can carry payloads up to 350 kg. The Falco Xplorer can fight for over 24 hours, at an altitude up to 30.000 ft. Actually, this UAS is undergoing for a Military Type Certification.[84]

Figure 2.19: Falco Xplorer (Source: https://it.wikipedia.org /wiki/Leonardo_Falco_Xplorer)

Falco Xplorer	
MTOW	7.5 kg
Max Payload Weight	1300 kg
Length	9 m
Wingspan	18.5 m
Endurance	>24 hours
Max Payload Weight	350 kg
Ceiling	>30.000 ft

Table 2.20: Falco Xplorer Technical Data (Source:https://unmanned.leonardo .com/it/products/falco-xplorer)



UAS CLASSIFICATION TABLE

Class	Category	Normal Employment	Normal Operating Altitude	Normal Mission Radius	Primary Supported Commander	Example Platform
Class III (> 600 kg)	Strike/ Combat*	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre COM	Reaper
	HALE	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre COM	Global Hawk
	MALE	Operational/Theatre	Up to 45,000 ft MSL	Unlimited (BLOS)	JTF COM	Heron
Class II (150 kg -600 kg)	Tactical	Tactical Formation	Up to 10,000 ft AGL	200 km (LOS)	Bde Com	SPERWER
Class I (< 150 kg)	Small (>15 kg)	Tactical Unit	Up to 5,000 ft AGL	50 km (LOS)	Battalion Regiment	Scan Eagle
	Mini (<15 kg)	Tactical Sub-unit (manual or hand launch)	Up to 3,000 ft AGL	Up to 25 km (LOS)	Company Squad Platoon Squad	Skylark
	Micro** (<66 J)	Tactical Sub-unit (manual or hand launch)	Up to 200 ft AGL	Up to 5 km (LOS)	Platroon, Section	Black Widow

* Note: In the event the UAS is armed, the operator should comply with the applicable Joint Mission Qualifications in AP XXXX (STANAG 4670) and the system will need to comply with applicable air worthiness standards, regulations, policy, treaty and legal considerations.

** Note UAS that have a maximum energy state less than 66 Joules are not likely to cause significant damage to life or property and do not need to be classified or regulated for airworthiness, training, etc. purposes unless they have the ability to employ hazardous payloads (explosive, toxic, biological, etc.).

Figure 2.20: NATO UAS CLASSIFICATION (Source: Book "A Comprehensive Approach to Countering Unmanned Aircraft Systems" by JAPCC, p. 510 (Source NATP ATP-3.3.8.1, Ed. B, Ver.1), 2021)

2.4 EASA Classification

EASA regulatory framework is based on the risk posed by UAS operations. The classification of unmanned systems also follows the same method. UAS for civilian purposes have to be integrated into the existing aviation system to guarantee safe operations. However unmanned aerial systems are different from manned vehicles, so existing rules cannot be simply applied. UAS are characterized by the absence of crew and passengers on board, so in case of a loss of control, the consequences depend especially on the operating scenario. A crash in a populated environment carries an increased level of danger compared to a crash in an unpopulated or isolated area. The EASA's aim is to establish a new and innovative regulation framework that is proportionate, progressive and risk-based, taking into consideration the danger to which overflown people are subjected to. A classification simply based on aircraft characteristics such as weight (used for example by the military sector) or other specifics is not adequate. Considering the wide range of operations and types of UAS, EASA proposed three categories to classify UAS, taking into consideration not only the specifics of the aerial platform employed but also the type of operation conducted, the payloads carried, the overflown areas and the airspace traveled. EASA classification consists of three classes from low to high risk called 'open', 'specific', and 'certified'. The level of risk depends on the kinetic and potential energy of the UAV, the population density of the overflown environment and the density of airspace traffic, evaluating harm to people, damage to critical infrastructures and mid-air collision with manned vehicles. Each category defines operational limitations, standards and requirements tailored to the increasing level of risk.

2.4.1 'Open' Category

The 'open' category includes low-risk operations. The risk to third parties on the ground and in the airspace is mitigated by operational limitations. UAS falling under this category do not require authorization for the flight but should be compliant with all limitations in force. Article (4) of 'Commission Implementing Regulation (EU) 2019/947' defines UAS requirements falling under 'open' category.

'Open' category includes UAVs with a maximum take-off mass of less than 25 kg, not carrying dangerous goods or dropping any material. During flight, UAS cannot exceed a height of 120 meters from the closest point of the earth's surface and the measurement

of distances shall be adapted to the geographical characteristics of the terrain [5]. If the UAV encounter an obstacle during flight and if it is higher than 105 meters, a clearance of 50 meters from the obstacle must be complied and the maximum height of operation may be increased up to 15 meters[6]. Operations falling under open category must be conducted in VLOS (visual line of sight)[7] and in UAS zones. The remote pilot has to keep the UAV at a safe distance from people and not fly over gatherings[8]. He is responsible for the safe separation from any other aircraft, uninvolved people, and property in the operational scenario. UAS operations in the 'open' category are further divided into three subcategories, as indicated in Article (4) Point (2) of 'Implementing Regulation (EU) 2019/947'. These sub-categories are called A1, A2, and A3, whose requirements are set out in Part A of Annex to (EU) 2019/947.
The three sub-categories are A1, A2, A3:

- A1:fly over people but not over assemblies of people;

- A2: fly close to people;

- A3: fly far from people.

It is important to identify the UAS subcategory of operation to determine which rules have to be applied, operational limitations and the type of training the remote pilot needs to undertake.

[5]EASA, Easy Access Rules for Unmanned Aircraft Systems, Implementing Regulation (EU) 2019/947, Article 4 Point (1)(b)(e)(f), p.29, 2022

[6]EASA, ANNEX TO IMPLEMENTING REGULATION (EU) 2019/947, Part A of Annex to Implementing Regulation (EU) 2019/947, GM1 UAS.OPEN.010 General provisions, p.249, 2022

[7]EASA, Easy Access Rules for Unmanned Aircraft Systems, Implementing Regulation (EU) 2019/947, Article 4 Point (1)(d), p.29, 2022

[8]EASA, Easy Access Rules for Unmanned Aircraft Systems, Implementing Regulation (EU) 2019/947, Article 4 Point (1)(c), p.29, 2022

UAS	Operation		Drone operator/pilot		
Max weight	Subcategory	Operational restrictions	Drone operator registration	Remote pilot competence	Remote pilot minimum age
< 250 g	A1 (can also fly in subcategory A3)	— No flight expected over uninvolved people (if it happens, overflight should be minimised) — No flight over assemblies of people	No, unless camera / sensor on board **and** the drone is not a toy	— No training required	No minimum age
< 500 g			Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Proof of completion for online training' for A1/A3 'open' subcategory	16*
< 2 kg	A2 (can also fly in subcategory A3)	— No flying over uninvolved people — Keep a horizontal distance of 50 m from uninvolved people	Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Remote pilot certificate of competency' for A2 'open' subcategory	16*
< 25 kg	A3	— Do not fly near or over people — Fly at least 150 m away from residential, commercial or industrial areas	Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Proof of completion for online training' for A1/A3 'open' subcategory	16*

Figure 2.21: Open Category Table, (Source: https://www.easa.europa.eu/en/domains/civil-drones/drones-regulatory-framework-background/open-category-civil-drones)

A brief overview of main requirements of each sub-category is given in the following sections.

A1 subcategory

UAS operations in subcategory A1 shall be performed by UA that:

- *"has a maximum takeoff weight (including payload) of less than 250 g and a maximum operating speed of less 19 m/s, in the case of a privately build UAS; or*
- *is marked as class C0 and complies with the requirements of that class, as defined in Part 1 of the Annex to Delegated Regulation (EU) 2019/945; or*
- *is marked as class C1 and complies with the requirements of that class, as defined in Part 2 of the Annex to Delegated Regulation (EU) 2019/945 and is operated with an active and updated direct remote identification system and geo-awareness function."*[9]

As a principle, UAS operations in subcategory A1 shall be conducted not to overfly assemblies of people and it is reasonably expected that no uninvolved person will be

[9] EASA, Annex to Implementing Regulation (EU) 2019/947, Part A of Annex to Implementing Regulation (EU) 2019/947, UAS.OPEN.020, p.251, 2022, [46]

overflown, but overflying isolated people is possible depending on the UAS class[10]. A UAS in class C0 or privately built with a MTOM of less than 250 g may fly over uninvolved people, but this should be avoided whenever possible. For UAS in class C1, the remote pilot should assess the area and should verify that no involved person will be overflown, in case of an unexpected overflight, the PIC should reduce as much as possible the overflight time[11].

A2 subcategory

UAS operations in subcategory A2 shall be performed by an unmanned aircraft marked as class C2, with an active and updated direct remote identification system and geo-awareness function[12]. UA shall not overfly uninvolved persons and maintain a safe horizontal distance of at least 30 meters from them. It is possible to reduce this distance to a minimum of 5 meters if the UA is operated with a low-speed mode function active, after evaluating weather conditions and UA performance[13]. The minimum separation distance between the unmanned aircraft (UA) and any uninvolved person should be established as the space between the location where the aircraft would impact the ground in the case of a vertical descent and the individual's position. Therefore, subcategory A2 addresses operations that involve flying close to people is intended for a significant portion of the flight, maintaining a minimum distance ranges from 5 m to 30 m from uninvolved people[14].

A3 subcategory

UAS operations in subcategory A3 shall be performed by UA that:

- *"has a maximum takeoff weight (including payload) of less than 25 kg in the case of a privately build UAS; or*

[10] EASA, Annex to Implementing Regulation (EU) 2019/947, Part A of Annex to Implementing Regulation (EU) 2019/947, UAS.OPEN.020, p.250, 2022, [46]

[11] EASA, Annex to Implementing Regulation (EU) 2019/947, Part A of Annex to Implementing Regulation (EU) 2019/947, AMC1 UAS.OPEN.020(1) and (2) UAS operations in subcategory A1, pp.251-252, 2022 , [46]

[12] EASA, Annex to Implementing Regulation (EU), Part A of Annex to Implementing Regulation (EU) 2019/947, UAS.OPEN.030 Point (3), p.258, 2022, [46]

[13] EASA, Annex to Implementing Regulation (EU), Part A of Annex to Implementing Regulation (EU) 2019/947 UAS.OPEN.030 Point (1), p.258, 2022, [46]

[14] EASA, Annex to Implementing Regulation (EU), Part A of Annex to Implementing Regulation (EU) 2019/947, AMC1 UAS.OPEN.030(1), pp.258-259, 2022, [46]

- *is marked as class C2 and is operated with an active and updated direct remote identification system and geo-awareness function;*
- *is marked as class C3 and is operated with an active and updated direct remote identification system and geo-awareness function;*
- *is marked as class C4 and is operated with active and updated direct remote identification system and geo-awareness function"*[15].

Operations shall be conducted in an area where no uninvolved person are expected to be posed at risk during the entire time of the UAS operation, in addition, the remote pilot has to maintain a safe horizontal distance of at least 150 meters from residential, commercial, industrial or recreational areas[16]. If an uninvolved person enters the range of the UAS (Unmanned Aircraft System) operation, the remote pilot should make necessary adjustments or halt the operation if safety cannot be guaranteed. A minimum horizontal separation distance of at least 30 meters and compliance with the '1:1 rule' for evaluated altitude must be maintained from individuals moving within the area. UAS operating in subcategory A2 are also permitted to operate in the A3 category.
In addition, UAS operations in subcategory A3 may also be conducted with an UA that has either:

- *"a class C0 class identification label; or*
- *a class C1 class identification label with an active and updated direct remote identification system and a geo-awareness function"*[17].

2.4.2 'Specific' Category

The 'specific' category includes medium-risk operations, such as operations beyond the visual line of sight of the pilot, sharing airspace with other users or operations above densely populated areas. As defined in Article (5) of (EU) 2019/947, where one or more requirements outlined in Article 4 (EU) 20197947 or in Part A of the Annex of Commission Implementing Regulation (EU) 2019/947 is not met, the UAS operation falls under 'specific'

[15] EASA, Annex to Implementing Regulation (EU), Part A of Annex to Implementing Regulation (EU) 2019/947, UAS.OPEN.040, p.266, 2022, [46]

[16] EASA, Annex to Implementing Regulation (EU), Part A of Annex to Implementing Regulation (EU) 2019/947, AMC1 UAS.OPEN.040(1), p.266, 2022, [46]

[17] EASA, Annex to Implementing Regulation (EU), Part A of Annex to Implementing Regulation (EU) 2019/947,GM1 UAS.OPEN.040(4) UAS operations in subcategory A3, p.267, 2022, [46]

category. The risk associated with this type of operation is higher than the danger posed by an ‘open’ category mission. However, ‘specific’ category operations do not require a safety level equal to manned aviation or the UAS certification as required in the ‘certified’ category. In the ‘specific’ category there are no weight limitations.([17], Article 5, p.30)

2.4.3 ’Certified Category

The ‘certified’ category includes high-risk operations. Article (6) of (EU) 2019/947 defines the conditions for classifying UAS operations shall in the ‘certified’ category. The following requirements must be fulfilled:

(a) *the UAS is certified pursuant to points (a), (b) and (c) of paragraph 1 of Article 40*[18] *of Delegated Regulation (EU) 2019/945; and*

(b) *the operation is conducted in any of the following conditions:*

i. *over assemblies of people;*

ii. *involves the transport of people;*

iii. *involves the carriage of dangerous goods, that may result in high risk for third parties in case of accident.”*[19]

In addition, a UAS (Unmanned Aircraft System) operation must be categorized as ’certified’ if the competent authority, upon evaluating the submitted risk assessment, determines that the risk linked to the proposed operation cannot be reduced or mitigated without certification. “UAS operations in the ‘certified’ category shall require the certification of the UAS in accordance to Delegated Regulation (EU) 2019/945, as well as the certification of the operator and, where applicable, the licensing of the remote pilot”[20].

[18] Article 40 addresses the UAS. The technical requirements for UAS are in delegated act.

[19] EASA, Easy Access Rules for Unmanned Aircraft Systems, Implementing Regulation (EU) 2019/947, Article 6 Point (1), p.31, 2022, [46]

[20] EASA, Easy Access Rules for Unmanned Aircraft Systems, Implementing Regulation (EU) 2019/947, Article 3 Point (c), p.28, 2022, [46]

Chapter 3

Civil Regulatory Framework

Chapter 3 aims to provide the reader with an overview of UAS legislative framework in the field of civil aviation.

The first part will offer a description of International, European and Italian regulatory bodies, underlining their main characteristics, their internal structure and their regulatory process.

The second part of the Chapter will focus on regulations related to unmanned aerial systems employed in civil aviation. A comprehensive and reliable regulatory framework is essential to integrate UAS into the existing aviation system, to conduct UAS operations and to ensure a high level of safety and the protection of the overflown population. Unmanned Systems are a "new" and evolving technology and due to their characteristics, such as the absence of personnel and crew on board and the wide variety of operations, they cannot be subjected to the existing provisions of general aviation. The goal is to create a new regulation that is suitable and proportionate to the new technology: an operation-centric and risk-based system of rules. The following civil regulatory bodies will be introduced:

- ICAO;
- EASA;
- JARUS;
- EUROCAE;
- RCTA;
- ENAC.

In addition, a list of the main European regulations, decisions and opinions related to UAS will be presented, to provide the reader with an overview of the main regulations currently in force and their evolution and future development.

The last section of the Chapter will be focused on the rules and formal procedures needed to operate a UAS falling in the 'specific' category, which is the UAS class of main interest for this study.

3.1 Regulatory Bodies

3.1.1 ICAO

The International Civil Aviation Organization (ICAO) is a United Nations specialized agency, established by States in 1944 to administer and govern the Convention on International Civil Aviation.

Figure 3.1: ICAO logo, (Source: Wikipedia, 2009, International Civil Aviation Organization logo, svg, https://en.wikipedia.org/wiki/International_Civil_Aviation_Organization, consulted in July 2023)

During the Second World War, significant advancement in aircraft technology occurred, which brought the emergence of safety concerns for the transport of civilian passengers. In response, the United States invited 55 States to attend an international conference held in Chicago. At its conclusion on 7 December 1944 the Chicago Convention was signed and approved by 54 nations to "promote cooperation and create and preserve friendship and understanding among the nations and peoples of the world"[1]. The Chicago Convention

[1] ICAO, "The History of ICAO and Chicago Convention", ICAO75, utr:https://www4.icao.int/icao75/History/ICAOAndChicagoConvention #:~:textThe%20Convention%20on%20International%20Civil,and%20peoples%20of%20the%20world .%E2%80%9D, consulted in July 2023

established the fundamental principles for international transport by air, leading the foundation for standards and procedures to facilitate peaceful global air navigation. The primary objective was the development of international civil aviation "in a safe and orderly manner"[2].[96][97]

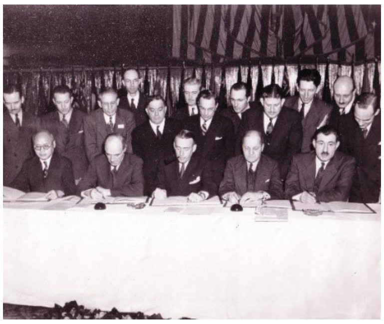


Figure 3.2: The Chicago Convention, (Source: Wikipedia, 1944, The Chicago Convention, https://en.wikipedia.org/wiki/Convention_on_International_Civil_Aviation#/media/File:Signature-OACI-Max-Hymans.JPG, consulted in 2023)

Presently, ICAO works with the Convention's 193 Member States, as well as industry groups and stakeholders, to achieve develop international civil aviation Standard and Recommended Practices (SARPs) and policies in support of safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. In addition, ICAO coordinates assistance for its Member States in support of numerous aviation development objective: it formulates global plans to coordinate multilateral strategic progress for safety and air navigation, monitors and reports on air transport sector performance metrics, and audits member states' civil aviation oversight capabilities in the areas of safety and security. [86][95]

Organization Structure

ICAO's governance structure consists of:

- ICAO Assembly
  The Assembly, composed of representatives from all 193 Member States, serves as the sovereign body of ICAO. It meets once every three years to review the work of

[2]ICAO, "The History of ICAO and Chicago Convention", ICAO75, url:https://www.icao.int/about-icao/history/pages/default.aspx, consulted in July 2023

the Organization to approve triennial budget and establishing forward-looking policy objectives.(ICAO Doc 7300. Edition 9, Part II Chapter VIII, 2006, [89])

- ICAO Council
  The Council is a 36-State governing and permanent body of the Organization, oversees and guides the work of ICAO. Council members are elected by the Assembly for a three-year term considering:

  - *"States of chief importance in air transport;*
  - *States which make the largest contribution to the provision of facilities for air navigation;*
  - *States which make the largest contribution to the provision of facilities for air navigation;*
  - *States ensuring effective and balanced geographic representation"*[3].

  The Council convenes the Assembly and adopts international SARPs, incorporating them as Annex to the Chicago Convention.(ICAO Doc 7300. Edition 9, Part II Chapter IX, 2006, [89], [92])

- ICAO Secretariat
  Led by the Secretary General, the ICAO Secretariat is composed of professional, technical and legal officers as well as administrative supporting staff. It consists of five bureaus:

  - Air Navigation Bureau;
  - Technical Cooperation Bureau;
  - Air Transport Bureau;
  - Legal Affairs and External Relations Bureau;
  - Bureau of Administration and Services.

  These officers provide expert support to Member States' civil aviation authorities. [93]

[3] ICAO,2006, Doc 7300. Edition 9, "Convention on International Civil Aviation", Part II Chapter IX, [89]

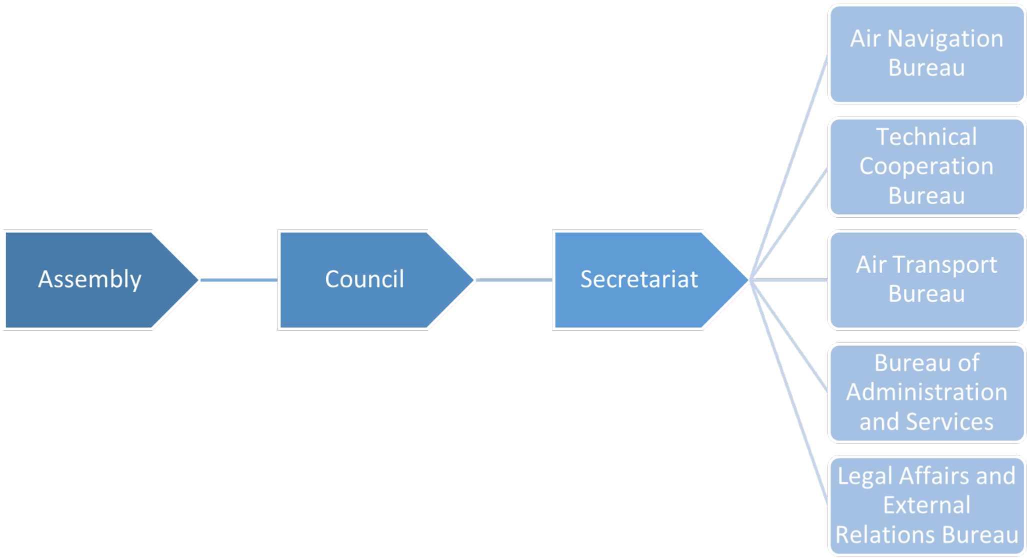


Figure 3.3: ICAO structure

Regulation Framework

ICAO's regulation framework is composed by:

- The Chicago Convention
  It is the document that established ICAO and the rules of airspace, aircraft registration, safety, security, and sustainability, and details the rights of the signatories in relation to air travel. Is composed of 96 articles.[89]

- Standards and Recommended Practices (SARPs)
  SARPs are technical specifications adopted by the ICAO Council to assist States in managing aviation safety risks to achieve *"the highest practicable degree of uniformity in regulations, standards, procedures and organization in relation to aircraft, personnel, airways and auxiliary services in all matters in which such uniformity will facilitate and improve air navigation"*[4] . SARPs represent the minimum requirements necessary to ensure safety, are published as Annexes to Chicago Convention and are not legally binding as the Convention itself, since they are not international treaties.(ICAO (2006), Doc 7300. Edition 9, Part I Chapter VI, [89])
  SARPs include:

[4] ICAO (2006), Doc 7300. Edition 9, "Convention on International Civil Aviation", Article 37, [89]

- Standards are *"any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38"*[5].
- Recommended Practices are *"any specification for physical characteristics, configuration, materiel, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention"*[6]

- Procedures for Air Navigation Services (PANSs)
  PANSs contain operational material that would be too detailed for SARPs, providing additional explanations material to standards and recommendations. Initially created based on common recommendations from regional meetings, these suggestions were subsequently implemented globally by the ICAO Council. PANSs have a different status from SARPs, are approved by the ICAO Council, and are not subjected to Articles 38[7] prescriptions.(Doc 7030 [90])

- Regional Supplementary Procedures (SUPPs)
  SUPPs are technical specification like PANS, however, are developed to meet needs of specific regions. They must not conflict with the provisions contained in the Annexes or PANS. SUPPs do not have the same status as SARPs, are approved by the Council and are recommended exclusively to Contracting States in respective regions.(Doc 7030 [90])

- Guidance Material (GM)
  GM refers to documents that are approved alongside SARPs, to which they are

[5]ICAO,AN-Conf/11-WP/142, APPENDIX "SARPs "NOTIFICATION OF DIFFERENCES" PROCEDURES AND PANS STATUS", [87]

[6]ICAO,AN-Conf/11-WP/142, APPENDIX "SARPs "NOTIFICATION OF DIFFERENCES" PROCEDURES AND PANS STATUS", [87]

[7] *"Any State which finds it impracticable to comply in all respects with any such international standard or procedure, or to bring its own regulations or practices into full accord with any international standard or procedure after amendment of the latter, or which deems it necessary to adopt regulations or practices differing in any particular respect from those established by an international standard, shall give immediate notification to the International Civil Aviation Organization of the differences between its own practice and that established by the international standard. . . "*, ICAO (2006), Doc 7300 Edition 9, "Convention on International Civil Aviation", Article 38, [89]

related. They can be published together with an Annex or in separate documents such as a Manual or a Circular. Guidance Materials are useful to implement SARPs and PANS provisions.

3.1.2 EASA

The European Union Aviation Safety Agency (EASA) is an independent agency of the European Union (EU) that ensures confidence in safe air operations in Europe.

Figure 3.4: EASA logo, (Source:Wikipedia, 2014, EASA logo, svg, url: https://it.m.wikipedia.org/wiki/File:EASA_Logo.svg, consulted in July 2023)

EASA proposes and formulates rules, standards, and guidance. Established in 2002, EASA reached full operability in 2008 and the headquarter is located in Cologne, with four permanent Representative Offices in Brussels, Beijing, Singapore and Washington.[63]

Regulation (EC) No 1592/2002 set the basis on common rules in the field of civil aviation and established the European Aviation Safety Agency, with the objective to ensure
“a high and uniform level of protection of the European citizen in civil aviation, by the adoption of common safety rules and by measures ensuring that products, persons and organizations in the Community comply with such rules and those adopted to protect the environment”[8] . Moreover, EASA’s mission includes the development of a unified regulatory and certification process among Member States with the aim of facilitating the European internal aviation market, establishing fair competition and working with other International Aviation Organizations and Regulators.[63]
The main tasks of the Agency include:

- *"Draft implementing rules in all fields pertinent to the EASA mission;*
- *Certify & approve products and organizations, in fields where EASA has exclusive competence (e.g. airworthiness);*

[8]European Parliament and the Council, Regulation (EC) No 1592/2022, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002R1592, Point(1), p.1, 2002

- *Provide oversight and support to Member States in fields where EASA has shared competence (e.g. Air Operations , Air Traffic Management);*
- *Promote the use of European and worldwide standards;*
- *Cooperate with international actors in order to achieve the highest safety level for EU citizens globally (e.g. EU safety list, Third Country Operators authorizations)"*[9]

Organization Structure

The Management Board consists of one representative from each Member State and one representative from the Commission. Its role is to define the Agency's priories, oversees its functions, establish budgets and adopt financial rules. In addition, the Management Board appoints the Executive Director, requiring a three-quarters majority of its members, based on the ground of merit, competence and experience relevant for civil aviation.((EC) 1592/2002[10] (2002), [132]))

As an independent body, the Executive Director manages and represents the Agency. He/she shall approve Agency measures, make decision regarding inspections and investigations, allocate certification tasks to NAA or qualified entities, and take all necessary steps to ensure the functioning of the Agency.((EC)1592/2002[11] (2002), [132])) The term of both the management Board and the Executive Director office is five years.((EC) 1592/2002[12] (2002),[132]))

In addition to the Executive Director, the Management Board shall establish advisory bodies[13] consisting of interested party directly affected by Agency decisions and considered valuable partners for achieving the Agency objectives. Advisory bodies serve as consultation forums of interested parties and national authorities on Agency priorities, both at strategic and technical level. For instance, the Member States' Advisory Body and the Technical Bodies comprise representative from EASA Members States and the European

[9]EASA, The Agency, EASA Task, url: https://www.easa.europa.eu/en/the-agency/the-agency, consulted in July 2023,[63].

[10]European Parliament and the Council. REGULATION (EC) No 1592/2002, Point(13) p.2 and Articles from 24 to 28 pp.10-11, 2002

[11]European Parliament and the Council. REGULATION (EC) No 1592/2002, Article 29, p.11, 2002

[12]European Parliament and the Council. REGULATION (EC) No 1592/2002, Article 30, p.11, 2002

[13]European Parliament and the Council, REGULATION (EC) No 1592/2002, Article 23 Point(4), p.10, 2002, [132]

Commission. They contribute to the implementation of actions and decisions related to regulatory matter. The Stakeholders Advisory Body with its Technical Committees (TECs) and overarching committees (COMs) offer a consultation forum between the Agency and Industry on both strategic (SAB) and technical (TECs, COMs) priorities. These bodies are composed of various associations in the sectors of commercial operators, aviation personnel, manufacturers, general and non-commercial operators, ATM/ANS, airports, training industry, air sports, maintenance industry and aerospace medicine. The non-EU industry is also represented.[41]

Regulation Framework

The legislative process in the European Union involves the following bodies:

- The Council of the European Union (It consists of a representative from each member state's government);
- The European Parliament (composed by representatives of the Member States);
- The European Commission;
- EASA.

The legislative process issues two types of laws: Hard Laws and Soft Laws. Hard Laws are binding and are adopted by the Council of the EU, the European Parliament, and the European Commission. The European Commission submits a proposal to the Council and the European Parliament: a legislative proposal is adopted by the two institutions, either at the first reading or at the second one, and if an agreement is reach the legislative act is adopted.[77]

Hard Laws includes:

- The Basic Regulation (EU) 2018/1139 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, adopted by European Parliament;
- Implementing Rules (IR) adopted by European Commission in the form or Regulations and drafted by EASA. Implementing Rules are binding and used to specify a high and uniform level of safety and uniform conformity and compliance in all Member States of the European Union without the need of formal act of transposition.[47]

Soft Laws are not legally binding and are issue by EASA ((EU)2018/1139[14], (2018). Soft Laws include:

- Certification Specification (CS) are technical standards adopted by EASA to define the Airworthiness requirements allowing to demonstrate compliance with essential requirements of the Basic Regulation. CSs are Soft Laws so they are non-binding but if used to define a Certification Basis, they become binding to the applicant.[47]

- Acceptable Means of Compliance (AMC) are non-binding rules. The AMC can be used as a means by which the requirements contained in the Basic Regulation and in the Implementing Rules can be met. Organizations complying with an Agency AMC must be recognized as compliant with the law, or may propose an alternative means of compliance which assure an equivalent level of safety. An AMC can be formally issued once the associated Hard Law is issued. [47]

- Guidance Materials (GMs) are non-binding materials developed by the Agency to better illustrate requirements, to understand the Basic Regulation, Implementing Rules and AMC. GM can be issued once the associated Hard Law is issued.[47]

In addition, EASA prepares draft of Opinions to assist the European Commission to prepare proposals for basic principles, applicability, amendment and essential requirements to the Basic Regulation and Implementing Acts((EU) 2018/1139[15], (2018)).

Agency Rulemaking Process

The Executive Director of EASA establishes a 5-year Rulemaking Programme which contains proposals for new regulations, amendments or documents. These proposals are developed through consultations with Member States, National Aviation Authorities, European Institutions or Aeronautical Industries((EU)2018/1139[16], (2018)). After a preliminary planning phase, the Executive Director issues a Terms of Reference, document that provides all the relevant information regarding the process for drafting the new document and its scope. Completed the drafting of the initial document, which typically takes between 3 to 18 months, the Executive Director issues a Notice of Proposed Amendment (NPA).

[14]European Parliament and the Council of the European Union, (EU) 2018/1139, Article 76 Point(3), p.57, 2018, [131]

[15]European Parliament and the Council of the European Union, (EU) 2018/1139, Article 76 Point(1), p.57, 2018, [131]

[16]European Parliament and the Council of European Union, (EU) 2018/1139, Article 115, p.73, 2018, [131]

During the following consultation period, which lasts from 1 to 3 months, any person or organization involved in or interested in the project may submit comments. These comment will be reviewed by the Agency with the assistance of competent personnel who were involved in the drafting of the initial document. At the end of the revision period, the Executive Director publishes the Comment Response Document and EASA publishes an Opinion to the European Commission if the objective of the Rulemaking process is the publication of a Hard Law, or a Decision in case of publication of a Soft Law. In the case of a Hard Law, the European Commission assesses the received Opinion, drafts a regulation and sends it to the Council of the EU and the European Parliament for final adoption.(Decision 01-2012, (2012)[11])

Figure 3.5: EASA Rulemaking Process

3.1.3 JARUS

JARUS is a group of experts from National Aviation Authorities and aviation safety organizations.

Figure 3.6: JARUS logo, (Source: JARUS, url:http://jarus-rpas.org/, consluted in July 2023)

Its mission is to *" develop technical and operational requirements for the safe, secure and efficient operation of UAS, to serve as a common reference for use in respective JARUS Member regulations and guidance, doing it in an effective and efficient manner, avoiding duplication of efforts with other international aviation organisations"*[17]. JARUS helps

[17] JARUS, 2022, Technical Report JARUS ToR v.8.1.2022, "Terms of reference", [108]

National Aviation Authorities to regulate, certify and approve UAS vehicles and operations in a simple and harmonized way. Each Member States can decide when and how to adopt JARUS's provisions.

Organization Structure

The JARUS structure consists of (JARUS ToR v8.1.2022, 2022, Chapter 3, [108]):

- Chair and Two Vice Chairs
  They represent the Organization, provide leadership to JARUS by leading the Plenary and Leadership Team meetings, and coordinating work progress.

- Leadership Team
  The Leadership Team includes high-level representatives from member authorities and organizations and is led by Chair and Vice Chairs. The LT reviews and coordinates working activities of JARUS.

- Plenary Team
  The Plenary Team includes one of representative from each NAA or other regulatory authorities. The PT oversees the rulemaking process and has the ultimate power of decision, proposing and adopting regulations, amending, and approving Terms of Reference, and establishing Working Groups.

- JARUS Secretariat
  The JARUS Secretariat is the central organ of the organization and is its administrative sector. The ST organizes the daily work of JARUS by managing Working Groups, official communications, documentation, and databases of all activities.

- Working Group Leaders
  Working Group Leaders oversee specialized groups, guiding and coordinating their work to develop standards and recommendations and ensure coordination with the Secretariat.

- Task Force Leaders
  Task Force Leaders are members of the Working Groups and are nominated by the WG Leader to lead temporary task forces established by JARUS to address specific challenges or issues. They coordinate efforts to achieve specific goals within a defined timeframe.

- Current JARUS & Work Program Structure
  This element outlines the existing structure of JARUS and its ongoing work programs

- JARUS Plenary Meeting
  Every year representatives from Member Authorities get together in the JARUS Plenary Meeting to discuss strategic matters, make important decisions, and shape the future direction of JARUS.
- Stakeholder Consultation Body
  The Stakeholder Consultation Body represents external stakeholders and provides input and feedback on JARUS activities, ensuring proper representation of all sectors of industry and aviation communities interested in JARUS work.

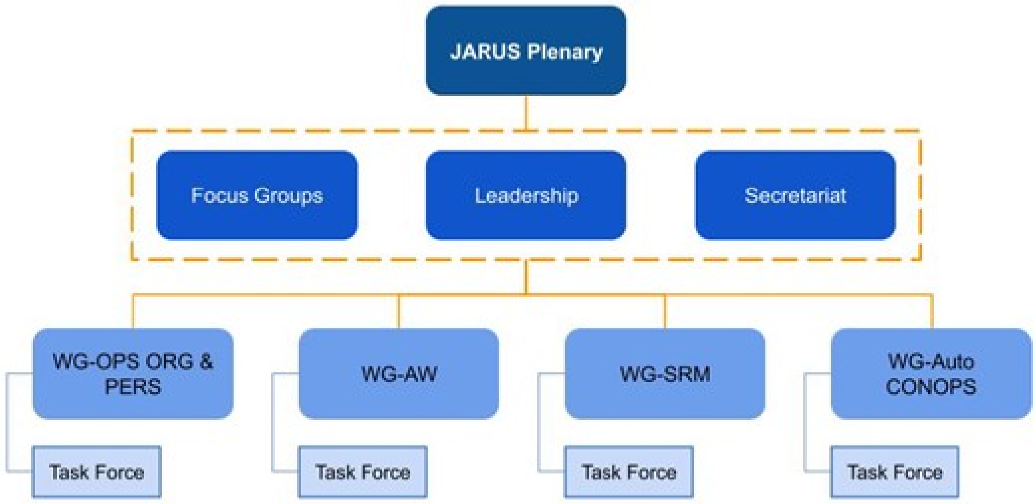


Figure 3.7: JARUS structure, (Source: JARUS, 2022, Jarus Structure, url: http://jarus-rpas.org/about-us/terms-of-reference/, p.6, consulted in July 2023,[108])

Rulemaking Process

The Plenary approves a new work task and adds it to the JARUS Working Programme. Then the Plenary assigns it to the appropriate Working Group which can create Task Forces to execute or help with the specific task. WG Leaders monitor the progress of tasks and verify if it respects the Working Programme. When the first task deliverables are ready, the Program Managers report the status of the task to the Plenary who approves its release for internal and external consultation. Once the consultation process is completed and external comments are evaluated, the Program Manager submits complete documents to the Plenary. If approved, it is released on the JARUS website or to ICAO.(ARUS ToR v8.1.2022, 2022, Chapter 5,[108])

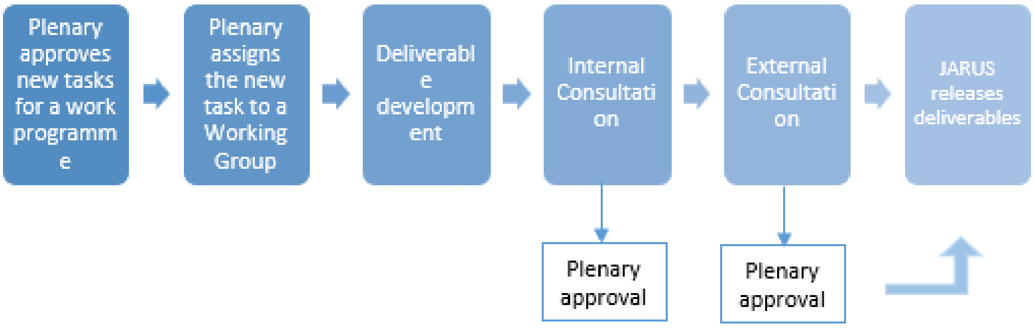


Figure 3.8: JARUS rulemaking process

3.1.4 EUROCAE

European Organization of Civil Aviation Equipment (EUROCAE) was founded in 1963 in Lucerne (Switzerland). This organization develops standards for aviation equipment and systems, involving manufacturers, operators, regulators and other stakeholders around the world, with the aim of “ensuring the interoperability, reliability, and safety of aviation equipment and systems”.[74]

Figure 3.9: EUROCAE Logo, (Source: https://www.atc-network.com/atc-organisations/eurocae)

Organization Structure

The EUROCAE has two main Governing Bodies. The Council and the Technical Advisory Committee. The Council, led by the Secretary General, meets at least four times a year at the General Assembly, during which the EUROCAE Full Members elect the 20 Council members. The Council’s main role is:

- *"to define the strategic objectives, policy, business plan and associated annual budget for EUROCAE and to periodically review the progress thereto;*

- *to approve the appointment of the Secretary General, contracts, agreements, and any expenses outside the budget, and to supervise the administration of the EUROCAE Association by the Secretary General;*
- *to appoint the Technical Advisory Committee Chairperson, its members; to set its objectives and approve its outputs;*
- *to approve the set up or continuation of Working Groups, the strategic part of the terms of reference, and the publication of EUROCAE Documents;*
- *to monitor and, when required, to support the supervision of Working Group activities;*
- *to agree the subscription ceiling for the following year that is submitted to the General assembly and to approve the membership fee categories below the approved ceiling"*[18].

The Technical Advisory Committee (TAC) is composed of 12 members, with high experience in topics of interest of the organization. They are appointed by the Council every three years. The TAC supports the Council in technical and operational decisions, in addition, provides recommendations, analyses the evolution of international regulations and supervises standardization activities accomplished by Working Groups.
Each Working Groups is created to develop standards and regulatory activities on a specific matter. A WG of particular interest for this study is the Working Group 105, whose aim is to "develop standards and guidance documents that will allow the safe operation of UAS in all types of airspace, at all times and for all types of operations"[19]. It is also divided into six Focus Teams addressing specific areas:

- *"Detect and Avoid (DAAA);*
- *Command, Control, Communication (C3);*
- *UAS Traffic Management (UAS);*
- *Design and Airworthiness Standards;*
- *Enhanced RPAS Automation (ERA);*
- *Specific Operations Risk Assessment (SORA)"*[20].

[18]EUROCAE, "EUROCAE Council, Consulted in November 2023, [73]
[19]EUROCAE, "Working Group", consulted in November 2023, [75]
[20]EUROCAE, "Working Group", consulted in November 2023, [75]

3.1.5 RTCA

The Radio Technical Committee for Aeronautics (RTCA) is a private organization founded in 1935 to "inspire the creation and implementation of integrated performance standards that meet the changing global aviation environment and ensure the safety, security, and overall health of the aviation ecosystem"[21]. RTCA collaborates with the Federal Aviation Administration, EUROCAE and industry experts from all the world to "develop comprehensive, industry-vetted, and endorsed recommendations on technical performance standards and the operating environment for utilizing standards. These standards can be used as means of compliance with FAA regulations and other aviation regulatory authorities"[22].

Figure 3.10: RTCA Logo, (Source: https://www.rtca.org/)

Organization Structure

The RTCA main governing body is the Board of Directors which is responsible for management and and fiduciary oversight. It collaborates with the RTCA Advisory Board to establish policies and programs.
The RTCA also includes the Program Management Committee which establishes and supervises Special Committees, dedicated to specific topics of interest, to satisfy government and industry needs, developing new standards and recommendations.

3.1.6 ENAC

ENAC, the Italian National Civil Aviation Authority, was established in 1997 by Legislative Decree 250/97.

[21] RTCA, "POWERFUL PROGRESS, COMMON GROUND", Mission, consulted in November 2023, [135]

[22] RTCA, "POWERFUL PROGRESS, COMMON GROUND", Who's RTCA? , consulted in November 2023, [135]

Figure 3.11: ENAC logo, (Source:Wikipedia, 2007, Logo dell'ENac, image/gif, url:https://it.wikipedia.org/wiki/File:ENAC.gif, consulted in July 2023)

It is a public agency with regulatory, organizational, administrative, and financial autonomy under the supervision and control of the Italian Minister of Transport. ENAC serves as the authority for technical safety regulation, certification, surveillance, and oversight in the civil aviation field.(Regio Decreto 30 marzo 1942, (1942) [23])[23]

In the sector of safety, ENAC guarantees the safety of flights and passengers, certifies aircrafts and airports, assesses the compliance of aircraft operators, flight crew, technical and maintenance personnel with regulations requirements to ensure safety in the design, construction, maintenance and operation of aircraft. Regarding security, ENAC is responsible for preventing and neutralizing acts of interference with the civil aviation system. In addition, ENAC supports the development of the civil aviation by ensuring service quality and preserving rights and fair competition.[67]

ENAC represents Italy in international civil institutions, such as ICAO, ECAC, EU, EASA and EUROCONTROL. It advocates for Italy's position in safety, security, quality of airport services, enforcement of passengers' rights, development of infrastructures, air transport regulations, etc.
ENAC's tasks includes:

- *"technical regulation and inspection, sanction, certification, authorization, coordination and control activities;*

[23]Regio Decreto,1942, n. 327, 30 marzo 1942, "Codice della Navigazione", Art.687: "L'Ente nazionale per l'aviazione civile (ENAC), nel rispetto dei poteri di indirizzo del Ministro delle infrastrutture e dei trasporti, nonche' fatte salve le competenze specifiche degli altri enti aeronautici, agisce come unica autorita' di regolazione tecnica, ((certificazione, vigilanza e controllo)) nel settore dell'aviazione civile, mediante le proprie strutture centrali e periferiche, e cura la presenza e l'applicazione di sistemi di qualita' aeronautica rispondenti ai regolamenti comunitari". [23]

- *rationalization and modification of the procedures relating to airport services, in accordance with the rules in force and in relation to the duties of guarantee, direction and planning performed;*
- *coordination activities with the National Flight Assistance Agency and the Air Force, within the scope of their respective responsibilities for flight assistance activities;*
- *relations with national and international entities, companies and bodies operating in the field of civil aviation and representation in international bodies, including under the authority of the Minister for Transport and Navigation;*
- *investigation of the acts concerning charges, charges and airport charges for the adoption of the consequent measures of the Minister for Transport and Navigation;*
- *definition and control of the parameters of quality of airport and air transport services within the limits provided for by the regulation referred to in article lo, paragraph 13, of Law 24 December 1993, n. 537;*
- *regulation, examination and evaluation of airport regulatory plans, action programs and airport investment plans, as well as possible participation in the management of airports of major tourist and social interest, or strategic-economic"*[24]

Organization Structure

The structure of ENAC consists of (D.L. 25 Luglio 1997 n.250, Art.4, [33]):

- The President, appointed by the Council of Ministers on the proposal of the Minister of Transports;
- The General Director, appointed with a Decree of the President of the Council of Ministers;
- Board of Directors, appointed with a Decree of the President of the Council of Ministers;
- The Board of Auditors;
- Central Departments.

[24]Governo della Repubblica Italiana, Decreto Decreto Legislativo 25 luglio 1997 n.250 "Istituzione dell'Ente nazionale per l'aviazione civile (E.N.A.C)", Article 2 Paragraph(1), 1997, [33]

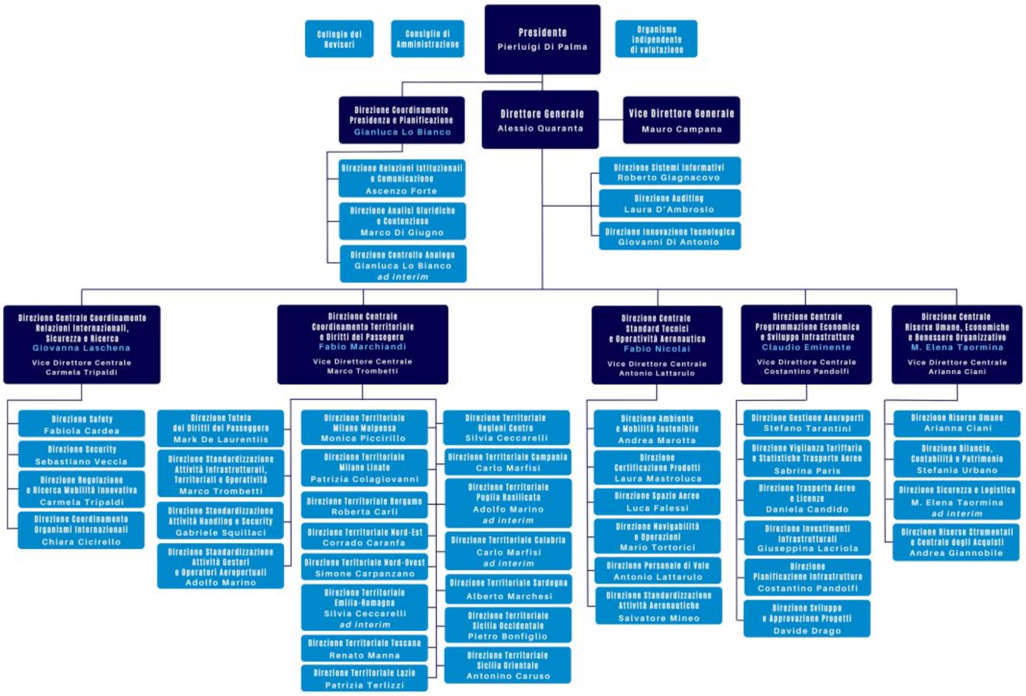


Figure 3.12: ENAC structure, (Source: ENAC, 2023, Organigramma ENAC, jpg, url:https://www.enac.gov.it/news/organigramma-enac, consulted in November 2023

Regulation Framework [68]

ENAC legislation is divided into:

- Agendas and Resolutions of the Board of Directors
- Regulations
- Circulars
- Ordinances
- Documentation
- Informative Notes
- Guidelines
- Disposition
- Directives, letters and documents

- Consultation Normativa
- Policy
- Technical specifications
- Alternative Means of Compliance

ENAC Regulations reflects the international standards set out in the ICAO Annexes or in the European Union Regulations. They contain technical and operational requirements for the proper exercise of the aeronautical activities to achieve safety standards and/or levels of efficiency compatible with the national civil aviation system. To develop and issue Regulations, ENAC establishes working groups of experts, who ensure compatibility with the existing regulatory framework and the international law. New regulations or amendments to existing regulations are adopted by publication in the Official Journal.[69] ENAC Regulations can be categorized into the following types:

- Technical Regulation;
- Administrative Accounting Regulation;
- Ad Hoc Regulations.

3.2 Introduction to UAS Regulatory Framework

Today, civil aviation represents a consolidated, reliable, and efficient means of transportation for goods and people. However, the aeronautics industry is always open to embrace innovations and new technologies. According to the Communication from the Commission to the European Parliament and the Council "A new era for air transport", it is expected that by 2050 many operations, conducted with manned aircraft, will be carried out by unmanned systems. As the UAS market expands, the full potential of these new systems can only be achieved when they are fully integrated into the common airspace. Consequently, a comprehensive and reliable regulatory framework is needed to facilitate the operation of remotely piloted or autonomous systems, ensuring a high level of safety and the protection of the overflown population.

The industry recognizes the primary urgency of establishing a regulatory foundation. Without it, investment in long-term design and production plans that attract investors would be considered useless.

The European strategy aims to create a unified UAS market to maximize its social benefits, while considering public acceptance and security. Progress has already been made in creating a regulatory basis, but due to the rapid evolution of UAS technologies, much work remains to be done. The efforts behind the development of the new regulatory framework also involves stakeholders such as EASA, EUROCAE, JARUS, SESAR, the European Defense Agency, the relevant manufacturing industry, and UAS system operators.

The objective of the following section is to provide the reader with an overview of the European regulatory framework for the UAS sector, by a regulation timeline: from the first initial legislative proposals to the current and future framework.

3.2.1 Regulatory Timeline

Since the first UAS were introduced in the civil market, the European authorities have recognized the necessity of establishing unified to allow the integration of remotely piloted or autonomous aircraft into the common airspace. This section will present the evolution of UAS European regulation provided by EASA, which is the reference Agency for Civil Aviation in Europe and cooperates with all Member States National Authorities and with international bodies to ensure an efficient and safe service.

2002

- ***Basic Regulation (EC) No. 1592/2002-15 July 2002*** **[132]**
  In 2002 (EC) No. 1592/2002 was published as Basic Regulation. It established the European Aviation Safety Agency EASA and laid down "common rules in the field of civil aviation"[25]. This Basic Regulation reports the first reference to UA: it covers the airworthiness and environmental regulation of unmanned aircraft with a maximum take-off mass of 150 kg or above[26] , while regulation of excluded UAS is a responsibility of National Authorities.

[25] European Parliament and the Council. REGULATION (EC) No 1592/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 July 2002 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, 2002, [132]

[26] EASA, Basic Regulation (EC) No. 1592/2002, Article 4 Point (1),(2) p.4 – Annex II Point (g) p. 21 , 15 July 2002, [132]

2005

- ***A-NPA 16/2005-7 November 2005*** [39]
  In 2005 the Advanced-Notice of Proposed Amendment No. 16/2005 was published with the aim of "propose a policy for the certification of UAV (Unmanned Aerial Vehicle) Systems and is a first step towards more comprehensive UAV regulation"[27]. This rulemaking activity was included in the EASA Rulemaking Programme 2005[28] as task number 21.034[29] . The policy aimed to provide a general framework for the certification for UAS, encouraging constructive debates on the development of a comprehensive regulation for unmanned aircraft.

2009

- ***Policy E.Y013-01-25 August 2009*** [56]
  Established as a direct result of A-NPA 16/2005, Policy E.Y013-01 sets general rules for type-certification of an Unmanned Aircraft System and serves as a means to standardize UAS certification procedure, facilitating acceptance of UAS civil airworthiness application and maintain a high unified level of civil aviation safety in Europe. Under this Policy, routine certification of UAS can be conducted based on the existing civil certification, through specific codes of airworthiness requirements to achieve type-certification and obtain Certificates of Airworthiness. At the time of the policy's issuance, the Agency had not yet developed specific Certification Specifications for UAS, hence, it was necessary to determine the UAS type-certification basis by selecting the applicable and equivalent manned CS. The Policy proposed the assessment of kinetic energy as methodology for determine the applicable manned airworthiness code. For example, the Global Hawk, classified as a HALE UAS, has an estimated maximum take-off weight of 11600 kg and a maximum speed of 347 kts, so the CS-25 standard is applicable to this vehicle[30] . Predator RQ-1A is a MALE UAS with a MTOW of 855 kg and maximum speed of 120 kts, so the certification

[27]EASA. A-NPA 16/2005. https://www.easa.europa.eu/en/document-library/ notices-of-proposed-amendment/npa-16-2005, 2005

[28]Attachment to Decision No. 2004/09/RM

[29]Development of civil UAV safety regulation based on the recommendations of the JAA/ EUROCONTROL UAV Task Force

[30]EASA, Policy E.Y013-01, Appendix 1 – Section 3 – Practical examples (a.), p. 16, 25 August 2008, [56]

basis should be the CS-23[31] .

2015

- ***Riga Declaration on Remotely Piloted Aircraft (drones)-6 March 2015* [94]**
  On 6 March 2015 the European Aviation Community gathered in Riga to discuss about the potential of the UAS market and expressed its intention to publish provisions and essential requirements as a progressive risk-based regulation of drones by the end of 2015. The Community acknowledged the importance of new services offered by this emerging UAS technology and confirmed the importance of a joint action to open European market to unmanned aerial vehicles. Additionally, it was emphasized the importance of unified regulation to effectively integrate and operate UAS in common airspace without compromising the level of safety achieved in civil aviation. To address these topics, the Conference established that "drones need to be treated as new types of aircraft with proportionate rules based on the risk of each operation". The Aviation Community requested EASA to issues simple, performance based and globally harmonized rules framework to allow individuals and companies to start low-risk operations and to help the private sector to take investment decisions.

- ***Concept of Operations for Drones-29 May 2015*** [44]
  To achieve integration and acceptance of UAS into aviation system in a safe and proportionate manner EASA published "Concept of Operations for Drones" which can be considered as a "risk based approach to regulation of unmanned aircraft". As reported in EASA's in the brochure published from 2015, Regulations need to be clear, proportionate, progressive and risk based, in order to guarantee safety and environmental protection and to offer enough flexibility for the new industry to evolve. Considering several types of operations and numerous models of UAS available on the market, EASA proposed to group operations in three categories: Open, Specific and Certified.

  - 'Open' Category is designated for the very low risk UAS operations therefore no authorization by an Aviation Authority is required for the flight. To conduct safe light, it is sufficient to define operational limits (e.g. distance from aerodromes, distance form people).

[31]EASA, Policy E.Y013-01, Appendix 1 – Section 3 – Practical examples (b.), p. 16, 25 August 2008, [56]

- ‘Specific’ Category includes operations that do not meet the characteristics of the ‘open’ category and requires a risk assessment that will lead to an Operations Authorization with specific limitations adapted to the operation.

- ‘Certified’ Category is applicable to UAS operations with a level of risk comparable to manned aviation. It requires multiple certificates similar to those required for manned aviation, along with additional specific requirements for unmanned aircraft.

- ***A-NPA 10/2015 and Technical Opinion-31 July/ 18 December 2015*** [40]
  In 2015, EASA published the Advanced-Notice of Proposed Amendment 10/2015, in response to the needs expressed by the European Aviation Community during the Riga Conference. The European Commission assigned EASA the task of developing a regulatory framework for the operation of UAS. The A-NPA includes a draft regulatory framework and proposals for the regulation of low-risk UAS operations to further develop dedicated IRs for open and specific category. The regulatory framework was “proposed to regulate commercial and non-commercial operations as the identical drone might be used for both commercial and non-commercial activities with the same risk to uninvolved parties”[32], and it addresses all UAS, overcoming the limit of 150 kg. It aligns with all the principles laid down in the Riga Declaration and offers an operation-centric and risk based approach by adopting the three category of drones’ ConOps. Unlike the classic approach used for manned aircraft, which seemed not suitable for UAS, the framework takes into consideration the absence of human operators on board, stating that the consequences of a failure or a loss of control are highly dependent on the type of operation and the operating scenario. The level of risk depends on the energy and the complexity of the UAV, the population density of the overflown area, the design of the airspace and density of air traffic. The requirements associated with each category are tailored to the risk of the operation, in a progressive manner. The related Technical Opinion[33] was published in December 2015. It includes 27 concrete proposals for a regulatory framework and for low-risk operations of all unmanned aircraft, regardless of their maximum certified take-off mass.

---

[32]EASA. A-NPA 2015-10,Introduction of a regulatory framework for the operation of drones, "Proposal 1", p.12, 2015, [40]

[33]EASA, Technical Opinion “Introduction of a regulatory framework for the operation of unmanned aircraft”, 18 December 2015

2016

- ***Terms of Reference for rulemaking task RMT.0230 Issue 1-22 December 2016*** [**62**]
  On 22 December 2016 EASA published the Terms of Reference for rulemaking task RMT.0230 Issue 1 titled "Regulatory framework to accommodate unmanned aircraft systems in the European aviation system" with the aim of planning and developing UAS regulations. This Terms of Reference is currently open and is periodically updated. The latest version is Issue 4 published on December 2022. RMT.0230 Issue 1 proposed to establish commons rules for all UAS regardless of their MTOM using an operation-centric and risk based approach, as previously suggested in the Technical Opinion "Introduction of a regulatory framework for the operation of unmanned aircraft" based on A-NPA 10/2015 and on EASA "Concept of Operation for drones". These documents were assumed as a starting point of this rulemaking task . The objectives of the present RMT were as follows:

  - *"To guarantee high and uniform level of safety for UASs;*
  - *To harmonise the regulatory framework in all Member States;*
  - *To foster an operation-centric, proportionate, risk- and performance-based regulatory framework;*
  - *To foster innovation and development in the field of UAS"*[34]

2017

- ***NPA 05/2017 (A) and (B)-4 and 12 May 2017*** [**49**]
  The Basic Regulation (EC) No. 216/2008 does not regulated UAS with a maximum take-off weight of less than 150 kg. This caused a fragmented regulatory system. To address this issue, a new proposed Basic Regulation aimed to the competence of EU to all UAS. In view of the adoption of this new document, the NPA 05/2017 proposed to create a regulation which defines the measures to mitigate the risk of operations in the 'open' and 'specific' category.

[34]EASA. Introduction of a regulatory framework for the operation of unmanned aircraft systems and for urban air mobility in the european union aviation system. Terms of reference for rulemaking task rmt.0230 issue 1, EASA, 2015, [62].

2018

- ***Opinion No. 01/2018-6 February 2018*** [55]
  On 6 February 2018 EASA published Opinion No. 10/2018 as a result of the previous consultation through NPA 05/2017 and was included in RMT.0230 Subtask A1. The Opinion contains two proposed draft regulations: an implementing rule and a delegated act.

- ***Basic Regulation (EU) 2018/1139-4 July 2018*** [131]
  The new Basic Regulation (EU) 2018/1139 was officially adopted in July 2018 and entered into force on 11 September 2018. It covers all unmanned aircraft for non-State operations regardless of the operating mass, remotely piloted aircraft, autonomous aircraft and optionally piloted aircraft.

2019

On 28 February 2019 the EASA Committee has given its positive vote to the European Commission's proposal on EASA's Opinion No. 01/2018 on Implementing Rule and Delegated Act regulating the operations of Unmanned Aircraft Systems in the open and specific categories.

- ***Commission Delegated Regulation (EU) 2019/945-12 March 2019*** [16]
  On 12 March 2019 the Commission Delegated Regulation (EU) 2019/945 on unmanned aircraft systems and on third-county operators of unmanned aircraft systems was adopted. The (EU) 2019/945 :

  - *"regulates the design and manufacturer of unmanned aircraft systems intended to be operated under the rules and conditions defined in Implementing Regulation (EU) 2019/947;*
  - *defines the type of UAS whose design, production and maintenance shall be subjected to certification;*
  - *establishes rules on making UAS intended for use in the 'open' category and remote identification add-ons available on the market and on their free movement in the Union;*
  - *lays down rules for third-country UAS operators, when they conduct a UAS operation pursuant to Implementing Regulation (EU) 2019/947 within the single European sky airspace"*[35].

[35]European Commission. COMMISSION DELEGATED REGULATION (EU) 2019/945 of 12 March

- ***Commission Implementing Regulation (EU) 2019/947-24 May 2019*** **[17]**
On 24 May 2019 the Commission Implementing Regulation (EU) 2019/947 was adopted, establishing the rules and procedures for the operation of unmanned aircraft was adopted. This Regulation lays down detailed provisions for the operation of unmanned aircraft systems as well as for personnel, including remote pilots and organizations involved . It is structured as follows:

    - Cover regulation, which includes 23 Articles;
    - Annex UAS - Subpart A: Open Category;
    - Annex UAS - Subpart B: Specific Category;
    - Annex UAS – Subpart C: LUC.

- ***Opinion 05/2019 - 25 September 2019*** **[54]**
On 25 September 2019 EASA published the Opinion 05/2019. Two new standards scenarios were proposed as a methodology to assist UAS operators to conduct a simplify operational risk assessment before submitting a declaration to the Competent Authority. These scenarios were included in Appendix 1 to the Annex to (EU) 2019/947. Moreover, the Opinion proposed the introduction of two new Parts in the Annex to Commission Delegated Regulation (EU) 2019/945, including the technical requirements that UAS need to meet in order to be operated in the STSs, and establishing two new UAS classes: C5 and C6. These proposals were adopted in Commission Implementing Regulation (EU) 2020/639 of 12 May 2020 amending Implementing Regulation (EU) 2019/947 as regards standard scenarios for operations executed in or beyond the visual line of sight.

- ***AMC and GM to Regulation (EU) 2019/947 - 9 October 2019*** **[43]**
On 9 October 2019 was published the Executive Director Decision 2019/021/R issuing Acceptable Means of Compliance and Guidance Material to Commission Implementing Regulation (EU) No. 2019/947. The new AMC and GM are expected to improve the harmonization of operations with unmanned aircraft within the EU. This rulemaking activity is included under the RMT.0230 subtask A2. The SORA methodology version 2.0 and PDRA-01 to assess the risk of UAS operations are included in AMC and GM to (EU) 2019/947.

2019 on unmanned aircraft systems and on third-country opera- tors of unmanned aircraft systems, Chapter 1 – General Provisions – Article 1, p.6, 2019, [16]

2020

- ***Opinion No. 01/2020 - 13 March 2020*** **[53]**
  On 13 March 2020 EASA published Opinion No. 01/2020. It is included in RMT.0230 as Subtask B1. This Opinion contained a draft regulation to rule the establishment of the U-space[36] airspace[37] and the provisions for U-space services[38] . The primary objective of this document was to create and harmonize the necessary conditions for manned and unmanned aircraft to operate in the U-space airspace[39] prevent collisions between aircraft and mitigate air and ground risk. The issue of a clear and simple regulatory framework for the U-space was to provide safe operations in all areas for all types of unmanned operations.

- ***Commission Implementing Regulation (EU) 2020/746 - 4 June 2020*** **[18]**
  This Regulation (EU) 2020/746 of 4 June 2020 amending Implementing Regulation (EU) 2019/947 postponed the date of application of (EU) 2019/947. Article 1 Point (4)(a) amended Article 23 as: 'It shall apply from 31 December 2020'.

- ***Special Condition for Light Unmanned Aircraft Systems – Medium Risk- 17 December 2020*** **[60]**
  UAS certification is not limited to the 'certified' category, but it can also be required in the 'specific' category for 'medium-risk' and 'high-risk' operations. Regulation (EU) 2019/947 and Regulation 2019/945 define the categorization of UAS operations into three categories. The 'Specific' Category Operations are based on a risk assessment and on operational authorization provided by the Competent Authority. However,

[36]The U-space is a set of new services relying on a high level of digitalization and automation of function and specific procedures, supported by AI, designed to provide safe, efficient and secure access to airspace for large numbers of unmanned aircraft, operating automatically and beyond visual line of sight.] [As such, U-space is an enabling framework designed to facilitate any kind of routine mission, in all classes of airspace and all types of environment - even the most congested - while addressing an appropriate interface with manned aviation and air traffic control.]All UAS operation in the U-space airspace shall be subjected to at least the following mandatory U-space services: (a) the network identification service referred to in Article 8; (b) the geo-awareness service referred to in Article 9; (c) the UAS flight authorization service referred to in Article 10; (d) the traffic information service referred to in Article 11. (EU) 2021/664 Chapter II – Article 3 – Point 2.

[37]'U-space airspace' means a geographical zone designated by Member States, where UAS operations are only allowed to take place with the support of U-space services. (EU) 2021/664 Article 2, Point (1)

[38]'U-space service' means a service relying on digital services and automation of function designated to support safe, secure and efficient access to U-space airspace for a large number of UAS. (EU) 2021/664 Article 2, Point (2)

[39],

there are instances when certification may be necessary. For example, a voluntary certification is always possible or when the Competent Authority does not rely on Operators' declarations for OSOs and mitigations measures a validation of the compliance with the requirements may be required. For this reason, on 7 July 2020 EASA issued a Proposed Special Condition, subsequently on 17 December 2020 the SC-Light UAS-Medium Risk was published. This Special Condition addresses airworthiness specifications for UA operated in the 'specific' category and EASA intends to transpose this SC into CS. The adopted Special Condition restrict the scope to SAIL III and IV (medium-risk) for UAS not intended to transport Humans, with maximum take-off weight up to 600 kg[40] .

2021

- ***Guidelines on Design Verification of UAS operating the 'specific' category and classified in SAIL III and IV-31 March 2021*** [**48**]
  On 31 March 2021 EASA released the Guidelines on Design Verification of UAS operating in the 'specific' category and classified in SAIL III and IV. This document established differences between verification methods of requirements linked to UAS design. Particularly, 'specific' category covers a wide range of UAS operations. Through the SORA application a SAIL is obtained. It refers to the ground and air risk related to the considered operation. In cases of UAS operations in SAIL III and IV, is requested a medium level of robustness of any OSOs linked with the design, mitigation means, and enhanced containments. To demonstrate the UAS compliance with the applicable OSOs, EASA established the Design Verification Report (DVR) as a more appropriate, simplified and flexible method, instead of requiring a type certificate, which is more suitable to high level risk operations. A UAS manufacturer must apply for a DVR using Application form for Unmanned Aircraft System Design Verification.

- ***Commission Implementing Regulation (EU) 2021/664 - 27 April 2021*** [**19**]
  The Opinion No. 01/2020 was adopted in April 2021 with the publication of Commission Implementing Regulation (EU) 2021/664, which provide a regulatory framework for the U-space. This regulation is scheduled to enter into force in January 2023. This

[40]"For UA of higher maximum take-off mass, closer to traditional aircraft or capable of carrying persons the certification basis may be established on the basis of existing manned aircraft CS (CS-23/27, CS-25/29), complemented with appropriate airworthiness standards from a CS-UAS, yet to be created, focused only on UAS-peculiar elements."

Regulation lays down comprehensive rules and procedures for the safe operations and integrations of UAS in the U-space airspace .

- ***NPA 2021/09-14 - July 2021*** [**50**]
  On 14 July 2019 EASA published the Notice of Proposed Amendment 2021/09 to present amendments to some of the existing, as well as introduce new, AMC and GM to Regulation (EU) 2019/947 for example, new AMC and GM determined the definition of 'geographical zones', for STSs, or means to comply with the mitigation requirements to meet the OSOs as defined in SORA.

- ***NPA 2021/14-16- December 2021*** [**51**]
  On 16 December 2021 EASA published the Notice of Proposed Amendment 2021/14 to present AMC and GM to the U-space Regulation . It proposed means to enhance safety in the U-space airspace and improve harmonization. This task is included in RMT.0230 as subtask B1.

- ***Special Condition for Light Unmanned Aircraft Systems – High Risk - 22 December 2021*** [**59**]
  On 22 December 2021 the Special Condition-Light UAS-High Risk was published. It is derived from the SC-Light UAS-Medium Risk, with some modification applied.

2022

- ***NPA 2022/06-30 - June 2022*** [**52**]
  On 30 June 2022 EASA published the NPA 2022/06 to establish a comprehensive regulatory framework to address new innovative technologies like UAS and VTOL aircraft. Related to Unmanned Aircraft Systems, the Notice of Proposed Amendments proposed to develop: - The initial airworthiness of UAS subject to certification; - The continuing airworthiness of UAS subject to certification and operated in the 'specific' category; This task is included in RMT.0230 Issue 3 as subtask C1.

- ***AMC and GM to Implementing Regulation (EU) 2021/664 – Issue 1-20 December 2022*** [**42**]
  On 30 June 2022 was published the Executive Director Decision 2022/022/R issuing Acceptable Means of Compliance and Guidance Material to Commission Implementing Regulation (EU) No. 2021/664 Issue 1, based on NPA 2021/14. This task is included in RMT.0230 Issue 3 Subtask B.

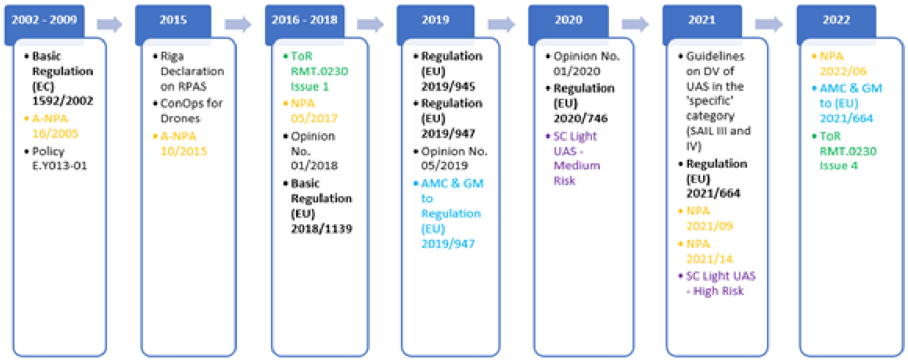


Figure 3.13: EASA regulation timeline

FUTURE TASK [61]

To provide an overview of the EASA rulemaking programme related to UAS, the ToR for rulemaking task 0230 Issue 4 published on 19 December 2022 is taken as a reference. The Annex of this documents contains the Project timeline. The following subtasks are of particular interest.

The Subtask RMT.0230 (C) refers to “Unmanned Aircraft System operations in the ‘certified’ category and urban air mobility” and is currently ongoing([61] Section 4.4). UAS operations in the ‘certified’ category are grouped into three categories:

- *"Type #1: Instrument flight rules (IFR) operations of UAS for the carriage of cargo in airspace classes A–C (ICAO airspace classification) and taking off from and/or landing at aerodromes falling under the Basic Regulation.*
- *Type #2: operations of UAS taking off and/or landing in a congested (e.g. urban) environment using predefined routes in the U-space airspace (part of the operation could be in a non-congested, e.g. rural, environment). These include operations of unmanned VTOL aircraft carrying passengers (e.g. air taxis) or cargo (e.g. goods delivery services).*
- *Type #3: operations: same as for type #2 operations with VTOL aircraft with a pilot on board, including operations out of the U-space airspace".*[41]

[41]EASA. Terms of reference for rulemaking task RMT.0230 - Issue 4, "In- troduction of a regulatory framework for the operation of unmanned aircraft systems and for urban air mobility in the European Union aviation system", Section 4.4, p.8, 2022

EASA has planned to publish three Opinions and their related Decision. The first Opinion has not yet been published but the related NPA was issued on 30 June 2022 . Subsequent Opinions will address the UAS 'certified' operations of the Type #1 and Type#3, while related Decisions will cover the publication of AMC and GM.

Table 3.1: RTM.0230 subtask C Timeline, (Source: EASA. Terms of reference for rulemaking task RMT.0230 - Issue 4,p.16, 2022, [61])

RMT.0230 subtask		Subject	Proposed amendment/ new rule	Input form	NPA publication date	Opinion/ Decision publication date
A	1	UAS operations in the 'open' and 'specific' categories	New	EASA ConOps	4.5.2017	Opinion No 01/2018 No 02/2018
A	2	AMC and GM for UAS in the 'open' and 'specific' categories	New	JARUS SORA & stakeholders	4.5.2017	ED Decision 2019/021/R 9.10.2019
B	1	U-space and airspace integration	New	N/a	N/a	Opinion No 01/2020 13.3.2020
B	2	AMC and GM for U-space and airspace integration	New	N/a	16.12.2021	Decision 2022/Q4
C	1	Manned VTOL and UAM (type 3 operations) IAW & CAW for certified UAS operated in the 'specific' category (high risk)	New/amend: Part 21 Part IAM Part ARO Part ORO Part SPA Part FCL SERA DA/IA CAW	stakeholders	30.06.2022	Opinion 2023/Q2
C	2	UAS operations in the 'certified' category and manned VTOL and UAM (type 1 and type 3 operations)	New/amend: DA CAW Part RPL Part CAT Part ARO Part ORO Part ARA Part ORA Part FCL Part MED SERA Part ATS Part ADR	stakeholders, ICAO	2024/Q3	Opinion 2025/Q3

The subtask RMT.0230 (D) refers to "Certification Specifications for Unmanned Aircraft Systems (CS-UAS and CS-Light UAS), Certification Specifications for vertical take-off and landing aircraft (CSVTOL), and CS-ETSO" and it is currently in the planning phase ([61], Section 4.5). EASA will issue new airworthiness Certification Specifications for UAS, based on the first deliverable of the JARUS:

- *"Certification Specification for Unmanned Aircraft System (CS-UAS): containing requirements for the specific systems of UAS (e.g. command unit, command and control link, etc.);*
- *Certification Specification for Light Unmanned Aircraft System (CS-Light UAS): containing requirements for small UAS for which equivalent manned-aircraft requirements are not available"*[42].

Table 3.2: RTM.0230 subtask D Timeline, (Source: EASA. Terms of reference for rulemaking task RMT.0230 - Issue 4, p.17, 2022 [61])

RMT.0230 subtask		Subject	Proposed amendment/ new rule	Input form	NPA publication date	Opinion/ Decision publication date
D	1	CS-UAS	New	JARUS CS-UAS JARUSAMC.RPAS.1309 EUROCAE	2025/Q3	Decision 2026/Q1
	2	CS-Light UAS	New	JARUS CS-LURS JARUS CS-LUAS	2025/Q3	Decision 2026/Q1

As a consequence of the integration of UAS within the common airspace and in the Regulatory Framework, EASA proposes the development of the Urban Air Mobility. It is expected to become a reality in Europe within 3-5 years. It represents a new air transportation system for passengers and cargo in and around densely populated and built environments. It will employ vertical take-off and landing electric aircraft with a pilot on board or remotely piloted. In addition, by 2035 it is expected to realize the first cargo international flight without pilot on board will be realized.

[42]EASA. Terms of reference for rulemaking task RMT.0230 - Issue 4, "Introduction of a regulatory framework for the operation of unmanned aircraft systems and for urban air mobility in the European Union aviation system", p.6, 2022, [61]

3.3 How to operate a 'Specific' Category UAS?

The timeline proposed in the previous section highlights how UAS regulation framework is not complete but it is enriching with new regulations, standards and documents as UAS evolve. Although unmanned aerial vehicles are not a new technology, the expansion of this market especially in the civil field is a recent phenomenon. Thus, the need to integrate UAS into the existing aviation system, in order to promote the development of the European drone industry, arises. The first step to achieve this aim is to create a regulatory framework that is as unified as possible between Member States, taking into consideration not only the needs of the Industry but also the safety of operations and an acceptable level of environmental protection to the society. In 2018, the new Basic Regulation (EU) 2018/1139 was issued, extending its scope to all unmanned aircraft: "Since unmanned aircraft also operate within the airspace alongside manned aircraft, the Regulation should cover unmanned aircraft, regardless of their operating mass"[43]. However, due to their features, remotely piloted systems cannot be considered as other general aviation aircraft and included in the common space simply by applying existing rules. Indeed, the main characteristics of UAS is the absence of personnel and crew on board and the wide variety of operations that can be conducted. Consequently, the risk associated with a UAS operation depends on the characteristics of the used aircraft and the operational scenario. Thus, regulations have to be proportionate, progressive, and risk-based.

"Technologies for unmanned aircraft now make possible a wide range of operations and those operations should be subject to rules that are proportionate to the risk of the particular operation or type of operation".[44]

As previously mentioned, in 2015 EASA proposed a classification of UAS according to operational risk defining the three categories: 'open', 'specific', and 'certified', and their associated regulatory regime. The technical characteristics and operational limitations of these categories have already been explained in Chapter 2, Section 2.3. So this section will focus mainly on formal procedures needed to conduct operations in the 'specific' category which is the UAS class of main interest for this study.

According to Point (5) of the Cover Regulation to Implementing Regulation (EU) 2019/945 *"the rules and procedures applicable to UAS operations should be proportionate to the*

[43]European Parliament and the Counci. REGULATION (EU) 2018/1139 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2018, Point (26), p. 2, 2018

[44]European Parliament and the Counci. REGULATION (EU) 2018/1139 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2018 , Point (26), p. 2, 2018

nature and risk of the operation or activity and tailored to the operational characteristics of the unmanned aircraft involved and the characteristics of the operational area, such as population density, surface characteristics and the presence of buildings"[45]. The 'specific' category covers operations that do not meet the characteristics of the open category. The risk associated with this type of operation is higher than the danger posed by an 'open' category mission. However, 'specific' category operations do not require a safety level equal to manned aviation or the UAS certification as required in the 'certified' category.

Article 7 of Implementing Regulation (EU) 2019/947 set out that *"UAS operations in the 'specific' category shall comply with the operational limitations set out in the operational authorization as referred to in Article 12 or the authorization as referred to in Article 16, or in a standard scenario defined in Appendix 1 to the Annex as declared by the UAS operator"*[46]. As a rule to conduct 'specific' category operations, the UAS operator has to obtain an operational authorization from the National Aviation Authority before starting the flight/s ([16], Article 5). It includes the main information about the operation/s intended to be approved such as the scope of the authorization, the conditions under which the operation can be conducted (operational limitations), the technical features and performances of UAS, the required skills of the operator of the remote pilots, etc ([17], Article 12). The competent authority grants the authorization if the operational scenario, the mitigation measures proposed by the applicant to reduce the risk, the competence of the personnel involved and the technical characteristics and performance of the unmanned aircraft are suitable to conduct operation safely ([17], Article 12).

In special cases, the application for an operational authorization is not required. The operator can follow simplified procedures to obtain operational approval by the competent authority. The operational authorization is not needed if the operation is compliant with a standard scenario[47]. In this case the operator can submit a declaration to the competent authority in accordance with point UAS.SPEC.020[48] laid down in Part B of the Annex to Regulation (EU) 2019/947. Moreover, authorization and declaration are not required if the UAS operator holds a LUC with appropriate privileges in accordance with Part C

[45]EASA, Easy Access Rules for Unmanned Aircraft Systems, Cover Regulation to Implementing Regulation (EU) 2019/947, Point (5) p. 17, 2022

[46]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU) 2019/947, Article 7, Point (2) p. 32, 2022

[47]Standard Scenarios are defined in Appendices to Annex to Implementing Regulation (EU) 2019/947

[48]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU) 2019/947, Article 5, Point (5), p. 30, 2022

of the Annex to Regulation (EU) 2019/947 or if the operation is conducted in a model aircraft clubs or associations[49].

The application for an operational authorization shall include:

(a) *“the registration number of the UAS operator;*

(b) *the name of the accountable manager or the name of the UAS operator in the case of a natural person;*

(c) *the operational risk assessment;*

(d) *the list of mitigation measures proposed by the UAS operator, with sufficient information for the competent authority to assess the adequacy of the mitigation means to address the risk;*

(e) *an operations manual when required by the risk and complexity of the operation;*

(f) *a confirmation that an appropriate insurance cover will be in place at the start of the UAS operations, if required by Union or national law”*[50].

The basis of the operational authorization is the operational risk assessment: “the operator shall perform a risk assessment in accordance with Article 11 and submit it together with the application”[51]. So, EASA proposes three different approaches to conduct risk analysis([46], GM1 AMC1 Article 11). The operational risk assessment may be conducted using the SORA process: the Specific Operation Risk Assessment developed by JARUS. This approach is one of the main topics of this study and it will be analyzed in detail in Chapter 5. Alternatively, UAS operators can use the following alternative methods:

- Standard Scenarios (STS);
- Predefined Risk Assessment (PDRA).

Standard Scenarios are the simplest methodology to evaluate risk, because under these conditions the risk analysis is already defined. Currently, in Europe, there are only two standard scenarios approved, whose limitations are quite severe and similar to those imposed in the ’open’ category. The following general provisions apply to both scenarios:

[49]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU) 2019/947, Article 5, Point (6), p.30

[50]EASA, Easy Access Rules for Unmanned Aircraft Systems, Part B of Annex to Implementing Regulation (EU) 2019/947, UAS.SPEC.030, Point (3), p.276, 2022

[51]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU) 2019/947, Article 5, Point (2), p. 30, 2022

1. *"during flight, the unmanned aircraft shall be maintained within 120 m from the closest point of the surface of the earth. The measurement of distance shall be conducted as indicated for 'open' category;*

2. *when flying an unmanned aircraft within a horizontal distance of 50 m from an artificial obstacle taller than 105 meters, the maximum height of the UAS operation may be increased up to 15 m above the height of the obstacle at the request of the entity responsible for the obstacle;*

3. *the maximum height of the operational volume shall not exceed 30 m above the maximum height allowed in points (1) and (2);*

4. *during flight, the unmanned aircraft shall not carry dangerous goods*"[52]

The first scenario includes "VLOS over a controlled ground area in a populated environment"[53] operations. These type of operations may be performed with an unmanned aircraft marked as class C5 and operated with an active and updated direct remote identification system. Operations must be conducted with the UA kept in VLOS at all times, and it can overflow a controlled ground area that might be located in a populated area. Airspace must be controlled or uncontrolled, with a low risk of encounter with manned aircraft. ([17], Appendix I, Chapter I))

The second scenario includes "BVLOS with airspace observers over a controlled ground area in a sparsely populate environment"[54] operations. This type of operation can be conducted with an unmanned aircraft which is marked as class C6[55], with an active system to prevent unmanned aircraft from breaching the flight geography and operated with active and updated direct remote identification system. Operations can be performed over a controlled ground area that is entirely located in a sparsely populated area. Flights are conducted in BVLOS. If no airspace observer is used, the unmanned aircraft shall not fly further than 1 km from the remote pilot. Conversely, if one or more airspace observers are used the UA can be operated within 2 km from the remote pilot and no further than 1 km from the observer. Airspace must be controlled or uncontrolled, with a low risk of encounter with manned aircraft.([17], Appendix I, Chapter II)

[52]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU) 2019/947, Appendix 1 to Annex to Implementing Regulation (EU)2019/947, Chapter I, UAS.STS-01.010 and Chapter II, UAS.STS-02.020, p.356, 366, 2022

[53]All provisions for STS-01 are reported in CHAPTER I Appendix 1 to Annex to Implementing Regulation (EU) 2019/947, 2022

[54]All provisions for STS-02 are reported in CHAPTER II Appendix 1 to Annex to Implementing Regulation (EU) 2019/947, 2022

[55]As defined in Part 17 of the Annex to Delegated Regulation (EU) 2019/945

Table 3.3: List of STSs published as 'Appendix 1 for standard scenario supporting a declaration to the Annex to the UAS Regulation (Source: EASA, Easy Access Rules for Unmanned Aircraft Systems, Implementing Regulation (EU) 2019/947, GM1 AMC1 Article 11, p.38, 2022)

STS	Date	UAS characteristics	BVLOS/ VLOS	Overflown area	Max range from remote pilot	Max height
STS-01	June 2020	Bearing a C5 class marking (maximum characteristic dimension of up to 3 m and MTOM of up to 25 kg)	VLOS	Controlled ground area that might be located in a populated area	VLOS	120m
STS-02	June 2020	Bearing a C6 class marking (maximum characteristic dimension of up to 3 m and MTOM of up to 25 kg)	BVLOS	Controlled ground area that is entirely located in a sparsely populated area	2km with an AO, 1km if no AO	120m

As previously said, if the UAS operation is compliant with standard scenario provisions the application for an operational authorization is not required. In this case, the operator shall submit a declaration to the competent authority. The NAA shall verify the declaration's validity and subsequently provide the UAS operator with a confirmation.

Predefined Risk Assessments are simplified risk analyses compared to the process provided by the SORA methodology. PDRAs are defined in a more generic way compared to STS, "to provide flexibility to UAS operators and competent authorities to establish more prescriptive limitations and provisions"[56] tailored to intended operation needs. Five PDRAs are currently approved. They can be divided into two groups:

[56]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU)2019/947, GM1 AMC1 Article 11, p. 37-40, 2022

- those derived from an STS, which allow the UAS operator to conduct similar operations but with some variations, for example, using a UAS without the class label that is mandatory for a STS. This type of PDRA is indicated with the letter 'S' to underline that it is derived from an STS and it has a corresponding level of prescriptiveness;
- generic PDRAs, indicated with the letter 'G'.

Table 3.4 provides a summary of PDRAs.

Table 3.4: List of PDRAs published as AMC to Article 11 of the UAS Regulation (Source: EASA, Easy Access Rules for Unmanned Aircraft Systems, Implementing Regulation (EU) 2019/947, GM1 AMC1 Article 11, p.40, 2022)

STS	Date	UAS characteristics	BVLOS/ VLOS	Overflown area	Maxi range from remote pilot	Maxi height
PDRA S01	Jan 2022	Maximum characteristic dimension of up to 3 m and take-off mass of up to 25 kg	VLOS	Controlled ground area that might be located in a populated area	VLOS	150m
PDRA S02	Jan 2022	Maximum characteristic dimension of up to 3 m and take-off mass of up to 25 kg	BVLOS	Controlled ground area that is entirely located in a sparsely populated area	2km with an AO, 1km if no AO	150m
PSRA G01	Jan 2022	Maximum characteristic dimension of up to 3 m and typical kinetic energy of up to 34 kJ	BVLOS	Sparsely populated area	If no AO, up to 1 km	150m

Continued on next page

Table 3.4: List of PDRAs published as AMC to Article 11 of the UAS Regulation (Source: EASA, Easy Access Rules for Unmanned Aircraft Systems, Implementing Regulation (EU) 2019/947, GM1 AMC1 Article 11, p.40, 2022) (Continued)

PDRA G02	Jan 2022	Maximum characteristic dimension of up to 3 m and typical kinetic energy of up to 34 kJ	BVLOS	Sparsely populated area	n/a (direct C2 link)	As established for the reserved or segregated airspace
PDRA 603	Jan 2022	Maximum characteristic dimension of up to 3 m and typical kinetic energy of up to 34 kJ	BVLOS	Sparsely populated area	n/a (direct C2 link)	50m from ground unless in reserved or segregated airspace

By using a Predefined Risk Assessment, UAS operations that are subject to operational authorizations can benefit from a simplified authorization process compared to SORA process application.([46],GM1 AMC1 Article 11, p. 37-40)

Furthermore, for 'specific' category operations, the requirements for operational authorization or the declaration are waved for UAS operators holding a LUC with appropriate privileges in accordance with UAS.LUC.060 of Part C of the Annex to Implementing Regulation (EU) 2019/947. UAS operators may decide to apply for a LUC. A LUC holder is a UAS operator capable of autonomously evaluating operational risk([46], Annex to IR (EU)2019/947, Part C). Upon obtaining the LUC from the competent authority on the presented evidence, the holder should be able:

(a) *"without prior declaration to the competent authority, to authorize its own operations based on an STS; and*

(b) *without prior approval of the competent authority, to authorize one or more of the following types of own operations:*

   (1) *one based on a PDRA that requires an authorization;*

   (2) *one based on one or more modifications of an STS (variants), which does not involve changes in the ConOps, the category of UAS used or the competencies of the remote pilots; or*

(3) *one that does not correspond to a PDRA, but falls within a type of activity already"*[57]

3.3.1 The SORA Process

As explained in Section 2.4.2, an operator needs to obtain an operational authorization from the Competent Authority to conduct 'specific' category operations, pursuant to Article 12 of (EU) 2019/947. A risk assessment is required to submit the authorization in accordance with Article 11 "Rules for conducting an operational risk assessment" of (EU) 2019/947. It sets that the *"operational risk assessment shall:*

(a) *Describe the characteristics of the operation;*

(b) *Identify the risks of the operation on the ground and in the air;*

(c) *Identify a range of possible risk mitigating measures;*

(d) *Determine the necessary level of robustness of the selected mitigating measures in such a way that the operation can be conducted safely; and,*

(e) *Propose adequate operational safety objectives"*[58]

To help Applicants, EASA provides recommended risk analysis methodologies such as standard scenarios, pre-defined risk assessment and the SORA Process. STSs and PDRAs are simplified methods applicable to special operations. This section will focus on the SORA Process, published by JARUS assumed by EASA as an acceptable means of compliance for the risk assessment. Actually version 2.0 is on force, so a detailed description of this edition will be presented. However, JARUS has already started to work on version 2.5. SORA 2.5 is currently under revision and it is planned to be published in 2024. This new version will be introduced in Section 3.3.3.

Before introducing the description of the SORA 2.0 Process, it is necessary to present two key concepts that represent the foundation basis of the method: risk and robustness.

What is the risk?
In literature, many definitions of the word "risk" are available. For example, the magazine

[57]EASA, Easy Access Rules for Unmanned Aircraft Systems, Annex to Implementing Regulation (EU) 2019/947, Part C, AMC1 UAS.LUC.060 Privileges of an LUC holder, p.354, 2022

[58]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU) 2019/947, Article 11, Point (1), p. 34, 2022

"Sicurezza del Volo" N° 339 published by the Italian Military Aeronautics, reports the following examples of definitions:

i. Annex 19 to the Chicago Convention defines risk as "The predicted probability and severity of consequences or effects of a hazard"[59].

ii. NATO STANAG 7160 defines risk as " The chance of injury or loss as defined by a measure of the probability and severity of an effect adverse to health, property or other things of value"[60]

The SORA methodology assumes as "risk" definition the one "provided in the SAE ARP 4754A / EUROCAE ED-79A: "The combination of the frequency (probability) of an occurrence and its associated level of severity"[61] . The consequence of an occurrence is defined as a harm, and the SORA process treats only "short-lived and usually give rise to near loss of life"[62] harms, such as fatal injuries to third parties on the ground and in the air, or damage to critical infrastructure.

What is the robustness?

Any risk mitigation measure and operational safety objective should be applied and demonstrated at different levels of robustness, commensurate with risk. The SORA proposes three levels of increasing robustness: Low, Medium and High.

Each level of robustness is achieved by evaluating the levels of integrity and assurance. The term integrity refers to the level of safety gained, while the term assurance refers to the method of proof that the integrity level has been achieved.

The levels of assurance are defined as follows:

(a) *"A low level of assurance is where the applicant simply declare that the required level of integrity has been achieved;*

(b) *A medium level of assurance is where the applicant provides supporting evidence that the required level of integrity has been achieved. This is typically achieved by means of*

[59]ICAO, Annex 19 to the Convention on International Civil Aviation, 'Safety Management', p.1-2, July 2013

[60]NATO, STANAG 7160 Edition A Version 1 paragraph 9.4.13, Aviation Safety, 2018

[61]JARUS, JARUS guidelines on Specific Operation Risk Assessment (SORA), Chapter 2 "The SORA Process", Section 2.1, Point (a), p.17, 2019

[62]JARUS, JARUS guidelines on Specific Operation Risk Assessment (SORA), Chapter 2 "The SORA Process", Section 2.1, Point (c), p.17, 2019

testing (e.g. technical mitigations) or by proof of experience (e.g. for human-related mitigations);

(c) *A high level of assurance is where the achieved integrity has been found acceptable by a competent third party"*[63]

To find the right level of robustness, the following table is provided.

Table 3.5: Determination of Robustness Level, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.15, 2019,[101])

	Low Assurance	Medium Assurance	High Assurance
Low Integrity	Low Robustness	Low Robustness	Low Robustness
Medium Integrity	Low Robustness	Medium Robustness	Medium Robustness
High Integrity	Low Robustness	Medium Robustness	High Robustness

What is SORA 2.0?

SORA 2.0 means Specific Operation Risk Assessment. It is a methodology for the classification of the risk posed by a UAS flight in the specific category and guides both the applicant and the competent authority in determining if an operation can be conducted safely. It does not contain prescriptive requirements but it is a "tailored guide" useful to identify mitigations and safety objectives to be met a various levels of robustness, to reduce risk to an acceptable level.

The SORA 2.0 is a 10 steps process. It starts with the description of the operations. Then the ground and the air risk are evaluated. Both depend on the characteristics of the operational scenario. The ground risk is the risk to which persons, properties and critical infrastructures are subjected to during a drone operation. The air risk represents the encounter rate between a UAS and a manned aircraft in the common airspace. After the identification and application of adequate mitigation measures, the SAIL (Specific assurance integrity level) is defined. Subsequently, the applicant has to show compliance with the 24 OSOs (Operational Safety Objectives) with a level of robustness derived from

[63]JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 1 "Introduction", Section 1.4.2, Point (d), p. 14, 2019

the SAIL. Finally, the level of risk of the area adjacent to the area of operation has to be defined.

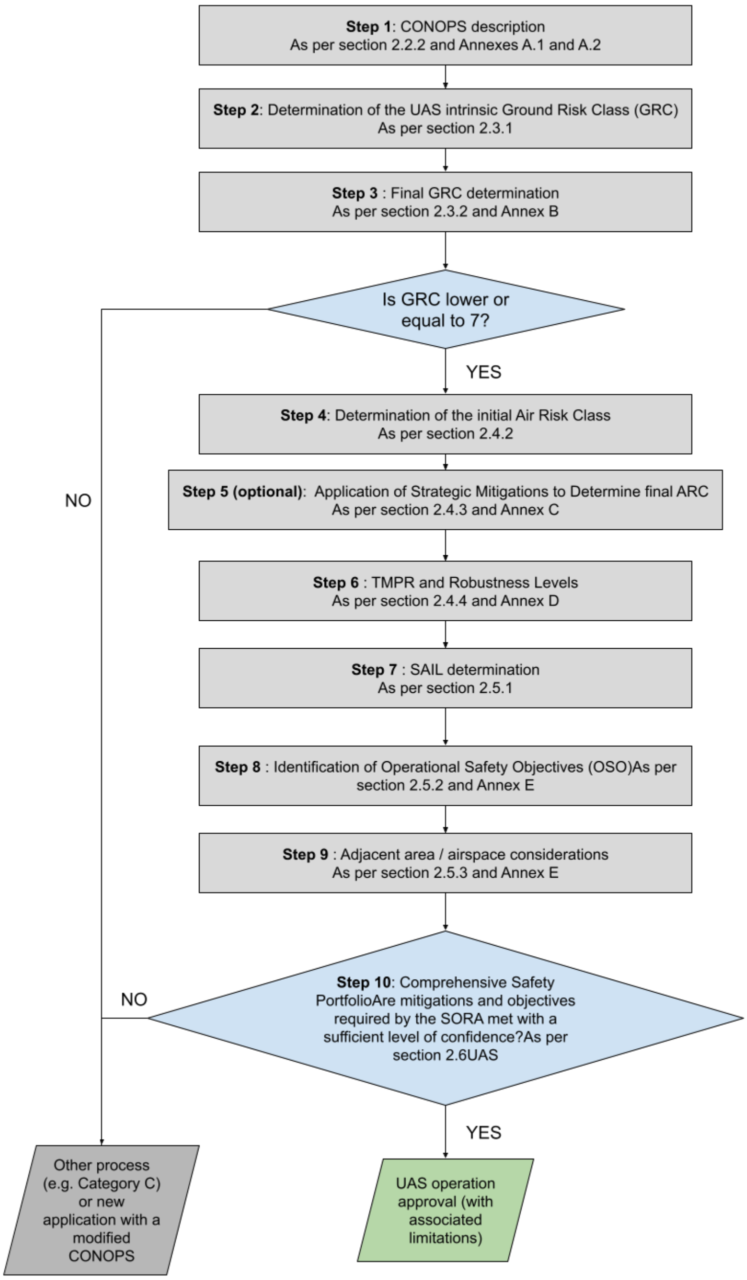


Figure 3.14: The SORA process Outline, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.18, 2019, [101])

This methodology is suited to be applied to specific category operations, but can be adapted to UAS of any class, size and type of operation for which a risk assessment is required. However, the SORA does not cover UAS dedicated to carry people or dangerous payloads, or the risk of collision between two unmanned aircraft or between a UA and a UA carrying people. In addition, security, privacy and financial aspects are excluded from the applicability of this methodology. The SORA Process is released with the following annexes.

Table 3.6: List of Annexes, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.10, 2019, [101])

Title	**Version/Status**
Annex A: ConOps Guidelines on collecting and presenting system and operation information for a specific UAS operation	1.0
Annex B: Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Classes	1.0
Annex C: Strategic Mitigation Collision Risk Assessment	1.0
Annex D: Tactical Mitigations Collision Risk Assessment	1.0
Annex E: Integrity and assurance levels for the Operational Safety Objectives (OSO)	1.0
Annex F: Supporting data for the Air Risk Model	In preparation
Annex G: Supporting data for the Air Risk Model	In preparation
Annex H: Unmanned Traffic Management (UTM) implications to SORA	In preparation
Annex I: Glossary	1.0
Annex J: Guidance to Regulators, ANSPs, and Other Third Parties	In preparation

Semantic Model

The methodology requires standardized use of terminology. A glossary providing most used abbreviations and definitions related to SORA is provided in the section "Definitions". In addition, the semantic model, proposed in the SORA documents, is reported below as a further aid to understanding the used terminology.

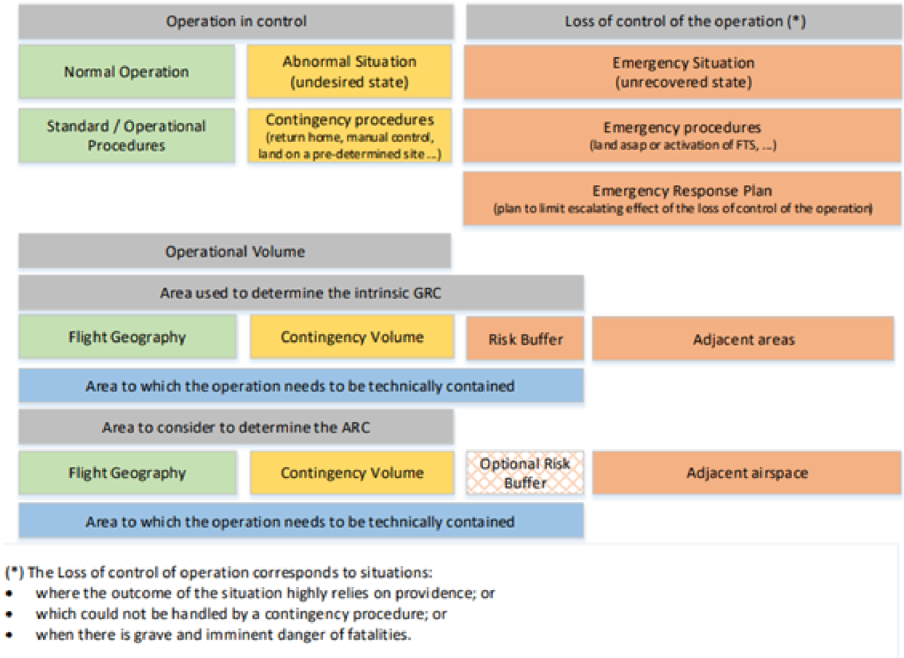


Figure 3.15: SORA Semantic Model part 1, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.13, 2019, [101])

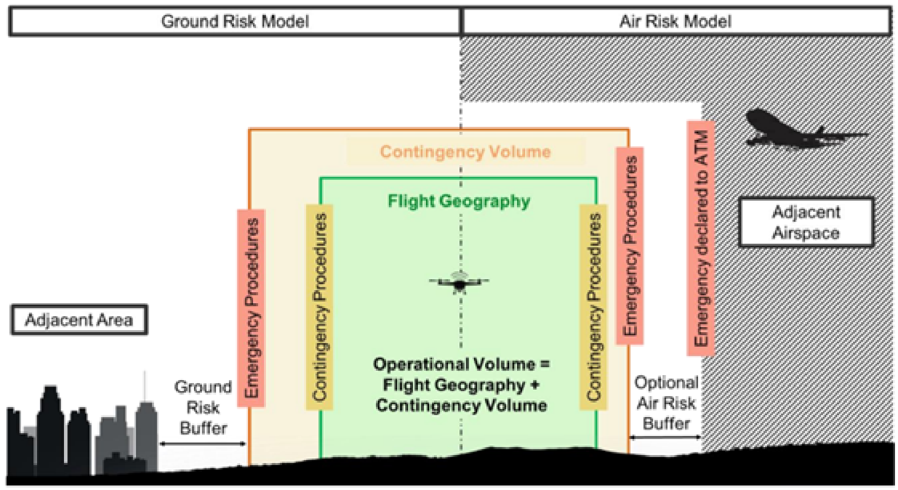


Figure 3.16: SORA Semantic Model part 2, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.14, 2019, [101])

3.3.2 SORA 2.0 Process Outline

Before starting the SORA process, it is necessary to verify if the proposed operation is feasible and if it can be subjected to this type of risk assessment or if exists a more suitable process to evaluate the hazard of the activities.
"*The applicant should verify:*

- *If the operation falls under the "open" category;*
- *If the operation is covered by a "standard scenario" recognized by the competent authority;*
- *If the operation falls under the "certified" category;*
- *If the operation is subject to specific NO-GO from the competent authority;*
- *If the competent authority has determined that the UAS is "harmless" for the ground risk."* [64]

The SORA process should be applied, if none of the previous conditions are applied.

Step#1 - ConOps Description

In accordance with GM1 AMC1 to Article 11 the ConOps description is the foundation for all other activities, so it should be as accurate as possible. Article 11 establishes that:

"*The description of the UAS operation shall include:*

(a) *the nature of activities;*

(b) *the operational environment and geographical area for the intended operation, in particular overflown population, orography, types of airspace, airspace volume where the operation will take place and which airspace volume is kept as necessary risk buffers, including the operational requirements for geographical zones;*

(c) *the complexity of the operation, in particular which planning and execution, personnel competencies, experience and composition, required technical means are planned to conduct the operation;*

[64] JARUS, JARUS guidelines on Specific Operation Risk Assessment (SORA), Chapter 2 "The SORA Process", Section 2.2.1, p.19, 2019

(d) *the technical features of the UAS, including its performance in view of the conditions of the planned operation and, where applicable, its registration number;*

(e) *the competence of the personnel for conducting the operation including their composition, role, responsibilities, training and recent experience"*[65]

Annex A "Guidelines on collecting and presenting system and operation information for a specific UAS operation"[66] of the SORA provides a detailed framework for data collection and presentation.

Risk Identification
As indicated in Article 11 Point (1)(c), the ground and the air risk are determined by considering:

(a) *"the extent to which third parties or property on the ground could be endangered by the activity;*

(b) *the complexity, performance and operational characteristics of the unmanned aircraft involved;*

(c) *the purpose of the flight, the type of UAS, the probability of collision with other aircraft and class of airspace used;*

(d) *the type, scale, and complexity of the UAS operation or activity, including, where relevant, the size and type of the traffic handled by the responsible organization or person;*

(e) *the extent to which the persons affected by the risks involved in the UAS operation are able to assess and exercise control over those risks"*[67].

The Ground Risk Process

The Ground Risk Class is related to the risk posed to persons, properties or critical infrastructures being struck by a drone. This evaluation takes into account third parties

[65]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU) 2019/947, Article 11, Point (2), p. 35, 2022, [46]

[66]JARUS. JARUS guidelines on SORA - Annex A – Guidelines on collecting and presenting system and operation information for a specific UAS operation. Annex JAR-DEL-WG6-D.04_A, JARUS, 2019, [102]

[67]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU) 2019/947, Article 11, Point (1)(c), p. 34, 2022, [46]

or properties on the ground that could be endangered by flight activities, but also the complexity, operational and technical characteristics of the unmanned aircraft. At first, the intrinsic GRC is determined, then after the application of the mitigations, the residual GRC is evaluated.

Step#2 - Determination of the intrinsic UAS Ground Risk Class (GRC)

Table 3.7 provides guidelines to determine the intrinsic GRC. To evaluate the GRC the type of operation, the operational scenario and the UA characteristics dimension must be known. The GRC is found at the intersection of the applicable operational scenario and the maximum UA dimensions.

Table 3.7: iGRC Determination, (Source: JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, Main Body, p.20, 2019, [101])

Intrinsic UAS Ground Risk Class				
Max UAS characteristics dimension	1 m / approx. 3ft	3 m / approx. 10ft	8 m / approx. 25ft	8 m / approx. 25ft
Typical kinetic energy expected	700 J (approx. 529 Ft Lb)	34 KJ (approx. 25000 Ft Lb)	1084 KJ (approx. 800000 Ft Lb)	1084 KJ (approx. 800000 Ft Lb)
Operational scenarios				
VLOS/BVLOS over controlled ground area	**1**	**2**	**3**	**4**
VLOS in sparsely populated environment	**2**	**3**	**4**	**5**
BVLOS in sparsely populated environment	**3**	**4**	**5**	**6**
VLOS in populated environment	**4**	**5**	**6**	**8**
BVLOS in populated environment	**5**	**6**	**8**	**10**
VLOS over gathering of people	**7**			
BVLOS over gathering of people	**8**			

The unmanned aircraft's maximum dimension is assumed as the wingspan for fixed wing vehicles, or as the blade diameter for rotorcraft. It is also considered the typical kinetic energy which is evaluated by the formula[68] reported in the E.Y013-01 Policy[56].

The Operational Volume is essential to estimate the population density of the interest area. As reported in the Semantic Model, the operational volume includes:

- Flight Geography, which is “the area where the UAS should fly in normal conditions”[69];
- Contingency Volume, which is the area where the unmanned vehicle “may fly in case of abnormal conditions”[70]. There the remote pilot has to execute the contingency procedures to return immediately in the flight geography.

In addition, the Ground Risk Buffer is necessary to determine the iGRC. The Ground Risk Buffer[71] is the limited area where the UA has to be contained and end its flight in the case of a loss of control.

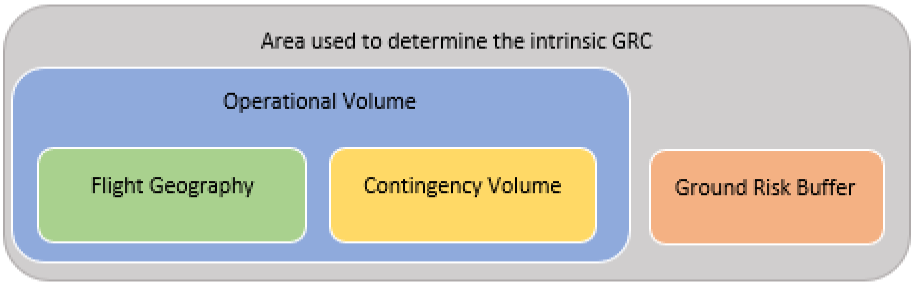


Figure 3.17: iGRC Footprint, (Source: EASA, SORA Workshop from version 2.0 to 2.5 (SORA), Documents after event "2 SORA", slide 19,February 2023)

[68] $KineticEnergy = (Mass(kg)xVelocity(kt)^2)/10^9$
$ForAirplanesV = 1.4xV_mo(themaximumoperatingspeed)$
$ForRotorcraftV = Terminalvelocitywithrotorsstationary$
EASA, Policy E.Y013-01, Appendix 1, p. 13-14, 2009

[69] EASA, SORA Workshop from version 2.0 to 2.5 (SORA), Documents after event "2 SORA", slide 15, February 2023, [58]

[70] EASA, SORA Workshop from version 2.0 to 2.5 (SORA), Documents after event "2 SORA", slide 16, February 2023, [58]

[71] The ground risk buffer can be determine through two criteria:

- 1:1 distance (if the UA is planned to operate at 150 m altitude, the ground risk buffer should at least be 150 m)
- Ballistic descend

EASA, SORA Workshop from version 2.0 to 2.5 (SORA), Documents after event "2 SORA", slide 17-18,February 2023

The overflown area can be classified progressively based on the increasing number of people at risk, as follows:

- controlled ground area[72];
- sparsely populated environment;
- populated environment[73];
- gathering of people.

The determination of population density is not yet standardized between the different EASA Member States. The Agency is currently working on a unique dynamic population density map service, but today each State may indicate one or more sources. In the absence of a specific direction, the EASA Workshop on SORA indicates the Global Human Settlement as a reference service.

Finally, type of the operation has to be considered. In Visual-Line-of-Sight, the Pilot in Command maintains the UAS close enough to be capable of seeing the aircraft without vision aids or other devices. BVLOS operations are flights without the direct visual supervision of the aircraft by the PIC. VLOS operations are typically safer than BVLOS operations. EVLOS[74] operations are to be considered as BVLOS for the GRC determination.

Step#3 - Final GRC Determination

The intrinsic Ground Risk Class can be lowered by means of mitigations. Mitigations can reduce the consequences of the impact of the UAS on the ground in the event of a loss of control.

[72]"A controlled ground area is an area where only active participants are involved." JARUS, JARUS guidelines on Specific Operation Risk Assessment (SORA), Chapter 2, Section 2.3.1, Point (h), p. 20, 2019, [101]

[73]"A 'populated area' should be understood as 'congested area', as defined in Regulation (EU) No 965/2012 (the 'Air Operations Regulation'): 'in relation to a city, town or settlement, any area which is substantially used for residential, commercial or recreational purposes'". EASA, Easy Access Rules for Unmanned Aircraft Systems, GM1 AMC1 Article 11, p. 40, 2022, [46]

[74]"EVLOS - An Unmanned Aircraft System (UAS) operation whereby the Pilot in Command (PIC) maintains an uninterrupted situational awareness of the airspace in which the UAS operation is being conducted via visual airspace surveillance through one or more human observers, possibly aided by technology means. The PIC has a direct control of the UAS at all time" JARUS, JARUS guidelines on SORA, Annex I, Glossary of Terms, p. 8, 2019, [107]

JARUS identified three means of mitigation. They have to be applied in numeric sequence to perform the assessment. Table 4 shows the list of mitigations for the ground risk, associated with the relative correction factor to be applied to the intrinsic Ground Risk Class. A proposed mitigation may or not have a positive effect on reducing the ground risk associated with the given operation. If the correction factor is a positive value, the applied mitigations increase the GRC, whereas a negative number results in a decrease in the GRC.

Table 3.8: Mitigations for Final GRC determination, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.21, 2019, [101])

		Robustness		
Mitigation Sequence	**Mitigations for ground risk**	Low/None	Medium	High
1	M1 - Strategic mitigations for ground risk	**0: None -1:Low**	**-2**	**-4**
2	M2 – Effects of ground impact are reduced	**0**	**-1**	**-2**
3	M3 – An Emergency Response Plan (ERP) is in place, operator validated and effective	**1**	**0**	**-1**

- M1 - Strategic mitigations for ground risk
  Strategic mitigations "reduce the number of people at risk on the ground"[75] . To define M1 mitigations, and the associated level of robustness, two criteria are taken into account:
    - Criterion #1: Definition of the ground risk buffer
    - Criterion #2: Evaluation of people at risk
- M2 - Effects of ground impact are reduced

[75] JARUS, JARUS guidelines on SORA, Annex B, Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class, p.4, 2019, [103]

M2 Mitigations "reduce the effect of ground impact"[76] , after the loss of control of the operation. The consequences of a ground impact are highly dependent on the unmanned aircraft dynamic, so M2 mitigations should act on parameters such as area, UA energy, kinetic energy, etc. A typical example of M2 mitigation is the employment of a parachute after the activation of the flight termination system. The parachute reduces the falling speed, and limits the kinetic energy when the UAS impacts on the ground.
Three criteria are used to evaluate the level of robustness of M2 Mitigations:

- Criterion #1: Technical design;
- Criterion #2: Procedures;
- Criterion #3: Training.

- M3 – An Emergency Response Plan is in place, operator validate and effective
The Emergency Response Plan is a "plan of actions to be conducted in a certain order or manner, in response to an emergency event"[77] that leads to an unrecoverable state that cannot be handled by a contingency procedure, and whose effects are highly dependent on providence and led to an imminent danger of fatalities. The ERP has to limit the consequences of a crash.

SORA Annex B 'Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class'[78] provides assessment criteria for the integrity and assurance of the applicant's proposed mitigations.

The Final GRC is established by adding all correction factors to the intrinsic Ground Risk Class. If the Final GRC is higher than 7, the operation is not supported by the SORA process.

The Air Risk Process

The mid-air collision (MAC) is defined as "an accident where two aircraft[79] come into

[76] JARUS, JARUS guidelines on SORA, Annex B, Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class, p.4, 2019, [103]

[77] JARUS, JARUS guidelines on SORA, Annex I, Glossary of Terms, p. 8, 2019,[107]

[78] JARUS, JARUS guidelines on SORA, Annex B, Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class, 2019, [107]

[79] The SORA process excludes collision between two UA or between a UA and a UA carrying people.

contact with each other while both are in flight"[80] .

Regulation (EU) 2019/947 establishes that the evaluation of mid-air collision risk of the operations shall take into account:

i. *"The exact airspace volume where the operation will take place, extended by a volume of airspace necessary for contingency procedure;*

ii. *The class of the airspace[81];*

iii. *The impact on other air traffic and air traffic management"[82].*

To define the airspace volume, the SORA uses the operational airspace previously defined in the ConOps. It includes:

- Flight Geography;
- Contingency Volume.

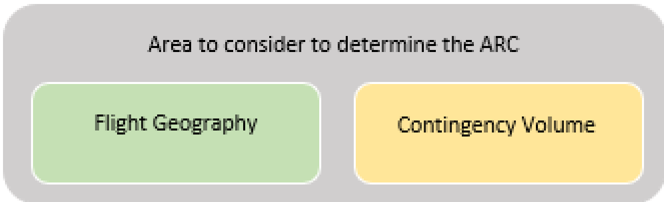


Figure 3.18: Areas to determine the ARC

The mid-air collision risk of the interested airspace estimate by the ARC. The ARC is "a qualitative classification of the rate at which a UAS would encounter a manned aircraft in typical generalized civil airspace"[83] . The first step of the Air Risk Process is to determine the initial Air Risk Class which depends on the characteristics of the airspace and represents its aggregated collision risk. The initial ARC can be modified and lowered by applying strategic mitigation, obtaining the residual ARC. The residual ARC is then

[80]JARUS, JARUS guidelines on SORA, Annex I, Glossary of Terms, p. 10, 2019, [107]

[81]Airspace classification consist of: Class A, B, C, D, E, F, G.

[82]EASA, Easy Access Rules for Unmanned Aircraft Systems, Regulation (EU) 2019/947, Article 11, Point (4)(b), p. 35, 2022, [46]

[83]JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 2, Section 2.4.2.1, Point (c), p.23, 2019, [101]

addressed by means of tactical mitigations.

The Air Risk Class is categorized into four increasing risk levels:

- ARC-a is defined as "airspace where the risk collision between a UAS and manned aircraft is acceptable without the addition of any tactical mitigation"[84], it corresponds to a negligible encounter rate;

- ARC-b, ARC-c, ARC-d are defined as "airspace with increasing risk of collision between a UAS and manned aircraft"[85] .

- ARC-b corresponds to a low encounter rate;

- ARC-c represents a medium encounter rate, and

- ARC-d refers to a high encounter rate.

Step#4 - Determination of the initial Air Risk Class (ARC)

To determine the Initial ARC, the applicant may use airspace collision risk maps provided by the competent authority or ANSP. These maps show the initial ARC. If the CAA does not provide maps, the applicant should determine the Air Risk Class by the decision tree in Figure 3.19.

[84]JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 2, Section 2.4.2.1, Point (e), p.24, 2019, [101]

[85]JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 2, Section 2.4.2.1, Point (f), p.24, 2019, [101]

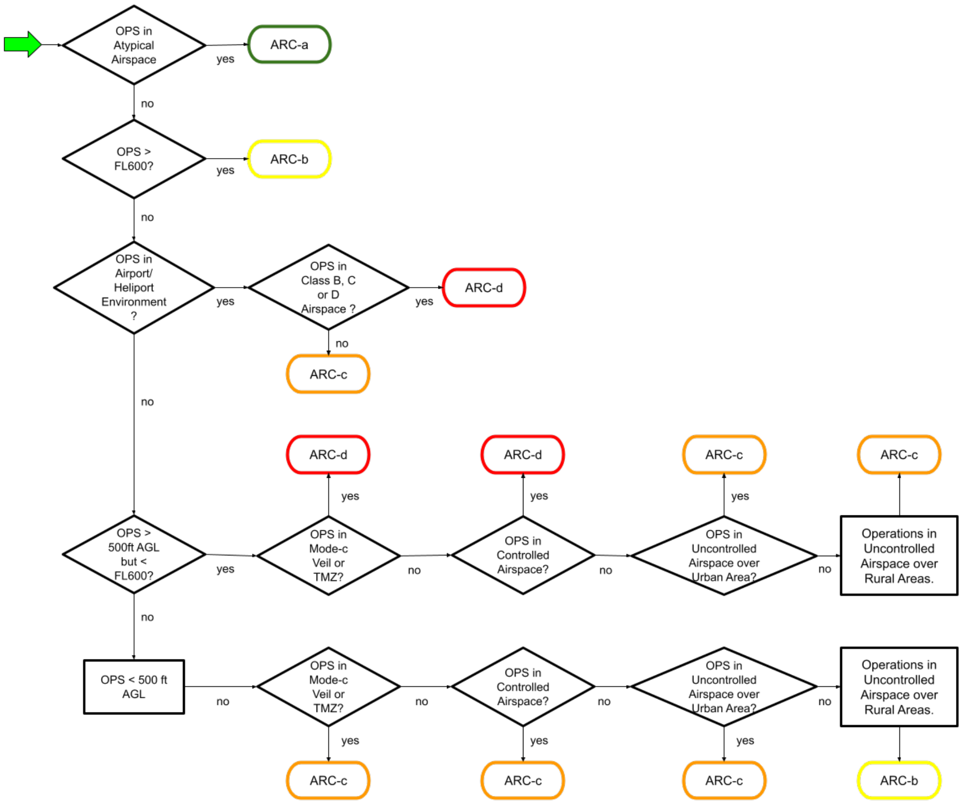


Figure 3.19: ARC assignment process, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.23, 2019, [101])

The flow chart in Figure 4 divides the airspace into 12 categories, according to the following characteristics:

- *"Altitude;*
- *Controlled versus uncontrolled airspace;*
- *Aerodrome versus non-aerodrome environment;*
- *Airspace over urban versus rural environment*[86]*;*
- *Atypical versus typical airspace."*[87]

[86] A 'rural area' is used in the context of the air risk and it means the volume outside a populated area and not within the aerodrome traffic zone (ATZ) of an aerodrome"

[87] EASA, Easy Access to Rules for Unmanned Aircraft Systems, Article 11, Point (4)(b)(iii.), p.35, 2022, [46]

Each category is associated to an Air Risk Class level.

To define the means of mitigations, the SORA recognizes the "three conflict management pillars"[88] defined in the ICAO Doc. 9854[89], and groups them into:

- Strategic Mitigations; and
- Tactical Mitigations.

Step#5 – Application of Strategic Mitigations to determine Residual ARC (Optional)

If the Applicant considers that the generalized and qualitative assessment of the mid-air collision risk resulting in the Initial ARC is too high or does not suit best the Operational Volume, Strategic Mitigations can be applied to reduce the Initial ARC to the Residual ARC.

Strategic Mitigations must be applied before the take-off. They have the essential purpose of reducing the UAS encounter rate or the time of exposure. Strategic Mitigations are further divided into:

- Mitigations by Operational Restrictions; and
- Mitigations by Common Structures and Rules.

---

[88]ICAO three conflict management pillars are:

a) *""Strategic Conflict Management" is the first layer of conflict management and is achieved through the airspace organization and management, demand and capacity balancing and traffic synchronization components.*

b) *"Separation provision" is the second layer of conflict management and is the tactical process of keeping aircraft away from hazards by at least the appropriate separation minima. Separation provision will only be used when strategic conflict management (i.e. airspace organization and management, demand and capacity balancing and traffic synchronization) cannot be used efficiently.*

c) *"Collision avoidance" is the third layer of conflict management and must activate when the separation mode has been compromised. Collision avoidance is not part of separation provision, and collision avoidance systems are not included in determining the calculated level of safety required for separation provision. Collision avoidance systems will, however, be considered as part of ATM safety management. The collision avoidance functions and the applicable separation mode, although independent, must be compatible.*

ICAO Doc. 9854, Conflict Management, p. 26-28, 2005 [91]

[89]ICAO. Doc 9854, "Global Air Traffic Management Operational Concept". https://www.icao.int/Meetings/anconf12/Document%20Archive/9854_ cons_en%5B1%5D.pdf, 2005.

Strategic Mitigations by Operational Restrictions

Strategic Mitigations by Operational Restrictions are the first means of mitigations that can be applied and are defined and managed by the operator. They can be classified as: mitigations that limit the geographic volume and means that limit the operational time frame. The first means of mitigation consists of limiting the operating volume within which the aircraft can fly. For example, the trajectory can be planned to avoid high-traffic areas, or the flight altitude can be limited to low areas where manned aviation does not usually operate. Mitigations on the operational time frame may be chronological, consisting of operating the UAS at a time of the day when the manned aircraft traffic is expected to be less intense, or limiting the exposure time, for example by optimizing the flight path to reduce as much as possible the time needed to complete the mission.

Strategic Mitigations by Common Structures and Rules

Strategic Mitigations by Common Structures and Rules require that UAS comply with the common rules and procedures of airspace due to they share it with manned aviation. These mitigations are provided by the Competent Authority and cannot be modified by the operator. The term “Structures” refers to all common structures of the airspace, such as the infrastructures and the procedures and techniques applied to reduce conflicts, such as airways or take-off landing procedures. Instead, the term “rules” indicates the common flight rules such as right of way rules, or the coordination schemes and cooperative identification systems.

Strategic Mitigations are used to reduce the Initial ARC to Residual ARC. The first step to lower the Initial ARC consists of applying Mitigations by Operational Restriction. First of all it is necessary to determine the Airspace Encounter Category (AEC) and the density rating using Table 3.9.

Table 3.9: Table to determine the AEC and the associated density rating, (Source: JARUS. JARUS guidelines on SORA - Annex C - Strategic Mitigation Collision Risk Assessment. Annex JAR-DEL-WG6-D.04_C, p.12, 2019, \cite{soraC})

The density rating of manned aircraft, assessed on a scale of 1 to 5, 1 representing a very low density and 5 representing a very high density				
Column	A	B	C	D
AEC	Initial Generalized Density Rating for the environment	Initial ARC	If the local density can be demonstrated to be similar to	New Lowered (Residual) ARC
AEC 1; or AEC 2	5	ARC-d	4 or 3	ARC-c
			2 or 1	ARC-b
AEC 3	4	ARC-d	3 or 2	ARC-c
			1	ARC-b
AEC 4	3	ARC-c	1	ARC-b
AEC 5	2	ARC-c	1	ARC-b
AEC 6 or; AEC 7 or; AEC 8	3	ARC-c	1	ARC-b
AEC 9	2	ARC-c	1	ARC-b
AEC 10 and AEC 11 are not included in this table as any ARC reduction would result in ARC-a. An operator claiming reduction to ARC-a must demonstrate that all requirements defining Atypical or Segregated Airspace of Annex G, section 3.20(d) have been met.				

The AEC is a *"qualitative classification of the rate at which a UAS would encounter a manned aircraft in typical civil airspace found in the U.S. and Europe. The airspace encounter risk was grouped by operational altitude, airport environment, controlled airspace, uncontrolled Mode C veil/TMZ airspace, and in uncontrolled airspace over rural and/or urban populations, into 12 categorizations. It is based on the assessment of the proximity, geometry and dynamics"*[90]. The AEC is associated with five levels of density rating from 1 to 5, with 1 being very low density and, 5 being very high density.

After that, using Table 6 it is possible to identify which residual ARC can be reached after the application of Strategic Mitigations. The first Column shows the AEC in the environment in which the operator wishes to operate, and obtained by Table 5. Column B shows the corresponding initial ARC. Column C is the key to reducing the risk class. This column shows the local density values the operator should demonstrate and justify to

[90]JARUS, JARUS guidelines on SORA, Annex I, Glossary of Terms, p. 5, 2019, [107]

the Competent Authority by applying Strategic Mitigations by Operational Restriction to lower the air risk class to the correspondent ARC shown in Column D.

Finally, Strategic Mitigations for Common Structures and Rules can be applied. As anticipated these rules and procedures must be applied since UAS share the airspace with general aviation. UAS typically fly in very low-level airspace which is crossed by manned aviation for takeoff and landing operations. Moreover, due to the increasing number of UAS operations the VLL is expected to become crowded, so flight rules became essential.

The Residual ARC is obtained and the operator is responsible to collect and analyze the data required to show to the Competent Authority the effectiveness of the Strategic Mitigations applied. The CAA can approve or reject the Residual ARC, increase the air risk class or require additional safety measures.

More details about Strategic Mitigations are provided in Annex C[104].

Step#6 – Tactical Mitigation Performance Requirement (TMPR) and Robustness Levels

Tactical Mitigations are mitigation measures that are applied after the take off and aim to reduce the risk of mid-air collision to ensure the safety objectives. A Tactical Mitigation can be seen as a "mitigating feedback loop", as "it reduces the rate of collision by modifying the geometry and dynamics of aircraft in conflict, based on real time aircraft conflict information"[91] . These means of mitigation “operate using a sensor to “see” the threat, “deciding” how to mitigate the risk, “acting” on the decision, and then having a system feedback to monitor the risk, and implementing new corrections if needed”[92] .

Tactical Mitigations and its Performance Requirements can vary on the base of the type of operation. Under VLOS operations[93], the UAS remains close enough to the remote pilot and/or the observer. They use human vision to detect and avoid collisions from other aircraft, without any other devices. VLOS is considered as an acceptable Tactical

[91] JARUS, JARUS guidelines on SORA, Annex D, Tactical Mitigation Collision Risk Assessment, p. 4, 2019, [105]

[92] JARUS, JARUS guidelines on SORA, Annex I, Glossary of Terms, p. 13, 2019, [107]

[93] For VLOS operations, it is assumed that an observer is not able to detect traffic beyond 2 NM. (Note that the 2 NM range is not a fixed value and may largely depend on atmospheric conditions, aircraft size, geometry, closing rate, etc.)

Mitigation for collision risk for all ARC levels, and under VLOS flight, UAS do not need to meet the TMPR. However, the operator has to produce a “documented VLOS de-confliction scheme”, which contains information about how the detection of possible incoming traffic will be carried out and the criteria that will be used to avoid it. The de-confliction scheme shall also include communication protocols if the pilot is assisted by an observer.

Under BVLOS operations, alternate means of mitigation to human vision are necessary to comply with “see and avoid” requirements. These mitigations are described as “Detect and Avoid”. DAA can be divided into five sub-functions namely Detect, Decide, Command, Execute, and Feedback Loop. It can be achieved through ground based systems, air based systems or combinations of the two. Tactical Mitigations may be combined, so it is important to analyze their level of interdependency and how it affects the effectiveness of the overall mitigation. The total performance required by all tactical mitigation means is named Tactical Mitigation Performance Requirement. It depends on the amount of residual risk: the higher the ARC, the greater the residual risk, the greater the TMPR.

The SORA provides the following table to determine the TMPR associated with the obtained Residual ARC.

Table 3.10: Tactical Mitigation Performance Requirement (TMPR) and TMPR Level of Robustness Assignment, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.25, 2019, [101])

Residual ARC	Tactical Mitigation Performance Requirements (TMPR)	TMPR Level of Robustness
ARC-d	High	High
ARC-c	Medium	Medium
ARC-b	Low	Low
ARC-a	No requirement	No requirement

- A High TMPR is required in airspace with a high encounter rate. These airspaces have high residual ARC and low Strategic Mitigations. Unmanned aircraft operating in this airspace must fly according to the operating rules and procedures applicable to the Integrated Airspace. The level of performance of tactical mitigations and/or the required variety of tactical mitigations is generally higher than other arcs.
- A Medium TMPR is required in airspace where the chance to encounter manned aircraft is reasonable and the Strategic Mitigations available are medium. Operations with a medium TMPR can be conducted by the use of supporting systems to aid the

pilot with detection of other aircraft currently used in manned aviation, or with new systems designed with an equivalent level of robustness.

- A Low TMPR is required in airspace where the encounter rate is low but not negligible. Strategic Mitigations available are generally low. Operations with a low TMPR can be supported by systems actually used in manned aviation to aid pilot in detecting other traffic, or with systems with lower requirements.

- The airspace where the manned aircraft encounter rate is expected to be extremely low has no performance requirement. The risk of collision between a UAS and manned aircraft is acceptable without the addition of any Tactical mitigation.

Annex D[105] provides additional information about Tactical Mitigations.

Step#7 - SAIL determination

After determining the Final GRC and the Residual ARC, the SORA process proposes Table 10 to determine the SAIL associated with the proposed ConOps. SAIL means

Table 3.11: SAIL determination, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.27, 2019, [101])

SAIL Determination				
	Residual ARC			
Final GRC	a	b	c	d
<=2	**I**	**II**	**IV**	**VI**
3	**II**	**II**	**IV**	**VI**
4	**III**	**III**	**IV**	**VI**
5	**IV**	**IV**	**IV**	**VI**
6	**V**	**V**	**V**	**VI**
7	**VI**	**VI**	**VI**	**VI**
<7	Category C operation			

Specific Assurance and Integrity Levels and represents "the level of confidence that the UAS operation will stay under control"[94]. The SAIL is not a quantitative parameter but it is related to all the activities that must be carried out by the applicant to demonstrate

[94] JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 2, Section 2.5.1, Point (a), p.26, 2019, [101]

that the operations proposed in the ConOps are operated safely. The SAIL correspond to "Operational Safety Objectives (OSO) to be compliant with", but also to the "description of activities that might support compliance with those objectives" and "the evidence that indicates the objectives have been satisfied"[95] .

The SAIL value increases with the potential risk of the operation: a high value SAIL represents an operation with high potential risk, a low value SAIL correspond to an operation with low potential risk.

Step#8 – Identification of Operational Safety Objectives (OSO)

The Operational Safety Objectives are operational requirements related to safety. The SORA process proposes a consolidated list of common twenty-three OSOs, grouped based on the threat they help to mitigate:

- Technical issue with the UAS;
- Deterioration of the external systems supporting UAS operation;
- Human Error;
- Adverse operating conditions.

Once determined the SAIL, the applicant uses it to determine the OSOs' associated level of robustness to be compliant with. The robustness level increases with SAIL:

- 'O' is Optional;
- 'L' is Low robustness;
- 'M' is Medium robustness;
- 'H' is High robustness.

Annex E[96] provides assessment criteria for the integrity and assurance of OSOs proposed by the applicant.

[95]JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 2, Section 2.5.1, Point (c), p.26-27, 2019, [101]

[96]JARUS. JARUS guidelines on SORA - Annex E - Integrity and assurance levels for the Operation Safety Objectives (OSO). Annex JAR-DEL-WG6-D.04_E, JARUS, 2019, [106]

Table 3.12: Recommended operational safety objectives (OSO), (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main BodyJAR-DEL-WG6-D.04, p.27, 2019, [101])

OSO Number (in line with Annex E)		**SAIL**					
	Technical issue with the UAS	**I**	**II**	**III**	**IV**	**V**	**VI**
OSO#01	Ensure the operator is competent and/or proven	O	L	M	H	H	H
OSO#02	UAS manufactured by competent and/or proven entity	O	O	L	M	H	H
OSO#03	UAS maintained by competent and/or proven entity	L	L	M	M	H	H
OSO#04	UAS developed to authority recognized design standards	O	O	O	L	M	H
OSO#05	UAS is designed considering system safety and reliability	O	O	L	M	H	H
OSO#06	C3 link performance is appropriate for the operation	O	L	L	M	H	H
OSO#07	Inspection of the UAS (product inspection) to ensure consistency to the ConOps	L	L	M	M	H	H
OSO#08	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H

OSO#09	Remote crew trained and current and able to control the abnormal situation	L	L	M	M	H	H
OSO#10	Safe recovery from technical issue	L	L	M	M	H	H
	Deterioration of external systems supporting UAS operation						
OSO#11	Procedures are in-place to handle the deterioration of external systems supporting UAS operation	L	M	H	H	H	H
OSO#12	The UAS is designed to manage the deterioration of external systems supporting UAS operation	L	L	M	M	H	H
OSO#13	External services supporting UAS operations are adequate to the operation	L	L	M	H	H	H
	Human Error						
OSO#14	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO#15	Remote crew trained and current and able to control the abnormal situation	L	L	M	M	H	H
OSO#16	Multi crew coordination	L	L	M	M	H	H
OSO#17	Remote crew is fit to operate	L	L	M	M	H	H
OSO#18	Automatic protection of the flight envelope from Human Error	O	O	L	M	H	H
OSO#19	Safe recovery from Human Error	O	O	L	M	M	H

OSO#20	A Human Factors evaluation has been performed and, the HMI found appropriate for the mission	O	L	L	M	M	H
	Adverse operating conditions						
OSO#21	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO#22	The remote crew is trained to identify critical environmental conditions and to avoid them	L	L	M	M	M	H
OSO#23	Environmental conditions for safeoperations defined, measurable and adhered to	L	L	M	M	H	H
OSO#24	UAS designed and qualified for adverse environmental conditions	O	O	M	H	H	H

Step#9- Adjacent Area/Airspace Consideration

This STEP is carried out at the end of the SORA process and has the purpose of assessing the risk due to a loss of control that caused the UAS to exit from the operating volume and to infringe the adjacent areas/airspace.

The following containment requirement has to be met *"No probable failure of the UAS or any external system supporting the operation shall lead to operation outside of the operational volume.*

But if the operations are conducted:

- *"Where adjacent areas are:*

  i. *Gatherings of people unless already approved for operations over gathering of people OR*

ii. *ARC-d unless the residual ARC is ARC-d*

- *In populated environments where:*

  i. *M1 mitigations have been applied to lower the GRC*

  ii. *Operating in a controlled ground area"*

The applicant needs to show compliance with the following three safety requirements:

1. *The probability of leaving the operational volume shall be less than* $10^{-4}/FH$.

2. *No single failure of the UAS or any external system supporting the operation shall lead to operation outside of the ground risk buffer.*
   Compliance with the requirements above shall be substantiated by analysis and/or test data with supporting evidence.

3. *Software (SW) and Airborne Electronic Hardware (AEH) whose development error(s) could directly lead to operations outside of the ground risk buffer shall be developed to an industry standard or methodology recognized as adequate by the competent authority.*[97]

Step#10 - Comprehensive Safety Portfolio

The Comprehensive Safety Portfolio is the SORA safety case submitted to the competent authority and the ANSP prior to final authorization. It contains:

- *"Migations used to modify the intrinsic GRC*
- *Strategic mitigations for the Initial ARC*
- *Tactical mitigations for the Residual ARC*
- *Adjacent Area/Airspace Considerations*
- *Operational Sagety Objectives"*[98]

[97]JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 2, Section 2.5.3, Point (b), p.29, 2019, [101]

[98]JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 2, Section 2.6, Point (a), p.30, 2019

3.3.3 The way forward: SORA 2.5 and 3.0

JARUS published the SORA 2.0 in 2019. During the last few years, this process has been applied to several UAS operations, but some critical points and implementation difficulties arose. So, the working group worked on an updated version to resolve these issues. The major changes introduced with SORA 2.5 are a quantitative approach to determine the ground risk assessment and a general review of the text to clarify questions raised during SORA 2.0 application. In addition, SORA 2.5 includes amendments to Annex A, B, E, F and I, while Annex C and D were not modified. Edition 2.5 has completed the internal consultation phase, and it is planned to be published for external public consultation in November/December 2023. JAURS expects to vote the final draft in May 2024 [34].

This section will present a brief description of SORA 2.5 contents, underlining the main difference with the previous version 2.0. The reference documents used to make the comparison are the SORA 2.5 main body [116] and annexes [112] [113] [114] [115] , and documents provided by EASA during the 'SORA Workshop: from version 2.0 to 2.5' [58] [110].

First of all, SORA 2.5 reviews the general text to simplify the language and clarify critical points raised during internal consultation. The semantic model changes as follows:

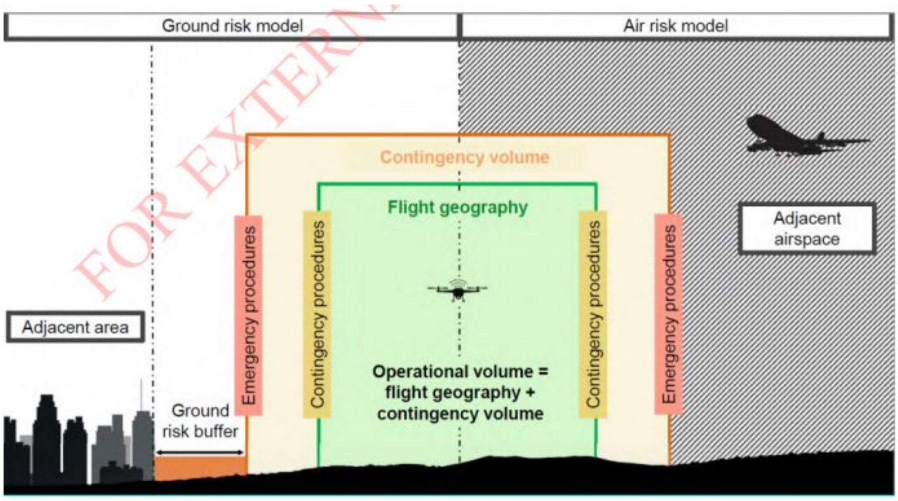


Figure 3.20: SORA 2.5 Semantic Model, (Source:JARUS. SORA Workshop: from version 2.0 to 2.5 "Summary of changes SORA", slide 8, 2023, [110])

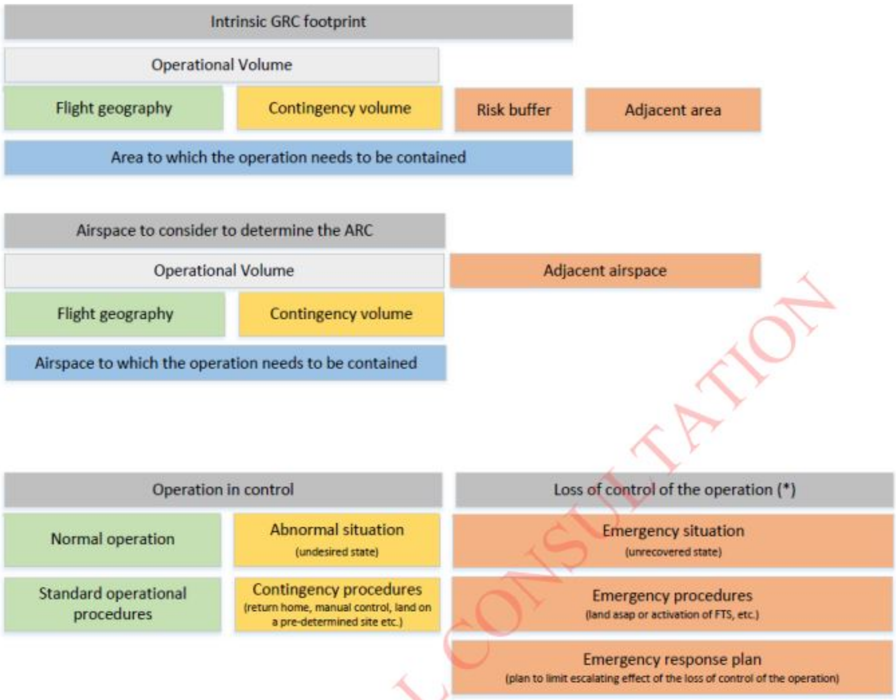


Figure 3.21: SORA 2.5 Semantic Model, (Source:JARUS. SORA Workshop: from version 2.0 to 2.5 "Summary of changes SORA", slide 7, 2023, [110])

In addition, JARUS introduces the “SORA Phases”, suggesting to split the application process into two phases, in order to “minimize the risk of further iterations in the UAS design, in the envisaged operations and the envisaged risk mitigations”[99].
Phase 1 consists of the implementation of the SORA process resulting in a preliminary SAIL level. In this phase, the applicant has not to prepare all the evidence material to demonstrate compliance with obtained requirements, but should only analyze the feasibility of the intended operation. Subsequently, the applicant gets in contact with the competent authority to evaluate the obtained results.
If a common initial understanding is achieved, the applicant can start phase 2 and prepare the required completed documentation.

The changes to the SORA Main Body are now analyzed. The table below can be used to make a point-by-point comparison between the structures of the two versions. Steps 1, 5, 8, 9 and the Ground Risk Process undergone major changes.

[99] JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.27, 2022

Table 3.13: Main Body Structure (Source:EASA. SORA Workshop: from version 2.0 to 2.5 "SORA", slide 72, 2023, [58])

Main Body Structure	
SORA 2.0	**SORA 2.5**
Step\#1 - ConOps	Step\#1 - Operation description
Step\#2 - iGRC	Step\#2 - iGRC
Step\#3 - Final GRC	Step\#3 - Final GRC
Step\#4 - iARC	Step\#4 - iARC
Step\#5 - Residual ARC	Step\#5 - Residual ARC
Step\#6 - TMPR	Step\#6 - TMPR
Step\#7 - SAIL	Step\#7 - SAIL
Step\#8 - OSOs	Step\#8 - Containment
Step\#9 - Adjacent Area/Airspace Considerations	Step\#9 - OSOs
Step\#10 - Comprehensive portfolio	Step\#10 - Comprehensive portfolio

Step#1 no longer refers to 'ConOps', but provides a more structured approach to present the interested operations. It is renamed as "Documentation of the proposed operation(s)" and covers the documentation that the applicant has to submit to the Competent Authority to obtain authorization. This documentation may include all the information related to the scenario, the unmanned aircraft, procedures, mitigations and evidence to demonstrate compliance with requirements obtained at the end of the risk assessment process.

SORA 2.5 introduces a new method for conducting ground risk assessment. Indeed, SORA 2.0 proposed a qualitative process in which the ground risk depends on the characteristics of the aircraft, dimensions and typical energy, and on the operational scenario. However, applicants highlighted several critical issues. Regarding the technical characteristics of the aircraft, it was pointed out that it is not always easy to determine the typical kinetic energy, so this parameter was replaced by the maximum cruise speed. While the operational scenario was classified according to:

- VLOS/BVLOS operation;
- overflown population density.

The Competent Authorities believe that conducting an operation in VLOS rather than

BVLOS does not impact the determination of the level of intrinsic ground risk class. This aspect can be evaluated as a means of mitigation. In SORA 2.5 the classification of the operative scenario depends always on the population density overflown but is evaluated now in quantitative terms. Thus, numerical ranges are introduced to classify the risk zone. A further innovation introduced in the ground risk process is the identification and assessment of the adjacent area. This area was already present in SORA 2.0 but was covered by Step#9 without no indications on how to calculate its size. Instead, the SORA 2.5 process provides well-defined guidelines for the identification of this space and for the evaluation of the related ground risk class.

As mentioned above the mitigations to achieve the residual GRC, have been modified. Mitigations M1 (with the addition of the VLOS aspect) and M2 are the same of SORA 2.0, but their corrective factors have been modified. Mitigation M3 has been removed as this is not considered to be an effective measure of mitigation to reduce risk.

SORA 2.5 also introduces some changes in the air risk process. The determination of risk class for operational volume remains almost unchanged, but the identification and analysis of adjacent airspace are now defined. In SORA 2.0 this aspect was covered in Step#9, but there was no guidance on how to size and evaluate the adjacent volume.

As a consequence of the new adjacent area and airspace assessment methodology, SORA 2.5 also introduces significant changes in the containment requirements. In SORA 2.0 they consisted mainly of “Basic Containment” ("No probable failure of the UAS or any external system supporting the operation should lead to operation outside the operational volume"[100]) and “Enhanced Containment” ("The probability of the UA leaving the operational volume should be less than 10-4/FH; and no single failure"[101]). SORA 2.5 introduces in the new Step#8 additional information, providing tables for determining the level of robustness required to meet the containment requirements for adjacent area and airspace.

Finally, SORA 2.5 moves the step dedicated to the identification of OSOs from Step#8 to Step#9, after the assessment of the containment. Version 2.5 lists only 18 OSOs, removing OSOs that share the same requirements, and indicates for each one the figure who should

[100]SORA 2.5 Semantic Model, (Source: JARUS. SORA Workshop: from version 2.0 to 2.5 "SORA", slide 70, 2023, [58])

[101]SORA 2.5 Semantic Model, (Source: JARUS. SORA Workshop: from version 2.0 to 2.5 "SORA", slide 769, 2023, [58])

provide related evidence, such as operator, manufacturer or training organization.

Also, Annexes have been modified. The Table below shows the content and status of each annex in the two versions.

Table 3.14: Annexes (Source:[101] [58] [110])

Annexes					
SORA 2.0			**SORA 2.5**		
Annex	Title	Version	Annex	Title	Version
A	ConOps, Guidelines on collecting and presenting system and operation information for a specific UAS operation	1.0	A	Guidelines on collecting and presenting system and operationinformation for a specific UASoperation	2.0
B	Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Classes	1.0	B	Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Classes	2.5
C	Strategic Mitigation Collision Risk Assessment	1.0	C	Strategic Mitigation Collision Risk Assessment	1.0
D	Tactical Mitigations Collision Risk Assessment	1.0	D	Tactical Mitigations Collision Risk Assessment	1.0
E	Integrity and assurance levels for the Operational Safety Objectives (OSO)	1.0	E	Integrity and assurance Levels for the Operational Safety Objectives (OSO	2.5 Cyber Annex 1.0
F	Supporting data for the Air Risk Model	/	F	Theoretical Basis for Ground Risk Classification	1.0
G	Supporting data for the Air Risk Model	/	G	Supporting data for the Air Risk Model	/
H	Unmanned Traffic Management (UTM) implications to SORA	/	H	UAS Safety Services Considerations	1.0
I	Glossary	1.0	I	Glossary	2.5
J	Guidance to Regulators, ANSPs, and Other Third Parties	/	J	Guidance to Regulators, ANSPs, and Other Third Parties	/

Annex A will be published as version 2.0, it is under final revision and it will be renamed into 'Operator Manual'. Annex B titled "Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Classes"[102] is updated to suit new mitigations introduced in SORA 2.5 and provides related clarifications. Annexes C and D are not updated due to lack of time. Annex E[103] covers levels of integrity and assurance of

[102] JARUS. "JARUS guidelines on SORA, Annex B, Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, JARUS, 2022.[112]

[103] JARUS. "JARUS guidelines on SORA, Annex E, Integrity and assurance levels for the Operational

Operational Safety Objectives. It has been adapted to follow the new structure of the OSOs' table, in addition, it contains a chapter dedicated to containment requirements. Two new Annexes will be published. Annex F[104] will propose a quantitative model of the ground risk, providing all the related details and justifications. Normally, the applicant is not required to consult this annex, but it may be useful if he/she wishes to propose to the Competent Authority a tailored solution to assess the ground risk class. Annex H will cover "UAS Safety Services Considerations". Finally, Annex I[105] contains an update of the terms and acronyms used in SORA 2.5.

3.3.4 Design Approval

After conducting the Specific Operation Risk Assessment, the applicant identifies the SAIL and uses it to determine the level of robustness at which OSOs have to be met. As mentioned in the previous section, the SAIL is proportional to the risk associated with the operation: the higher the SAIL, the greater the complexity of the activities that must be carried out to demonstrate compliance with safety requirements is.

In particular, to verify compliance with design related OSOs and obtain UAS design approval, EASA proposes guidelines to define appropriate verification methods, proportionate to the operational risk level.

SAIL I, II and III

SAIL I, II and III correspond to low/medium-low risk operations. So, an operator can demonstrate compliance with design related OSOs by employing a UAS with a class identification label or by submitting a declaration to the National Aviation Authority.

In addition, the competent authority may request a design verification report to evaluate the compliance of technical mitigations and enhanced containment, if applicable.

Safety Objectives (OSO)" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, JARUS, 2022. [113]

[104]JARUS. "JARUS guidelines on SORA, Annex F, Theoretical Basis for Ground Risk Classification" Edition 0.3. Draft for external consultation JAR-DEL-WG6-D.04, JARUS, 2022. [114]

[105]JARUS. "JARUS guidelines on SORA, Annex I, Glossary of Terms" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, JARUS, 2022. [115]

SAIL IV

SAIL IV is associated with medium risk operations. The National Aviation Authority requires operators to obtain a UAS Design Verification Report.

Design Verification Report and applicability
The Design Verification Report is "a report issued by EASA that documents that the UAS design complies with the applicable OSOs, which includes any possible limitations or assumptions the actual drone model needs to operate"[106] . It is not a type certificate. The operator applies to the National Aviation Authority to obtain a UAS operational authorization, submitting the application form, a risk assessment and a copy of the operator manual. Then the NAA evaluate applicant's documents and decides if a UAS and/or a mitigation and/or a containment verification is required. If the competent authority mandates a verification, the manufacturer/operator has to apply to EASA for a Design Verification Report.

The NAA specifies the need for a DVR in the operational authorization. It is especially required:

- *"If an operation is classified as SAIL IV, and/or*
- *"Mitigation means linked with design when claimed at high robustness, and/or*
- *"For the verification of the 'enhanced containment' as currently defined by SORA when no declarative MoC can be applied"*[107]

Application phase
To apply to a DVR the applicant has to determine and specify all the characteristics of the "typical" operation the interest UAS has to conduct and develop a related Specific Operation Risk. For example, operational limitation, environmental conditions, operational areas and buffers dimensions, measures of mitigations and containment if applicable. Subsequently, he/she has to submit EASA an application for design verification using the application form "Application for UAS design verification"[108] . It requests information

[106]EASA, Design Verification Report, https://www.easa.europa.eu/en/domains/civil-drones-rpas/specific-category-civil-drones/design-verification-report, consulted in October 2023

[107]EASA, Guidelines on Design verification for UAS operated in the 'specific' category – Issue 2, Background and applicability, p.4, 2023

[108]EASA, "FO.CSERV.00198-001 Application form for Unmanned Aircraft System Design Verification", https://www.easa.europa.eu/en/document-library/application-forms/focserv00198-001, 2021

about the design verification basis[109] , the design verification programme[110] and a project schedule, in addition to the UAS design description and the risk assessment.

Firstly EASA and the applicant conduct a pre-application meeting. Useful information about the DVR process, costs and design verification schedule are discussed. Then EASA experts will agree with the manufacturer/operator on the applicable design verification basis and the relevant requirements. So, EASA accepts the submitted application and the design verification phase starts. The applicant has to provide EASA with the means (MoC) by which the compliance has to be demonstrated. MoCs should "clarify the safety objectives derived from the Design Verification Basis' paragraph and should allow EASA Certification Experts to understand the adequateness of the proposed MoCs as well as how the applicant intends to show compliance to those paragraphs"[111] . For example, MoCs include the design objective to achieve, the activities to be carried out to demonstrate compliance, relevant parameters for the objective, references to standards, specifications and GM/AMC and, pass/fail criteria.

After a positive evaluation of the documentation EASA will issue the DVR. Finally, the applicant submits documentation, the obtained DVR and other evidence of compliance with non-design linked OSOs to the competent authority to obtain operational authorization.

[109]The design verification basis "identify those paragraph that are applicable to the UAS for which the verification is required" [48]

[110]The design verification programme (DVP) is "a document that allows the applicant and EASA to manage and control the evolving UAS design, as well as the process of compliance demonstration by the applicant" [48]

[111]EASA, Guidelines on Design verification for UAS operated in the 'specific' category – Issue 2, Provision of a design verification service in the specific category-medium risk, p.8, 2023, [48]

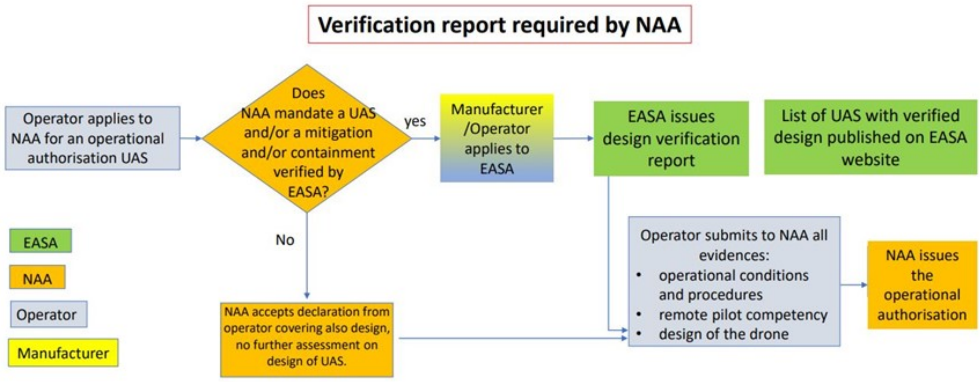


Figure 3.22: Verification report process required by the NAA, (Webinar, The specific category and the drone design verification process, EASA Drones Team, May 2021)

SAIL V and VI

SAIL V and VI represent high risk operations, so the National Aviation Authority requires operators to use UAS with a Type Certificate according to Regulation (EU) 748/2012.

3.3.5 Type Certificate

For operations with an elevate level of risk, such as 'specific' category high risk operations[112] (or 'certified' category operations) the Design Verification Report is not enough to guarantee compliance with design-link OSOs. So, the National Aviation Authority requires the operator to employ a UAS with a Type Certificate.

"Airworthiness of an aircraft is the fitness of an aircraft for flight in all conditions for which it has been designed, and to which it may therefore be exposed"[113]. To that end, the aircraft must follow a certification process, also known as Initial Airworthiness. At the end of this process, a Type Certificate is issued by EASA. The Type Certificate is a document declaring that "the type of aircraft meets the safety requirements set by the European Union"[114]. It shows that the product has been designed and manufactured following all requirements of the applicable regulations, thus it certifies that the security level needed

[112] SAIL V and VI

[113] European Commission, Airworthiness, https://transport.ec.europa.eu/transport-modes/air/aviation-safety-policy-europe/aviation-safety-rules/airworthiness$_en, consulted in October$2023

[114] EASA, Aircraft certification, https://www.easa.europa.eu/en/domains/aircraft-products/aircraft-certification, consulted in October 2023

to operate has been achieved.

The essential requirements for airworthiness are set out in Annex II of the Basic Regulation (EU) 2018/1139. In 2003 to implement these requirements, the European Commission issued Regulation (EU) No 1702/2003[115] and its Annex Part 21. In addition, EASA developed Certification Specifications to be used in the certification process.

Once the Initial Airworthiness is obtained, the Continuing Airworthiness can be maintained according to the provisions of Regulation (EU) No 2042/2003 "on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks"[116]. This regulation contains four Annexes:

- Part M – Continuing airworthiness requirements
- Part 145 - Maintenance organisation approvals
- Part 66 – Maintenance certifying staff
- Part 147 - Organisations training Part 66 license applicants

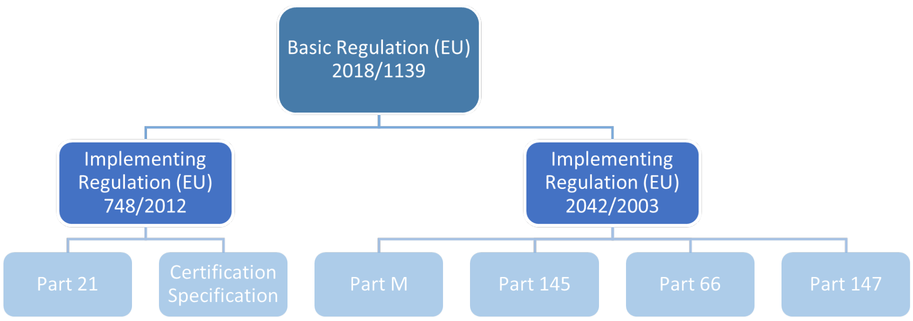


Figure 3.23: EASA regulations related to Airworthiness

[115] Now repealed by (EU) 748/2012

[116] Commission of the European Communities. COMMISSION REGULATION (EC) No 2042/2003 of 20 November 2003 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks, 2003, [22]

The Commission Regulation (EU) No 748/2012 lays down "implementing rules for the airworthiness and environmental certification of aircraft and related products, part and appliances, as well as for the certification of design and production organisations"[117] .

The scope of this document is defined in Article (1):
"This Regulation lays down, in accordance with Article 5(5) and Article 6(3) of Regulation (EC) No 216/2008, common technical requirements and administrative procedures for the airworthiness and environmental certification of products, parts and appliances specifying:

(a) *the issue of type-certificates, restricted type-certificates, supplemental type-certificates and changes to those certificates;*

(b) *the issue of certificates of airworthiness, restricted certificates of airworthiness, permits to fly and authorised release certificates;*

(c) *the issue of repair design approvals;*

(d) *the showing of compliance with environmental protection requirements;*

(e) *the issue of noise certificates;*

(f) the identification of products, parts and appliances;

(g) *the certification of certain parts and appliances;*

(h) *the certification of design and production organisations;*

(i) *the issue of airworthiness directives."*[118]

In particular, Annex I to (EU) No 748/2012, known as Part 21, defines "the requirements and procedures for the certification of aircraft and related products, parts and appliances, and of design and production organizations"[119]. Part 21 is divided into two sections:

---

[117]European Commission. REGOLAMENTO (UE) N. 748/2012 DELLA COM- MISSIONE del 3 agosto 2012 che stabilisce le regole di attuazione per la cer- tificazione di aeronavigabilità e ambientale di aeromobili e relativi prodotti, parti e pertinenze, nonché per la certificazione delle imprese di progettazione e di produzione, 2012, [20]

[118]European Commission. REGOLAMENTO (UE) N. 748/2012 DELLA COM- MISSIONE del 3 agosto 2012 che stabilisce le regole di attuazione per la cer- tificazione di aeronavigabilità e ambientale di aeromobili e relativi prodotti, parti e pertinenze, nonché per la certificazione delle imprese di progettazione e di produzione, Article 1, 2012, [20]

[119]EUROPEAN COMMISSION, COMMISSION REGULATION (EU) No 748/2012, Article (1), Point (2), Paragraph (c), p.2, 2012

- Section A "Technical Requirements"
  "establishes general provisions governing the rights and obligations of the applicant for, and holder of, any certificate issued or to be issued in accordance with this Section"[120].

- Section B "Procedures for Competent Authority"
  "This Section establishes the procedure for the competent authority, when exercising its tasks and responsibilities concerned with the issuance, maintenance, amendment, suspension and revocation of certificates, approvals and authorisations referred to in this Annex I"[121].

Section B of Part 21 also refers to the possibility by the Agency to "develop in accordance with Article 19 of Regulation (EC) No 216/2008 certification specifications and guidance material"[122] . Certification Specifications related to Initial Airworthiness are documents that define, according to the type of aircraft and/or equipment to be certified, the rules to be compliant with to obtain the type certificate. These documents "shall be sufficiently detailed and specific to indicate to applicants the conditions under which certificates are to be issued, amended or supplemented"[123] and can be used by competent authority, organizations and personnel "to demonstrate compliance of products, parts and appliances with the relevant essential requirements"[124].

Some of the Certification Specifications related to Initial Airworthiness published by EASA and currently in effect are reported in the following table:

[120] EUROPEAN COMMISSION, COMMISSION REGULATION (EU) No 748/2012, Annex I, Section A, Subpart A – General Provisions, 21.A.1, 2012

[121] EUROPEAN COMMISSION, COMMISSION REGULATION (EU) No 748/2012, Annex I, Section B, Subpart A – General Provisions, 21.B.5 Point(a), 2012

[122] EUROPEAN COMMISSION, COMMISSION REGULATION (EU) No 748/2012, Annex I, Section B, Subpart A – General Provisions, 21.B.5, Point (b), 2012

[123] EUROPEAN COMMISSION, COMMISSION REGULATION (EU) No 748/2012, Annex I, Section B, Subpart B, 21.B.70, 2012

[124] EUROPEAN COMMISSION, COMMISSION REGULATION (EU) No 748/2012, Annex I, Section B, Subpart B, 21.B.70, 2012

CS-22	Sailplanes and Powered Sailplanes
CS-23	Normal, Utility, Aerobatic and Commuter Aeroplanes
CS-25	Large Aeroplanes
CS-26	Additional airworthiness specification for operations
CS-27	Small Rotorcraft
CS-29	Large Rotorcraft
CS-31 GB	Gas Balloons
CS-31 HB	Hot Air Balloons
CS-34	Aircraft Engine Emissions and Fuel Venting
CS-36	Aircraft Noise
CS-LSA	Light Sport Aeroplanes
CS-VLA	Very Light Aeroplanes
CS-VLR	Very Light Rotorcraft

Figure 3.24: Some Certification Specifications related to Initial Airworthiness, (Source: https://www.easa.europa.eu/en/document-library/certification-specifications)

Today a Certification Specification dedicated to UAS has not yet been published: the certification basis is actually based on manned aircraft Certification Specifications, Special Conditions dedicated to specific UAS aspects, or Special Conditions developed by JARUS. However, EASA is laying the groundwork for future aircraft certification reference documents.

In 2020, EASA issued a dedicated Special Condition for Light UAS addressing "airworthiness specifications for UA operated in the specific category"[125] . This SC does not contain detailed technical specifications but it is objective-based. This approach seemed more appropriate for this type of Unmanned Systems. Once more experience has been gained with the certification of UAS with the application of the SC light UAS, EASA intends to transpose this SC into a CS. Instead, for UA of higher maximum take-off mass, closer to traditional aircraft, an appropriate CS-UAS focused on unmanned systems peculiar elements will be developed based on existing manned aircraft CS.

[125]EASA, Special Condition Light Unmanned Aircraft Systems – Medium Risk, Identification of Issue, p. 1, 2020

EASA intends to organize the future CS as presented in Figure 3.25:

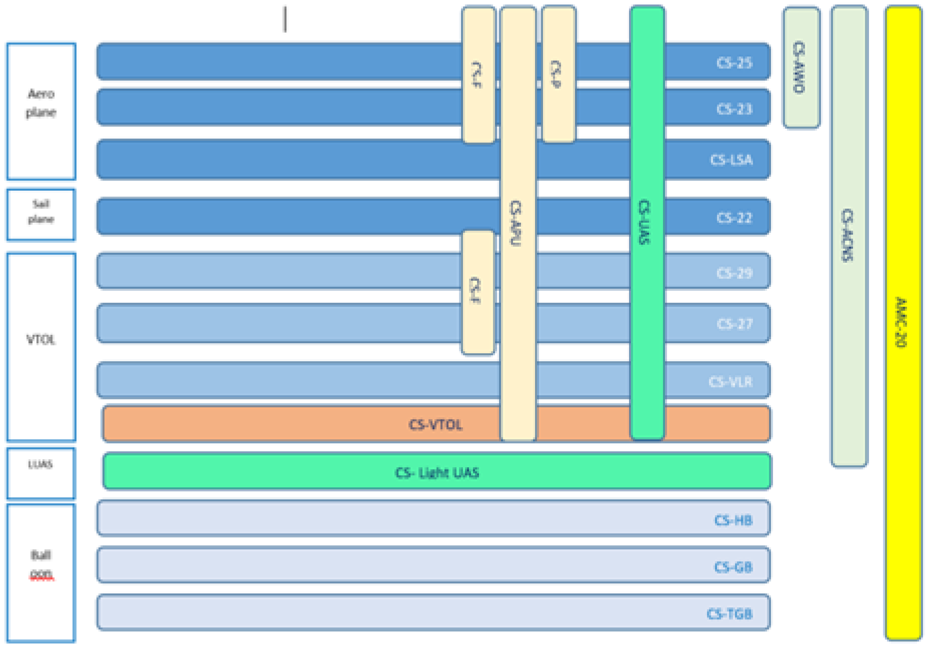


Figure 3.25: CS Organization (Source: EASA. Special Condition for Light Unmanned Aircraft Systems – Medium Risk, p.2,2020, [60])

3.3.6 Special Condition for Light Unmanned Aircraft Systems

As previously mentioned, in 2020 EASA published the Special Condition for Light UAS.

The Special Condition was issued to "address airworthiness specifications for UA operated in the specific category"[126] . Unlike other Certification Specification, this new SC is objective-based: it does not prescribe detailed technical specifications. This approach respects the innovative regulatory philosophy that EASA wants to adopt for unmanned aircraft: an operation-centric and risk-based approach. Due to the absence of personnel on board, the risk associated with UAS operations depends essentially on the main characteristics of the UA, such as size and kinetic energy, and on the operational volume in which it operates. Thus, also the certification rules and procedures must be proportionate to type of operations and the associated risk. According to EASA this approach will "provides

[126]EASA, Special Condition Light Unmanned Aircraft Systems – Medium Risk, Identification of Issue, p. 1, 2020 [60]

a safe environment while leaving flexibility to certify various design concepts in an area where the technology and design solutions rapidly evolve"[127].

On December 2020, EASA issued the SC Light UAS – Medium Risk, applicable to UAS:

- *"Not intended to transport Humans;*
- *Operated with intervention of the remote pilot or autonomous;*
- *With MTOW up to 600 kg;*
- *Operated in the specific category of operations, medium risk"*[128].

Medium risk refers to operations conducted at SAIL III and IV. As previously said, this document can be assumed as a reference for the design verification basis needs to conduct a Design Verification Report to validate design related OSOs for operations conducted at SAIL IV, design related mitigation means and/or containment requirements. This document is divided in:

- Subpart A – General;
- Subpart B – Flight ;
- Subpart C – Structures;
- Subpart D – Design and Construction;
- Subpart E – Lift/Thrust/Power System Installation;
- Subpart F – Systems and Equipment;
- Subpart G – Remote Crew Interface and Other Information;
- Subpart H – C2 Link.

In December 2021, EASA issued the Special Condition for Light UAS applicable to 'high risk'[129]- 'specific' category operations.

[127]EASA, Special Condition Light Unmanned Aircraft Systems – Medium Risk, Identification of Issue, p. 1, 2020, [60]

[128]EASA, Special Condition Light Unmanned Aircraft Systems – Medium Risk, Identification of Issue, p. 1, 2020, [60]

[129]EASA, Special Condition Light Unmanned Aircraft Systems – High Risk, Identification of Issue, p. 1, 2020, [59]

In conclusion, it can be said that the UAS civil regulatory framework is evolving quite rapidly, using a very different approach from traditional manned aviation. UAS's operators, designers and manufacturers have to face with incomplete and constantly changing regulations with operational procedures and system design requirements not yet completely defined. One example is the SC-Light UAS, which, as previously said, is currently used as a Special Condition but will be transformed into the future Certification Specification for UAV systems certifications. This SC was developed on the basis of an operation-centric and risk-based approach, to be applicable to the wide variety of UAS and operations falling into the 'specific' category. Indeed, it can be considered as an high level regulations, whose requirements are not prescriptive but more qualitative to ensure enough flexibility. The applicant has to consult with the Competent Authority to identify requirements applicable to the intended operation/UAS and to establish suitable methods of verification. Since this document will be used in the future as the certification basis, regulatory bodies such as EASA and EUROCAE are working on it and on the development of acceptable means of compliance to provide applicants with guidelines to show compliance with needed requirements. For example, EASA has recently released the MOC related to requirement Light-UAS.2510[130] (Equipment, Systems and Installation), whose consultation period ended in September 2023.

The uncertainty and the lack of well-defined regulations and requirements pose a significant challenge to industries. Investing in unmanned aircraft systems design development can be very risky, especially for projects that require consistent economic efforts. The risk is spending a large amount of money on products that, after a few years, might be results inadequate to perform the operations for which they were designed, due to a change in operating rules, requirements, or compliance evidence, leading to additional costs for product and manufacturing process adaptation or a complete design review.

Despite this, the transitional phase is necessary to integrate UAS into the general aviation system. A new regulatory framework, based on a proportionate and risk-based approach, seems to be the best methods to regulate UAV systems for Civil Authorities, ensuring adequate operability and safety, but enough flexibility to encourage market growth without being to prescriptive for the type of aircraft employed and operations conducted.

[130]EASA. Doc. MOC Light-UAS.2510-01, "Means of Compliance with Light-UAS.2510", 2023, [45]

Chapter 4

Military Regulatory Framework

4.1 Regulatory Bodies

4.1.1 NATO

The North Atlantic Treaty Organization is an intergovernmental military alliance established after World War II. NATO aims to "guarantee the freedom and security of its members through political and military means"[1], promoting democratic values, enabling cooperation to prevent conflicts, and if diplomatic efforts fail, it has the capability to undertake crisis-management operations.

Figure 4.1: NATO logo (Source: Wikipedia, svg, https://it.wikipedia.org/wiki/File:NATO _OTAN_landscape_logo.svg, consulted in October 2023

[1]NATO, consulted in October 2023, "What is NATO?", NATO, https://www.nato.int/nato-welcome/

Organization Structure [123]

NATO's organization structure can be divided into NATO Delegations and Military Representatives.
NATO Delegations include:

- The North Atlantic Council (NAC) is the main political decision-making body. It consists of Member States representatives and meets at least once a week to take major decisions regarding NATO's policies. It is chaired by the Secretary-General.

- The Nuclear Planning Group (NPG) holds equivalent aithority to the NAC concerning nuclear policy matters.

- Subordinate Committees are committees composed by national representatives and experts form NATO member states, established to address political and technical issues.

Military Representatives include:

- The Military Committee is composed of the Chiefs of Defence of NATO member countries (CHOD), the International Military Staff, the Military Committee's executive body, and the military command structure, which includes:

  - Allied Command Operations (ACO) consists of permanently established headquarters to plane and execute Alliance operations at strategic, operational and tactical levels [119];

  - Allied Command Transformation (ACT) is responsible for the transformation and training of NATO forces. It has to identify future military challenges and guide the innovation of NATO forces to ensure interoperability, warfighting capabilities, and technological progress [120].

NATO also includes organizations and agencies specialized in technical fields, an example of NATO's Agency is the NATO Standardization Office.

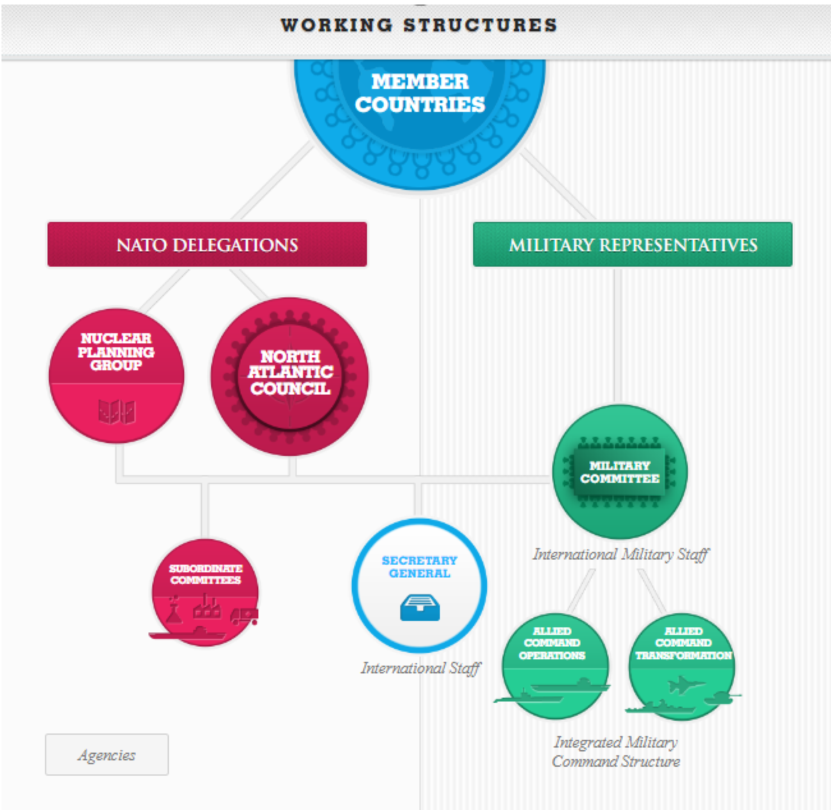


Figure 4.2: NATO working structure, (Source: NATO, What is NATO?, https://www.nato.int/nato-welcome/, 2023, [123])

Cooperation is at the basis of the NATO's success. To carry out international operations and to guarantee military efficiency and interoperability NATO understood the need for a common set of standards, rules and guidelines. In 1951 the Military Office for Standardization was established in London for military-only activities. Then the MOS headquarter moved to its current location in Brussels and in 1994 the Office for NATO Standardization for civilian staff was created. From 1998-2000 the MOS was combined with ONS and the NATO Standardization Agency was created. Finally, in 2014 the NSA became the NATO Standardization Office.[121]

NATO Standardization Office [121] [122]

The NATO Standardization Office is under the authority of the Committee for Standardization. The CS operates under the authority of the North Atlantic Council and is composed of representatives from all NATO nations. The Committee issues policy and guidance for all NATO standardization activities, contributing to the Allies' development

of interoperable and cost-effective military forces and capabilities. The NSO Director is assisted by the NATO Standardization Staff Group. This is a staff-level forum that facilitates the coherence of NATO standardization activities across NATO bodies.
The NSO standardizes activities with "the goal of enhancing the interoperability and operational effectiveness of Alliance military forces"[2]. It initiates, coordinates, supports, and administers the standardization process.
NATO defines a standard as:

"document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context."[3]

NSO publishes standardization documents to enable people from all the member states to have compatible equipment, comprehend each other procedures, and maintain commonly required levels of compatibility and interchangeability to operate together in common missions. An example of a standardization document is a Standardization Agreement (STANAG) which is a document that "specifies the agreements of member countries to implement a standard"[4] in order to meet an interoperability requirement. STANAGs are published in a database in English and French.

4.1.2 ARMAEREO

The DAAA also known as ARMAEREO is the Directorate of Aeronautical Armaments and Airworthiness[5] which is the only regulatory body in the Italian military sector. Its mission is to "acquire and make available, at a reasonable price, to the Italian Armed Forces and other Government Organizations aerospace defense systems that can ensure airworthiness, from commissioning to their decommissioning, and that are safe for the crew, transported people and the overflight population and that meet operational requirements"[6].

[2]NATO, Standardization Office, https://www.nato.int/cps/en/natohq/topics_124879.htm, 2023

[3]NATO's standard definition, Source: NATO, Standardization, https://www.nato.int/cps/en/nato.htm, 2023

[4]STANAG definition, Source: NATO, Standardization, https://www.nato.int/cps/en/nato hq/topics_69269.htm, consulted in October 2023

[5]Repubblica Italiana, D.P.R 15 marzo 2010 n-90, Art. 113 "Principi e disposizioni comuni delle direzioni generali", consulted in October 2023, [28]

[6]ARMAEREO's Mission, Soruce: Ministero della Difesa, ARAMEREO, https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/Pagine/default.aspx, consluted in October 2023, [31]

Figure 4.3: DAAA logo (Source:https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/ChiSiamo/Pagine/Compiti.aspx)

In Italy, the Navigation Code governs and regulates maritime, internal, and air navigation in maritime and air space under the sovereignty of the Italian Republic. It specifies that this Regulation does not apply to military[7], custom[8] and State[9] aircrafts, whose operations shall be managed, controlled, and regulated by DAAA.
According to Article 15 of the Legislative Decree of 16 January 2013[10], DAAA:

- *"admits military aircraft to air navigation by aircraft type certification and their registration in the Register of Military Aircraft (RAM);*
- *performs and represents the Italian Military Airworthiness Authority in National and International Organizations;*
- *acquires and uses military aircraft, weapons, armaments, and equipment;*
- *issues technical regulations and airworthiness training;*
- *supervises study, design, technical development, construction, production, transformation, modernization and technical investigations activities"[11].*

The DAAA is the only regulatory organization in the Italian Military sector. The comparison with International Regulatory Framework is important. As a NATO member, Italy is

[7]R.G 30 marzo 1942 n.327, Art. 745 “Codice della navigazione”, consulted in October 2023

[8]R.G 30 marzo 1942 n.327, Art. 744, 746 “Codice della navigazione”, consulted in October 2023

[9]R.G 30 marzo 1942, n.327, Art. 748 “Codice della navigazione”, consulted in October 2023

[10]Ministero della Difesa Italiana, Decreto 16 gennaio 2013, https://www.gazzettaufficiale.it/eli/id/2013/03/26/13A02532/sg, consulted in October 2023

[11]Ministero della Difesa Italiana, Decreto 16 gennaio 2013, Art. 15, https://www.gazzettaufficiale.it/eli/id/2013/03/26/13A02532/sg, consulted in October 2023

involved in the unifying regulations process with Allies. Where applicable, ARMAEREO adopts and integrates NATO standards. In addition, EASA, FAA and ENAC regulation activities are always considered.

Organization Structure [32]

ARMAEREO structure is composed of a management body including a Director and two Deputy Directors, three offices, three departments, ten divisions, and ten non-executive level services.[12] The Director is nominated by the Minister of Defence and is supported by the Technical Deputy Director and the Administrative Deputy Director.

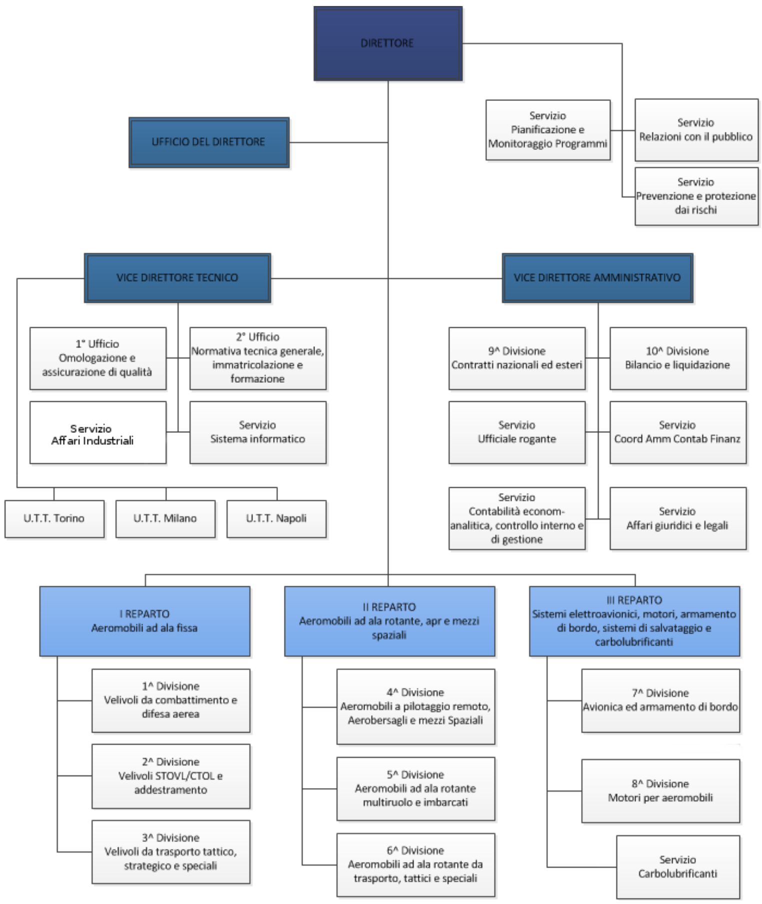


Figure 4.4: ARMAEREO organization chart, Source: ARMAEREO https://www.difesa.it/SGD-DNA/Staff/Pagine/Organigramma.aspx

[12] Art. 15 DPR 16 Gennario 2013

The Technical Deputy Director supervises:

- The Approval and Quality Assurance Office
  It is headed by an officer with the rank of Colonel of the Aeronautical Corps and performs the following tasks:

  - determination and approval of qualification program;
  - analysis of the test reports for the purposes of the type-approval and qualification of military aircraft and their systems;
  - issuing the type-approval and qualification certificates for military aircraft and their systems;

- The General Technical Regulations, Registration and Training Office
  It is headed by an officer with the rank of Colonel of the Aeronautical Corps, and performs the following tasks:

  - Acts preparation for the registration of military aircraft;
  - Maintenance and management of the Register of Military Aircraft and the control of registered military aircraft;
  - Investigation activities in the event of flight accidents;
  - Coordination and adoption of NATO Standard Agreements;
  - Training and qualification of military personnel and State Armed Corps in the field of technical legislation.

- Computer service
- Industrial Affair Service
- Three UTT offices

The Administrative Deputy Director, coordinates and controls the activities of the administrative divisions, supervising:

- 9° Division - National and foreign contracts;
- 10° Division - Budget and liquidations;
- Department of Administrative Financial Accounting;
- Economic, analytical, internal and management accounting service;

- Legal Affairs Service.

In addition, DAAA includes three departments:

- I Department - Fixed-wing aircraft
  Headed by an Air Force officer with the rank of General Commander of the Aeronautical Corps, is divided into:
  - 1° Division - Combat and air defense aircraft;
  - 2° Division - STVOL/CTOL airplanes and training;
  - 3° Division - Tactical, Strategic and Special Transport Aircraft;
- II Department - Rotary wing aircraft, APR and spacecraft
  It is divided into:
  - 4° Division - Unmanned aircraft, Aircraft targets and special vehicles;
  - 5° Division - Multirole and boarded rotary wing aircraft;
  - 6° Division - Transport, tactical and special rotary wing aircraft.
- III Department - Electro-avionics systems, engines, on-board armament, rescue systems and carbon lubricants
  It is divided into:
  - 7° Division - Avionics and onboard armament;
  - 8° Division – Aircraft engines;
  - Fuel Service.

4.2 Introduction to Military Regulatory Framework

4.2.1 NATO [117]

As defined by the International Convention of Civil Aircraft (ICAO), aircrafts can be divided into civil and state. State aircrafts employed by the government for safety, security and welfare of the public, are regulated independently by competent authorities of national governments and are not subordinate to civil standards. Also UAS, operated for the same purposes, are subjected to this regulatory system. Initially, military unmanned aerial systems were designed to operate on the battlefield and/or in segregated airspace. However, the rapid development of this technology has brought out its potential and highlighted the critical issues of this approach: these operational limitations provide great restrictions on the use of UAS, not allowing the full potential of these systems to be exploited. For example, many unmanned systems are used in civil airspace for surveillance missions or have to transit in civil airspace during normal operations. For this reason, it is necessary to integrate them within the common airspace, ensuring adequate levels of safety and performance.

NATO started to work on the development of airworthiness standards for UAS about 20 years ago. The Joint Capability Group Unmanned Aircraft Systems was formed to improve the operational effectiveness of UAS and to provide a basis to meet the full potential of unmanned aerial systems ensuring availability, interoperability, utility and operational integrity of UAS. In addition, due to the complexity of operating in non-segregated airspaces a dedicated working group was established. The FINAS was formed within JCGUAS to provide standards to design, build and test UAS to be compliant with the airworthiness requirements needed to operate them in the common civil airspace.

In 2009, FINAS issued the first NATO UAS Airworthiness Standard: the standard agreement 4671 Edition 1. In 2019 the updated third edition was published. This airworthiness code is applicable to fixed wing UAS of maximum take-off weight of more than 150 kg and less than 20.000 kg[13].

The work conducted on STANAG 4671 and the NATO classification of UAS highlighted the need for additional airworthiness standards to cover smaller UAS types. The STANAG 4671 is suitable to cover larger types of UAS, so three additional standard agreements were developed: STANAGs 4702 (for rotary wing), 4703 (for light UAS) and 4746 (for

[13] NATO, AEP-4671 Edition B Ver.1, Book 1 - Airworthiness Code, Subpart A - General, USAR.1 Applicability, p.1-A-1, 2019

small VTOL UAS, still to be ratified).

As will be highlighted in the following paragraphs, these STANAGs are mainly based on Certification Specification used in manned civil aviation, and assumed as a reference considering the addressed type of aircraft and its weight. Indeed, civil aviation CS represent the minimum airworthiness requirements for flight in non-segregated airspace with minimal or no restrictions. Currently, one of the main differences between civil and military aviation is the type of approach used in the regulatory process. As introduced in the previous chapter, the civil aviation is replacing the traditional classification approach based on aircraft characteristics and weight, proposing for UAS a new regulatory method risk-oriented and operation-centric. On the other hand, the military aviation regulatory system is still built on the traditional weight approach. Indeed, during the development of military UAS regulations, experts identified 16 items that would not be included in standards, the type of operation is one of them.

STANAG 4671 [126] [127]

In 2009, the first edition of Standardization Agreement 4671 was published to respond to the necessity of "use common standards for the production of airworthiness requirements for unmanned aircraft systems"[14]. The related standard was the AEP-4671 Edition A. Actually, the third edition (2019) is on force.

AEP-4671 contains "a set of technical airworthiness requirements for the certification of fixed-wing military Unmanned Aircraft Systems with a maximum take-off weight between 150 and 20.000 kg that intend to regularly operate in non-segregated airspace"[15]. This document is derived form EASA CS-23 and 14 CFR Title 14 Part 23, with additional new requirements and sub-parts related to unique features of unmanned aircraft.

The AEP-4671 includes an introduction and two books. Book 1 is the Airworthiness Code, named USAR (UAV Systmes Airworthiness Requirements). Book 2 contains the related Acceptable Means of Compliance.
Book 1 is further divided into nine interrelated sub-parts, covering the following areas, as shown in table below.

[14]NATO, STANAG 4671, Edition 3, Interoperability Requirements, p.1, 2019

[15]NATO, AEP-4671, Book 1-Airworthiness Code, Subpart A-General, USAR.1-Applicability, 2019

Table 4.1: USAR Structure, (Source: NATO, AEP-4671 Ed.B Ver.1, Paragraph 1.2.3 "USAR Structure", p. 4, 2019)

		UA System				
		UA	Command and control data link	Communication system	UA control station	Other ancillary elements
A	General	x	x	x	x	x
B	UA Flight	x				
C	UA Structure	x				x
D	UA Design and Construction	x				x
E	UA Powerplant	x				
F	Equipment	x				
G	Operating limitations and information	x	x	x	x	x
H	Command and control data link Communication system		x	x		
I	UA control station				x	

Subparts numbers throughout sub-parts A-G correspond directly to CS-23, while section H and I are unique to USAR.
Book 2 contains materials describing acceptable means of compliance.
The USAR is expected to be used to define the UAS Type Certification Basis using the applicable paragraphs of the Airworthiness Code (Book 1), completed by the related USAR Acceptable Means of Compliance (Book 2).

STANAG 4702 [124] [125]

In 2014, NATO published the Standardization Agreement 4702 Edition 1, addressing "common standards for the production of airworthiness requirements for Rotary Wing Unmanned Aerial Systems"[16]. The related standard is the AEP-80, Edition A.
In 2016 STANAG 4702 Edition 2 and AEP-80 Edition B were issued.
This document contains a set of technical airworthiness requirements, which represents

[16]NATO, STANAG 4702, Edition 2, Interoperability Requirements, p.1, 2016

the minimum acceptable airworthiness requirements, "for the airworthiness certification of rotary-wing military UAV Systems with a maximum take-off weight between 150 and 3.175 kg that intended to regularly operate in non-segregated airspace"[17].
The airoworthiness code, named USAR-RW, is based on EASA CS-27 amendment 2 with additional requirements derived form STANAG 4671.

NATO issued this document to be used to define the certification basis for rotary-wing UAV Systems to obtain the Type Certificate. The AEP-80 is divided into two books. Book 1 is the Airworthiness Code, while Book 2 include the related acceptable means of compliance. Applicant should identify applicable paragraphs of USAR-RW and the appropriate AMC. The USAR-RW is further divided into nine sub-parts, coverign the following areas as shown in table below. Subparts from A to G are derived from CS-27 amendment 2, while subpart H and I have been previously introduce in STANAG 4671.

Table 4.2: USAR-RW structure, (Source:[124])

#	TITLE	UAV	C2-DL	CS	UAV control station	Other ancillary elements
A	General	**x**	**x**	**x**	**x**	**x**
B	UA Flight	**x**				
C	UA Structure	**x**				**x**
D	UA Design and Construction	**x**				**x**
E	UA Powerplant	**x**				
F	Equipment	**x**				
G	Operating limitations and information	**x**	**x**	**x**	**x**	**x**
H	Command and control data link Communication system		**x**	**x**		
I	UA control station				**x**	

[17] NATO, AEP-80 Ed.B Ver.1, Book 1-Airworthiness Code, Subpart A-General, USAR-RW.1-Applicability, 2019

STANAG 4703 [129] [128]

In 2014, NATO issued the Standardization Agreement 4703 Edition 1, addressing "common standards for the production of airworthiness requirements for Light Unmanned Aerial Systems"[18]. In this document participating nations agree to implement the standard AEP-80 Edition A. In 2023 STANAG 4703 Edition 3 and AEP-83 Edition C were issued.

The AEP-83 contains "the minimum set of technical airworthiness requirements intended for the airworthiness certification of fixed-wing Light UAS with a maximum take-off weight not grater than 150 kg and an impact energy greater than 66 J[19] that intend to regularly operate in non-segregated airspace"[20].

This document is expected to be assumed as certification basis for Light UAS. The following rules and standards have been used as reference material[21] to define this STANAG:

- STANAG 4761[22];
- CS-VLA[23];
- CS-22 amendment 1[24];
- ASTM F2245-06[25];
- DEF STAN 00-56[26].

but due to the large variety of type, configurations and technology included in the Light UAS class, it was not created on the structure of an existing civil Certification Specification or other military regulations. Military experts considered that a traditional prescriptive set of airworthiness requirements was not suitable to cover this type of unmanned aircraft,

[18] NATO, STANAG 4703, Edition 3, Interoperability Requirements, p.1, 2023

[19] This lower limit is assumed considering that below this level it is reasonably expected that a fatal injury should not occur if the UA strikes a person.

[20] NATO, AEP-83 Edition C Version 1, Scope, p.12, 2023

[21] NATO, AEP-83 Ed.C Ver.1, Source Document, p.3, 2023

[22] UAV Systems Airworthiness Requirements for North Atlantic Treaty Organization Military UAV Systems

[23] Certification Specifications for Very Light Aeroplanes

[24] Certification Specifications for Sailplanes And Powered Sailplanes

[25] Standard Specification for Design and Performance of a Light Sport Airplane

[26] Safety Management Requirements for Defence Systems

and a hybrid approach was preferred.
This STANAG was issued with the following objectives:

- *"require no more than the minimum amount of certification evidence that is needed to substantiate an acceptable level of airworthiness;*
- *address all design attributes which may endanger safety;*
- *be flexible by being non-prescriptive, in order not to limit the design solution"*[27].

The starting point was a set of the "Military Essential Requirements for Airworthiness", to which other types of qualitative criteria were added, to achieve a high level of confidence that the type design is airworthy.
The result is a set of certification requirements for Light UAS in the form of a three column table in which:

i. *"the first column expresses the mandatory Minimum Essential Requirements for Airworthiness;*

ii. *the second column presents a detailed argument to elaborate the Essential Requirements in the first column into an Airworthiness Basis for a specific type of UA;*

iii. *the third column presents an acceptable set of evidence that may be provided to the Certifying Authority in order to demonstrate compliance with the detailed arguments in the second column"*[28].

Requirements are organized as follows:

Table 4.3: Light UAS Airworthiness Requirements structure

ER.1	System integrity
ER.1.1	Structures and materials
ER.1.2	Propulsion
ER.1.3	Systems and equipment
ER.1.4	Continued airworthiness of the UAS
ER.2	Airworthiness aspects of system operation
ER.3	Organizations

[27] NATO, AEP-83 Ed.C Ver.1, Introduction, p.1, 2023
[28] NATO, AER-83 Ed.C Ver.1, Requirements, p.4, 2023

STANAG 4746 [117]

STANAG 4746 is actually in development and still to be ratified. It will focused on Light Rotary Wing UAS, containing the "minimum set of technical airworthiness requirements intended for the airworthiness certification of light rotary-wing UAS with a maximum takeoff weight not greater than 150 kg and impact energy greater than 66 joules (49 ft-lb) that intend to regularly operate in non-segregated airspace"[29].

[29] Jhon E. Mayer, State of Art of Airworthiness Certification, NATO, Paragraph 6.2.4, 2017

4.2.2 ARMAEREO

In Italy, the only Military Regulatory Authority is the "Direzione degli Armamenti Aeronautici e per l'Aeronavigabilità"(DAAA or ARMAEREO). According to the Convention on International Civil, whose provisions were acquired and implemented in Italy by the Navigation Code, Military Aircrafts are not subordinate to civil regulations, but fall under the jurisdiction of National Governments. Indeed, pursuant to Article 745 of the Navigation Code: " Sono military gli aeromobili conderati tali da leggi speciali e comunque quelli, progettati dai costruttori secondo caratteristiche costruttive di tipo militare, destinati ad usi militari. Gli aeromobili militari sono ammessi alla navigazione, certificati ed immatricolati nei registri degli aeromobili militari dal ministero della difesa"[30]. DAAA accomplishes this task through the development, issuance and enforcement of regulations for the airworthiness of military aircraft and the verification of their performance. These regulations are taken as the basis for certifying and qualifying aerial vehicles, issuing the Military Type Certificate and the Military Qualitifcation, that are needed to perform UAS operations in Italy.[29]

The certification of an aircraft, engines, APUs and propellers or type-approval of an aircraft's equipment and systems is the formal recognition by a competent authority that the technical, performance and safety characteristics defined in the certification basis have been met. The military type certificate and/or type qualification certificate are issued containing main information characteristics, performance and limitations of the design, as well as a technical report containing a summary of the assessments made and the reference documentation used in the whole process (MOC, MOE, Compliance Matrix, etc.)
The relevant applicable Italian regulations containing the information to identify and define the requirements, necessary documents and procedures to be followed to obtain military certificates and operate military aircrafts are:

- AER(EP).P-2;
- AER(EP).P-6;
- AER(EP).P-7.

These regulations were developed to regulate all aircraft for military use employed by the Armed Forces or as State aircraft, but have also been adapted for unmanned aircraft systems.

[30] Repubblica Italiana, Codice della Navigazione, Art. 745, 2018 [23]

The AER(EP).P-2, titled "Omologazione, Certificazione e Qualificazione di Tipo Militare, Idoneità alla Installazione"[31], establishes the procedures to certify and qualify military aircraft, engines, APU and propellers and how to show compliance with airworthiness and performance requirements, contained in Technical Specifications ([24], p.1). To operate an aircraft, this regulation requires the fulfillment of two main objectives: the 'fit for flight' and the 'fit for purpose'. In the first case, compliance with airworthiness requirements must be demonstrated, whereas in the second case, evidences must be provided to show the capability of the aircraft to accomplish mission's activities for which it was designed ([24], p.2). So, the military-type certificate is issued to ensure compliance with airworthiness requirements, and the military qualification is issued to formalize the fulfillment of performance requirements.

The AER(EP).P-6 titled "Istruzioni per la compilazione dei Capitolati Tecnici per Aeromobili Militari" aims to:

- *"Define the structure of a Technical Specification;*
- *specify the type of requirements it should contain;and*
- *provide guidelines for defining quantitative performance and airworthiness requirements"*[32]

Particularly, the Part 3° contains instructions to identify the contents of the Technical Specifications and its structure. It sets the document has to be composed of three parts:

- Part I - Specifica Tecnica
  It collects performance requirements and can be filled out in accordance with Annex A to AER(EP).P-6, containing a standardized list of technical specifications topics;
- Part II - Airworthiness Basis
  It contains airworthiness requirements, which can be derived form applicable STANAGs for UAV Systems. Annex B of AER(EP).P-6 includes essential minimum airworthiness requirements.
  This part will also include Safety Requirements. Annex C provides instructions to identify safety requirements and to quantify them, for example, it contains guidelines to determine the cumulative probability of catastrophic event.

[31]DAAA, AER(EP).P-2 "Omologazione, Certificazione e Qualificazione di Tipo Militare, Idoneità alla Installazione", 2010

[32]DAAA, AER(EP).P-6, Scopo, p.1, 2012

- Part III - Other prescriptions.

All applicable performance and airworthiness requirements and the related means of compliance have to be defined using the relevant international regulations, such as STANAGs or CSs, and have to be agreed with DAAA.

The AER(EP).P-7 titled "Norma per l'iscrizione e la tenuta del registro degli aeromobili militari (R.A.M)" aims to:

- *"establish criteria and procedures to register military aircrafts in the R.A.M. and the relative competence levels of teh pilots in command;*
- *describe the procedure used to assign Military Registration Numbers, Temporary Registration Numbers, Experimental and Prototype Tail Numbers to military aircraft and RPAS with an empty weight equal or higher than 20 kg;*
- *describe how to enter the Type, for RPAS with an empty weight of less than 20 kg; and*
- *establish the procedure to request and assign the 24 bit codes for Mode S Transponder and Emergency Locator Transmitters (ELT) in line with ICAO regulations"*[33].

The Military Aircraft Register includes five type of registration:

- Prototype Tail Numbers
  It "enables experimental ground and flight testing activities [...] within an authorized area"[34]
- Experimental Tail Numbers
  It addresses "aircraft that have not yet received a Military Registration Number"[35] or aircraft subjected to "technical modifications which impact the approved configuration"[36] and allows them to perform experimental and test activities.

[33]Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Regulation for Recording and Maintaining the Military Aircraft Register (Registro degli Aeromobili Militari - R.A.M)", p.2, 2012

[34]Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Regulation for Recording and Maintaining the Military Aircraft Register (Registro degli Aeromobili Militari - R.A.M)", p.10, 2012

[35]Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Regulation for Recording and Maintaining the Military Aircraft Register (Registro degli Aeromobili Militari - R.A.M)", p.13, 2012

[36]Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Regulation for Recording and Maintaining the Military Aircraft Register (Registro degli Aeromobili Militari - R.A.M)", p.13, 2012

- Temporary Registration Numbers
  It is issued "to aircraft compliant with a First Production Sample already in service to perform [...] activities to be carried out before the completing acceptance procedure, or, [...] SDR activities on aircraft already delivered to the Armed Force or State Corp, and that return to the SDR's availability"[37].

- Military Regiustration Numbers
  It "uniquely identify military aircraft whose use is authorized and regulated by the D.A.A.A"[38].

- Alphanumeric codes for Micro and Mini RPAs
  It is associated "with the single aircraft until the end of its operational life, and is stored in the on-board Mode S Transponder, ELTs or both"[39].

How to operate a military UAS in Italy

Hence, to employ an unmanned aircraft system in Italy it is required that the UAS obtained the military type-certificate and the qualification certificate according to AER(EP).P-2 provisions and that is admitted to flight navigation and registered in the R.A.M according to AER(EP).P-7.

To obtain the type and qualification certificates, the AER(EP).P-2 sets in subsection 3.2, that the SDR, in addition to the application form for the type/qualification certificate, must send to the 1° VDT Office of the DAAA the following documentations:

- Technical specification, containing airworthiness and performance requirements;

- Design Organization Manual, demonstrating eligibility to hold the military type certificate and military type qualification certificate ([24], p.6);

- Type Certification Progam Plan, containing a description of the verification activities for certification, and the means of compliance related to each airworthiness requirement ([24], p.7); and

[37]Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Regulation for Recording and Maintaining the Military Aircraft Register (Registro degli Aeromobili Militari - R.A.M)", p.18, 2012

[38]Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Regulation for Recording and Maintaining the Military Aircraft Register (Registro degli Aeromobili Militari - R.A.M)", p.13, 2012

[39]Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Regulation for Recording and Maintaining the Military Aircraft Register (Registro degli Aeromobili Militari - R.A.M)", p.22, 2012

- Type Qualification Progam Plan, containing the description of verification activities for qualification, and the means of compliance used for each performance requirement ([24], p.7).

AER(EP).P-2 indicates the AER(EP).P-6 as the reference regulations to fill out Technical Specifications. As defined in this regulation, the technical specification must contains performance and airworthiness requirements, which have to be identified in the international regulations such as STANAGs and CSs, for example for rotary-wing UAS the reference document can be the STANAG 4702, and defined in accordance with the authority (ARMAEREO). The compliance with these requirements must be demonstrated through suitable means of compliance, in addition the applicant has to provide two compliance matrices (one for performance requirements and the other for airworthiness requirements) relating each requirements with the appropriate MOC and MOE.

Safety requirements must also be included within the Airworthiness Basis. Annex C of AER(EP).P-6 contains guidelines to define them. They are essential to guarantee the airworthiness of the system, taking into also the risk posed to overflown people. As mentioned earlier, this regulation addresses all type of aircraft, however, the unmanned aircraft systems are characterized by the absence of people on board, so the risk to which people are subjected to corresponds to the risk posed to overflown people. All requirements, so even safety requirements must be defined taking into consideration the peculiarities of UAS and their differences from manned aircraft, proposing solutions tailored to the type of aircraft involved, agreed with DAAA.
The safety requirements that must be defined are reported below:

- Fail-Safe
  The SDR has to design all aircraft systems to guarantee that all possible failure conditions do not lead to a catastrophic event, considering each system individually and in relation with other systems. ([25], Annex C, p.C-1)

- Cumulative probability of catastrophic event
  This requirement will be presented in details in Chapter 6.

- Hazard Risk Index Matrix
  To assess the risk it is necessary to define severity categories (Catastrophic, Critic, Major, Minor) and the related level of probability of occurrence (Frequent, Probable, Remote , Improbable). This matrix will define the inverse relationship between these to aspect.

- Hazard Zonal Analysis
  It is used to evaluate safety aspects related to the installation of systems.
- System Safety Program Plan
- Software Requirements.

In order to verify the compliance with the safety requirements, AER(EP).P-2 sets that the SDR has to perform a System Safety Assessment (SSA) since the earliest stages of design. It consists essentially of the following steps:

- *"A qualitative assessment, using a Top-Down approach, and subsequent classification of the severity categories of the risk due to the loss or malfunction of major aircraft functions (Functional Hazard Assessment);*
- *A qualitative assessment, using a Down-Top, FMECA ("Failure Mode effects and Criticality Analysis");*
- *A quantitative assessment, for the failure conditions with a severity level equal to catastrophic or critic, using a Top-Down Approach ("Fault Tree Analysis");*
- *Acceptability assessment of the level of risk and related probabilities of the failure conditions identified, according to the matrix of risk categories defined in the technical specifications (Hazard Risk Index Matrix);*
- *The identification of safety devices, warning devices and any appropriate and established procedures to mitigate the risk;*
- *A Common Cause Analysis, that includes an Hazard Zonal Analysis, to assess the safety level of installation aspects"*[40].

Finally, in order to operate a military aircraft, the DAAA has to assign a military registration number and register it in the R.A.M, specifying the authorized configuration, employment envelop and operational limitations contained in the related military certificates. ([26], p.19)

[40] DAAA, AER(EP).P-2 "Omologazione, Certificazione e Qualificazione di Tipo Militare, Idoneità alla Installazione", p.8, 2013

Chapter 5

The Grottaglie-Taranto Scenario

This chapter covers the implementation of the SORA process for a practical operational scenario that falls into the 'specific' category. To conduct the operational risk assessment, the SORA 2.0 methodology will be applied following the steps described in Chapter 3. In addition, the SORA 2.5 will be applied to the Taranto-Grottaglie scenario in the last section of this chapter, highlighting the main differences between this new version and the SORA 2.0 to assess the impact of changes introduced in the future updated edition.

In the following lines, main information about the proposed operational scenario and the organization, common to both versions of the SORA, will be presented.
The proposed operational scenario is intended to cover UAS operations performed in the 'specific' category with the following main attributes:

- Unmanned Aerial System (UAS) with a maximum characteristic dimension of about 4 meters;
- UAS operations beyond visual line of sight (BVLOS);
- UAS flying over controlled ground area or sparsely populated areas;
- UAS flying within airspace which is reserved for the operation under the presence of dynamic segregation (i.e. activation/deactivation of NOTAM and airspace monitoring by ATC/UAS Operator Traffic Control).

The UAS of interest has similar characteristics and performance to AWHERO RPAS designed by Leonardo S.p.A Helicopter Division.

In addition, in order to conduct the risk assessment process based on SORA methodology it is useful to note that it is assumed that the designing and producing organization obtained the Design Organization Approval and the Production Organization Approval, issued by EASA. DOA and POA ensure that the organization is able “to establish and to maintain a design assurance systems for the control and supervision of the design, and of design changes, of products, parts”[1] and is able to establish and maintain a quality system that “ensure that each product, part or appliance produced by the organization or by its partners, or supplied from or subcontracted to outside parties, conforms to the applicable design data and is in condition for safe operation”[2]. For example, the quality system shall contain control procedures for document issues, manufacturing processes, inspection and testing, personnel competence and qualification, etc.[20]

5.1 Risk assessment based on SORA 2.0

5.1.1 Pre-application evaluation

Before starting the SORA process, a pre-assessment must be carried out ([101], 2019, p. 19). The applicant should verify that the proposed operation is feasible and compliant with the conditions for which the SORA process applies, answering the following questions:

- The operation falls under the “open” category?
  The operation consists of a BVLOS operation conducted by a UAS with a maximum take-off weight of 200 kg. So, the operation does not fall under the "open" category.

- The operation falls under the “certified” category?
  Operation does not involve the transport of people or the carriage of dangerous goods, are not conducted over assemblies of people. So, the operation does not fall under the "certified" category.

- The operation is covered by a “standard scenario” recognized by the competent authority?
  Standard scenarios currently approved by the competent authority are: STS #01[3](over

[1] European Commission. Commission Regulation (EU) No 748/2012 of 3 August 2012,Subpart J, 21.A.239, 2012, [20]

[2] European Commission. Commission Regulation (EU) No 748/2012 of 3 August 2012, Subpart G, 21.A.139, 2012, [20]

[3] EASA. Appendix 1, Annex to Implementing Regulation (EU) 2019/947,"Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and 2019/945)", p.356, 2022, [46]

sparsely populated areas, in uncontrolled airspace, at very low levels, BVLOS with visual air risk mitigation, using unmanned aircraft up to 3m dimensions (wingspan or rotor diameter), and STS#02[4] (over sparsely populated areas, in airspace reserved for the operation, BVLOS, using unmanned aircraft up to 3m dimensions (wingspan or rotor diameter)). The maximum characteristic dimension of the employed UAS is 4 m (rotor diameter) so, the operation does not fall under a standard scenario.

- The operation is subjected to specific NO-GO from a competent authority?
  No.
- The competent authority has determined that the UAS is "harmless" for the ground risk.
  No.

None of the above cases applies, so the SORA process can be applied.

5.1.2 Step#1 - ConOps description

The applicant has to "collect and provide the relevant technical, operational and system information needed to assess the risk associated with the intended operation of the UAS"[5]. The applicant shall use as reference SORA Annex A, which contains a detailed framework for data collection and presentation. For example, the applicant has to submit information such as: organization overview, a description of the involved personnel, training activities and operational procedures, as well as a detailed description of the UAS (unmanned aircraft, control station, C2 link, etc.). The collection of all these aspects is essential for conducting a proper risk assessment, but due to the complexity and nature of this information will be omitted. However, it is possible to assume without further evidence that the organization, due to the DOA and POA approvals issued by EASA, has all the necessary information and procedures in place to collect and provide all the relevant data in compliance with the guidelines of Annex A.
For convenience, only a brief description of the operations, the main characteristics of the system employed, the soil area overflown and the airspace of interest will be reported below.

The purpose of the proposed operation is to conduct surveillance activities over a portion

[4]EASA. Appendix 1, Annex to Implementing Regulation (EU) 2019/947,"Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and 2019/945)", p.366, 2022, [46]

[5]JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, JARUS, p.19, 2019, [101]

of the sea a few kilometers from the coast. The unmanned aircraft will take-off from the Taranto-Grottaglie Airport. After leaving the Airport Area, the UA will follow a planned flight path in a Corridor Area, connecting the airport with the Operations Area, extended in front of the coastline from about Talsano to Campomarino. The "Marcello Arlotta" Airport is located about 4 km from Grottaglie and 16 km from Taranto, at a distance from the coast (in a beeline) of about 18 km. Figure 5.1 shows a satellite view of the area around the interested zone.

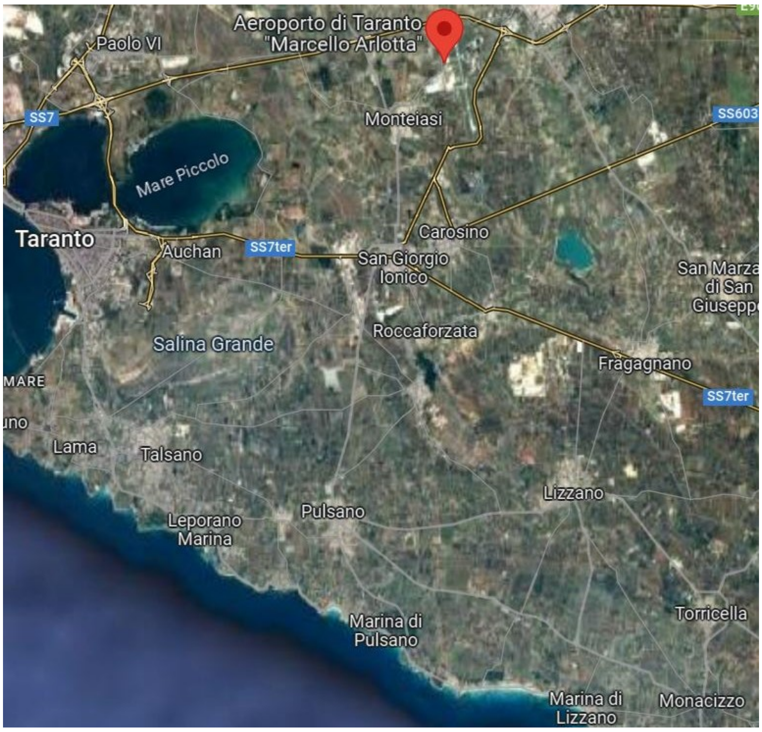


Figure 5.1: Satellite view of the area around the Taranto Airport, (Source: Google Maps)

The UAS employed is a rotor-wing unmanned aerial system with a maximum characteristic dimension of about 4 meters.
A typical flight operation can be divided into three main phases:

- Take-off from the Taranto-Grottaglie Airport;
- Flight over a Corridor Area connecting the Airport Area with the Operation Area;
- Flight over the Operation Area.

The flights will be performed in an segregated airspace. The airspace inside the boundary of the segregated airspace has the structure depicted in Figure 5.2

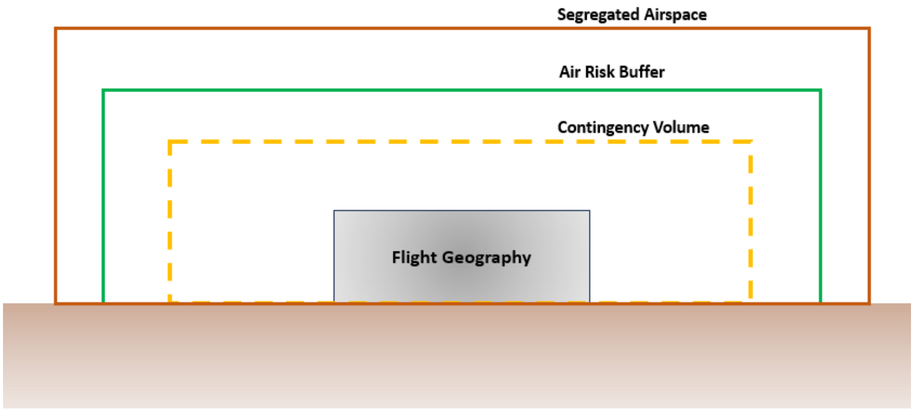


Figure 5.2: Air volumes sectional view

It is divided in:

- The Flight Geography, the airspace where the planned flight will be performed;
- The Contingency Volume, the airspace where the UAS may fly in case of abnormal conditions. There contingency procedures must be executed to return the unmanned aircraft into the Flight Geography. For the intended operation, this volume corresponds to the FTS[6] Activation Volume which is the airspace whose boundary is the ultimate limit within which the Flight Termination System has to be activated, in case of unrecoverable loss of control of the AV;
- The Air Risk Buffer, the ultimate limit within the UAS shall be contained to end its flight in case of a loss of control. This is a safe volume whose boundary is the ultimate limit within which it is planned that the AV would crash, in case of Flight Termination System activation.

The Contingency Volume and the Risk Buffer are sized on the basis of the flight termination procedures and the dynamic behaviour of the aerial vehicle in case of loss of control.

The soil area beneath the Safe Volume can be divided into three different area types:

- Airport areas, restricted to authorized staff involved in the flight activities;
- Corridor area, connecting the Airport Area with the Operation Area, in a sparsely populated environment;
- Operation area, over the sea.

[6]Flight Termination System

5.1.3 The Ground Risk Process

The Ground Risk Class is related to the risk posed to persons, properties or critical infrastructures being struck by an unmanned aircraft. This evaluation takes into account third parties or properties on the ground that could be endangered by flight activities, but also the complexity of operations and the technical characteristics of the unmanned aircraft. At first, the intrinsic GRC is determined, then after the application of the mitigations, the residual GRC is evaluated.[101]

Step#2 - Determination of the intrinsic UAS Ground Risk Class (GRC)

The intrinsic UAS ground risk relates to the unmitigated risk of a person being stuck by the UAS, in case of loss of UAS control, and it is derived from the intended operational scenario and the UAS maximum dimension, as shown in Table 5.1

Table 5.1: iGRC Determination, (Source: JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, Main Body, p.20, 2019, [101])

Intrinsic UAS Ground Risk Class				
Max UAS characteristics dimension	1 m / approx. 3ft	3 m / approx. 10ft	8 m / approx. 25ft	8 m / approx. 25ft
Typical kinetic energy expected	700 J (approx. 529 Ft Lb)	34 KJ (approx. 25000 Ft Lb)	1084 KJ (approx. 800000 Ft Lb)	1084 KJ (approx. 800000 Ft Lb)
Operational scenarios				
VLOS/BVLOS over controlled ground area	**1**	**2**	**3**	**4**
VLOS in sparsely populated environment	**2**	**3**	**4**	**5**
BVLOS in sparsely populated environment	**3**	**4**	**5**	**6**
VLOS in populated environment	**4**	**5**	**6**	**8**
BVLOS in populated environment	**5**	**6**	**8**	**10**
VLOS over gathering of people	**7**			
BVLOS over gathering of people	**8**			

The maximum characteristic dimension of the employed UAS is about 4 m.

Operations are carried out in BVLOS conditions, so the pilot cannot remain in visual direct contact with the aircraft.
To determine the intrinsic GRC it is also necessary to define and analyze the area at risk where conducting operations.
To conduct operations, the flight path, the operational volume and the ground risk buffer have to be defined. Figure 5.3 shows the complete map of the operation. The blu line represents the flight path. The red perimeter is the Flight Termination Boundary, which corresponds to the Contingency Volume. The green line represents the Risk Buffer Boundary: the ultimate limit area within which it is planned that the aerial vehicle would crash, in case of Flight Termination System activation [71].

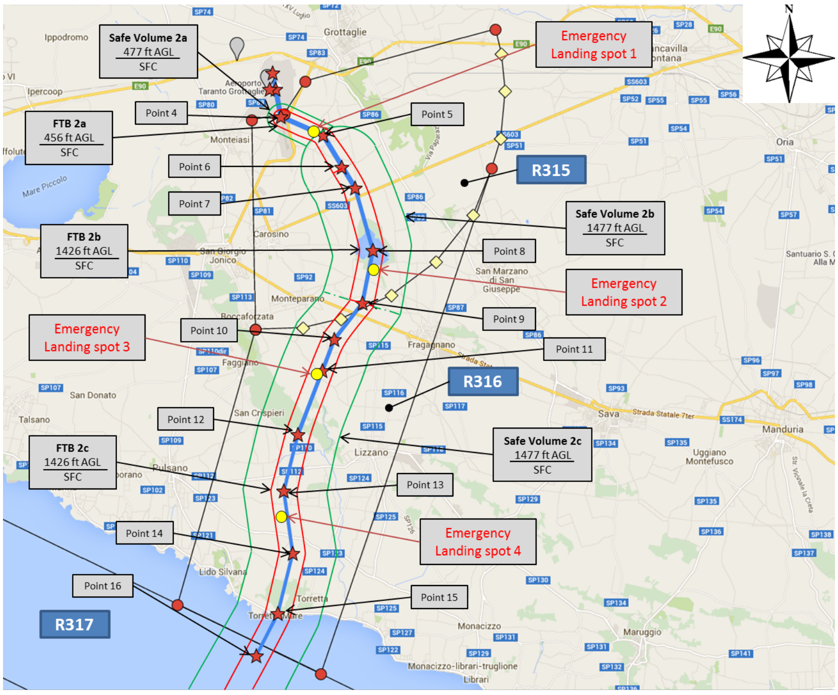


Figure 5.3: Flight path, safe volume and FTB for the mission from the airport (complete map)

As previously described, the area at risk can be divided into:

- Airport or dedicated landing areas, restricted to authorized staff involved in flight activities;
- Corridor area, connecting the airport area with the restricted access area;
- Operation area, over the sea.

The SORA 2.0 process classifies operational scenarios according to population density as:

- controlled ground area;
- sparsely populated environment;
- populated environment.

A controlled ground area is a zone where only active participants are allowed to access. While no quantitative criteria are specified to distinguish between sparsely populated or populated areas. So, for this purpose, this study will assume the limit value as 300 ppl/km^2 (recognized and shared by many European aviation authorities).

The Taranto-Grottaglie area is a restricted access area, so it can be classified as a controlled ground area, where only active participants are allowed to access.

The zone dedicated to surveillance operations corresponds to the area below the R317 airspace dedicated to drone experimental flight activities which is completely located above the sea. Although it is an area dedicated to military activities, it is not physically delimited to prevent access to uninvolved personnel. In addition, the SORA 2.0 process gives no specific guidance to classify sea areas, so to define the GRC of this zone it is assumed as a reference the approach used by Military Forces to operate in areas over the sea. The population density is considered equal to 1 inhabitant per square kilometer. The Operation Area is classified as a sparsely populated environment.

The corridor area, connecting the airport with the sea, is used only to perform pass-through operations with a limited exposure time. This area is prevalent dedicated to agricultural activities, but it includes zones where urban settlements are located. However, the flight path and safe volume are planned in such a way to avoid settlements as much as possible to minimize the risk to the third parties overflown. To determine the population density of this area, the data provided by Gistat are taken as a reference. Gistat is an online system that stores, organizes and manages the information on a geographical basis of the ISTAT, such as population and housing census data.

Figure 5.4: Population density distribution, (Source: Gistat, https://gisportal.istat.it/index.html)

The proposed map has a resolution of 1 square kilometer. Figure 5.5 shows the legenda of the population data.

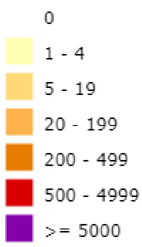


Figure 5.5: Population density data legenda, (Source: Gistat, https://gisportal.istat.it/index.html)

As shown in Figure 5.4, the area of interest is mostly uninhabited and dedicated to agriculture. Some areas are populated but with a maximum population density of 24 inhabitants per square kilometer. These zones are located especially between Monteparano and Fargagnano, San Crispieri and Lizzano, and near the coast. So, according to Istat estimates,the maximum population denisty in the operational volume and in the ground risk buffer is lower than 25 ppl/km^2 (< 300 ppl/km^2). The corridor area can be classified as a sparsely populated environment. Additional data used to determine the population density in this area are reported in Appendix A.

Table 5.2: Cell distribution by population density range

Population density range	N° of cells (resolution 1 km^2)	Note
1-4	3	
5-19	5	All < 16 ppl/km^2
20-199	4	All < 25 ppl/km^2

Due to the different characterization between each identified zone, the intrinsic Ground Risk Class is evaluated for each single area by using Table 5.1 and reported in Table 5.3.

Table 5.3: Obtained iGRC

	Airport Area	**Corridor Area**	**Operation Area**
Operational Scenario	BVLOS overControlled Ground Area	BVLOS in Sparsely Populated Environment	BVLOS in Sparsely Populated Environment
iGRC	**3**	**5**	**5**

Step#3 - Final GRC Determination

To determine the Final GRC, SORA proposes mitigations to modify the intrinsic GRC. Mitigations have a direct effect on the safety objectives associated with a particular operation, so it is important to ensure their robustness. SORA identifies three types of mitigation: M1, M2 and M3. The Final GRC is based on the availability of these mitigations, applied in numeric sequence, and their level of robustness.([101], 2019, p.21)
Table 3.8 shows the list of mitigations for the ground risk, associated with the relative correction factor, depending on the level of robustness, to be applied to the intrinsic Ground Risk Class.

For the present operational scenario, the M1 and M3 mitigations for final GRC determination have been considered with a level of robustness equal to “Medium”[7]. (Appendix C lists the rationale that lead to assess the mitigations M1 and M3 as reported in Table 5.4 and 5.5). As done for the determination of intrinsic GRC, mitigations will be evaluated for each zone into which the area at risk has been divided. The Airport area is a restricted access zone. The iGRC obtained is equal to the lower value in the applicable column. M1 mitigation cannot be applied because it is not possible to reduce the number of people at risk below that of a controlled area (the GRC cannot be reduced to a value lower than the lowest value in the applicable column in Table 5.1). Only M3 mitigation at "Medium" level will be applied. Table 5.4 shows the obtained GRC correction for the Airport Area.

Table 5.4: Applied mitigations for Final GRC determination (Airport area), (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.21, 2019, [101])

		Robustness			**Correction**
Mitigation Sequence	**Mitigations for ground risk**	Low/None	Medium	High	
1	M1 - Strategic mitigations for ground risk	**0: None -1:Low**	**-2**	**-4**	\
2	M2 – Effects of ground impact are reduced	**0**	**-1**	**-2**	\
3	M3 – An Emergency Response Plan (ERP) is in place, operator validated and effective	**1**	**0**	**-1**	**0**
Total correction					**0**

The Corridor area, connecting the airport area with the Operation area, and Operation Area have been classified as a sparsely populated environment, with a iGRC equal to 5. There M1 and M3 mitigations at robustness level equal to “Medium” are applied. Table 5.5 shows the obtained correction for this areas.

[7] See JARUS. Doc.JAR-DEL-WG6-D.04_B Annex B, "JARUS guidelines on SORA - Annex B - Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class", Version 2.0, 2019, [103], for additional explanatory information

Table 5.5: Mitigations for Final GRC determination (Corridor and Operation Area), (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.21, 2019, [101])

		Robustness			Correction
Mitigation Sequence	**Mitigations for ground risk**	Low/None	Medium	High	
1	M1 - Strategic mitigations for ground risk	**0: None -1:Low**	**-2**	**-4**	**-2**
2	M2 – Effects of ground impact are reduced	**0**	**-1**	**-2**	\
3	M3 – An Emergency Response Plan (ERP) is in place, operator validated and effective	**1**	**0**	**-1**	**0**
Total correction					**-2**

Table 5.6 shows the Finale Ground Risk Class obtained for each area.

Table 5.6: Final GRC

	Airport Area	**Corridor Area**	**Operation Area**
Final GRC	**3**	**3**	**3**

5.1.4 The Air Risk Process

The first step of the Air Risk Process is to determine the initial Air Risk Class which depends on the characteristics of the airspace and represents its aggregated collision risk. The initial ARC can be modified and lowered by applying strategic mitigation, and obtaining the residual ARC. The residual ARC is then addressed by means of tactical mitigations.[101]

Step #4 - Determination of the Initial Air Risk Class

To evaluate the initial Air Risk Class, the airspace within the safe volume has to be analyzed. It is completely located in a segregated airspace composed of the following restricted zones:

- LI R315 Grottaglie Area 1B;
- LI R316 Grottaglie Corridor B;

- LI R317 Grottaglie Area 2B.

These areas are dedicated to experimental UAS flight activities and are activated by NOTAM[8][70]. When the NOTAM is active other air traffic is prohibited and the airspace is monitored by ATC/UAS Operator Traffic Control. The initial ARC can be determined by Figure 5.6. The obtained initial Air Risk Class is ARC-a, with an associated AEC-12 (obtained by Table 3.9).

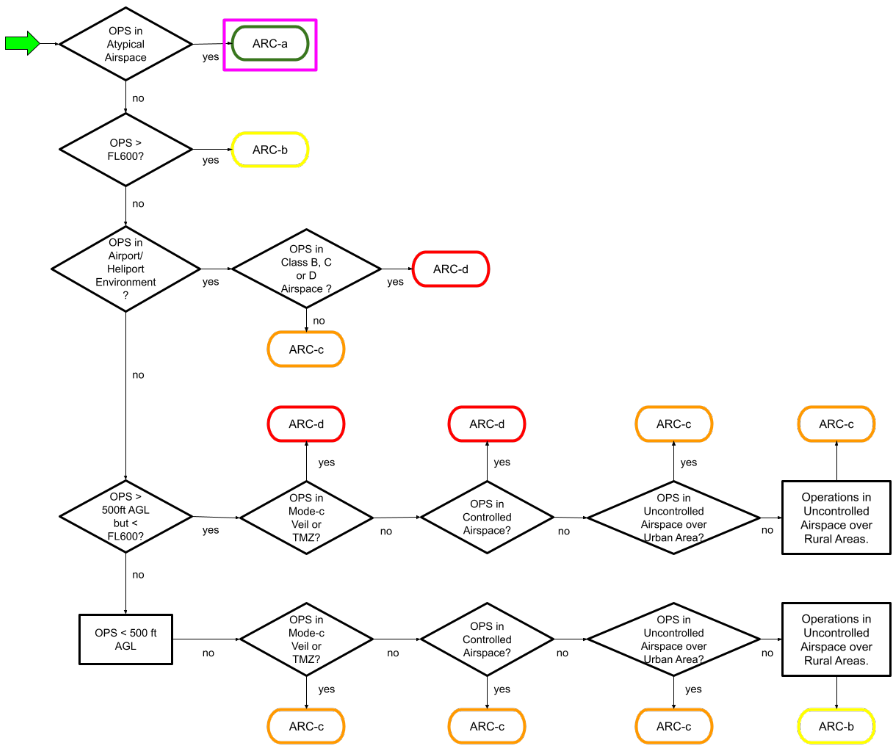


Figure 5.6: ARC assignment process, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.23, 2019, [101])

[8]NOtice To AirMen is a notification distributed through telecommunication media, containing information regarding the establishment, condition, or modification of facilities, services, procedures or aeronautical hazards, whose timely knowledge is essential for the personnel involved in flight operations [see Reg. (EU) 2017/373]

Step #5 - Application of Strategic Mitigations to determine Residual ARC (optional)

Strategic Mitigations can be applied to lower the initial ARC, if it is considered too high or does not suit best the Operational Volume.[101]
The obtained Initial ARC is ARC-a, so no Strategic Mitigations are applied to this operational scenario. The initial ARC becomes the residual ARC.

Step #6 – Tactical Mitigation Performance Requirement (TMPR) and Robustness Levels

Tactical Mitigations are applied to mitigate any residual risk of a mid-air collision needed to achieve the applicable airspace safety objective[101].
Operations will be conducted in BVLOS, so the SORA Process requires that the Residual ARC and Table 5.15 will be used to determine the Tactical Mitigation Performance Requirement (TMPR) and the associated level of robustness.

Table 5.7: Tactical Mitigation Performance Requirement (TMPR) and TMPR Level of Robustness Assignment, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.25, 2019, [101])

Residual ARC	Tactical Mitigation Performance Requirements (TMPR)	TMPR Level of Robustness
ARC-d	High	High
ARC-c	Medium	Medium
ARC-b	Low	Low
ARC-a	No requirement	No requirement

As obtained in Table 5.15 the TMPR and the TMPR robustness are 'none', so it can be concluded that the proposed operational scenario complies with the SORA criteria for TMPR and associated robustness level.

5.1.5 Final Specific Assurance and Integrity Levels (SAIL) and Operational Safety Objectives (OSO) Assignment

Step #7 SAIL determination

After determining the Final GRC and the Residual ARC, the SORA process proposes Table 5.16 to determine the SAIL associated with the proposed operational scenario. Since the Residual ARC and Final GRC are the same for all three areas into which the area at risk was divided, a unique SAIL can be calculated for the entire operational scenario.

- Final GRC = 3;
- Residual ARC = ARC-a.

The resulting SAIL is II, so the proposed operation is classified as a low-risk 'specific' category operation.

Table 5.8: SAIL determination, (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.27, 2019, [101])

SAIL Determination				
	Residual ARC			
Final GRC	a	b	c	d
<=2	**I**	**II**	**IV**	**VI**
3	**II**	**II**	**IV**	**VI**
4	**III**	**III**	**IV**	**VI**
5	**IV**	**IV**	**IV**	**VI**
6	**V**	**V**	**V**	**VI**
7	**VI**	**VI**	**VI**	**VI**
<7	Category C operation			

Step #8 - Identification of Operational Safety Objectives (OSOs)

Once determined, the SAIL is used to evaluate the defenses within the operation in the form of operational safety objectives (OSOs) and to determine the associated level of robustness [101]. The SORA process proposes a consolidated list of common twenty-three OSOs, grouped based on the threat they help to mitigate and reported in Table 5.9.

Table 5.9: Recommended operational safety objectives (OSO), (Source: JARUS. Specific Operation Risk Assessment (SORA) Version 2.0. Main Body JAR-DEL-WG6-D.04, p.27, 2019, [101])

OSO Number (in line with Annex E)		**SAIL**					
	Technical issue with the UAS	**I**	**II**	**III**	**IV**	**V**	**VI**
OSO#01	Ensure the operator is competent and/or proven	O	L	M	H	H	H
OSO#02	UAS manufactured by competent and/or proven entity	O	O	L	M	H	H
OSO#03	UAS maintained by competent and/or proven entity	L	L	M	M	H	H
OSO#04	UAS developed to authority recognized design standards	O	O	O	L	M	H
OSO#05	UAS is designed considering system safety and reliability	O	O	L	M	H	H
OSO#06	C3 link performance is appropriate for the operation	O	L	L	M	H	H
OSO#07	Inspection of the UAS (product inspection) to ensure consistency to the ConOps	L	L	M	M	H	H
OSO#08	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO#09	Remote crew trained and current and able to control the abnormal situation	L	L	M	M	H	H

OSO#10	Safe recovery from technical issue	L	L	M	M	H	H
	Deterioration of external systems supporting UAS operation						
OSO#11	Procedures are in-place to handle the deterioration of external systems supporting UAS operation	L	M	H	H	H	H
OSO#12	The UAS is designed to manage the deterioration of external systems supporting UAS operation	L	L	M	M	H	H
OSO#13	External services supporting UAS operations are adequate to the operation	L	L	M	H	H	H
	Human Error						
OSO#14	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO#15	Remote crew trained and current and able to control the abnormal situation	L	L	M	M	H	H
OSO#16	Multi crew coordination	L	L	M	M	H	H
OSO#17	Remote crew is fit to operate	L	L	M	M	H	H
OSO#18	Automatic protection of the flight envelope from Human Error	O	O	L	M	H	H
OSO#19	Safe recovery from Human Error	O	O	L	M	M	H
OSO#20	A Human Factors evaluation has been performed and, the HMI found appropriate for the mission	O	L	L	M	M	H
	Adverse operating conditions						

OSO#21	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO#22	The remote crew is trained to identify critical environmental conditions and to avoid them	L	L	M	M	M	H
OSO#23	Environmental conditions for safeoperations defined, measurable and adhered to	L	L	M	M	H	H
OSO#24	UAS designed and qualified for adverse environmental conditions	O	O	M	H	H	H

Step#9 - Adjacent Area/Airspace Considerations

The adjacent area includes populated environment areas, located around the Taranto-Grottaglie airport, around the Corridor Area and along the coast zone. The adjacent airspace is generally classified as a class D airspace.
To assess the risk of a loss of control of the operation resulting in an infringement of the adjacent areas on the ground and/or adjacent airspace:

- A Safety Report Activity is carried out for experimental activities;
- For operations with a certified system a Safety Assessment Process as defined within the Safety Management Plan is carried out in order to demonstrate the level of integrity of the system.

In order to demonstrate that:

- *"No probable failure of the UAS or any external system supporting the operation shall lead to operation outside of the operational volume;*
- *It can be reasonably expected that a fatality will not occur from any probable failure of the UAS, or any external system supporting the operation;*
- *The probability of leaving the operational volume is less than 10-4/FH;*
- *No single failure of the UAS or any external system supporting the operation leads to operation outside of the ground risk buffer"*[9].

[9]JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 2, Section

In addition:

- *"Software (SW) and Airborne Electronic Hardware (AEH) whose development error(s) could directly lead to operations outside of the ground risk buffer are developed and tested at a level adequate. The SW and AEH clearance for flight is substantiated within Flight Clearance Justification for the UAS;*
- *Electro-magnetic Compatibility (EMC) aspects for all equipment that could directly lead to operations outside of the ground risk buffer are addressed and clearance for flight is substantiated within Flight Clearance Justification for the UAS and UAS Block Clearance"*[10].

Step#10 - Comprehensive Safety Portfolio

The Comprehensive Safety Portfolio is the SORA safety case submitted to the competent authority and the ANSP prior to final authorization. It consists of all documents useful to the specific operation risk assessments and it should include all the evidence of the compliance with a level of confidence that demonstrates that the operation can be safely conducted.

2.5.3, Point (b), p.29, 2019, [101]

[10]JARUS, JARUS guidelines on Specific Operations Risk Assessment (SORA), Chapter 2, Section 2.5.3, Point (b), p.29, 2019, [101]

5.2 Risk assessment based on SORA 2.5

This section will focus on the implementation of the SORA 2.5 Process to the Taranto-Grottaglie Scenario. Main information about the proposed operational scenario and the organization have been already reported at the beginning of Chapter 5.

5.2.1 Pre-application Evaluation

Before starting the SORA process, the operator has to verify if the proposed operation is feasible and falls under the condition for which the Specific Operation Risk Assessment should be applied. SORA 2.5 does not introduce changes in this phase, so for the proposed scenario the results are the same obtained in SORA 2.0 "Pre-application Evaluation".([116], 2022, p.27)

5.2.2 Step #1 - Documentation of the proposed operation(s)

Step#1 is the primary tool through which the Competent Authority evaluates the proposed operation. It is considered as essential to the whole risk assessment because its purpose is to present all relevant information affecting the intended operation. For this reason, edition 2.5 of the SORA process modifies Step#1, to provide a more structured approach and to remove the term ConOps, which can assume several meanings in different domains. The new Step#1 is renamed as "Documentation of the proposed operation(s)" as the purpose of this step is "to describe the documentation set that should be complied with and presented to the competent authority for assessment after Step#10 completion"[11].
This documentation consists of:

- Operator manual, which is an operator-centric document that is intended to collect and present procedures, data and information used to describe or conduct operations. For example, it may include a description of the proposed operations, the UAS, etc;
- Compliance evidences, which are all necessary evidence supporting the claims of the risk assessment that are not included in the operator manual (i.e. test data and evaluation); and
- SORA safety case, which includes a description of all the steps used to carry out the SORA process.

[11] JARUS. Doc. JAR-DEL-WG6-D.04 "JARUS SORA 2.5 Explanatory notes", Version 1.0. Draft, JARUS, p.50, 2022, [111]

As done for the SORA 2.0 process, the full documentation required by this step cannot be included in this study. For the proposed scenario, the essential information are reported in Step#1 of the SORA 2.0 Process.

5.2.3 The Ground Risk Process

Step#2 - Determination of the intrinsic UAS Ground Risk Class

This step is one of the key differences between version 2.0 and 2.5. Indeed, one of the main difficulties highlighted by the application of SORA 2.0 is the evaluation of the ground risk class. As previously introduced, the GRC depends on the aerial platform (maximum size and kinetic energy) and on the operational scenario, which is classified on the basis of the related population density and on the type of operation conducted (VLOS/BVLOS). However the population density is evaluated in a qualitative manner and divided into three classes: controlled ground area, sparsely populated or populated area. This classification is not easy to implement because no clear distinction between density classes is introduced in SORA 2.0. To solve this problem, SORA 2.5 introduces a new table (Table 5.10) to evaluate the GRC. It relates the aircraft characteristics with a quantitative population density value.

Table 5.10: Intrinsic Ground Risk Class Determination, (Source:JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.31, 2022, [110])

Intrinsic UAS Ground Risk Class						
Max UA characteristics dimension		1 m	3 m	8 m	20 m	40 m
Max cruise speed		25 m/s	35 m/s	75 m/s	150 m/s	200 m/s
Maximum iGRC population density (ppl/km^2)	Controlled ground area	1	2	3	4	5
	$<$ 25	3	4	5	6	7
	$<$ 250	4	5	6	7	8
	$<$ 2,500	5	6	7	8	9
	$<$ 25,000	6	7	8	9	10
	$<$ 250,000	7	8	9	10	11
	$>$ 250,000	7	9	Category C Operations		

To determine the population density to calculate the iGRC the applicant has to consider the segment with the highest population density and the maximum cruise speed has to be assumed as the maximum possible commanded airspeed of the UA, as defined by the manufacturer, equal to 100 kts (51,4 m/s).
For the Grottaglie-Taranto scenario, the assessments carried out in Step#2 for the SORA 2.0 are assumed as a reference. The maximum UA dimension is equal to 4 m, so the "8 m" column is the applicable one. The airport area is classified as a controlled ground area, while the corridor and the operation area have a population density lower than 25 ppl/km^2. So the obtained intrinsic Ground Risk Classes are:

Table 5.11: Obtained iGRC

	Airport Area	**Corridor Area**	**Operation Area**
Operational Scenario	BVLOS overControlled Ground Area	BVLOS in Sparsely Populated Environment	BVLOS in Sparsely Populated Environment
iGRC	**3**	**5**	**5**

Determination of the adjacent area size and adjacent area intrinsic GRC
Another innovation introduced in Step#2 is the new approach to evaluate the adjacent area. This zone is defined as "a reasonably probable ground area where an UA may fly or crash after a flyaway"[12]. In SORA 2.0, the adjacent area was covered by Step#9, but no detailed guidelines were provided for defining it, leaving the identification and analysis to the discretion of the applicant. Instead, in the updated version 2.5, quantitative criteria, based on UA's performance, are introduced.
The inner limit of the adjacent area is assumed coincident with the outer limit of the ground risk buffer. The outer limit is calculated as follows:

- *"The distance flown in 3 minutes at maximum cruise speed of the UA:*
  - *If the distance is less that 5 km, use 5 km;*
  - *If the distance is between 5 km and 35 km, use the distance calculated;*
  - *If the distance is more that 35 km, use 35 km"*[13]

Thus, for the operational scenario of interest, the following data are taken into consideration:

[12] JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.38, 2022, [116]

[13] JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.33, 2022, [116].

- time of the flight = 3 $minutes$;
- maximum cruise speed of the UA = 50 kts (92,6 km/h)

So, the distance flown by the UA is 4,63 km. The outer limit of the adjacent area is assumed to be at a distance of 5 km from the boundary of the ground risk buffer.
Figure 5.7 shows the obtained adjacent area.

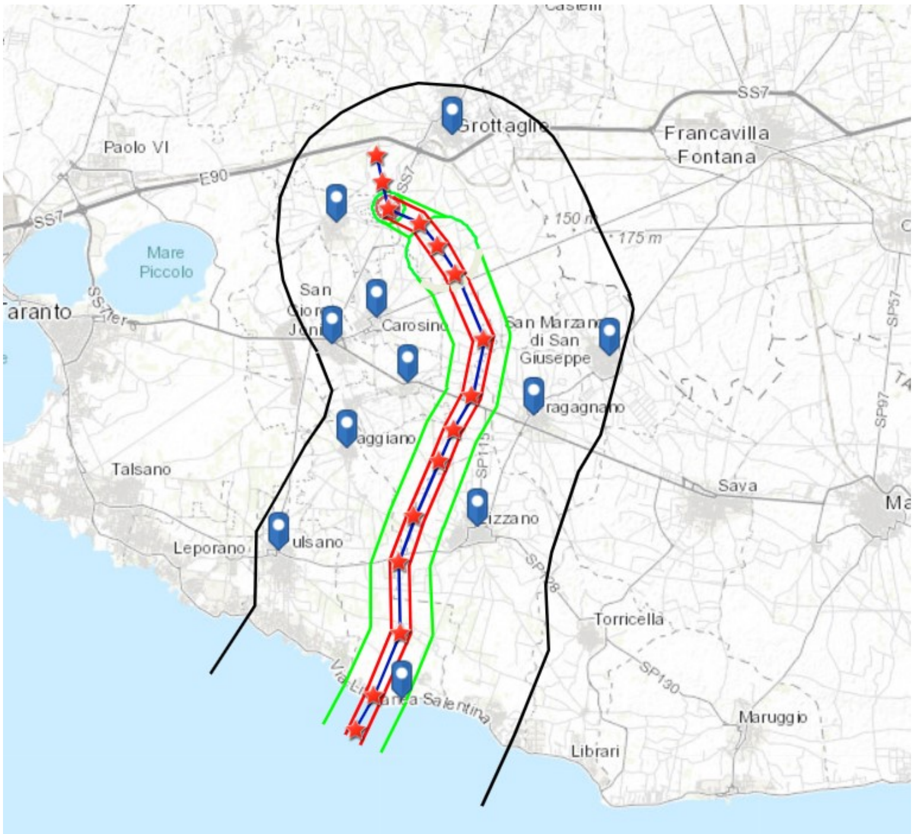


Figure 5.7: Adjacent Area, (Source: Gistat https://gisportal.istat.it/index.html)

The adjacent area includes suburban and urban areas, for example, Grottaglie, San Giorgio Ionico, Carosino, San Marzano di San Giuseppe, Fragagnano, Lizzano, Monteparano, Pulsano, Faggiano and Torretta Mare are now located within the interested zone.

In order to determine the intrinsic ground risk of the adjacent area, the applicant needs to evaluate the average population density of the obtained zone. Unlike the iGRC evaluation of the operational volume that required the assessment of maximum population density, the adjacent area requires the assessment of the average population density, because it is assumed that the operator may fly in this area only in the event of a loss of control, where the direction and duration of the fly away is considered to be random, so the average population density is assumed as more representative of the scenario.

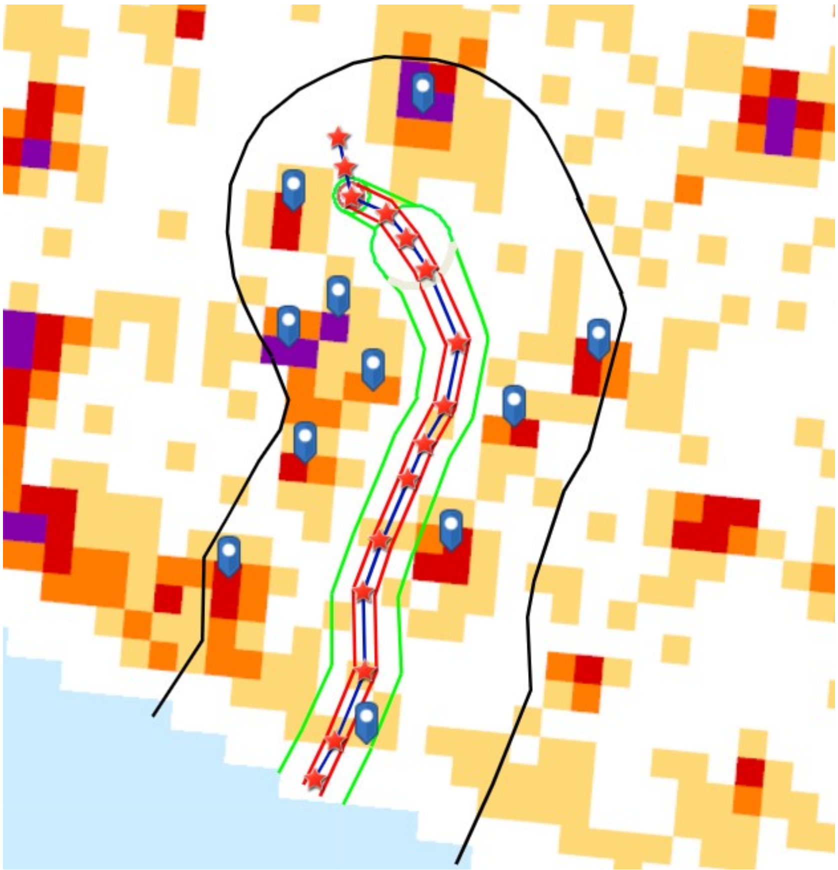


Figure 5.8: Population density Adjacent Area, (Source: Gistat https://gisportal.istat.it/index.html)

As shown in Figure 5.8, the average population density distribution in the adjacent area is higher than that contained in the safe volume. The adjacent area is divided into 312 cells of one square kilometer each. The average population density obtained is equal to 319 ppl/km^2. This value was obtained by using population density data obtained by the Istatviewer tool by Gistat for the Adjacent Area reported in Appendix B.

In addition, the SORA 2.5 also requires the identification of potential locations for non-sheltered assemblies of people 1 km beyond the outer limits of the operational volume during the operation. Typical operations take place after the consultation and approval of the competent local authorities (such as police departments, municipal bodies etc.), excluding periods of the year when a high presence of people is expected, such as the summer season when large assemblies are located on the beaches along the coast, or days in which festivals, concerts, political demonstrations, parades are planned. Thus, it can be reasonably assumed that within a 1 km radius from the outer limit of the ground risk buffer, no assemblies of people exceeding 20,000 individuals are expected. So, the average population density previously evaluated is assumed as a reference to assign the iGRC to the adjacent area.

Table 5.12: iGRC Determination for Adjacent Area, (Source:JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.31, 2022, [110])

Intrinsic UAS Ground Risk Class						
Max UA characteristics dimension		1 m	3 m	8 m	20 m	40 m
Max cruise speed		25 m/s	35 m/s	75 m/s	150 m/s	200 m/s
Maximum iGRC population density (ppl/km^2)	Controlled ground area	1	2	3	4	5
	< 25	3	4	5	6	7
	< 250	4	5	6	7	8
	< 2,500	5	6	7	8	9
	< 25,000	6	7	8	9	10
	< 250,000	7	8	9	10	11
	> 250,000	7	9	Category C Operations		

The obtained intrinsic Ground Risk Class for the Adjacent Area is equal to **7**.

Step#3 - Determination of final GRC

An additional change introduced in SORA 2.5 are the new mitigations to modify the intrinsic ground risk class. In SORA 2.0 mitigations were [101]:

- M1 - Strategic mitigations for ground risk;
- M2 - Effects of ground impact are reduced;
- M3 - An Emergency Response Plan (ERP) is in place, operator validated and effective.

Instead, SORA 2.5 introduces the following mitigations [116]:

- M1(A) - Strategic mitigations for ground risk;
- M1(B) - Visual Line of Sight (VLOS) - avoid flying over people;
- M2 - Effects of UA impact dynamics are reduced.

Mitigation M1 is subdivided into M1(A) and M1(B). M1(A) reduces the number of people at risk. M1(B) considers if the operation can be conducted in VLOS or in BVLOS. In SORA 2.0 this aspect was evaluated in Step#2 to characterize the operational scenario and calculate the intrinsic GRC, while in SORA 2.5 the possibility of conducting operation in VLOS it is assumed as a means of mitigation.
M2 mitigation has been updated only in terms of correction factor: for a high level of robustness, a reduction of up to 3 credits is allowed.
M3 Mitigation has been removed, because, from the experience gained, the ERP is not an effective method to reduce the population at risk, except in very rare cases.

The table shows the list of mitigations for the ground risk with the related correction factors.

Table 5.13: Mitigations for Final GRC Determination, JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition2.5", Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.34-35, 2022, [116])

	Level of Robustness		
Mitigations for ground risk	**Low**	**Medium**	**High**
M1(A) - Strategic mitigations for ground risk	-1	-2	-3
M1(B) - Visual Line of Sight (VLOS) - avoid flying over people	-1	N/A	N/A
M2 - Effects of UA impact dynamics are reduce	0	-1	-2/-3

The Airport area is a restricted access zone. The iGRC obtained is equal to the lower value in the applicable column. M1 mitigation cannot be applied because it is not possible to reduce the number of people at risk below that of a controlled area. M2 mitigation is not available for the proposed operation. So no correction is applicable to the GRC of the Airport Area.

The Corridor Area and the Operation Area are classified as Rural Area, with a population density lower than $25ppl/km^2$. There the M1(A) mitigation has been considered with a level of robustness equal to “Low”. M2 mitigation is not available for the proposed operation. So, a total correction factor equal to **-1** is applied. (Appendix C lists the rationale that lead to assess the mitigations M1(A)).
Table 5.14 shows the Final Ground Risk Class obtained for each area:

Table 5.14: Final GRC

	Airport Area	**Corridor Area**	**Operation Area**
Final GRC	**3**	**4**	**4**

Determination of the final adjacent area GRC
As mentioned in Paragraph [], SORA 2.5 requires the determination of the ground risk class for the adjacent area. Consequently, the Final GRC must also be evaluated through the application of mitigation measures, following a similar process as done for the operations area.
Mitigations that can be used for the adjacent area GRC without additional justification are:

- M1 for using the assumption of sheltering;
- M2 mitigations based on passive designs or inherent UA characteristics.

As done for the determination of Final GRC of the operational volume, a M1(A) mitigation at a level of robustness equal to "low" can be applied, obtaining a correction factor of **-1**. The obtained levels of integrity and of assurance are the same as M1(A) mitigation for the operational volume, reported in Appendix C.

So the obtained Final GRC for the Adjacent Area is equal to **6**.

5.2.4 The Air Risk Process

The Air Risk Process consists of the determination of the air risk class related to the operational airspace. The first step of the Air Risk Process is to determine the initial Air Risk Class which depends on the characteristics of the airspace and represents its aggregated collision risk. The initial ARC can be modified and lowered by applying

strategic mitigation and obtaining the residual ARC. The residual ARC is then addressed by means of tactical mitigations.
SORA 2.5 does not introduce great changes in the Air Risk process. Steps #4,#5,#6 are almost the same of SORA 2.0. The main difference between version 2.5 and edition 2.0 is the assessment of the size and the air risk class of the adjacent airspace.

Step#4 - Determination of the Initial Air Risk Class (ARC)

The operational airspace is completely located in segregated airspace, as previously described in Step#4 of SORA 2.0. So, also for SORA 2.5 the obtained initial ARC is ARC-a.

Determination of adjacent airspace size
The main difference introduced in the Air Risk Process by SORA 2.5 is the determination and analysis of the adjacent airspace. The adjacent airspace was covered by Step#9 in SORA 2.0, but no guidelines were provided to determine it, leaving the identification and analysis to the discretion of the applicant.
SORA 2.5 defines the adjacent area as the "reasonably probable airspace where a UA may fly after a loss of control situation"[14]. The lateral limits of the adjacent airspace are the same as for the adjacent area, while the vertical limits can be calculated as follows:

- *"Maximum Altitude*
  - *Calculate the altitude gained in 3 minutes using the maximum climb rate of the UA and add it to the maximum altitude of the operational volume;*
  - *If the above value is less than 500 m above the maximum altitude of the operational volume, use 500 m above the maximum altitude.*
- *Minimum Altitude*
  - *If the operational volume does not reach the ground, any airspace below the operational volume is considered adjacent airspace."*[15]

The black boundary in Figure 5.10 shows the lateral limit of the adjacent airspace. The orange boundary is the perimeter of the segregated airspace (LI R315, LI R316, LI R317).

[14] JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.38, 2022, [116]

[15] JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.38, 2022,[116]

These areas are located in the Grottaglie Control Zone classified as class 'D' airspace. To determine the air risk class of the adjacent airspace the assignment process reported in Figure 5.9 can be followed.

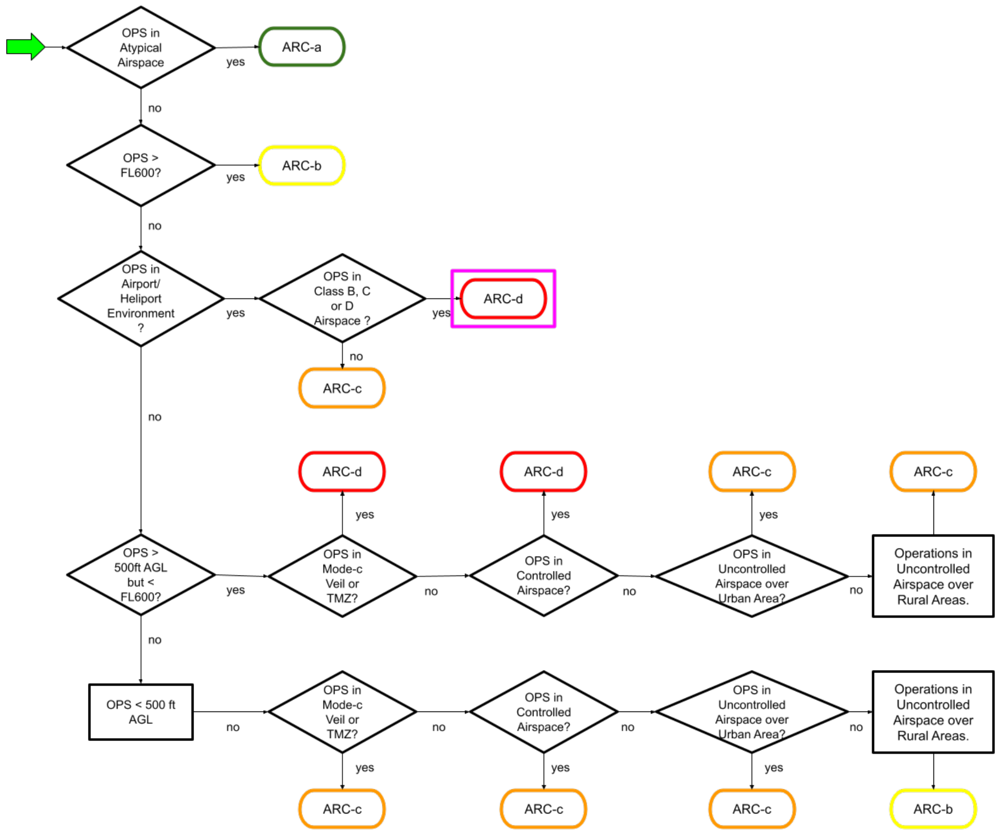


Figure 5.9: ARC assignment process, (Source: JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p. 37, 2022, [116]

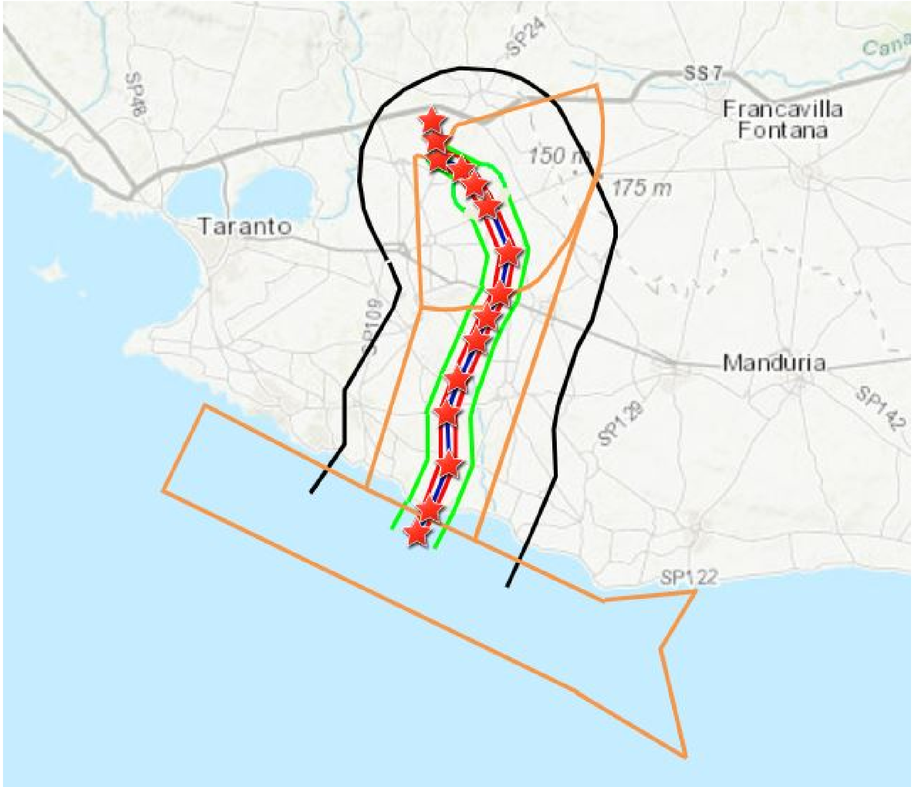


Figure 5.10: Adjacent area and restricted airspace, (Source: https://gisportal.istat.it/index.html)

However a section of the interest airspace is located within the restricted area so would fall in the atypical airspace category, a great part of the airspace surrounds the Grottaglie Airport (class D airspace which touches an aerodrome and/or controlled airspace) or is located in a range of 5 nautical miles from an airport having an operational control tower. So, the adjacent airspace can be defined as an aerodrome environment in Class D airspace and the obtained air risk class is equal to ARC-d.

Step #5 - Application of Strategic Mitigations to determine Residual ARC (optional)

SORA 2.5 does not apply changes to this step for BVLOS operations so the results obtained with SORA 2.0 are reported. Strategic Mitigations can be applied to lower the initial ARC if it is considered too high. The obtained Initial ARC is ARC-a, so no Strategic Mitigatios are applied to this operational scenario. The initial ARC becomes the residual ARC.

Step#6 – Tactical Mitigation Performance Require- ment (TMPR) and Robustness Levels

Tactical Mitigations are applied to mitigate any residual risk of a mid-air collision needed to achieve the applicable airspace safety objective. Operations will be conducted in BVLOS, so the SORA Process requires that the Residual ARC and Table 5.15 will be used to determine the Tactical Mitigation Performance Requirement (TMPR) and the associated level of robustness.

Table 5.15: Tactical Mitigation Performance Requirement (TMPR) and TMPR Level of Robustness Assignment, (Source: JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.40, 2022, [116])

Residual ARC	Tactical Mitigation Performance Requirements (TMPR)	TMPR Level of Robustness
ARC-d	High	High
ARC-c	Medium	Medium
ARC-b	Low	Low
ARC-a	No requirement	No requirement

As obtained in Table 5.15 the TMPR and the TMPR robustness are 'none', so it can be concluded that the proposed operational scenario complies with the SORA criteria for TMPR and associated robustness level.

5.2.5 Final Specific Assurance and Integrity Levels(SAIL) and Operational Safety Objectives (OSO) Assignment

Step#7 - SAIL determination

This Step corresponds exactly with Step#5 of SORA 2.0. The SAIL is always determined by the ground and air risk class. However, the Final GRC obtained for the proposed operational volume by the implementation of SORA 2.5 is not equal to the value obtained with version 2.0. The Final GRC is equal to **3** for the Airport Area, while is equal to **4** for the Corridor and the Operation Area. The obtained Residual ARC is the same for all three zones into which the operational volume has been divided. So, the SAIL will be determined from the most onerous conditions:

- Final GRC = 4;

- Residual ARC = ARC-a;

The resulting SAIL is **III**, so the proposed operation is classified as a medium-risk 'specific' category operation.

Table 5.16: SAIL determination, (Source: JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.42, 2022, [116])

SAIL Determination				
	Residual ARC			
Final GRC	a	b	c	d
<=2	**I**	**II**	**IV**	**VI**
3	**II**	**II**	**IV**	**VI**
4	**III**	**III**	**IV**	**VI**
5	**IV**	**IV**	**IV**	**VI**
6	**V**	**V**	**V**	**VI**
7	**VI**	**VI**	**VI**	**VI**
<7	Category C operation			

Step#8 - Identification of containment requirements

This step corresponds to Step#9 of SORA 2.0 and has been significantly updated. SORA 2.5 introduces containment requirements to be applied at the adjacent area and airspace. They depend on the SAIL and on the Final GRC and ARC obtained for the adjacent volume. SORA 2.5 defines five levels of containment:

- *"**no containment**, largely uncommon, only in sparsely populated areas with a large class G airspace above;*

- ***low robustness containment**, very common, most operations will require this (in SORA 2.0 this corresponded to 'basic containment' and it was mandatory for all operations), in densely populated parts of the world like East Asian or European countries, it can be expected that due to airspace and population distribution, this will be the required minimum).*

- ***medium robustness containment**, common in large cities and close to gatherings of people. This is a new intermediate robustness level that sits between the mandatory basic containment and the enhanced containment of SORA 2.0.*

- ***high robustness containment**, only needed in rare cases for SAIL I and II. In SORA 2.0 was called enhanced containment.*
- ***consult with authority**."[16]*

The Adjacent Area containment requirements can be determined using the following table.

Table 5.17: Adjacent Area Containment Requirements (Source:JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.43, 2022, [116])

Adjacent area final GRC	SAIL					
	I	II	III	IV	V	VI
<=3	N					
4	L	N				
5	L	L	N			
6	M	M	L	N		
7	H	H	M	L	N	
8	C	C	C	M	L	N
9				C	M	L
10					C	M

The Adjacent airspace requirements can be identified using teh following table:

[16]JARUS. Doc. JAR-DEL-WG6-D.04 "JARUS SORA 2.5 Explanatory notes", Version 1.0. Draft, JARUS, p.10, 2022, [116]

Table 5.18: Adjacent Airspace Containment Requirements (Source:JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.43, 2022, [116])

Highest Adjacent Airspace	SAIL I, II, III, IV	SAIL V, VI
ARC-a or ARC-b	None	None
ARC-c or ARC-d	Low	None

For the proposed scenario:

- Adjacent Area Containment Requirements = **L**;
- Adjacent Airspace Containment Requirements = **Low**

The final containment requirements to be applied to the system are the highest from the Adjacent Area containment level determination and Adjacent Airspace containment level determination as shown in the following table.

Table 5.19: Final Containment Requirements ,(Source:JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.44, 2022, [116])

		Adjacent Area Containment Requirements			
Adjacent Airspace Containment Requirements		None	Low	Medium	High
	None	None	Low	Medium	High
	Low	Low	Low	Medium	High

For the proposed scenario the final level containment requirements is equal to **Low**. Appendix [] shows details about levels of integrity and assurance for the containment requirements for the proposed scenario.

Step#9 - Identification of Operational Safety Objectives (OSO)

This step corresponds to Step#8 of SORA 2.0. The previously proposed list of OSOs has been reorganized. In version 2.0, 24 OSOs were identified and they were grouped according to the threat they help to mitigate. In the new updated version, OSOs are 18 (renumbered using roman numbers), removing duplication of OSOs that share the same requirements. The SORA 2.0 levels of compliance were: optional, low, medium and high. Now the term optional is replaced with 'not required'.

In addition, the new OSOs' table indicates for each OSO the figure who should provide related evidences, introducing 3 columns titled 'operator', 'training organization' and 'manufacturer'. The operator is responsible for the implementation of the entire process. However, to demonstrate compliance with requirements, information provided by the manufacturer for the design of the UA or a component or by the training organization are needed. These columns help to identify the source of useful evidence.

The full list of new OSOs is reported below.

Table 5.20: Recommended operational safety objectives (OSO), (Source: JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.44-46, 2022.)

New OSO	Old OSO		SAIL						Operator	Training Org.	Manufact.
			I	II	III	IV	V	VI			
# I	#01	Ensure the operator is competent and/or proven	NR	L	M	H	H	H	x		
# II	#02	UAS manufactured by competent and/or proven entity	NR	NR	L	M	H	H			x
# III	#17	Remote crew is fit to operate	L	L	M	M	H	H	x	x	
# IV	#08, #11, #14, #21	Operational procedures are defined, validated and adhered to address normal, abnormal and emergency situations potentially resulting from technical issues with the UAS or external systems supporting UAS operation, human errors or critical environmental conditions	L	M	H	H	H	H	x		
# V	#03	UAS maintained by competent and/or proven entity	L	L	M	M	H	H	Crit 1 Crit 2		Crit 1

Continued on next page

Table 5.20: Recommended operational safety objectives (OSO), (Source: JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.44-46, 2022.) (Continued)

# VI	#07	Conformity check of the UAS configuration	L	L	M	M	H	H	Crit 1	Crit 2	
# VII	#23	Environmental conditions for safe operations are defined, measurable and adhered to	L	L	M	M	H	H	Crit 2	Crit 3	Crit 1
# VIII	#13	External services supporting UAS operations are adequate for the operation	L	L	M	H	H	H	x		
# IX	#16	Multi-crew coordination	L	L	M	M	H	H	Crit 1 Crit 3	Crit 2	
# X	#09, #15, #22	Remote crew trained and current and able to control the normal, abnormal and emergency situations potentially resulting from technical issues with the UAS or external systems supporting UAS operation, human errors or critical environmental conditions	L	L	M	M	H	H		x	
# XI	#19	Safe recovery from human error	NR	NR	L	M	M	H	Crit 1 Crit 2	Crit 2	Crit 3
# XII	#04	UAS components essential to safe operations are designed to an Airworthiness Design Standard (ADS)	NR	NR	NR	L	M	H			x
# XIII	#05	UAS is designed considering system safety and reliability	NR	NR	L	M	H	H			x
# XIV	#18	Automatic protection of the flight envelope from human error	NR	NR	L	M	H	H			x
# XV	#20	A human factors evaluation has been performed and the human machine interface (HMI) found appropriate for the mission	NR	L	L	M	M	H			x
# XVI	#06	C3 link characteristics (e.g. performance, spectrum use) are appropriate for the operation	NR	L	L	M	H	H			x

Continued on next page

Table 5.20: Recommended operational safety objectives (OSO), (Source: JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, p.44-46, 2022.) (Continued)

# XVII	#24	UAS designed and qualified for adverse environmental conditions (e.g. adequate sensors, DO-160 qualification)	NR	NR	M	H	H	H			x
# XVIII	#10, #12	Safe recovery from technical issue with the UAS or external systems supporting UAS operation	L	L	M	M	H	H			x

Step#10 - Comprehensive Safety Portfolio

As introduced in Step#1, the Comprehensive Safety Portfolio consists of the operator manual, compliance evidence(s) and documentation of the SORA process. This step was updated to clarify the documentation that the applicant has to collect and submit to the Competent Authority.

5.2.6 Final Considerations

Comparing the implementations of both versions of the SORA process, it can be said that, the major innovation introduced by SORA 2.5 is a new quantitative approach to assess the ground risk class. The general revision of the text, the language and the structure are useful to simplify the process implementation, but the main problem revealed by the application of SORA 2.0 to real operational scenarios is the determination of people at risk. The approach proposed by the first version of SORA is considered too qualitative: the overflown population is classified according to three macro categories that are considered too general and without numerical references, leaving too much freedom of interpretation to the applicant. This led to a non-homogeneous application of the process, with very different results among member states. So, JARUS found it necessary to revise the document to resolve the critical points and provide stakeholders with an effective and clear risk assessment process.

The new ground risk assessment method is quantitative but still flexible to be adapted to the wide variety of operations that can be performed by UAS belonging to the specific category. The ground risk depends on the characteristics of the UA and on the maximum population density overflown. The applicant determines this value on the basis of maps and data available and compares it with the population density range provided by the iGRC table.

The qualitative approach proposed by the new version of SORA 2.5, can also be found in the new method to identify and analyze the adjacent area and airspace. These zones were also covered in SORA 2.0 but no indications on how to calculate its size were provided.

However, version 2.5, which is still under development, will not be the final version of the document. Indeed, JARUS is already working on version 3.0, which aims to deepen the aspects not updated in version 2.5. According to the working group, the SORA 3.0 will include a revision of the air risk model, whose details will be provided in the new Annex G, and updated Annexes C and D.

So, the risk assessment process necessary to obtain approval to conduct operations in the 'specific' category is still in development. The SORA is an innovative approach necessary to integrate UAS in general aviation but not easy to define. The aim of JARUS is to publish a complete and effective risk assessment that can be used by applicants to evaluate the feasibility of UAS operations and conduct them in a safe manner. A new updated version will be proposed to improve and simplify the use of SORA, taking into account critical application points and the suggestions of the competent authorities and the stakeholders. Although this adaptation and updating phase is necessary, it poses difficulties. The absence of definitive and comprehensive regulations can discourage investment and interest from industries. Indeed, SORA is used to determine the risk associated with an operation. After conducting the Specific Operation Risk Assessment, the applicant identifies the SAIL and uses it to determine the level of robustness at which Operational Safety Objectives have to be met. The grater is the SAIL, the grater is the risk of the operation, so more complex activities have to be carried out to demonstrate compliance with safety requirements. For example, low-risk operations with SAIL equal to I or II require a declaration to show compliance evidence, while SAIL equal to V or VI correspond to high-risk operations, so a Type Certificate is needed to conduct operations.
Modifying the parameters and methodologies for determining ground and air risk, mitigations, integrity and assurance levels, can lead to significant changes in SAIL. For example, in the Taranto-Grottaglie application case, the SAIL obtained by the implementation of SORA 2.5 (III) is one point higher than the one resulting from SORA 2.0 (II). This difference derived from the revision of the ground risk class determination and the related mitigations, bringing the risk level associated with the operational scenario from low to medium.
Such an outcome can potentially be critical because an operator has to demonstrate compliance with safety objectives, mitigation and containment measures at a higher level of robustness. This aspect can be very problematic, especially for unmanned systems already in production, designed and tested to operate in well-defined operational scenarios. An increase in the level of risk may result in the need to produce evidence of compliance with

higher standards, increasing costs, or in extreme cases a complete revision of the design and production of the systems, causing serious damage to the operators and manufacturing industries.

Therefore, it is clear that the need for adequate, effective and comprehensive regulation is not only essential to promote the UAS's public acceptance, ensuring the safety of people on the ground and a correct integration in the general aviation airspace, but it is also important to encourage industries to invest in this sector, supporting the market growth.

Chapter 6

Civil and Military UAS regulations comparison

As introduced in previous chapters, the world of UAS is extremely complex and constantly evolving and this aspect is reflected in the regulations associated with it. In fact, in order to use this new technology, integrate it within the existing aviation system, and exploit its full potential, it is necessary to develop a dedicated regulatory framework. Both the civil and military sectors have been working on this for years, but there is still much to be done because UAS are an innovative technology, with features often also very different from traditional manned aviation. The new regulatory framework has to take into consideration the peculiarities of UAS but at the same time it must ensure safe operations, to satisfy public acceptance, and meet industry standards to encourage investment. Both the civil and military sectors have been moving in this direction with the common goal of establishing a set of rules that ensure that UAS will be designed, manufactured, and operated effectively and safely. However, the two sectors adopted two different approaches to deal with this issue. This chapter aims to analyze the main similarities and differences between civil and military regulations addressing rotary-wing UAS falling into the 'specific' category, such as (EU) 2019/947, STANAG 4702 and AER(EP).P-2, AER(EP).P-6.

6.1 Classification and regulatory approach

Before comparing the two regulatory approaches in detail, it is useful to summarize UAS classification methods adopted by the two sectors because the classification represents the basis on which the regulatory framework is developed. All relevant information related to classification were reported in Chapter 2.

The military sector bases the classification on traditional general aviation methodology: UAS are divided according to weight. For example, NATO classifies them into three categories: class I for UA lighter than 150 kg, class II for UA weighing between 150 kg and 600 kg, and class III for UA heavier than 600 kg. Also, the type of wing, fixed or rotary wing, is a useful parameter to group unmanned aircraft.

This classification system is not considered suitable for UAS technology by civil authorities. Unmanned Aircraft Systems have to be integrated into the existing aviation system but they are quite different from manned vehicles, so the existing classification and the associated rules are not appropriate. They are characterized by the absence of crew and passengers on board, in addition they can be employed in several types of operations: from simpler tasks such as operations for recreational use, such as taking photos or filming, to more complex activities such as transporting goods or flight in high-risk scenarios. So, EASA, to classify UAS available on the market, variable in size, configuration and complexity, proposed an innovative approach: they are now divided not only on the basis of the feature of the aerial platform but also on the type of operation conducted, the payload carried, the overflown areas and the airspace traveled. Civil UAS are classified into three categories from low to high risk called 'open', 'specific' and 'certified'.
As previously mentioned, the classification is the basis on which rules for design, production and operability are defined. Both civil and military competent authorities assume the same considerations and parameters used in the development of UAS classification to define and organize the related regulation. Therefore, different approaches found in classification methods are detectable also in regulations.

As explained in Chapter 4, military regulations address UAS on the base of weight and type of the wing. For example, NATO Standard Agreements 4671 covers technical airworthiness requirements for the airworthiness certification of fixed-wing UAS with a maximum take-off weight between 150 and 20.000 kg [127], whereas the STANAG 4702 covers the certification of rotary-wing military UAS with a maximum take-off weight between 150 and 3175 kg [125].
The type of operation is an aspect completely excluded from military regulations as reported in the paragraph "Scope" of each STANAG of interest. Instead, this issue is a peculiar aspect of the civil sector. EASA believes that often the requirements derived from manned aviation seems to be much prescriptive for certain type of activities. So, to develop a regulatory framework that guarantees the safety of operations, but also enough flexibility for the industry to evolve, the type of operation is a fundamental aspect. EASA has not

only divided UAS into three categories, but for each of them issued rules, operational limitations, standards, procedures and requirements tailored on the increasing level of risk. The obtained result is a new and innovative regulation framework that is proportionate, progressive, operation-centric and risk-based.[44]
As a consequence of the two regulatory approaches, the design, the production and the operability of UAS follow different procedures in civil and military sectors.
Particularly, military UAS always need to obtain a type-certificate to show compliance with airworthiness requirements. Whereas civil UAS may follow different clearance procedures to ensure the safety of operations. 'Open' category includes very low-risk drone operations, so no airworthiness approval, licenses for operators and pilots are required to perform activities. Operations that fall into this class have to be conducted according to operational limitations imposed by the category and the aerial platform employed has to be compliant with acceptable Industry Standards, as demonstrated by market labels.[44]
'Certified' category includes high-risk operations, comparable to manned aviation activities. So, UAS operating in this category need to obtain a type certificate to verify the design, in addition, the designer and the manufacturer have to demonstrate their capability through design and production organization approvals respectively.[44]
The 'Specific' category is an intermediate class, including medium-risk operations. This category is of special interest to the following study. It covers a wide variety of operations, in very different operational scenarios and employs UA diversified in size and characteristics. Typically, to operate 'specific' category operation an operational authorization issued by the National Aviation Authority is required. The operational authorization "should clearly specify the specific conditions and limitations for the intended operation and can be issued to authorize a single event or a series of operations under specified conditions"[1]. In order to obtain the OA, a specific operation risk assessment has to be performed. It addresses "airworthiness, operating procedures and environment, competence of involved personnel and organization"[2]. EASA accepted the SORA process as a methodology for assessing the risk associated with the specific operations. As discussed in Chapter 3, the applicant has to demonstrate compliance with Operational Safety Objectives on the basis of the SAIL obtained: non-design related OSOs are verified in accordance with the related level of robustness, whereas the compliance with is shown in a proportionate manner to the increasing level of operational risk.

[1]EASA. Concept of Operations for Drones A risk based approach to regulation of unmanned aircraft, p.5, 2015, [44]

[2]EASA. Concept of Operations for Drones A risk based approach to regulation of unmanned aircraft, p.5, 2015, [44]

It is evident that the civil and military approaches to UAS sector are very different. Some peculiar aspects of both regulations will be analyzed below, considering for the civilian sector the 'specific' category which is the object of particular interest for this study.

6.2 Risk Assessment

The main common point between civil and military regulations is the shared objective of ensure the safety of operations. In order to do this, the risk needs to be assessed. It is defined, for both civil and military sectors, as "the combination of the frequency (probability) of an occurrence and its associated level of severity"[3], but it is evaluated in a very different manner.

In the civil sector, EASA indicates the SORA process as the methodology to determine the risk related to a UAS operation falling in the 'specific' category. The risk is assessed as a characteristic of each operation. Indeed, to determine it, the SORA takes into account not only the design feature of the employed UA (maximum dimension and kinetic energy), but also the operational scenario. Two typical examples useful to understand the variability of the risk associated with the type of operation may be: a UAS employed to monitor the status of fields, vegetation and agricultural crops, such as the DJI Mavic 3, with a maximum take-off weight of 1 kg and equipped with cameras and sensors [35]; and the Wing's UAS, weighing about 5 kg, used for delivery in residential area in Australia [150]. In the first case, the operational scenario consists of fields, where it is not expected the presence of people. In the second case, the operational environment is urban areas, so the UAS is employed in a densely populated scenario. In addition, the crossed airspace has to be taken into account, for example in future airspaces above urban areas will include routes dedicated to Urban Air Mobility. Hence, the risk associated with agriculture 4.0 activities is quite less than the danger posed to people by the delivery UAS. The SAIL consolidates the risk of the 'specific' category operation, "it represent the level of confidence that the UAS operation will stay under control"[4]. To determine it EASA adopted the SORA process which assesses the risk in relation to the characteristics of the portion of ground overflown, due to the absence of people on board, and the type of airspace traveled. Indeed,

[3]JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, Main Body, p.17, 2019, [101]

[4]JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, Main Body, p.26, 2019, [101]

the SORA requires the evaluation of the Ground Risk Class, taking into consideration the portion of the ground overflown, the population density and the presence of critical infrastructure, and the Air Risk Class, through the evaluation of the type of airspace and the presence of manned aircraft involved in it, that could be subject to mid-air collision.

On the other hands, drones were initially designed for military purpose. Military forces needed the availability of operable and effective UAS as quickly as possible, so military authorities chose to not develop a new and innovative regulatory framework as done in the civil sector, but to use the existing regulations of manned aircraft and adapt them to the needs of UAS for example simply adding requirements for the control station or the C2 link. So, military regulations are not based on the type of operation: the operational scenario, people at risk on the ground, and the airspace traveled are not considered. The risk is covered at the level of the design of the UAV System.
For example in the AEP-80 (STANAG 4702), which is a NATO document containing the airworthiness requirements and related AMCs for obtaining the military type certificate for rotary-wing UAS, the risk assessment is addressed by requirement USAR.RW.1309, related to "Equipment, system and installations"[5]. This requirement sets that "the UAS must be designed to reduce the risk to people including UAS crew, ground staff and third parties to a level acceptable to the Certifying Authority"[6]. In order to ensure this, the design of each item of equipment, each system, and each installation must be investigate and any function of the UAS which can compromise the safety of operations must comply with the applicable airworthiness requirements, for example using AMC.1309[7] as a guidance.
To identify the risk and evaluate its acceptance the AMC.1309 sets a severity reference system and a probability reference system for UAS failure conditions. A failure condition is defined as *"a condition having an effect on either the UAS, people (including UAS crew, ground staff and third parties) either directly or consequentially, which is caused or contributes to by one or more failures, considering flight phases and relevant adverse operational or environmental conditions or external events"*[8]. Each failure condition has to be associated with a severity level, according to the following criteria:

---

[5]NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, p. 93, 2016, [124]

[6]NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard,USAR.RW.1309, p. 93, 2016, [124]

[7]NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, AMC.1309, p.194,[124]

[8]NATO. AEP-4671, "Unmanned Aircraft Systems Airwothiness Requirements (USAR)", Ed.B Ver.1. Nato standard, AMC.1309, p. 2-F-1, 2019, [126]

- ***"Catastrophic***
  Failure conditions that are expected to result in at least uncontrolled flight (including outside of pre-planned or contingency flight profiles/area) and/or uncontrolled crash.
  Or
  Failure conditions which may result in a fatality to UAS crew, ground staff, or third parties

- ***Hazardous***
  Failure conditions that either by themselves or in conjunction with increased crew workload, are expected to result in a controlled-trajectory termination or forced landing potentially leading to the loss of the UA where it can be reasonably expected that a fatality will not occur.
  Or
  Failure conditions for which it can be reasonably expected that a fatality to UAS crew, ground staff or third parties will not occur

- ***Major***
  Failure conditions that either by themselves or in conjunction with increased crew workload, are expected to result in an emergency landing of the UA on a predefined site where it can be reasonably expected that a serious injury will not occur.
  Or
  Failure conditions which may result in an injury to UAS crew, ground staff, or third parties

- ***Minor***
  "Failure conditions that do not significantly reduce UAS safety and involve UAS crew actions that are well within their capabilities. These conditions may include a slight reduction in safety margins or functional capabilities, and a slight increase in UAS crew workload.

- ***No safety effect***
  Failure conditions that have no effect on safety"[9]

There should be a rational and acceptable inverse correlation between the probability per flight hour and the severity of failure condition effects. For example the STANAG 4702 defines the probability reference system applicable to USAR-RW.1309 on the assumption that the System individual catastrophic failure conditions are 10:

[9]NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, AMC.1309, p. 197-198, 2016, [124]

- *"Extremely Improbable: occurrence less than or equal to* 10^-6 *per flight hour;*
- *Extremely Remote: occurrence less than or equal to* 10^-5 *and greater than* 10^-6 *per flight hour;*
- *Remote: occurrence less than or equal to* 10^-4 *and greater than* 10^-5 *per flight hour;*
- *Probable: occurrence less than or equal to* 10^-3 *and greater than* 10^-4 *per flight hour;*
- *Frequent: occurrence greater than* 10^-3 *per flight hour"*[10].

To verify safety objectives, ensuring the achievement of the system and equipment design acceptable level of safety, for rotorcraft UAS the following relationship between probability and severity of failure condition effects shall be taken as reference:

Table 6.1: Risk Reference System (Source:NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, AMC.1309, p. 198, 2016, [124])

		Catastrophic	Hazardous	Major	Minor	No Safety Effect
Frequent	$P > 10^-3/h$	U	U	U	U	A
Probable	$10^-3/h \geq P > 10^-4/h$	U	U	U	A	A
Remote	$10^-4/h \geq P > 10^-5/h$	U	U	A	A	A
Extremely Remote	$10^-5/h \geq P > 10^-6/h$	U	A	A	A	A
Extremely Improbable	$10^6/h \geq P$	A	A	A	A	A

Where U: Unacceptable, A: Acceptable

The applicant is responsible for identifying and classifying each failure condition, considering the potential effects of failures on the UAS, ground staff and third parties. The safety assessment process can be conducted through FHA, PSSA, SSA and CCA at rotocraft UAV System level and then at rotorcraft UAV subsystem level.[124]
The FHA is a "systematic, comprehensive examination of UAS and system functions to identify potential failure conditions as a result of malfunctions or failure to function or as result of normal responses to unusual or abnormal external factors"[11]. It is usually

[10]NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, AMC.1309, p. 198, 2016, [124]

[11]NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, Terms and Definition, p.1, 2016, [124]

performed early in the design and used to define the high-level UAS or system safety objectives. It consists of:

- *"identifying all the functions at the level under study and its interfaces (e.g. UA, UCS, data link, payloads, etc.*
- *identifying and describing the failure conditions associated with these functions, and*
- *and determining the effects and the severity of these failure conditions"*[12]

The PSSA and SSA "addresses all significant failure conditions identified in the FHA and aims at justifying their compliance with the quantitative safety objectives"[13] set in the Risk Reference System reported in Table 6.1.

The Italian Military Regulation addressing the definition of safety requirements is the AER(EP).P-6, specifically Annex C. This Annex provides guidelines to quantify cumulative requirement for catastrophic events per flight hour. Since, UAS do not carry people on board, the cumulative probability requirement of catastrophic event is defined through a new formula reported in the table below:

Table 6.2: Cumulative requirement for catastrophic events per flight hour (Source: Direzione degli Armamenti Aeronautici. AER(EP).P-6, "Istruzioni per la com- pilazione dei capitolati tecnici per aeromobili militari", Annex C, p. C-4/-5, 2010, [25])

(Classe di Safety) Peso dell'APR [kg]	Probabilità cumulativa di evento catastrofico/fh (valori che non comportano alcuna limitazione di densità di popolazione)
(S7) MTOW <= 15 kg	<= 10^(-4)
(S8) 15 kg <= MTOW < 150 kg	<= 0.0015/MTOW
(S9) 150 kg< = MTOW < 750 kg	<= 10^(-5)
(S10) 750 kg <= MTOW < 4000 kg	<= 0.0813/(MTOW)^(1.36)
(S11) MTOW <= 4000 kg	<= 10^(-6)

[12]NATO. AEP-4671, "Unmanned Aircraft Systems Airwothiness Requirements (USAR)", Ed.B Ver.1. Nato standard, AMC.1309, p. 2-F-7, 2019, [126]

[13]NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, AMC.1309, p.195, 2016, [124]

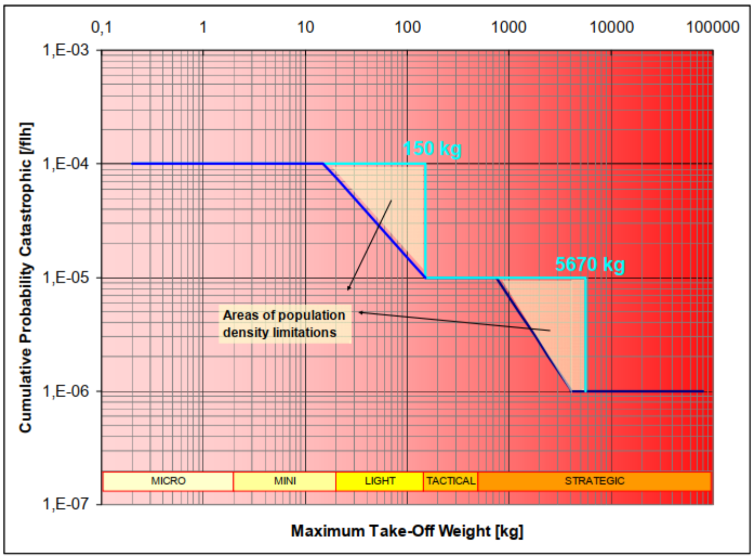


Figure 6.1: Cumulative Probability Catastrophic, (Source: Direzione degli Armamenti Aeronautici. AER(EP).P-6, "Istruzioni per la com- pilazione dei capitolati tecnici per aeromobili militari", Annex C, p. C-7, 2010, [25])

From cumulative quantitative requirement the quantitative safety objective for single events can be defined, considering a number of catastrophic events obtained by a FHA or using a preliminary estimate provided in the Table 3 of Annex C. To classify each failure condition, AER(EP).P-6 [25] recommends to use the severity classes defined in STANAG 4671 (AMC.1309) [127], also adopted by STANAG 4702 [125].
The relationship between severity level and occurrence of each failure condition can be determine by the risk acceptability matrix, according to the Hazard Reference System and shown in Table 6.3.

Table 6.3: Hazard Reference System (HRI), (Source:Direzione degli Armamenti Aeronautici. AER(EP).P-6, "Istruzioni per la com- pilazione dei capitolati tecnici per aeromobili militari", Annex C, p. C-10, 2010, [25])

Hazard Risk Index	(1) Catastrofica	(2) Critica	(3) Maggiore	(4) Minore	Nessun Effetto sulla Safety
(A) FREQUENTE	1A	2A	3A	4A	Nessun Effetto sulla Safety
(B) PROBABILE	1B	2B	3B	4B	
(C) OCCASIONALE	1C	2C	3C	4C	
(D) REMOTO	1D	2D	3D	4D	
(E) IMPROBABILE	1E	2E	3E	4E	

For example, the cumulative quantitative requirement for catastrophic events for an UAS with a maximum take-off weight of 200 kg is equal to 10^{-5}. Given an expected number of catastrophic events $N_{EC} = 10$ the quantitative probability levels are:

Table 6.4: Quantitative probability levels

Probabile (B)	Occasionale (C)	Remoto (D)	Improbabile (E)
$P_B = 10 \cdot P_C$ $P_B = 1x10^{-3}/h$	$P_C = 10 \cdot P_D$ $P_C = 1x10^{-4}/h$	$P_D = 10 \cdot P_E$ $P_D 1x10^{-5}/h$	$P_E = P_{CUM-CAT}/N_{EC}$ $P_E = 1x10^{-6}/h$

Therefore, the risk is addressed in both regulatory approaches, but from the military perspective it is evaluated from the point of view of the system and its failure conditions, as done for manned aviation, whereas civil methodology is based on the UAS employed, the type of activities and the operational scenario.
Indeed, military regulations assess the risk in term of failure conditions of system, subsystems and equipment, and their occurrence, by setting quantitative probability requirement to ensure safety of operations.
In civil regulations, the risk assessment is performed through the SORA process, based on the operational viewpoint. SORA does not analyze only UAV System's features, it also takes into account the nature of operations, environmental characteristics, and implemented mitigations aimed to reduce operational hazards. The objective is to establish an acceptable level of risk and validate compliance with safety objectives across different levels of robustness. An additional distinction between the two approaches is that unlike the military sector which evaluates the risk in quantitative terms, by setting probability target requirements, the civil methodology is qualitative. Indeed, the SORA process output is the SAIL, which represents the risk level associated whit the specific operation and all mitigations and activities measures that must be implemented to ensure that the operation remains under control and to verify the compliance with operational safety objectives.
However, the system and its failure conditions are also assessed in the SORA process, particularly in OSO#5 (SORA 2.0)[14]. This safety objective is titled "UAS is designed considering system safety and reliability"[15] and sets that the equipment, systems, and installations have to be developed in order to ensure safety of operations. Table below reports the OSO#5's level of integrity for an increasing level of robustness.

[14] JARUS. Doc.JAR-DEL-WG6-D.04_E Annex E, "JARUS guidelines on SORA - Annex E - Integrity and assurance levels for the Operation Safety Objectives (OSO)", Version 2.0. , 2019

[15] JARUS. Doc.JAR-DEL-WG6-D.04_E Annex E, "JARUS guidelines on SORA - Annex E - Integrity and assurance levels for the Operation Safety Objectives (OSO)", Version 2.0, p.8, 2019, [106]

Table 6.5: OSO#05 level of integrity, (Source:JARUS. Doc.JAR-DEL-WG6-D.04_E Annex E, "JARUS guidelines on SORA - Annex E - Integrity and assurance levels for the Operation Safety Objectives (OSO)", Version 2.0, p.8, 2019, [106])

Technical Issue with the UAS		LEVEL OF INTEGRITY		
		Low	Medium	High
OSO#05 UAS is designed considering system safety and reliability	Criteria	The equipment, system, and installation are designed to minimize hazards in the event of a probable malfunction or failure of the UAS	Same as Low. In addition, the strategy for detection, alerting and management of any malfunction, failure or combination thereof, which would lead to a hazard is available.	Same as Medium. In addition: -Major Failure Conditions are not more frequent than Remote; -Hazardous Failure Conditions are not more frequent than Extremely Remote; -Catastrophic Failure Conditions are not more frequent than Extremely Improbable; -Software (SW) and Airborne Electronic Hardware (AEH) whose development error(s) may cause or contribute to hazardous or catastrophic failure conditions are developed to an industry standard or a methodology considered adequate by the competent authority and/or in accordance with means of compliance acceptable to that authority;

This OSO covers a safety objective similar to provisions contained in USAR.RW. 1309.

Table 6.6: OSO#05 level of assurance, (Source:JARUS. Doc.JAR-DEL-WG6-D.04_E Annex E, "JARUS guidelines on SORA - Annex E - Integrity and assurance levels for the Operation Safety Objectives (OSO)", Version 2.0, p.8, 2019, [106])

Technical Issue with the UAS		LEVEL OF ASSURANCE		
		Low	Medium	High
OSO#05 UAS is designed considering system safety and reliability	Criteria	A Functional Hazard Assessment and a design and installation appraisal that shows hazards are minimized are available.	Same as Low. In addition: -Safety analysis are conducted in line with standards considered adequate by the competent authority and/or in accordance with a means of compliance acceptable to that authority; -A strategy for detection of single failures of concern includes pre-flight checks.	Same as Medium. In addition, safety analysis and development assurance activities are validated by a competent third party.

As reported in table above, the SORA process indicates the Functional Hazard Assessment to show compliance with OSO#5, as required in military regulations. Malfunction and failure conditions must be always evaluated and classified in terms of severity and occurrence, but the level of integrity at which the safety and reliability of the System must be demonstrated, and the relative level of assurance increase with the risk of the operation. The severity of failure conditions of equipment, system and installation have to be classified according to JARUS AMC RPAS.1309 Issue 2[16], but for low robustness level the probability of occurrence is assessed in qualitative terms and simply interpreted as "to occur one or more times during the entire system/operational life of an UAS"[17]. Whereas, for high risk operations, the system safety and reliability is assessed in a more quantitative manner. Indeed, as done in military regulation, OSO#5 requires to set an inverse relationship between severity level and occurrence, which is now evaluated numerically as reported in Table 6.7.

[16] JARUS. Doc. No. :SC-RPAS.1309-01 Issue 2,"SPECIAL CONDITION Equipment, systems, and installations", 2015, [100]

[17] JARUS. Doc.JAR-DEL-WG6-D.04_E Annex E, "JARUS guidelines on SORA - Annex E - Integrity and assurance levels for the Operation Safety Objectives (OSO)", Version 2.0, p.8, 2019, [106]

Table 6.7: Relationship among Severity of Failure Conditions and Probabilities, (Source:JARUS. Doc. No. :SC-RPAS.1309-01 Issue 2,"SPECIAL CONDITION Equipment, systems, and installations",Allowable Probability, Table 1, p.9, 2015, [100])

Classification of Failure Conditions				
No Safety Effect	Minor	Major	Hazardous	Catastrophic
Allowable Qualitative Probability				
No Probability Requirement	Probable	Remote	Extremely Remote	Extremely Improbable
Allowable Quantitative Probabilities				
No Probability Requirement	$< 10^{-3}$	$< 10^{-4}$	$< 10^{-5}$	$< 10^{-6}$

An additional difference between civil and military approach that can be pointed out is the definition of the failure conditions. The adopted definition, provided by AMC RPAS.1309 Issue 2, are reported below:

- ***"No safety effect***
  Failure conditions that would have no effect on safety. For example, failure conditions that would not affect the operational capability of the RPAS or increase the remote crew workload.

- ***Minor***
  Failure conditions that would not significantly reduce RPAS safety and that involve remote crew actions that are well within their capabilities. Minor failure conditions may include a slight reduction in safety margins or functional capabilities, a slight increase in remote crew workload, such as flight plan changes

- ***Major***
  Failure conditions that would reduce the capability of the RPAS or the ability of the remote crew to cope with adverse operating conditions to the extent that there would be a significant reduction in safety margins, functional capabilities or separation assurance. In addition, the failure condition has a significant increase in remote crew workload or impairs remote crew efficiency

- ***Hazardous***
  Failure conditions that would reduce the capability of the RPAS or the ability of the remote crew to cope with adverse operating conditions to the extent that there would be the following:

i. *Loss of the RPA where it can be reasonably expected that one or more fatalities will not occur, or*

ii. *A large reduction in safety margins or functional capabilities or separation assurance, or*

iii. *Excessive workload such that the remote crew cannot be relied upon to perform their tasks accurately or completely*

- ***Catastrophic***
  Failure conditions that are expected to result in one or more fatalities"[18]

Comparing the two probability reference systems are almost equivalent. Whereas the severity levels are quite different.

Table 6.8: Civil and Military failure conditions severity levels definition, (Source: JARUS. Doc. No.SC-RPAS.1309-01 Issue 2,"SPECIAL CONDITION Equipment, systems, and installations", Failure Conditions Classification, p.7 2015, [100] and NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, AMC.1309, p. 197-198, 2016, [124]

AMC RPAS.1309 (Civil)	**STANAG 4702 (AEP-80) (Military)**
Catastrophic	
Failure conditions that are expected to result in one or more fatalities	Failure conditions that are expected to result in at least uncontrolled flight (including outside of pre-planned or contingency flight profiles/area) and/or uncontrolled crash. Or Failure conditions which may result in a fatality to UAS crew, ground staff, or third parties
Hazardous	

Continued on next page

[18]JARUS. Doc. No. :SC-RPAS.1309-01 Issue 2,"SPECIAL CONDITION Equipment, systems, and installations", Failure Conditions Classification, p.7 2015, [100].

Table 6.8: Civil and Military failure conditions severity levels definition, (Source: JARUS. Doc. No.SC-RPAS.1309-01 Issue 2,"SPECIAL CONDITION Equipment, systems, and installations", Failure Conditions Classification, p.7 2015, [100] and NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, AMC.1309, p. 197-198, 2016, [124] (Continued)

Failure conditions that would reduce the capability of the RPAS or the ability of the remote crew to cope with adverse operating conditions to the extent that there would be the following: - Loss of the RPA where it can be reasonably expected that one or more fatalities will not occur, or - A large reduction in safety margins or functional capabilities or separation assurance, or - Excessive workload such that the remote crew cannot be relied upon to perform their tasks accurately or completely	Failure conditions that either by themselves or in conjunction with increased crew workload, are expected to result in a controlled-trajectory termination or forced landing potentially leading to theloss of the UA where it can be reasonably expected that a fatality will not occur. Or Failure conditions for which it can be reasonably expected that a fatality to UAS crew, ground staff or third parties will not occur
Major	
Failure conditions that would reduce the capability of the RPAS or the ability of the remote crew to cope with adverse operating conditions to the extent that there would be a significant reduction in safety margins, functional capabilities or separation assurance. In addition, the failure condition has a significant increase in remote crew workload or impairs remote crew efficiency	Failure conditions that either by themselves or in conjunction with increased crew workload, are expected to result in an emergency landing of the UA on a predefined site where it can be reasonably expected that a serious injury will not occur. Or Failure conditions which may result in an injury to UAS crew, ground staff, or third parties
Minor	
Failure conditions that would not significantly reduce RPAS safety and that involve remote crew actions that are well within their capabilities. Minor failure conditions may include a slight reduction in safety margins or functional capabilities, a slight increase in remote crew workload, such as flight plan changes	Failure conditions that do not significantly reduce UAS safety and involve UAS crew actions that are well within their capabilities. These conditions may include aslight reduction in safety margins or functional capabilities, and a slight increase in UAS crew workload.
No Safety Effect	
Failure conditions that would have no effect on safety. For example, failure conditions that would not affect the operational capability of the RPAS or increase the remote crew workload.	Failure conditions that have no effect on safety

The civil ones are more generic and focused especially on the reduction of safety margins, system functionality, and on the increasing remote crew workload. Conversely, the severity of the military failure conditions is easier to determine since, the definitions refer not only to the aspects covered by civil formulations, but also to operational consequences such as an emergency, forced or uncontrolled landing, and the possibility and occurrence of injuries or fatalities to UAS crew, ground staff and third parties. It can be noticed that 'Minor' and 'No Safety Effect' severity definitions are equivalent, while the other ones presented some differences. For instance, the civil and military definitions share for the 'Major' condition the increased workload on the crew, but the military approach also introduces the consequence on flight activities such as emergency landing where an injury will not occur. Similarly, the 'Hazardous' condition shares the increased workload and the loss of UA where a fatality will not occur, but the military approach introduces the concept of uncontrolled trajectory or forced landing. The definition of 'Catastrophic' failure is of particular interest. In the military case, in addition to the concept of fatality as for the civil definition, a failure condition resulting in an uncontrolled flight or in an uncontrolled crash is classified as catastrophic. This is because in military regulations, the concept of the airspace traversed or the type of third-party overflown is not considered, so any uncontrolled flight or crash can potentially lead to a fatality. On the other hand, civil regulations evaluate the GRC and the ARC of the operational scenario. For example, an uncontrolled flight or a crash in an atypical airspace/controlled ground environment will not lead to a fatality because it is reasonably assumed that any people will be located in the flight activities area, so the civil 'catastrophic' severity level must be evaluated also in relation with the characteristics of the operational scenario.

6.3 Overflown Population Density

In the civil sector, the risk associated with a specific category operation, assessed through the application of the SORA process, derived from two contributes: the risk associated "of a person being struck by the UAS (in case the loss of UAS control with a reasonable assumption of safety"[19] and the risk of a mid-air collision with a manned aircraft.

Overflown population density is a key item for ground risk assessment. After determining the applicability of the risk assessment process and defining the ConOps of the intended operation, SORA requires the calculation of the intrinisc Ground Risk Class that depends on the operational scenario. Specifically, the environment is classified according to the population density in it.
In SORA 2.0, the determination of the density overflown is done through a qualitative

[19] JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, Main Body, Step#2, Paragraph(a), p.19, 2019, [101]

assessment of the scenario, which can be classified according to the following macro categories: controlled ground area, sparsely populated environment, populated environment or gathering of people. Instead in SORA 2.5, the determination of population density becomes quantitative. The updated version introduces numerical population density ranges from 25 ppl/km^2 *to* 250.000 ppl/km^2. The applicant has to evaluate the maximum population density overflown and compares it with these ranges.

Although the method of population density classification changes between sora 2.0 and 2.5, this density issue remains essential to the risk assessment process. This is a consequence of the new methodology by which EASA defines regulations and rules for the use of unmanned systems. The new approach requires evaluating not only the characteristics of the employed aircraft, but also all aspects related to the type of operation being conducted including the operational scenario characteristics. The population density overflown is an input to obtain the risk class associated with the intended operation, for example the ground risk class for an UAS with a maximum characteristic dimension of $8m$ performing BVLOS operation is equal to 5 if activities are conducted in a sparsely populated environment, while is equal to 8 in populated areas. All the operational safety objectives will be demonstrated at a level of robustness depending on the population density and the operational authorization will be issued for the specific operation designed to overfly a defined number of people at risk.

On the other hand, the military sector does not take into account the type of operation and the operational scenario in the evaluation of the risk to which crew, ground staff and third parties are subjected. Overflown population density is evaluated as a limitation to the operability of the aircraft, if the safety requirements are not satisfied. For example, in Italian Military Regulations, the starting point to evaluate UAS risk is the assessment of the Cumulative Probability for Catastrophic Events per flight hours. This value can be calculated as shown in Table 6.1. If this requirement is not met or the probability target level for each single failure is not satisfied, the competent authority shall impose a limitation on the average population density allowed to be overflown during flight activities ([24], Annex G).
The DAA, to evaluate this limitation, sets the methodology defined in the Annex G to AER(EP).P-2[20] and summarized below.

Three scenarios have to be defined:

[20]Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Omologazione, Certificazione e Qualificazione di Tipo Militare, Idoneità alla Instal- lazione", Annex G, p.G-1, 2012, [24]

S1. *"In the non-terminal phases of the flight, unrecoverable loss of control of the UA with the activation of the recovery system (near-vertical descent with low kinetic energy on impact);*

S2. *In the non-terminal phases of the flight, unrecoverable loss of control of the UA with a failure of the recovery system (descent with high kinetic energy at impact);*

S3. *In the terminal phases of the flight, unrecoverable loss of control of the UA at low-speed (descent from low altitude, without activation of the recovery system, with medium kinetic energy at impact)"*[21]

The probability of occurrence and the area of ground dispersion of debris following an impact have to be evaluated for each scenario.

Probability of each scenario ([24], p.G-3)
Scenario 1:

$$P_{s-1} = P_{uncontrolled-loss} \cdot (1 - P_{failure-recovery-system}) \cdot (1 - T_{exposure-time-flight-phases}) \tag{6.1}$$

Scenario 2:

$$P_{s-2} = P_{uncontrolled-loss} \cdot (P_{failure-recovery-system}) \cdot (1 - T_{exposure-time-flight-phases}) \tag{6.2}$$

Scenario 3:

$$P_{s-3} = P_{uncontrolled-loss} \cdot (1 - T_{exposure-time-flight-phases}) \tag{6.3}$$

Where,
$P_{uncontrolled-loss}$ is the probability of unrecoverable loss of control of the UA
$P_{failure-recovery-system}$ is the probability of recovery system failure, and
$T_{exposure-time-flight-phases}$ is the duty cycle for flight terminal phase.

Lethal Areas ([24], p.G-3)
Scenario 1:

[21] Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Omologazione, Certificazione e Qualificazione di Tipo Militare, Idoneità alla Installazione", Annex G, p.G-2, 2012, [24]

$$\begin{aligned} A_1 =& A_{geom-1} \cdot K1 \\ K1 =& max(1.1; min(7; 1.4 \cdot (E_{tot1})^{0.2})) \\ E_{tot1}[kJ] =& 1/2 \cdot MTOW \cdot ((V_{z-chute})^2 + (0.40 \cdot V_{x-wind})^2) \end{aligned} \tag{6.4}$$

Scenario 2:

$$\begin{aligned} A_2 =& A_{geom-2} \cdot K2 \\ K2 =& max(1.1; min(7; 1.4 \cdot (E_{tot2})^{0.2})) \\ E_{tot2}[kJ] =& 1/2 \cdot MTOW \cdot (V_{max-operative})^2 + \\ & 0.90 \cdot (MTOW \cdot 9.81 \cdot h_{max-operative}) \end{aligned} \tag{6.5}$$

Scenario 3:

$$\begin{aligned} A_3 =& A_{geom-3} \cdot K3 \\ K3 =& max(1.1; min(7; 1.4 \cdot (E_{tot3})^{0.2})) \\ E_{tot3}[kJ] =& 1/2 \cdot MTOW \cdot (1.3 \cdot V_{stall})^2 + \\ & 0.95 \cdot (MTOW \cdot 9.81 \cdot h_{max-final-phase}) \end{aligned} \tag{6.6}$$

Where,
A_{geom-i} is the geometrical lethal areas, that shall be calculated in accordance with Advisory Circular FAA AC-431.35-1, as reported in the Section 'Critical Area' of this Chapter,
$V_{z-chute}$ is the UA vertical speed with parachute opened [m/s],
$h_{max-operative}$ is the maximum AGL altitude (operative ceiling) [m],
$h_{max-finla-phase}$ is the maximum AGL altitude for final approach phase [m],
K_i is the geometric area correction factor, depending on the Kinetic Energy.

Population Density Equation ([24], p.G-3)
The Population Density limit can be evaluated by the following equation:

$$DP[inh/km^2] = \frac{P_{cum-death}}{(P_{s-1} \cdot A_1 + P_{s-2} \cdot A_2 + P_{s-3} \cdot A_3)} \tag{6.7}$$

Where $P_{cum-death}$ is the cumulative probability of hitting overflown people derived from Table 6.1.

The operational scenarios defined above are suitable for UAS equipped with a recovery system, such as a parachute. If this equipment is not available on the interested aerial vehicle equations can be simplified.

In the following lines, the population density limit will be evaluated for a UAV system with a maximum take-off weight of 200 kg and a A_c calculated as sets by the regulation AER(EP).P-2 of DAAA (equation 6.24) and reported in the section "Critical Area" of this Chapter. Assuming that the vehicle is not equipped with a parachute, the following assumptions are introduced:

- Assumption 1: It is assumed that the probability of the recovery system failure is 1;

- Assumption 2: It is assumed that the unrecoverable loss of control of the UA results always in a high speed crash and the lethal area is always conservatively equal to the lethal area calculated for high risk speed condition (maximum lethal area). These parameters are obtained:

  - $T_{exposure-time-flight-terminal-phase} = 0$;

  - $A_{s-i} = A_c$;

  - $K_i = 7$.

So, the Population Density Equation 6.7 becomes:

$$DP[inh/km^2] = \frac{P_{cum-death}}{P_c \cdot A_c} \tag{6.8}$$

Where,
$P_{cum-death}$ is the target cumulative probability as determine by Table 6.1, and equal to $1e^{-5}$, for the UA employed;
A_c is the UA lethal area with a correction factor equal to 7, and equal to $204.53m^2$; and
P_c is the $P_{uncontrolled-loss}$.

Assuming that the P_c obtained from the system analysis is lower than the required value according to Table 6.2, the population density limits obtained from typical values for real P_c are reported in Table 6.9.

Table 6.9: Popultation density limitation (Typical Values)

P_c	$DP[inh/km^2]$
$1e^{-2}$	5
$5e^{-3}$	10
$1e^{-3}$	49
$5e^{-4}$	98
$1e^{-4}$	489
$5e^{-5}$	978
$1e^{-5}$	unlimited

The maximum allowable population density obtained when the cumulative probability for catastrophic events requirement is not met shall be reported in the "Operational Limitation" of the Military Type Certificate.
These results can be compared with the output of the SORA 2.5 process applied to the study-case in Chapter 5.
Indeed, the implementation of SORA 2.5 results in a SAIL equal to III. To ensure the safety of people at the ground and in the airspace, for example, OSO#XII titled "UAS components essential to safe operations are designed to an Airworthiness Design Standard" requires that "the UAS components essential to safe operations are designed to an Airworthiness Design Standard (ADS) considered adequate by the competent authority and/or in accordance with a means of compliance acceptable to that authority to contribute to the overall safety objective of 10-5/FH for the loss of control of the operation". The SAIL and this requirement derive from a GRC associated with a maximum population density that the UAS will have to overfly to perform its activities in the interested operational scenario, lower than 25 inhabitants per square kilometer.
In the military sector, assuming the same value of maximum population density, the related requirement of cumulative probability of catastrophic events is equal to 10-3/FH. So, it can be noticed that the concept of maximum population density is closely correlated, both in the civil and military sectors, with the requirement for the probability of system/subsystem failure conditions that could lead to a loss of control of the system and, therefore, to a catastrophic event. However, it can also be noted that the obtained requirement varies significantly between the two sectors, the civil approach is much more demanding compared to the military one. This is not an aspect that should be underestimated, as such differences in system requirements pose significant challenges from the perspective of design, production, and industry investments, especially considering the development of dual-use drones.

In conclusion, comparing the two approaches, it can be said that the overflown population density is an issue addressed in both the civil and the military sector, but it is handle in different ways.
The civil sector uses the overflown population density as the starting point to determine the risk associated with the interned operation. All results obtained at the end of the SORA process will be dependent on the population density assessment made in the second step of the process.
Instead, the military methodology sets the population density as an operational limitation, when the cumulative probability for catastrophic events requirement is not met by the employed unmanned vehicle.
In both cases, the UA can be employed in compliance with the assessments made on population density. But in the first case, the applicant to obtain the Operational Approval for a specific operation has to define the operational scenario and the maximum population overflown since the beginning of the risk assessment process, having a clear idea of the environment within which the intended operation will be performed. In the second case, the limitation on the operational scenario in terms of population density overflown is a consequence of the safety assessment process and it is obtained at its end.
An additional difference is that the civil approach uses the maximum population density to determine the intrinsic Ground Risk Class, while the military one uses the average population density to impose the operational limitation.
Finally, a further difference is that the civil approach is quite qualitative while the military method is quantitative. In SORA 2.0 the operational scenario can be classified by choosing between 4 macro categories with increasing density, which leaves much freedom of interpretation to the applicant. SORA 2.5 introduces a more quantitative density assessment, but still considers wide ranges of population density as a reference. Whereas the Italian military regulation sets an exact numerical value.

6.4 Critical Area

In this section, the concept of critical area will be examined, both in the civil and military sectors. Currently, several calculation models are available, but they are often based on numerous and diversified assumptions and can lead to different results. Particularly, the JARUS Model (SORA 2.5), FAA and DAAA model will be presented. In addition, EASA published in October guidelines to propose a new model to evaluate the critical area suitable especially for rotary-wing aircrafts. It has recently completed its consultation period and it is under review.

6.4.1 The JARUS Model

The Ground Risk Class depends on the maximum characteristics dimension of the UA. For each threshold of maximum size in the iGRC, a Critical area value can be associated, as reported in the following table:

Table 6.10: SORA process Critical Area thresholds (Source: EASA. "Proposed Guidelines for the calculation of the crit- ical area of Unmanned Aircraft", p.4, 2023, [57])

Max. characteristic dimension (m)	≥ 1	≥ 3	≥ 8	≥ 20	≥ 40
Critical area (m^2)	8	80	800	8.000	80.000

If the applicant considers these values as too conservative to represent the aircraft, the SORA 2.5 proposes guidelines to evaluate the critical area of the UA and, if possible, reduce the iGRC. To describe the JARUS model, Annex F of SORA 2.5 is taken as reference [114].

The critical area is *"the sum of all areas on the ground where a person standing would be expected to be impacted by the UA system during or after a loss of control event, and thus the area where a fatality is expected to occur if a person were within it"*[22]
By analyzing several approaches available in the literature, the following variables, contributing to A_C evaluation, have been identified by JARUS ([114], 2022, p.16):

- glide;
- slide;
- bounce;
- splatter;
- secondary effects;
- blade throw;
- explosion and deflagration.

[22] EASA. "Proposed Guidelines for the calculation of the crit- ical area of Unmanned Aircraft", p.2, 2023, [57].

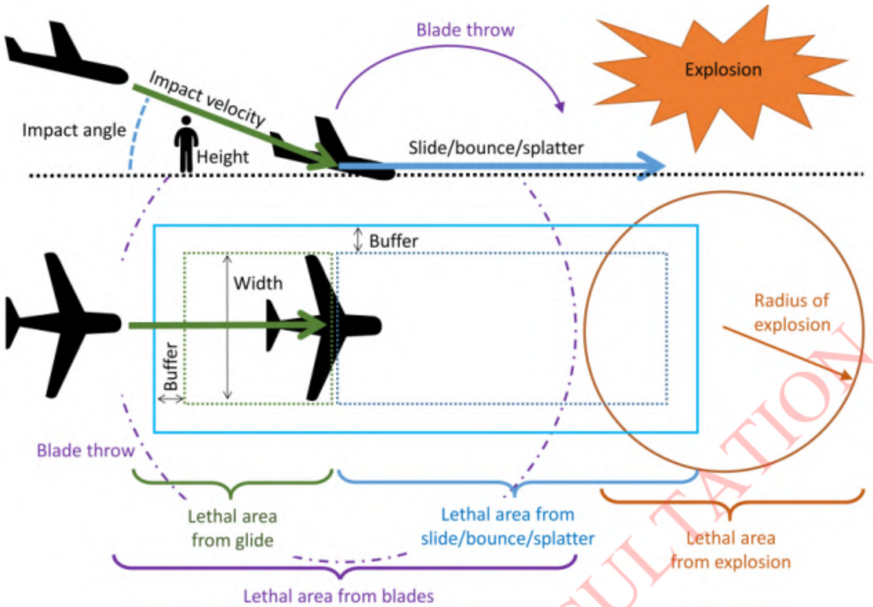


Figure 6.2: General depiction of the critical area, (Source: JARUS. "JARUS guidelines on SORA, Annex F, Theoretical Basis for Ground Risk Classification" Edition 0.3., p.17, 2022, [114])

However, all these aspects are often difficult to determine, and in order to provide a model that is simple but still representative and suitable for all aircraft belonging to the specific category to which the critical area calculation is addressed, the SORA process adopts some simplifications. The model obtained consists only of glide and slide effects, excluding other contributions.

The glide critical area is defined as *"the area covered by the path of the aircraft at an altitude equal to or below the height of an average standing person, but before it contacts the ground"*[23]. The slide effect, after the impact, depends on aircraft speed and friction between the UA and the ground.
Particularly, the JARUS model is the result of two critical area models: the RTI and NAWCAD.
The RTI model is used for "estimating casualty area for falling inert debris from missile

[23] JARUS. "JARUS guidelines on SORA, Annex F, Theoretical Basis for Ground Risk Classification" Edition 0.3., p.16, 2022, [114]

and space vehicles"[24], and covers glide, slide, and the coefficient of restitution[25] related to bounce. Whereas the NAWCAD model evaluates "the critical area resulting from the crash of an unmanned aircraft"[26], including the slide effect and its reduction due to that a sliding aircraft becomes non-lethal before the complete rest. As a result the JARUS model combines the glide and slide effects and the coefficient of restitution from the RTI model, and the slide area reduction of the NAWCAD model ([114], 2022, p.79).

The critical area is calculated with the following equation ([114], 2022, p.76-79):

$$A_c = 2 \cdot r_D(d_{glide} + d_{slide,reduced}) + \pi \cdot r_D^2 \tag{6.9}$$

where

$$d_{slide,reduced} = e \cdot v_{horizontal} \cdot t_{safe} - 0.5 \cdot C_g \cdot g \cdot t_{safe}^2 \tag{6.10}$$

$$v_{non-lethal} = \sqrt{\frac{2 \cdot K_{non-lethal}}{m}} \tag{6.11}$$

$$t_{safe} = \frac{v_{non-lethal} - e \cdot v_{horizontal}}{-C_g \cdot g} \tag{6.12}$$

$$v_{horizontal} = v \cdot cos\theta \tag{6.13}$$

$$d_{glide} = \frac{h_{person}}{\tan\theta} \tag{6.14}$$

$$r_D = r_{person} + \frac{w}{2} \tag{6.15}$$

With:

- e is the coefficient of restitution, is evaluated as $e = 0.8 - \frac{0.3}{81} \cdot (\theta - 10)$[27];
- v is the maximum cruise speed;
- Cg is the coefficient of friction, depending on the type of the ground and the aircraft. A conservative value equal to 0.65 can be assumed;

[24] JARUS. "JARUS guidelines on SORA, Annex F, Theoretical Basis for Ground Risk Classification" Edition 0.3, p.76, 2022, [114]

[25] It represents the reduction of velocity from before an impact to after and impact and takes into account the energy dissipated to the environment and aircraft deformation. (JARUS. "JARUS guidelines on SORA, Annex F, Theoretical Basis for Ground Risk Classification" Edition 0.3, p.58, 2022, [114])

[26] JARUS. "JARUS guidelines on SORA, Annex F, Theoretical Basis for Ground Risk Classification" Edition 0.3, p.78, 2022, [114]

[27] JARUS. "JARUS guidelines on SORA, Annex F, Theoretical Basis for Ground Risk Classification" Edition 0.3, p.58, 2022, [114]

- g is equal to $9.8m/s$;
- h_{person} is the height of a person set to $1.8m$;
- r_{person} is the radius of a person of $0.3m$;
- θ is the impact angle between the direction of travel and ground;
- w is the aircraft maximum dimension;
- $K_{non-lethal}$ equal to the maximum non-lethal kinetic energy (highest non-lethal kinetic energy at impact equal to $290J$).

So, the JARUS model considers an unmanned aircraft that glides until the impact with the terrain.

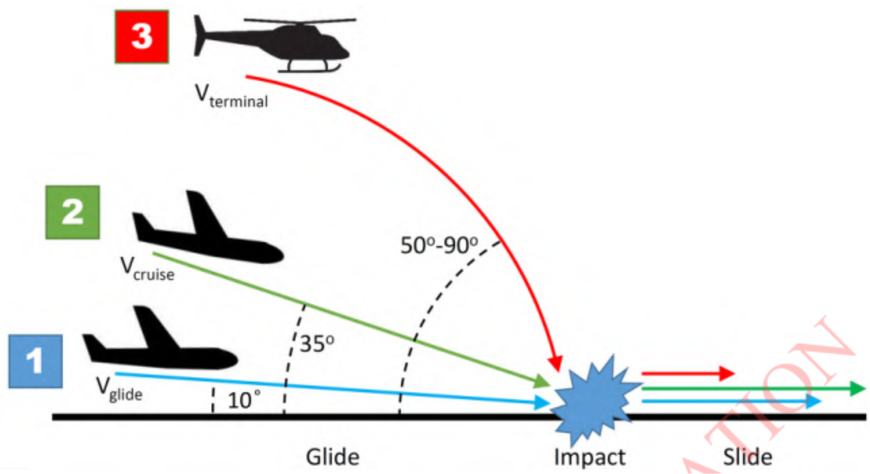


Figure 6.3: The three different descent scenarios used to compute critical areas, (Source: JARUS. "JARUS guidelines on SORA, Annex F, Theoretical Basis for Ground Risk Classification" Edition 0.3, p.56, 2022, [114])

For example, the scripts below reports the JARUS models applied to an UAS with a maximum take-off weight of 200 kg and a maximum characteristic dimension of 4.95 m and flying at a maximum cruise speed equal to 90 kts. The results have been evaluated for increasing angles of descent varying between 10 and 50 degrees.

```
%% JARUS Model
e = 0.8;
g = 9.8; %[m/s]
Cg = 0.65;
```

```
h_person = 1.83; %[m]
r_person = 0.304; %[m]
m = 200; %[kg]
w = 4.95; %[m]
v = 46.3; %[m/s]  % 90 kts
K_nonlethal = 290; %[J]

for theta = [10 15 25 35 45 50]
rD = r_person + w/2;
d_glide = h_person / tand(theta);
v_horizontal = v*cosd(theta);
v_nonlethal = sqrt(2*K_nonlethal/m);
t_safe = (v_nonlethal -e*v_horizontal)/(-Cg*g);

d_slide_reduced = e*v_horizontal*t_safe-0.5*Cg*g*t_safe^2;

Ac_jarus_model = 2*rD*(d_glide+d_slide_reduced)+ pi*rD^2;

fprintf('Descent angle = %d (deg)   Critical Area is equal to %f [m^2]\n', theta, Ac_jarus_model)
figure(1)
plot(theta, Ac_jarus_model, 'x', 'LineWidth', 2)
axis([5 61 160 750])
xlabel('(deg)')
ylabel('m^2')
hold on
end

%% Results
Descent angle = 10  Critical Area is equal to 661.16 [m^2]
Descent angle = 15  Critical Area is equal to 619.39 [m^2]
Descent angle = 25  Critical Area is equal to 536.44 [m^2]
Descent angle = 35  Critical Area is equal to 439.14 [m^2]
Descent angle = 45  Critical Area is equal to 332.43 [m^2]
Descent angle = 50  Critical Area is equal to 278.83 [m^2]
```

Figure 6.4 shows the variation of the critical area in relation to the angle of descent. The

JARUS model was developed to be applied to aircraft with the ability to glide, for which the descent angle is usually low (ranging from 10 to 50 degrees). Indeed, it can be seen that as the angle increases, the critical area decreases significantly. Indeed, as illustrated in Figure 6.3, it can be noticed that the ballistic descent, associated with higher impact angles, results in a smaller critical area. This type of descent is typical of rotor or multirotor aircraft that do not have the capability of gliding.

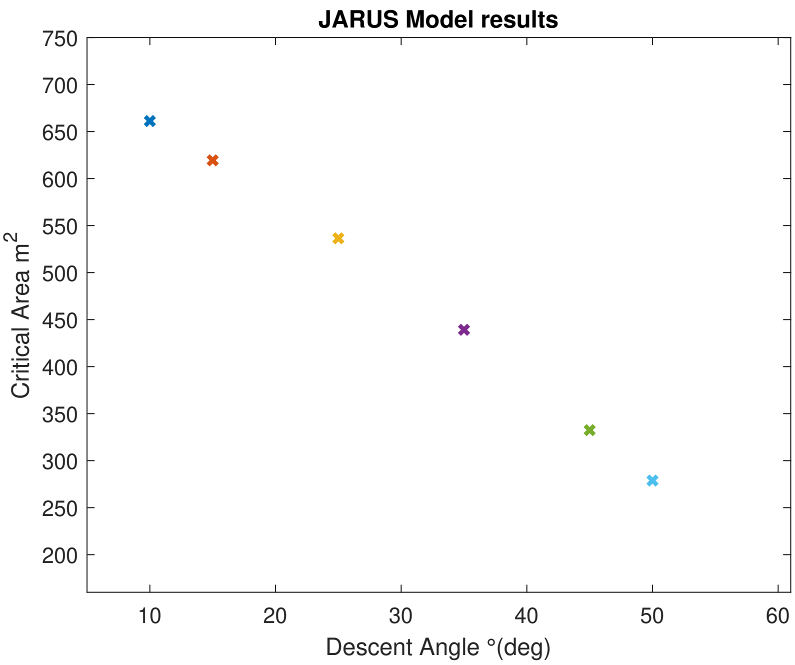


Figure 6.4: JARUS Model Critical Areas

For this reason, EASA has recently released guidelines to propose a new calculation method for the critical area of Unmanned Aircraft, introducing a new model named "High Angle Impact Model"[28] that seems more suitable for this class of UAS. This model has been released as a proposal to collect stakeholders comments, the consultation period ended in November 2023.

[28] EASA. "Proposed Guidelines for the calculation of the critical area of Unmanned Aircraft", 2023, [57]

6.4.2 High Angle Impact Model

The High Angle Impact Model describes "a crash resulting from a free fall of the UA in case of a loss of power, and where the impact is so high such that the impact dynamics are different from the ones described in the JARUS model"[29]. It is based on the following assumptions:

- *"the UA should not be capable of gliding;*
- *"the impact angle of the UA with the ground should be higher than* 60*deg "*[30]

The critical area is now evaluated as a circle with a radius depending on the maximum characteristic dimension of the UA and on the radius of a person.

$$rD = r_{person} + \frac{w}{2} \tag{6.16}$$

$$A_c = F_s \cdot \pi \cdot rD^2 \tag{6.17}$$

Unlike the JARUS model, which only considered slide and glide, the high impact angle model now takes into account effects such as bounce, blade throw, and splatter effects through the safety factor ([57], 2023, p.8). The F_s depends on the kinetic energy of the UA calculated at the terminal velocity and varies between 2 an 7.
It can be determined using the following chart:

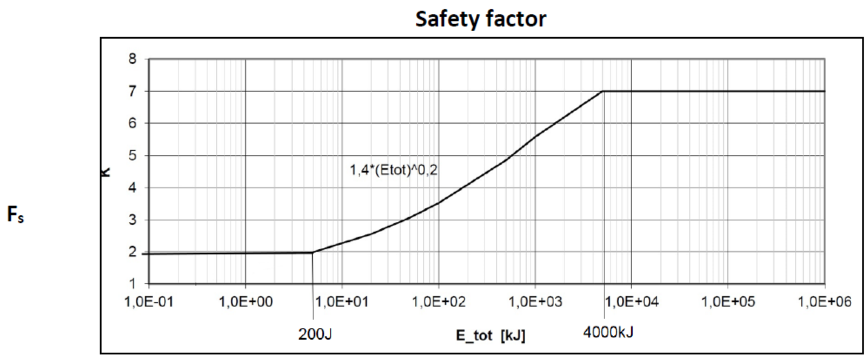


Figure 6.5: Safety factor High Angle Impact Model, (Source: EASA. "Proposed Guidelines for the calculation of the critical area of Unmanned Aircraft", p.8, 2023, [57])

[29]EASA. "Proposed Guidelines for the calculation of the critical area of Unmanned Aircraft", p.3, 2023, [57]

[30]EASA. "Proposed Guidelines for the calculation of the crit- ical area of Unmanned Aircraft", p.2, 2023, [57].

	E_k	F_s
Lower limit	$\leq 0.2kJ$	2
Equation	$0.2kJ \leq E_k \leq 4000kJ$	$1.4 * E_k(kJ)^{0.2}$
Upper limit	$> 4000kJ$	7

Figure 6.6: Safety factor High Angle Impact Model, (Source:EASA. "Proposed Guidelines for the calculation of the critical area of Unmanned Aircraft", p.8, 2023, [57])

Where,

$$E_{K,terminal} = \frac{1}{2} m V_{terminal}^2 \tag{6.18}$$

$$V_{terminal} = \sqrt{\frac{2 \cdot m \cdot g}{\rho \cdot A \cdot C_d}} \tag{6.19}$$

The script below shows the implementation of the High Impact Angle model for a UA with a maximum take-off weight of 200 kg, with a maximum characteristic dimension of 4.95 m and flying at a maximum cruise speed equal to 90 kts. A safety factor equal to 7 is assumed to maintain a conservative approach.

```
%% High Angle Impact Model
Fs = 7;
rD = r_person +(w/2);
Ac_high_angle_impact = Fs*pi*rD^2
r_high_angle_impact = sqrt(Ac_high_angle_impact/pi)

% Results
Ac_high_angle_impact =   169.8341 [m^2]
r_high_angle_impact =  7.3525 [m]
```

6.4.3 FAA AC 431.35-1 Model

In the military sector, the FAA proposed the Circular FAA AC 431.35-1[31] as reference. The critical area is defined as *"the aggregate casualty area of each piece of debris created by a vehicle failure at a particular point on its trajectory. The casualty area for each piece of debris is the area within 100 per cent of the unprotected population on the ground is*

[31] FAA. FAA AC 431.35-1, "EXPECTED CASUALTY CALCULATIONS FOR COMMERCIAL SPACE LAUNCH AND REENTRY MISSIONS", 2000, [79]

assumed to be a casualty"[32]. Unlike the civil model proposed by JARUS, which considered only glide and slide, the military one takes into account aspects such as: *"debris piece including its size, the path angle of its trajectory, impact explosion, skip, splatter, and bounce as well as the size of a person"*[33]. The total casualty area is evaluated by the following equation:

$$A_c = 7 \cdot A_{c-inert} + A_{c-explosive} \tag{6.20}$$

The inert debris $A_{c-inert}$ is calculated as ([79], 2000, p.12):

$$A_{c-inert} = 2 \cdot [r(p) + r(f)] \cdot d + \pi[r(p) + r(f)]^2 \tag{6.21}$$

Where,

- $r(p)$ is the radius of person, equal to $1ft$;
- $r(f)$ is the radius of the fragment;
- d is the height of person ($6ft$) / tangent(impact angle), and it is equal to the "horizontal distance that the debris travels as it falls the height of a person"[34];
- γ is the impact angle is "the angle that the velocity vector makes with the horizontal plane surface impacted"[35].

In addition, to consider the possibility of debris to slide, skid, bounce, ricochet or splatter after the impact, the casualty area of inert debris is conservative increased by a factor equal to 7.

[32] FAA. FAA AC 431.35-1, "EXPECTED CASUALTY CALCULATIONS FOR COMMERCIAL SPACE LAUNCH AND REENTRY MISSIONS", p.10, 2000, [79]

[33] FAA. FAA AC 431.35-1, "EXPECTED CASUALTY CALCULATIONS FOR COMMERCIAL SPACE LAUNCH AND REENTRY MISSIONS", p.11, 2000, [79]

[34] FAA. FAA AC 431.35-1, "EXPECTED CASUALTY CALCULATIONS FOR COMMERCIAL SPACE LAUNCH AND REENTRY MISSIONS", p.13, 2000, [79]

[35] FAA. FAA AC 431.35-1, "EXPECTED CASUALTY CALCULATIONS FOR COMMERCIAL SPACE LAUNCH AND REENTRY MISSIONS", p.13, 2000, [79]

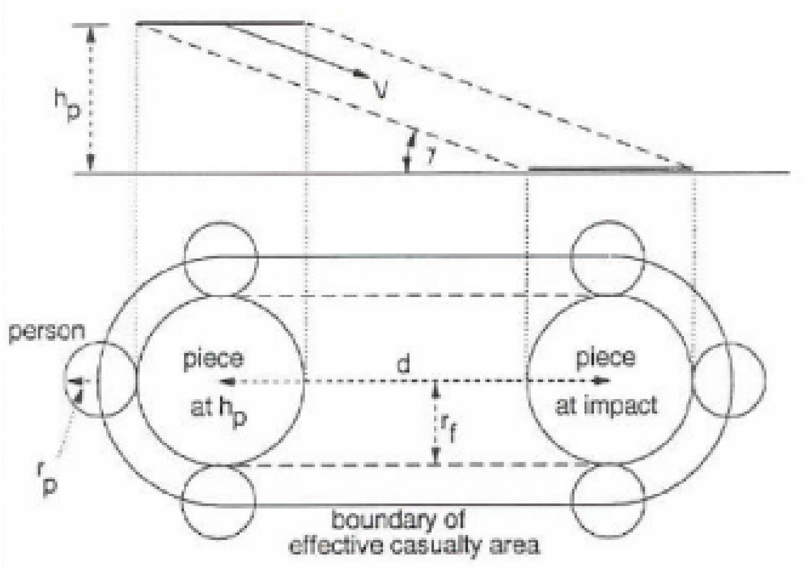


Figure 6.7: Inert Casualty Area (Source: FAA. FAA AC 431.35-1, p.13, 2000, [79])

The explosive debris $A_{c-explosive}$ is obtained by the following equation ([79], 2000, p.14):

$$A_{c-explosive} = \pi \cdot D^2 \tag{6.22}$$

The explosion area is assessed a circular area, with D as the radius of the explosive debris casualty area:

$$D = K \cdot W^{(1/3)} \tag{6.23}$$

Where,

- D is the distance (ft);
- K is the scaling factor ($ft/lb^{(1/3)}$);
- W is the net equivalent weight of TNT (lb).

For simplicity, the only explosive material assumed to be on board of the UA is the fuel (gasoline or kerosene).
The total casualty area is conservatively calculated as the sum of the inert and explosion areas.

```
%% FAA
rp = 1; %[ft]
rf = 4.95/2*3.28;  %[ft]
hp = 6;  %[ft]
gamma = 45; %[deg]

d = hp/tand(gamma);

A_b = 2*(rp+rf)*d+pi*(rp+rf)^2;
A_inert = 7*A_b;  %[ft^2]
d_inert_prova = sqrt(7)*hp/tand(gamma)+sqrt(7)*(rf+rp); %[ft]

V = 50;
K = 18;
W = 3.57e-4 * V;

D = K*W^(1/3);

A_exp = pi*D^2;  %[ft^2]
r_exp = sqrt(A_exp/pi);  %[ft]

Ac_FAA = (A_inert + A_exp)*0.305^2;

%% Results
The FAA Model retruns:
 A_basic = 34.475204 [m^2]
 A_explosion =6.467256 [m^2]
 A_critic =247.793682 [m^2]
```

6.4.4 DAAA Model

The AER(EP).P-2 indicates the FAA AC 431.35-1 as a reference to evaluate the critical area useful to determine the maximum density population that can be overflown if the cumulative probability requirement is not satisfied. However, some changes have been adopted. The DAAA model evaluates the geometric area according to Figure 6.8.

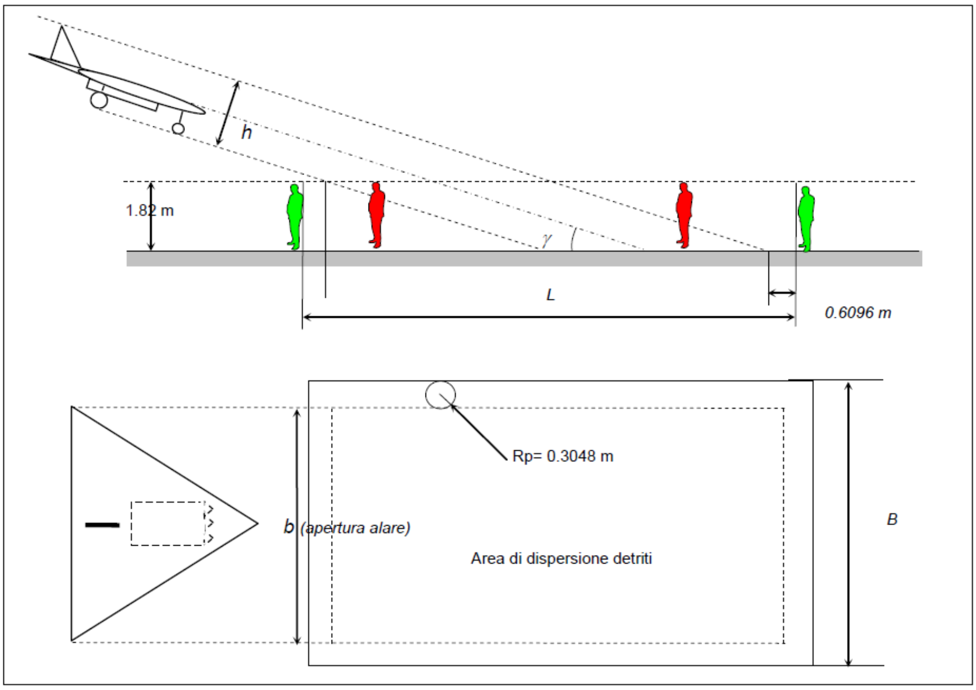


Figure 6.8: Geometrical Area, (Source: Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Omologazione, Certificazione e Qualificazione di Tipo Militare, Idoneità alla Instal- lazione", p.G-4, 2012, [24])

The geometric area can be calculated with the following equation:

$$A_{geometric} = K \cdot (d_{inert} + 4 \cdot r_p) \cdot (\frac{h_{av}}{sin(\gamma)} + h_p \cdot cotan(\gamma) + 4 \cdot r_p) \tag{6.24}$$

Where,

- d_{inert} is UAV lethal inertial area length [m];
- h_{av} is the height of the rotorcraft [m];
- r_p is the radius of a person [m];
- h_p is the height of a person [m];

- K is the amplification factor to take into account the possible projection of fragments or parts, varying between 1.1 and 7;

- γ is the impact angle equal to the angle between the landing or impact surface and the impact velocity vector of the rotorcraft.

By applying this model at an UAS with a maximum dimension of $4.95m$, descending with an angle of $45 degrees$, the following results are obtained:

```
%% DAAA Model
K =7;
d_inert = 4.95; %[m]
rp = 0.3048;  %[m]
hav= 1.2;  %[m]
hp = 1.82; %[m]
gamma= 45; %[deg]

A_c_safety_just = K*(d_inert+4*rp)*(hav/sind(gamma)+hp/tand(
    gamma)+4*rp)

%% Results
A_c_safety_just = 204.5324 [m^2]
```

Hence, both civil and military sectors assess critical area but in two different ways. In the civil sector, the SORA process uses it to evaluate the ground risk class, confirming the danger posed to overflown people or reducing the GRC obtained through the assessment of the population density at risk, the type of operation and the maximum dimension of the UAS. Annex F of SORA 2.5 proposes the JARUS Model to evaluate the critical area. This methodology considers only slide and glide effects so it is suitable for fixed-wing aircraft. This approach is considered too conservative for rotary-wing aircraft, which in case of a loss of control usually fall following a ballistic descent. In October 2023, EASA issued a proposal for a more adequate and simplified model based on impact angle higher than 60° which takes into account also effects such as bounce, blade throw, and splatter, excluded in the previous. The High Impact Angle Model provides smaller critical areas than the JARUS Model.
In the military sector, the regulation AER(EP).P-2 requires the assessment of the critical area to determine the limit of the maximum population density that can be overflowed

during operations In case of non compliance with the cumulative probability of catastrophic event requirement. It proposes a model derived from the FAA AC 431.35-1 to evaluate the geometric area. Whereas the FAA AC 431.53-1 proposes a model to evaluate the critical area as the result of the vertically falling of inert debris (or the UA), their possibility of slide, bounce or splatter, and the explosion of the UAS. The inert area depends on the size of the debris (or UAS) and the radius of a human being, while the explosion area depends on the presence on board of explosive material such as fuel.
Comparing the critical areas, for a rotary wing UAS with a maximum characteristic size of 4.95 meters and with a descending angle of 45 deg, it can be noticed that the JARUS Model is the more conservative approach. The model that returns the lowest result is the High Impact Angle Model. This approach is not yet completely defined and still under development, it is quite simplified: the critical area is calculated as a circular area dependent on the maximum size of the aircraft, while other aspects considered, mentioned above, are quantified only by a safety factor varying between two and 7.

Table 6.11: Critical areas obtained

JARUS Model	High Impact Angle Model	FAA Model	DAAA Model
$332.43m^2$	$169.83m^2$	$249.79m^2$	$204.53m^2$

6.5 Airspace assessment

As mentioned, civil and military regulations approach the topic of airspace assessment differently. In the civil sector, the airspace assessment is an essential part of the SORA process, whose second part is dedicated to the Air Risk Process to evaluate the mid-air collision risk. "The airspace is categorized into 13 aggregated collision risk categories [...] characterized by altitude, controlled versus uncontrolled airspace, airport/heliport versus non-airport/non-heliport environments, airspace over urban versus rural environments, and lastly atypical (e.g. segregated) versus typical airspace"[36]. Based on these characteristics, the initial air class is classified into 4 categories of increasing risk: ARC-a, ARC-b, ARC-c, ARC-d.
On the other hand, the classification of traveled airspace is not assessed in military regulations, for example the STANAG 4702 reports clearly that "the airspace integration and

[36] JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, Main Body, p.22, 2019, [101]

segregation of aircraft (including “sense and avoid)"[37] is not a covered issue.

However, some similarities between the two approaches can be identified. For example, in SORA 2.0, once obtained the residual ARC, Tactical Mitigations have to be applied to achieve applicable airspace safety objectives. They are means of mitigation “operate using a sensor to “see” the threat, “deciding” how to mitigate the risk, “acting” on the decision, and then having a system feedback to monitor the risk, and implementing new corrections if needed”[38]. Tactical Mitigations and its Performance Requirements vary on the base of the type of operation, for example VLOS or BVLOS operations, and are more demanding as the airspace risk level increases. For example, under BVLOS operations, the UAS has to comply with "see & avoid" requirements, renamed as "detect and avoid" and subdivided into five functions named Detect, Decide, Command, Execute, and Feedback Loop. The main requirements associated with these functions can be summarized as [105]:

- Detect: consist of the ability of the UAS to analyze the interested airspace and identify manned aircraft with an increasing level of accuracy;

- Decide: refers to the availability of procedure, tools, methods to understand detected data and use them to avoid incoming traffic;

- Command: is essentially a requirement covering the latency between the pilot command and the UA execution;

- Execute: consist of a set of requirements covering speed, rate of climb/descent, turn rate to execute the avoidance maneuver;

The "Detect" aspect is of particular interest for this comparison:

[37]NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, NATO, Scope, p.2, 2016, [124]

[38]JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, Main Body, p.24-25, 2019, [101]

	Function	TMPR Level				
		VLOS	No Requirement (ARC-a)	Low (ARC-b)	Medium (ARC-c)	High (ARC-d)
Tactical Mitigation Performance Requirements (TMPR)	Detect[1]	No Requirement	No Requirement	The expectation is for the applicant's DAA Plan to enable the operator to detect approximately 50% of all aircraft in the detection volume[2]. This is the performance requirement in absence of failures and defaults. It is required that the applicant has awareness of most of the traffic operating in the area in which the operator intends to fly, by relying on one or more of the following: • Use of (web-based) real time aircraft tracking services • Use Low Cost ADS-B In /UAT/FLARM[3]/Pilot Aware[3] aircraft trackers • Use of UTM Dynamic Geofencing[4] • Monitoring aeronautical radio communication (i.e. use of a scanner)[5]	The expectation is for the applicant's DAA Plan to enable the operator to detect approximately 90% of all aircraft in the detection volume[2]. To accomplish this, the applicant will have to rely on one or a combination of the following systems or services: • Ground based DAA /RADAR • FLARM [3/6] • Pilot Aware [3/6] • ADS-B In/ UAT In Receiver[6] • ATC Separation Services[7] • UTM Surveillance Service[4] • UTM Early Conflict Detection and Resolution Service[4] • Active communication with ATC and other airspace users[5]. The operator provides an assessment of the effectiveness of the detection tools/methods chosen.	A system meeting RTCA SC-228 or EUROCAE WG-105 MOPS/MASPS (or similar) and installed in accordance with applicable requirements.

[1]For an in depth understanding of the derivation, please see Annex G. Detection should be done with adequate precision for the avoidance manoeuvre to be effective.
[2]The detection volume is the volume of airspace (temporal or spatial measurement) which is required to avoid a collision (and remain well clear if required) with manned aircraft. It can be thought of as the last point in which a manned aircraft must be detected, so that the DAA system can performance all the DAA functions. The detection volume in not tied to the sensor(s) Field of View/Field of Regard. The size of the detection volume depends on the aggravated closing speed of traffic that may reasonably be encountered, the time required by the remote pilot to command the avoidance manoeuvre, the time required by the system to respond and the manoeuvrability and performance of the aircraft. The detection volume is proportionally larger than the alerting threshold.
[3]FLARM and PilotAware are commercially available (trademarked) products/brands. They are referenced here only as example technologies. The references do not imply an endorsement by JARUS or the authors of this document for the use of these products. Other products offering similar functions may also be used.
[4]These refer to possible future applications of automated traffic management systems for unmanned aircraft in an UTM/U-space environment. These applications may not exist as such today.
[5]If permitted by the authority. May require a Radio-License or Permit.
[6]The selection of systems to aid in electronic detection of traffic should be made considering the average equipage of the majority of aircraft operating in the area. For example: In areas where many gliders are known to operate, the use of FLARM7 or similar systems should be considered whereas for operations in the vicinity of large commercially operated aircraft, ADS-B IN is probably more appropriate. In areas where aircraft are known not to These refer to possible future applications of automated traffic management systems for unmanned aircraft in an UTM/U-space environment. These applications may not exist as such today. A subscription to these services may be required.
[7]The selection of systems to aid in electronic detection of traffic should be made considering the average equipage of the majority of aircraft operating in the area.

Figure 6.9: TMPR Detect, (Source:JARUS. Doc.JAR-DEL-WG6-D.04_D Annex D , "JARUS guidelines on SORA - Annex D - Tactical Mitigation Collision Risk Assessment", Version 2.0, p.7, 2019, [105])

It may be noted that in order to integrate drones into the existing airspace and avoid collisions with other aircraft, SORA 2.0 (same for SORA 2.5) requires that for Air risk class equal to or greater than ARC-b, the aircraft has to detect aircraft in the airspace of interest with an increasing level of accuracy. To this end, dedicated equipment, function or services must be provided for the UAV system employed. For example, ADS-B, RADAR or separation and surveillance services.

Similar provisions can be traced in Annex G of AER(EP).P-2, assessing the operational aspects of APR employment, includes a section dedicated to mid-air collision. It set that the mid-air collision probability is "directly related to the technical issues of "see&avoid", to flight rules (VFR/IFR), to operational limitations,to the chosen employmet areas, and to the communication procedures with the Air Traffic Controller (ATC)"[39]. So, to reduce the air risk and ensure safety of operation, this regulation requires the installation of a minimum set of equipment/systems such as:

- *"Navigation and anti-collision lights (24 hours a day);*
- *Communication System "Earth/Board/Earth" for communications between the remote pilot and ATC;*
- *direct connection (e.g., a telephone) between the Ground Control Station and the ATC, for communications in case of Communication System failure;*
- *IFF transponder"*[40].

In addition, the need of the following systems has to be evaluated([24], Annex G):

- TCAS;
- Low Alititude Alerting System;
- GPWS;
- TAWS;
- ADS-B.

If the UAS is not equipped with these equipment, or they are not considered adequate to mitigate the mid-air collision risk, the operator has to perform flight activities in VLOS or with the activation of a NOTAM.

6.6 UAS design assessment

This section aims to compare how civil and military sectors assess the design of unmanned aircraft systems and their compliance with airworthiness requirements.
At the end of the SORA process, a SAIL associated with the intended operation is obtained. This parameter ensures the operations are conducted safely also through compliance with Operational Safety Objectives. OSOs can be categorized into two major categories:

[39] Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Omologazione, Certificazione e Qualificazione di Tipo Militare, Idoneità alla Installazione", Annex G, p. G-1, 2012, [24]

[40] Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Omologazione, Certificazione e Qualificazione di Tipo Militare, Idoneità alla Installazione", Annex G, p. G-1, 2012, [24]

- non-design related, and
- design related

This classification will be used as the basis upon which develop the comparison between civil and military approaches.

6.6.1 Non-Design Related OSOs

Non-design related OSOs are operational safety objectives that are not related to the design of the UAS but cover operational aspects of the system, such as operational procedures, remote crew training, the competence of the operator and manufacturer. SORA 2.0 non-design related OSOs are reported in table below:

Table 6.12: Non-design related OSOs SORA 2.0, (Source: JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, 2019, [101])

OSO#-	
01	Ensure the operator is competent and/or proven
02	UAS manufactured by competent and/or proven entity
03	UAS maintained by competent and/or proven entity
07	Inspection of the UAS (product inspection) to ensure consistency to the ConOps
08	Operational procedures are defined, validated and adhered to (to address technical issues with the UAS)
09	Remote crew trained and current and able to control the abnormal and emergency situations (i.e. Technical issue with the UAS)
11	Procedures are in-place to handle the deterioration of external systems supporting UAS operation
14	Operational procedures are defined, validated and adhered to (to address Human Errors)
15	Remote crew trained and current and able to control the abnormal and emergency situations (i.e. Human Error)
16	Multi crew coordination
17	Remote crew is fit to operate
21	Operational procedures are defined, validated and adhered to (to address Adverse Operating Conditions)
22	The remote crew is trained to identify critical environmental conditions and to avoid them
23	Environmental conditions for safe operations defined, measurable and adhered to

These aspects are not covered by military regulations of interest, because they are not related to performance and airworthiness requirements. For example, the STANAG 4702 as an airworthiness code, explicitly excluded from its area of competence aspects such as "the competence, training and licensing of UAS crew, maintenance and other staff"[41], "approval of operating, maintenance and design organizations"[42]. Non-design related issues are subjected to other regulations and approvals by the Competent Authority, that are not of interest for this thesis.

6.6.2 Design Related OSOs

Instead, the design-related OSOs identify the design requirements that the UAS must comply with to ensure the safety of operations.

Table 6.13: Design-related OSOs SORA 2.0 (Source: JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, 2019, [101])

OSO#-	
04	UAS developed to authority recognized design standards
05	UAS is designed considering system safety and reliability
06	C3 link characteristics (e.g. performance, spectrum use) are appropriate for the operation
10	Safe recovery from technical issue
12	The UAS is designed to manage the deterioration of external systems supporting UAS operation
13	External services supporting UAS operations are adequate to the operation
18	Automatic protection of the flight envelope from human errors
19	Safe recovery from Human Error
20	A Human Factors evaluation has been performed and the Human-Machine Interface (HMI) found appropriate for the mission
24	UAS designed and qualified for adverse environmental conditions (e.g. adequate sensors, DO-160 qualification)

The UAS design evaluation is something that is addressed in both civil and military regulations.
In the military sector and particularly for the Italian armed forces, an aircraft, before

[41] NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, Scope, p.2, 2016, [**?**]

[42] NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. Nato standard, Scope, p.2, 2016, [**?**]

being produced and operated must satisfy two objectives: 'fit for flight', ensuring the airworthiness of the aircraft, and 'fit for purpose', ensuring that the aircraft is capable of performing the missions for which it was designed, through the fulfillment of performance requirements. These two aspects are verified by obtaining respectively military-type-certificate and military-qualification. Within these approvals, the design of the UAS is evaluated and verified to ensure that operations are conducted in a safe manner.[24]
The AER(EP).P-2 establishes the procedures to verify the compliance with airworthiness and performance requirements, which have to be defined and organized according to guidelines provided by the AER(EP).P-6.
Airworthiness and performance requirements have to be defined according to international regulations. For example, the STANAG 4702 is taken as reference for rotary-wing unmanned aircraft systems, whereas the STANAG 4671 addresses fixed-wing UAS. The airworthiness requirements contained in these codes derive from Certification Specifications used in manned civil aviation, because it is assumed that they represent the minimum airworthiness requirements for design and construction of UAS to be compliant with to operate in non-segregated airspace. As a result, the military regulations defining airworthiness requirements are often too demanding, prescriptive and over-sized to be applied successfully to UAV systems. For this reason, before undertaking the military type-certificate and qualification process, the applicant shall consult the DAAA (italian military competent authority) in order to carry out a tailoring of requirements, identifying those that should be appropriate for the type of aircraft employed and how to demonstrate compliance with them.

In the civil sector, on the other hand, obtaining a type certificate is not the only way to demonstrate that design-related OSOs are met, especially for UAS operating in a specific category. Indeed, EASA proposes several procedures for evaluating the design of the aircraft and its associated elements (communication link and control center) that are as proportionate as possible to the type of operation.
In order to demonstrate compliance with design-related OSOs three different possibility are available:

- declaration;
- design verification report;
- type-certificate.

For low-risk operation, with a resulting SAIL equal to I or II, EASA simply requires a declaration to show the fulfillment of safety objectives or, alternatively, the operator can employ a UAS with a market label that ensures that the design of the aerial platform

meets regulatory standards. Such low-demanding evidences are considered suitable for these type of operations, because for SAIL I or II, the required robustness associated with design-related OSOs varies from optional to low level.
For SAIL III, the operational risk is medium-low, the design-related requirements has to be demonstrated through the evidence required by each OSOs, typically by tests, analysis, simulations, inspections, design review or operational experience. The required robusteness is quite low, only for OSOs 10,12,13,24 it reaches the medium level.
For medium-risk operations, with a SAIL equal to IV, EASA requires that the UAS design and zthe compliance with design-related OSOs has to be verified through the design verification report. This procedure was presented in detail in Chapter 3, so only essential information will be reported to analyze the difference from the military case. The design verification report documents that the UAS design comply with applicable OSOs, but it is less demanding than the type-certificate process. A design verification basis must be identified and the applicable airworthiness requirements defined. EASA indicates the Special Condition Light UAS Medium Risk as the reference document. It contains " airworthiness specifications for UA operated in the specific category"[43] and was developed to fit into the new EASA operation-centric and risk-based regulations. Indeed, it is not prescriptive and does not contain detailed technical specifications. The SC Light UAS includes high-level objective-based requirements to be adaptable to the type of operation. For that reason the operator has to conduct a pre-application meeting with EASA to choose applicable airworthiness requirement and the suitable MOC/MOE to demonstrate compliance with them. EASA is currently working on developing and publishing MOCs that can be taken as references for future applications.
Finally, for high-risk operations, with SAIL V or VI, the UAS design is verified by type-certificate. Currently, the Certification Specification for UAS is still under development, so the reference regulations for defining airworthiness requirements are the Certification Specifications issued for manned aircraft (e.g., CS-27[44]) to which the Special Condition Light UAS High Risk can be added because it will be adopted as the basis from which the future CS-UAS will be developed.

In conclusion, civil and military approaches to verifying system design and ensuring that airworthiness requirements are met is quite different at the procedural level. The military provides only one methodology through which System approval can be obtained.

[43]EASA. Special Condition for Light Unmanned Aircraft Systems – Medium Risk, 2019, [60]

[44]The STANAG 4702 derives from this CS, so the military requirements for rotary-wing UAS are almost the same of the provisions contained in the CS-27

It requires the compliance with demanding requirements derived from the current civilian manned regulations.
Civil methodology, on the other hand, offers a set of different procedures proportional to the type of operation, defining increasingly demanding requirements based on the risk of the activities for which the UAS has to be employed. However, for high-risk operations, the reference airworthiness codes for civil UAS are similar to the military ones, as both are derived from the same civil manned regulations. So, it can be said that the major difference between the two approaches can be found in the management and regulation of operations that the civil sector classifies as specific category low and medium risk.
Another difference is that military regulations are complete and defined as they are derived from existing airworthiness codes, in contrast civil ones are under development, and especially for operations that fall into the specific category medium risk, the associated airworthiness codes are quite generic and qualitative. However, in both cases, the applicant who decide to design UAS needs to consult the competent authority prior to starting his developing activities to identify applicable and suitable requirements for UAS design, on the military side because they are often too prescriptive and demanding, whereas on the civil side to define contents, quantitative criteria and appropriate means of compliance.

Chapter 7

Conclusions

This thesis aims to analyze and compare regulatory frameworks governing Unmanned Aircraft Systems (UAS) in both civil and military contexts. UAS are considered as the future of aviation, but to fully exploit the potential and new services offered by this emerging technology, encouraging market growth, it is essential to define a comprehensive system of rules and procedures. A comprehensive and complete regulatory system is essential not only to operate UAS safely and efficiently, maximizing social benefits and sustaining public acceptance, integrating them into the general aviation system, but it is also essential to encourage industry investments that need well-defined rules to invest in long-term design and production plans.
The state of the art of UAS, their evolution and main classifications have been presented in the initial chapters of this work. Then the current civil and military regulatory frameworks have been analyzed, describing regulatory bodies and the main rules and procedures to design and operate UAS in Europe and in Italy, in order to compare the two approaches, highlighting similarities and differences.
This comparison showed that the civilian and military sectors have two very different approaches to regulating UAS. The military sector, because of the need for ready-to-use aircraft, has decided to use the traditional aeronautical method of classification and regulation, based on weight and wing type, adopting design, safety, performance and airworthiness requirements, as well as operational procedures similar to those of manned aviation. On the other hand, civil authorities considered this approach too demanding for UAS technology. Despite UAS are comparable to manned aircraft,the main difference is that they do not have a pilot and crew on board, so the risk associated with operations depends on the danger posed to overflown people and the probability of a mid-air collision with manned aircrafts. For this reason, the civil sector developed a new classification and

regulatory method based not only on the type of vehicle employed and its weight but also on the type of operation conducted, the payload carried, the overflown areas and the crossed airspace. EASA introduced three new categories to classify UAS based on the risk associated with each operation: 'open', 'specific, and 'certified'. These categories are now the basis on which a proportionate, progressive, risk-based and operation-centric regulation system has been and will be developed.

Hence, it can be said that despite the progress made in recent years to establish a system of rules, requirements, and procedures for operating drones safely and effectively, there is still much work to be done, especially to obtain a regulatory framework that is as comprehensive and harmonized as possible between the civil and military sectors. Aeronautical companies believe that in the future, the majority of UAS will be designed to be employed in both military and civil activities, but the existing regulatory system is not suitable to encourage dual-use UA technology. Both civil and military regulatory bodies have to collaborate to develop a common solution, identifying the strengths of each approach and using them as a starting point to lay the basis for a new shared regulatory system. For example, it is evident that due to the wide variety of UAVs available on the market, weighing from a few grams up to many kilograms, the many types of payloads that can be carried, and the numerous fields of application in which UAS employed, the static military approach is not appropriate to classify and regulate this emerging and dynamic technology. EASA proposed a more innovative solution that aims to create rules proportionate to the operational risk that ensure the safety of activities but being enough flexible to cover the wide variety of UAS available on the market and all types of operations. On the other hand, military regulations include well-defined requirements and procedures, derived from manned aviation, that can be assumed as the basis to set rules, provisions and means of compliance appropriate for UAS. In addition, as suggested during the Amsterdam Drone Week 2023, an essential aspect to develop a harmonized regulatory framework is the methodology to evaluate and classify the operational risk: EASA adopted the SORA process as acceptable means of compliance to assess the risk associated with a specific operation, in future, this process may be also adopted by the military sector.

To support the results obtained and in particular the need for harmonized civil and military regulatory systems, it is useful to highlight that in the second half of November 2023, DAAA published an update to AER(EP).P-7 and a new regulation AER(EP).P-22 "Certification of Military Remotely Piloted Aircraft Systems" introducing "three military RPAS certification categories, sorted in ascending maturity of certification: open, specific and certified"[1] and adopting "the approach scenario/risk based captured by the European Aviation and Safety Agency (EASA) in the Specific Operational Risk Assessment (SORA) methodology"[2] to innovate the military regulatory strategy. These new regulations will be taken as a starting point for future work to extend and enrich the comparison between civil and military UAS regulatory approaches.

[1]DAA, AER(EP).P-22, "Certification of Military Remotely Piloted Aircraft Systems", p.8, https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/Biblioteca/5Categoria/Pagine/Home.aspx, 2023

[2]DAA, AER(EP).P-22, "Certification of Military Remotely Piloted Aircraft Systems", p.1-2, https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/Biblioteca/5Categoria/Pagine/Home.aspx, 2023

Appendix A

Population density data for Operational Volume of the Corridor Area

Only the data related to cells with a non-zero population density are reported.

GRD_ID	CENS_POP2021
CRS3035RES1000mN1957000E4954000	24
CRS3035RES1000mN1946000E4950000	23
CRS3035RES1000mN1954000E4954000	16
CRS3035RES1000mN1950000E4951000	15
CRS3035RES1000mN1946000E4952000	12
CRS3035RES1000mN1951000E4953000	10
CRS3035RES1000mN1946000E4951000	7
CRS3035RES1000mN1946000E4953000	7
CRS3035RES1000mN1947000E4953000	6
CRS3035RES1000mN1953000E4952000	4
CRS3035RES1000mN1953000E4953000	2
CRS3035RES1000mN1948000E4952000	1

Appendix B

Population density data for Adjacent Area

Only the data related to cells with a non-zero population density are reported.

GRD_ID	POP2021
CRS3035RES1000mN1968000E4952000	8916
CRS3035RES1000mN1969000E4952000	7793
CRS3035RES1000mN1968000E4953000	7124
CRS3035RES1000mN1959000E4949000	6593
CRS3035RES1000mN1959000E4948000	5884
CRS3035RES1000mN1960000E4950000	5288
CRS3035RES1000mN1951000E4947000	4387
CRS3035RES1000mN1960000E4959000	4174
CRS3035RES1000mN1952000E4954000	3524
CRS3035RES1000mN1959000E4959000	3261
CRS3035RES1000mN1964000E4948000	3234
CRS3035RES1000mN1957000E4957000	3196
CRS3035RES1000mN1950000E4947000	2900
CRS3035RES1000mN1952000E4955000	2567
CRS3035RES1000mN1953000E4955000	2399
CRS3035RES1000mN1969000E4953000	2165

Continued on next page

(Continued)

CRS3035RES1000mN1955000E4949000	1732
CRS3035RES1000mN1963000E4948000	1715
CRS3035RES1000mN1957000E4956000	1314
CRS3035RES1000mN1955000E4950000	1258
CRS3035RES1000mN1967000E4952000	1176
CRS3035RES1000mN1970000E4952000	1114
CRS3035RES1000mN1958000E4951000	1103
CRS3035RES1000mN1960000E4949000	1004
CRS3035RES1000mN1957000E4949000	928
CRS3035RES1000mN1958000E4952000	880
CRS3035RES1000mN1960000E4960000	860
CRS3035RES1000mN1957000E4950000	825
CRS3035RES1000mN1967000E4953000	787
CRS3035RES1000mN1960000E4948000	740
CRS3035RES1000mN1953000E4954000	684
CRS3035RES1000mN1951000E4946000	666
CRS3035RES1000mN1948000E4948000	559
CRS3035RES1000mN1950000E4948000	516
CRS3035RES1000mN1948000E4947000	495
CRS3035RES1000mN1958000E4949000	427
CRS3035RES1000mN1959000E4960000	353
CRS3035RES1000mN1951000E4948000	328
CRS3035RES1000mN1949000E4947000	324
CRS3035RES1000mN1968000E4951000	297
CRS3035RES1000mN1961000E4950000	268
CRS3035RES1000mN1968000E4954000	246
CRS3035RES1000mN1964000E4949000	237
CRS3035RES1000mN1960000E4951000	231
CRS3035RES1000mN1963000E4956000	224
CRS3035RES1000mN1957000E4951000	216
CRS3035RES1000mN1959000E4950000	208

Continued on next page

(Continued)

CRS3035RES1000mN1961000E4947000	189
CRS3035RES1000mN1947000E4950000	186
CRS3035RES1000mN1958000E4957000	185
CRS3035RES1000mN1970000E4951000	180
CRS3035RES1000mN1951000E4949000	164
CRS3035RES1000mN1947000E4949000	162
CRS3035RES1000mN1954000E4950000	162
CRS3035RES1000mN1949000E4948000	160
CRS3035RES1000mN1963000E4949000	159
CRS3035RES1000mN1947000E4948000	158
CRS3035RES1000mN1945000E4956000	143
CRS3035RES1000mN1953000E4950000	139
CRS3035RES1000mN1948000E4946000	136
CRS3035RES1000mN1959000E4951000	122
CRS3035RES1000mN1958000E4958000	113
CRS3035RES1000mN1949000E4946000	109
CRS3035RES1000mN1959000E4956000	108
CRS3035RES1000mN1967000E4954000	108
CRS3035RES1000mN1968000E4955000	97
CRS3035RES1000mN1960000E4958000	95
CRS3035RES1000mN1961000E4951000	63
CRS3035RES1000mN1956000E4949000	61
CRS3035RES1000mN1970000E4953000	61
CRS3035RES1000mN1952000E4947000	59
CRS3035RES1000mN1952000E4956000	59
CRS3035RES1000mN1967000E4951000	56
CRS3035RES1000mN1966000E4954000	54
CRS3035RES1000mN1955000E4956000	53
CRS3035RES1000mN1962000E4958000	50
CRS3035RES1000mN1950000E4946000	47
CRS3035RES1000mN1944000E4957000	45

Continued on next page

(Continued)

CRS3035RES1000mN1966000E4952000	42
CRS3035RES1000mN1958000E4950000	39
CRS3035RES1000mN1946000E4956000	36
CRS3035RES1000mN1954000E4955000	35
CRS3035RES1000mN1966000E4955000	34
CRS3035RES1000mN1948000E4950000	33
CRS3035RES1000mN1954000E4949000	33
CRS3035RES1000mN1956000E4950000	29
CRS3035RES1000mN1948000E4949000	28
CRS3035RES1000mN1952000E4948000	28
CRS3035RES1000mN1964000E4947000	26
CRS3035RES1000mN1950000E4955000	25
CRS3035RES1000mN1956000E4957000	25
CRS3035RES1000mN1946000E4950000	23
CRS3035RES1000mN1951000E4956000	23
CRS3035RES1000mN1950000E4954000	19
CRS3035RES1000mN1960000E4952000	19
CRS3035RES1000mN1953000E4956000	17
CRS3035RES1000mN1969000E4954000	17
CRS3035RES1000mN1954000E4947000	16
CRS3035RES1000mN1954000E4954000	16
CRS3035RES1000mN1947000E4958000	15
CRS3035RES1000mN1950000E4951000	15
CRS3035RES1000mN1969000E4951000	15
CRS3035RES1000mN1951000E4955000	14
CRS3035RES1000mN1958000E4959000	13
CRS3035RES1000mN1962000E4950000	13
CRS3035RES1000mN1946000E4952000	12
CRS3035RES1000mN1963000E4958000	11
CRS3035RES1000mN1951000E4953000	10
CRS3035RES1000mN1960000E4957000	10

Continued on next page

(Continued)

CRS3035RES1000mN1966000E4953000	10
CRS3035RES1000mN1967000E4955000	9
CRS3035RES1000mN1946000E4955000	8
CRS3035RES1000mN1946000E4953000	7
CRS3035RES1000mN1965000E4955000	7
CRS3035RES1000mN1947000E4953000	6
CRS3035RES1000mN1959000E4947000	6
CRS3035RES1000mN1961000E4958000	6
CRS3035RES1000mN1949000E4950000	4
CRS3035RES1000mN1953000E4952000	4
CRS3035RES1000mN1965000E4952000	4
CRS3035RES1000mN1945000E4957000	3
CRS3035RES1000mN1952000E4946000	3
CRS3035RES1000mN1963000E4947000	3
CRS3035RES1000mN1955000E4951000	2
CRS3035RES1000mN1956000E4956000	2
CRS3035RES1000mN1965000E4948000	2
CRS3035RES1000mN1946000E4957000	1
CRS3035RES1000mN1952000E4958000	1
CRS3035RES1000mN1955000E4958000	1
CRS3035RES1000mN1959000E4952000	1
CRS3035RES1000mN1965000E4949000	1

Appendix C

Mitigations to reduce the iGRC

Table C.1	SORA 2.0, Mitigation M1 - Level of Integrity
Table C.2	SORA 2.0, Mitigation M1 - Level of Assurance
Table C.3	SORA 2.0, Mitigation M3 - Level of Integrity
Table C.4	SORA 2.0, Mitigation M3 - Level of Assurance
Table C.5	SORA 2.5, Mitigation M1(A) - Level of Integrity
Table C.6	SORA 2.5, Mitigation M1(A) - Level of Assurance
Table C.7	SORA 2.5, Containment - Level of Integrity
Table C.8	SORA 2.5, Containment - Level of Assurance

Table C.1: SORA 2.0, Mitigation M1 - Level of Integrity, (Source: JARUS. Doc.JAR-DEL-WG6-D.04_B Annex B, "JARUS guidelines on SORA - Annex B - Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class",Version 2.0, 2019, [103])

Mitigations used to modify the iGRC		**Level of Robustness**	**Criteria in SORA**	**Provisions for the proposed Scenario**
M1 - Strategic Mitigations for Ground Risk	Level of Integrity	Medium	M1 mitigations are “strategic mitigations” intended to reduce the number of people at risk on the ground. To assess integrity levels of M1 mitigations the following needs to be considered: • Definition of the ground risk buffer and resulting ground footprint, • Evaluation of people at risk. Criterion #1 (Definition of the ground risk buffer) Ground risk buffer takes into consideration: • Improbable single malfunctions or failures (including the projection of high energy parts such as rotors and propellers) which would lead to an operation outside of the operational volume, • Meteorological conditions (e.g. wind), • UAS latencies (e.g. latencies that affect the timely maneuverability of the UA), • UA behavior when activating a technical containment measure, • UA performance. For the purpose of this assessment, the term “improbable” should be interpreted in a qualitative way as, “Unlikely to occur in each UAS during its total life but which may occur several times when considering the total operational life of a number of UAS of this type”.	The ground risk buffer is established to protect third parties on the ground outside the operational volume. To determine this area all provisions requested by SORA have been taken into account. - The presence of the Flight Termination System avoids the presence of any single point of failure that could lead to an operation outside the flight volume; - Contingency and Emergency procedures are defined to end the flight in case of a loss of control; - UA performances, latencies and behavior are taken into consideration; - Flight Operations are conducted in accordance with the weather limitations.
			Criterion #2 (Evaluation of people at risk) The applicant makes use of authoritative density data (e.g. data from UTM data service provider) relevant for the proposed area and time of operation to substantiate a lower density of people at risk. AND/OR If the applicant claims a reduction, due to a sheltered operational environment, the applicant: • uses a drone below 25 kg and not flying above 174 knots, • demonstrates that although the operation is conducted in a populated environment, it is reasonable to consider that most of the non-active participants will be located within a building.	Population density in the areas of interest was assessed through data provided by ISTAT. For the corridor, the area was classified as sparsely populated with a maximum density value of 24 inhabitants per square kilometer. This value correspond to a rural area. Indeed, most of the soil overflown is dedicated to agricultural activities, mostly uninhabited. While, cells with higher value of population density are located in small suburban residential centers. In order to reduce people at risk, the flight path was planned to avoid as much as possible urban settlements. In addition flight activities are allowed during the period October-May only and in time of day when people are mostly located inside the buildings or are at work away from the residential area. Streets and highway are crossed with orthogonal trajectory to reduce the overflight time, and avoiding traffic rush hours (8:00-9:00 and 17:00-18:00). In addition, before conducting flight operations, the operator consults local authorities to ensure that no public events, which could lead to gatherings of people in the interested area, are planned. The Operation Area is entirely located on the sea. SORA process does not provide guidelines to assess population density in sea area, so the value of 1 inhabitant per square kilometer was taken as reference. However, this value is very low, and a GRC of 5 in this area appears to be too high for the type of area overflown. Indeed, this area is dedicated to military activities, so although not physically delimited, warning systems are provided to alert boats that may be in this area at the time of operations. An additional action that can be planned to reduce people at risk is to plan the path of operations to avoid the busiest shipping routes as much as possible.

Table C.2: SORA 2.0, Mitigation M1 - Level of Assurance, (Source: JARUS. Doc.JAR-DEL-WG6-D.04_B Annex B, "JARUS guidelines on SORA - Annex B - Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class",Version 2.0, 2019, [103])

Mitigations used to modify the iGRC		Level of Robustness	Criteria in SORA	Provisions for the proposed Scenario
M1 - Strategic Mitigations for Ground Risk	Level of Assurance	Medium	Criterion #1 (Definition of the ground risk buffer) The applicant has supporting evidence to claim the required level of integrity has been achieved. This is typically done by means of testing, analysis, simulation, inspection, design review or through operational experience. When simulation is used, the validity of the targeted environment used in the simulation needs to be justified.	All supporting evidences to claim the required level of integrity are reported in Organization Documents (such as Flight Manual, Safety Justification, Test reports, etc.) compiled in compliance with DOA/POA provisions.
			Criterion #2 (Evaluation of people at risk) The density data used for the claim of risk reduction is an average density map for the date/time of the operation from a static sourcing (e.g. census data for night time ops). In addition, for localized operations (e.g. intra-city delivery or infrastructure inspection) the applicant submits the proposed route/area of operation to the applicable authority (e.g. city police, office of civil protection, infrastructure owner etc.) to verify the claim of reduced number of people at risk.	The population density was calculated by Istatviewer provided by Istat. In addition, the operator sumbits proposed route/area of operation to the local applicable authorities before flights operations.

Table C.3: SORA 2.0, Mitigation M3 - Level of Integrity, (Source: JARUS. Doc.JAR-DEL-WG6-D.04_B Annex B, "JARUS guidelines on SORA - Annex B - Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class",Version 2.0, 2019, [103])

Mitigations used to modify the iGRC		**Level of Robustness**	**Criteria in SORA**	**Provisions for the proposed Scenario**
M3 - An Emergency Response Plan (ERP) is in place, operator validated and effective	Level of Integrity	Medium	An Emergency Response Plan (ERP) shall be defined by the applicant to cope with cases of loss of control of the operation. These are emergency situations where the operation could result in an unrecoverable state. These are cases in which: • the outcome of the situation highly relies on providence; or • could not be handled by a contingency procedure; or • when there is grave and imminent danger of fatalities The ERP proposed by an applicant is different from the emergency procedures. The ERP is expected to cover: • a plan to limit the escalating effect of an eminent crash (e.g. notify first responders), and • the conditions to alert ATM The ERP shall: • be suitable for the situation; • limit the escalating effects; • define criteria to identify an emergency situation; • be practical to use; • clearly delineate Remote Crew member(s) duties.	An Emergency Response Plan is available. The ERP clearly identifies an emergency situation and defines and governs the responsibilities and actions of the various subjects involved in the organization of assistance and relief during the occurrence of a crisis state (Alarm, Emergency, Accident). All Entities, Services and the Operator, involved in the Emergency Plan, are responsible, for the parts of competence, for the correct application of the provisions, according to their own procedures

Table C.4: SORA 2.0, Mitigation M3 - Level of Assurance, (Source: JARUS. Doc.JAR-DEL-WG6-D.04_B Annex B, "JARUS guidelines on SORA - Annex B - Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class",Version 2.0, 2019, [103])

Mitigations used to modify the iGRC		Level of Robustness	Criteria in SORA	Provisions for the proposed Scenario
M3 - An Emergency Response Plan (ERP) is in place, operator validated and effective	Level of Assurance	Medium	Criterion #1 (Procedures) • The ERP shall be developed to standards considered adequate by the competent authority and/or in accordance with means of compliance acceptable to that authority. • The ERP shall be validated through a representative tabletop exercise consistent with the ERP training syllabus. 1 National Aviation Authorities may define the standards and/or the means of compliance they consider adequate. The SORA Annex E [63] will be updated at a later point in time with a list of adequate standards based on the feedback provided by the NAAs. 2 The tabletop exercise may or may not involve all third parties identified in the ERP. environment used in the simulation needs to be justified.	The ERP is developed following the standard procedures used by the Organization in the event of serious incidents or accidents. All supporting evidences to claim the required level of integrity are reported in Organization Documents.
			Criterion #2 (Training) • Training syllabus shall be available • Competency-based theoretical and practical training shall be organized by the operator.	The entire remote crew (i.e. any person involved in the operation) and emergency personnel are provided with competency -based theoretical and practical training specific to their duties. A Training syllabus is available.

Table C.5: SORA 2.5, M1(A) - Level of Integrity, (Source: JARUS. "JARUS guidelines on SORA, Annex B, Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, 2022, [112])

Mitigations used to modify the iGRC		Level of Robustness	Criteria in SORA	Provisions for the proposed Scenario
M1 Strategic Mitigations for Ground Risk	Level of Integrity	Medium	M1 mitigations are "strategic mitigations" intended to reduce the number of people at risk on the ground. To assess integrity levels of M1 mitigations the following needs to be considered: • Definition of the ground risk buffer and resulting ground footprint, • Evaluation of people at risk. Criterion#1 (Evaluation of people at risk) The applicant evaluates the area of operations by means of appraisals/on-site inspections to justify lowering the density of population at risk (e.g. residential area during daytime when some people may not be present or an industrial area at night time for the same reason). Increased accuracy static population density maps should not be used as a mitigation, but as the baseline in Step #2. AND/OR If the applicant claims a reduction, due to a sheltered operational environment, the applicant: • uses a drone that is not expected to penetrate structures under which people are sheltered, • it is reasonable to consider that most of the non-active participants will be located under a structure. Low robustness for sheltering is achieved for operators of most small UAS by citing a study, while avoiding flights next to large gatherings of people 20,000 ppl or more. AND/OR The applicant makes use of dynamic density data (e.g. data from UTM supplemental data service provider) relevant for the proposed area and restricts time of operation to substantiate a lower density of population at risk. This can incorporate real time or historical data or dasymetric mapping techniques that are not part of standard maps used for Step\#2.	Population density in the areas of interest was assessed through data provided by ISTAT. For the corridor, the area was classified as sparsely populated with a maximum density value of 24 inhabitants per square kilometer. This value corresponds to a rural area. Indeed, most of the soil overflown is dedicated to agricultural activities, mostly uninhabited. While, cells with higher value of population density are located in small suburban residential centers. In order to reduce people at risk, the flight path was planned to avoid as much as possible urban settlements. In addition flight activities are allowed during the period October-May only and in time of day when people are mostly located inside the buildings or are at work away from the residential area. Streets and highway are crossed with orthogonal trajectory to reduce the overflight time, and avoiding traffic rush hours (8:00-9:00 and 17:00-18:00). In addition, before conducting flight operations, the operator consults local authorities to ensure that no public events, which could lead to gatherings of people in the interested area, are planned. The Operation Area is entirely located on the sea. SORA process does not provide guidelines to assess population density in sea area, so the value of 1 inhabitant per square kilometer was taken as reference. However, this value is very low, and a GRC of 5 in this area appears to be too high for the type of area overflown. Indeed, this area is dedicated to military activities, so although not physically delimited, warning systems are provided to alert boats that may be in this area at the time of operations. An additional action that can be planned to reduce people at risk is to plan the path of operations to avoid the busiest shipping routes as much as possible.
			Criterion#2 (Impact on at risk population) The at-risk population is lowered by at least 1 iGRC population bands (90%) using one or more methods described in the Level of Integrity for Criterion#1 above.	The operational volume is mostly used for agricultural activities with small inhabited areas. The population density both in the corridor and on the operation area is very low and classifiable as rural. By applying the methods outlined in Criterion 1, a significant reduction in people at- risk can be achieved.

Table C.6: SORA 2.5, M1(A) - Level of Assurance, (Source: JARUS. "JARUS guidelines on SORA, Annex B, Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, 2022, [112])

Mitigations used to modify the iGRC		Level of Robustness	Criteria in SORA	Provisions for the proposed Scenario
M1-Strategic Mitigations for Ground Risk	Level of Assurance	Medium	Criterion #1 (Evaluation of people at risk) All mapping products, data sources and processes used to claim lowering the density of population at risk are accepted/approved by the competent authority.	The population density was calculated by Istatviewer provided by Istat. In addition, the operator submits proposed route/area of operation to the local applicable authorities before flights operations.
			Criterion #2 (Impact on at risk population) The applicant has supporting evidence that the required level of integrity is achieved. This is typically done by means of testing, analysis, simulation, inspection, design review or through operational experience.	All supporting evidences to claim the required level of integrity are reported in Organization Documents (such as Flight Manual, Safety Justification, Test reports, etc.) compiled in compliance with DOA/POA provisions.

Table C.7: SORA 2.5, Containment - Level of Integrity, (Source: JARUS. "JARUS guidelines on SORA, Annex B, Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, 2022, [112])

Containment	Level of Integrity	
	Low	Provisions for the Proposed Scenario
Criterion #1- Operational Volume Containment	(Qualitative) No probable failure of the UAS or any external system supporting the operation shall lead to operation outside of the operation volume OR (Quantitative) The probability of the failure condition "UA leaving the operational volume" considering all failure modes of interest shall be less than 10-3/Flight Hour (FH).	It is demonstrate that • No probable failure of the UAS or any external system supporting the operation shall lead to operation outside of the operational volume; • It can be reasonably expected that a fatality will not occur from any probable failure of the UAS, or any external system supporting the operation; • The probability of leaving the operational volume is less than 10-4/FH; • No single failure of the UAS or any external system supporting the operation leads to operation outside of the ground risk buffer.
Criterion #2- End of Flight upon exit of the operational volume	When the UA leaves the operational volume, an immediate end of the flight must be initiated through a combination of procedures/processes alongside technical means.	When the UA leaves the operational volume the independent Flight Termination System has to be activated to immediately end the flight.
Criterion #3- Definition of the GRC buffer	The Ground Risk Buffer must at least adhere to the 1:1 principle. A smaller ground risk buffer value may be proven by the applicant for a rotary wing UA using a ballistic methodology approach acceptable to the competent authority	The Ground Risk Buffer has be determined following the 1:1 principle.
Criterion #4- GRC buffet containment	N/A	/

Table C.8: SORA 2.5, Containment - Level of Assurance, (Source: JARUS. "JARUS guidelines on SORA, Annex B, Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, 2022, [112])

Containment	Level of Assurance	
	Low	Provisions for the Proposed Scenario
For all criteria	The applicant declares that the required level of integrity has been achieved. In addition: For criterion #1, compliance is to be substantiated by a design and installation appraisal and includes as a minimum: design and installation features (independence, separation and redundancy); any relevant particular risk (e.g. hail, ice, snow, electro-magnetic interference. . .) associated with the operation. For criterion #2, the adequacy of Emergency Procedures to terminate flights are tested.	The applicant declare that the required level of integrity has been achieved. In addition, all supportingevidences to claim the required level of integrity are reported in Organization Documents. For criterion #1: to demonstrate the compliance with criterion \#1 requirement a Safety Assessment Process has been carried out, all the evidence are provided in the Safety Report. For criterion #2: all emergency procedures are val- idated and tested. All procedures follows the standard set by the Organization. In addition, the entire remote crew (i.e. any person involved in the operation) and emergency personnel are provided with competency-based theoretical and practical training specific to their duties. A Training syllabus is available.

Bibliography

[1] General Atomics Aeronautical. Mojave. https://www.ga-asi.com/remotely-piloted-aircraft/mojave, Consulted in July 2023.

[2] General Atomics Aeronautical. MQ-9A "Reaper". https://www.ga-asi.com/remotely-piloted-aircraft/mq-9a, Consulted in July 2023.

[3] General Atomics Aeronautical. Predator C Avenger. https://www.ga-asi.com/remotely-piloted-aircraft/predator-c-avenger, Consulted in July 2023 2023.

[4] AeroVironment. Raven RQ-11. https://www.avinc.com/images/uploads/product_docs/Raven_Datasheet_v1.1.pdf, Consulted in July 2023.

[5] Amazon. Amazon Prime Air – Petition for Exemption Under 49 U.S.C. 44807 and 14 C.F.R. Parts 61, 91, and 135. https://www.aviationtoday.com/wp-content/uploads/2019/08/amazon_-_exemption_rulemaking.pdf, 2019.

[6] Maziar Arjomandi, Shane Agostino, Matthew Mammone, Matthieu Nelson, and Tong Zhou. "Classification of unmanned aerial vehicles". *Report for Mechanical Engineering class, University of Adelaide, Adelaide, Australia*, pages 1–48, 2007.

[7] Avia.Pro. Sagem Sperwer LE. Specifiche tecniche. https://avia-pro.it/blog/sagem-sperwer-le-tehnicheskie-harakteristiki-foto, 2017, Consulted in July 2023.

[8] Dassault Aviation. nEUROn. https://www.dassault-aviation.com/en/defense/neuron/introduction/, Consulted in July 2023.

[9] Richard K. Barnhart. "INTRODUCTION TO UNMANNED AIRCRAFT SYSTEMS". https://ftp.idu.ac.id/wp-content/uploads/ebook/tdg/MILITARY%20PLATFORM%20DESIGN/Unmanned%20Aircraft%20Systems.pdf, 2012.

[10] Ronfl Nadaud Catherine Black George Thomas, Cohen Kelly. "Integration in the national airspace (europe and USA)–UAV classification and associated missions, regulation and safety, certification and air traffic management". In *Multi-Rotor Platform-Based UAV Systems*, pages 1–25. Elsevier, 2020.

[11] EASA Management Board. Decision 01-2012, "DECISION OF THE MANAGEMENT BOARD1 AMENDING AND REPLACING DECISION 08-2007 CONCERNING THE PROCEDURE TO BE APPLIED BY THE AGENCY FOR THE ISSUING OF OPINIONS, CERTIFICATION SPECIFICATIONS AND GUIDANCE MATERIAL ('RULEMAKING PROCEDURE')". https://www.easa.europa.eu/sites/default/files/dfu/MB%20Decision%2008-2007%20amending%20rulemaking%20procedure.pdf, 2012.

[12] Boeing. MQ-28 Ghost Bat. https://www.boeing.com.au/products-services/Defense-Space-Security/ghost-bat.page, Consulted in July 2023.

[13] CAA. RIGA DECLARATION ON REMOTELY PILOTED AIRCRAFT (drones) "FRAMING THE FUTURE OF AVIATION" . https://eu2015.lv/images/news/2016_03_06_RPAS_Riga_Declaration.pdf, 2016.

[14] Joint Air Power Competence Centre. "A Comprehensive Approach to Countering Unmanned Aircraft Systems". https://www.japcc.org/books/a-comprehensive-approach-to-countering-unmanned-aircraft-systems/, 2020.

[15] Langstaff Meredith Roller Melanie Cohn Pamela, Green Alastair. "Commercial drones are here: The future of unmanned aerial systems", McKinsey & Company. https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/commercial-drones-are-here-the-future-of-unmanned-aerial-systems, 2017, Consulted in July 2023.

[16] European Commission. COMMISSION DELEGATED REGULATION (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0945, 2019.

[17] European Commission. COMMISSION IMPLEMENTING REGULATION (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0947, 2019.

[18] European Commission. COMMISSION IMPLEMENTING REGULATION (EU) 2020/746 of 4 June 2020 amending Implementing Regulation (EU) 2019/947 as regards postponing dates of application of certain measures in the context of the COVID-19 pandemic. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0746, 2020.

[19] European Commission. COMMISSION IMPLEMENTING REGULATION (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R0664, 2021.

[20] European Commission. Commission Regulation (EU) No 748/2012 of 3 August 2012 laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations. https://eur-lex.europa.eu/eli/reg/2012/748/oj/eng, 2012.

[21] European Commission. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, "A Drone Strategy 2.0 for a Smart and Sustainable Unmanned Aircraft Eco-System in Europe", SWD(2022) 366 final. https://transport.ec.europa.eu/system/files/2022-11/COM_2022_652_drone_strategy_2.0.pdf, 2022.

[22] Commission of the European Communities. COMMISSION REGULATION (EC) No 2042/2003 of 20 November 2003 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks . https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003R2042, 2003.

[23] Regio Decreto. N.327,R.D. 30 marzo 1942, "Codice della Navigazione", https://www.gazzettaufficiale.it/dettaglio/codici/navigazione , 1942,Testo aggiornato al 18 maggio 2018.

[24] Direzione degli Armamenti Aeronautici. AER(EP).P-2, "Omologazione, Certificazione e Qualificazione di Tipo Militare, Idoneità alla Installazione". https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/Biblioteca/5Categoria/Pagine/Home.aspx, 2012.

[25] Direzione degli Armamenti Aeronautici. AER(EP).P-6, "Istruzioni per la compilazione dei capitolati tecnici per aeromobili militari". https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/Biblioteca/5Categoria/Pagine/Home.aspx, 2010.

[26] Direzione degli Armamenti Aeronautici. AER(EP).P-7, "Norma per l'iscrizione e la tenuta del registro degli aeromobili militari (R.A.M)". https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/Biblioteca/5Categoria/Pagine/Home.aspx, 2016.

[27] Direzione degli Armamenti Aeronautici. AER(EP).P-7, "Regulation for Recording and Maintaining the Military Aicraft Register (Registro degli Aeromobili Militari - R.A.M)". https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/Biblioteca/5Categoria/Documents/AER_P_7EN_Ed_13072018.pdf, 2012.

[28] Decreto del Presidente della Repubblica. "D.P.R 15 marzo 2010, Testo unico delle disposizioni regolamentari in materia di ordinamento militare, a norma dell'articolo 14 della legge 28 novembre 2005, n. 246". https://www.difesa.it/AID/Documents/DPR_15_marzo_2010_n_90_Testo_unico_disposizioni_regolamentari_materia_ordinamento_militare.pdf, 2010.

[29] Ministero della Difesa. Aeronavigabilità. https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/NormeTecniche/Pagine/default_.aspx, Consulted in 2023.

[30] Ministero della Difesa. Certificazione e Qualificazione. https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/NormeTecniche/Omologazione/Pagine/default.aspx, Consulted in September 2023.

[31] Ministero della Difesa Italiana. Direzione degli armamenti aeronautici e per l'aeronavigabilità (armaereo). https://www.difesa.it/SGD-DNA/Staff/DT/ARMAEREO/Pagine/default.aspx, Consulted in October 2023.

[32] Ministero della Difesa Italiana. GU n.72 26/03/13 "Decreto 16 gennaio 2013, Struttura del Segretariato generale, delle Direzioni generali e degli Uffici centrali del Ministero della difesa, in attuazione dell'articolo 113, comma 4 del decreto del Presidente della Repubblica 15 marzo 2010, n. 90, recante il testo unico delle disposizioni regolamentari in materia di ordinamento militare". https://www.gazzettaufficiale.it/eli/id/2013/03/26/13A02532/sg, 2013.

[33] Governo della Repubblica Italiana. Decreto Legislativo 25 luglio 1997 n.250 Istituzione dell'Ente nazionale per l'aviazione civile (E.N.A.C). https://www.enac.gov.it/repository/ContentManagement/information/N368160543/Decreto_legislativo_250-97_2011.pdf, 1997.

[34] J. Dittrich. JARUS WG SRM Update EASA GRC Workshop. https://www.easa.europa.eu/en/newsroom-and-events/events/workshop-population-density-services-uas-operations, 2023.

[35] DJI. DJI Mavic 3. https://www.dji.com/it/mavic-3, consulted in Novermber 2023.

[36] DJI. DJI Mini III. https://www.dji.com/it/mini-3, Consulted in July 2023.

[37] DJI. Inspire 1 - DJI . https://www.dji.com/it/inspire-1, Consulted in July 2023.

[38] DJI. Inspire 3 - DJI. https://www.dji.com/it/inspire-3, Consulted in July 2023.

[39] EASA. A-NPA 16/2005, "Policy for Unmanned Aerial Vehicle (UAV) certification". https://www.easa.europa.eu/en/document-library/notices-of-proposed-amendment/npa-16-2005, 2005.

[40] EASA. A-NPA 2015-10, "Introduction of a regulatory framework for the operation of drones". https://www.easa.europa.eu/en/document-library/notices-of-proposed-amendment/npa-2015-10, 2015.

[41] EASA. Advisory Bodies. https://www.easa.europa.eu/en/the-agency/advisory-bodies, Consulted in August 2023.

[42] EASA. AMC and GM to Implementing Regulation (EU) 2021/664 — Issue 1. https://www.easa.europa.eu/en/document-library/acceptable-means-of-compliance-and-guidance-materials/amc-and-gm-implementing, 2022.

[43] EASA. AMC and GM to Regulation (EU) 2019/947. https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulations-eu, 2019.

[44] EASA. Concept of Operations for Drones A risk based approach to regulation of unmanned aircraft. https://www.easa.europa.eu/en/document-library/general-publications/concept-operations-drones, 2015.

[45] EASA. Doc. MOC Light-UAS.2510-01, "Means of Compliance with Light-UAS.2510". https://www.easa.europa.eu/en/document-library/product-certification-consultations/means-compliance-light-uas2510, 2023.

[46] EASA. "Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and 2019/945)". https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulations-eu, 2022.

[47] EASA. Faq n.19117, what is the status of ir, amc,cs, altmoc, fm, sc and faq? https://www.easa.europa.eu/en/faq/19117, Consulted in August 2023.

[48] EASA. Guidelines on Design Verification of UAS operating the 'specific' category and classified in SAIL III and IV . https://www.easa.europa.eu/en/guidelines-design-verification-uas-operated-specific-category, 2021.

[49] EASA. NPA 05/2017 (A) and (B)-4. https://www.easa.europa.eu/en/document-library/notices-of-proposed-amendment/npa-2017-05, 2017.

[50] EASA. NPA 2021-09 Regular update of the AMC and GM to Regulation (EU) 2019/947 on the rules and procedures for the operation of unmanned aircraft. https://www.easa.europa.eu/en/document-library/notices-of-proposed-amendment/npa-2021-09, 2021.

[51] EASA. NPA 2021-14 Development of acceptable means of compliance and guidance material to support the U-space regulation. https://www.easa.europa.eu/en/document-library/notices-of-proposed-amendment/npa-2021-14, 2021.

[52] EASA. NPA 2022-06 Introduction of a regulatory framework for the operation of drones — Enabling innovative air mobility with manned VTOL-capable aircraft, the IAW of UAS subject to certification, and the CAW of those UAS operated in the 'specific' category. https://www.easa.europa.eu/en/document-library/notices-of-proposed-amendment/npa-2022-06, 2022.

[53] EASA. Opinion 01/2020 High-level regulatory framework for the U-space. https://www.easa.europa.eu/en/document-library/opinions/opinion-012020, 2020.

[54] EASA. Opinion 05/2019. https://www.easa.europa.eu/en/document-library/opinions/opinion-052019, 2019.

[55] EASA. Opinion No. 01/2018-6. https://www.easa.europa.eu/en/document-library/opinions/opinion-012018, 2018.

[56] EASA. Policy Statement Airworthiness Certification of Unmanned Aircraft Systems (UAS) E.Y013-01. https://www.easa.europa.eu/sites/default/files/dfu/E.Y013-01_%20UAS_%20Policy.pdf, 2009.

[57] EASA. "Proposed Guidelines for the calculation of the critical area of Unmanned Aircraft". https://www.easa.europa.eu/en/document-library/product-certification-consultations/proposed-guidelines-calculation-critical-area, 2023.

[58] EASA. SORA Workshop: from version 2.0 to 2.5 "SORA". https://www.easa.europa.eu/en/newsroom-and-events/events/sora-workshop-version-20-25, February 2023.

[59] EASA. Special Condition for Light Unmanned Aircraft Systems – High Risk. https://www.easa.europa.eu/en/document-library/product-certification-consultations/special-condition-light-uas, 2021.

[60] EASA. Special Condition for Light Unmanned Aircraft Systems – Medium Risk. https://www.easa.europa.eu/en/document-library/product-certification-consultations/special-condition-light-uas, 2020.

[61] EASA. Terms of reference for rulemaking task RMT.0230 - Issue 4, "Introduction of a regulatory framework for the operation of unmanned aircraft systems and for urban air mobility in the European Union aviation system". https://www.easa.europa.eu/en/document-library/terms-of-reference-and-rulemaking-group-compositions/tor-rmt0230, 2022.

[62] EASA. Terms of reference for rulemaking task RMT.0230 Issue 1, "Introduction of a regulatory framework for the operation of unmanned aircraft systems and for urban air mobility in the European Union aviation system". https://www.easa.europa.eu/en/document-library/terms-of-reference-and-rulemaking-group-compositions/tor-rmt0230, 2015, Consulted in August 2023.

[63] EASA. The Agency. https://www.easa.europa.eu/en/the-agency/the-agency, Consulted in August 2023.

[64] EASA. "UAS Safety Risk Portfolio and Analysis", Safety Intelligence and Performance SM1.1. https://www.easa.europa.eu/en/document-library/general-publications/uas-safety-risk-portfolio-and-analysis, 2016.

[65] EASA. Urban Air Mobility. https://www.easa.europa.eu/en/light/topics/urban-air-mobility-uam, Consulted in August 2023.

[66] ENAC. Doc. 2017/001-NAV, "GROUND RISK ANALYSIS FOR RPAS OPERATIONS", Ed.2. https://www.enac.gov.it/la-normativa/normativa-enac/linee-guida/lg-2017001-nav, 2020.

[67] ENAC. Home, Mission. https://www.enac.gov.it/mission, ,consulted in July 2023.

[68] ENAC. Normativa ENAC. https://www.enac.gov.it/la-normativa/normativa-enac, Consulted in August 2023.

[69] ENAC. Regolamenti ENAC. https://www.enac.gov.it/la-normativa/normativa-enac/regolamenti, Consulted in August 2023.

[70] ENAC. SPL-10 NOTAM, "NOTAM: Istruzioni per l'uso". https://www.enac.gov.it/sicurezza-aerea/flight-safety/safety-promotion/safety-promotion-leaflet/spl-10-notam-istruzioni-per-luso, 2021.

[71] E.Piccione. SAFETY JUSTIFICATION AWHERO. Technical Report, Leonardo Helicopter Division, 2017.

[72] E.Piccione. AWHERO RPAS SPECIFIC OPERATION AND RISK ASSESSMENT (SORA). Technical report, Leonardo Helicopter Division, 2021.

[73] EUROCAE. "Governing Bodies". https://www.eurocae.net/about-us/governing-bodies/, Consulted in November 2023.

[74] EUROCAE. "Our history". https://www.eurocae.net/about-us/our-history/, Consulted in November 2023.

[75] EUROCAE. "Working Groups". https://www.eurocae.net/about-us/working-groups/, Consulted in November 2023.

[76] Trasporto Europa. "DHL abbandona il drone per consegne Parcelcopter". https://www.trasportoeuropa.it/notizie/aereo/dhl-abbandona-il-drone-per-consegne-parcelcopter/, 2021, Consulted in July 2023.

[77] Council of the European Union European Council. The ordinary legislative procedure. https://www.consilium.europa.eu/en/council-eu/decision-making/ordinary-legislative-procedure/, 2023.

[78] Fung Arthur European Parliament, Carippo Fabrizio. RESEARCH FOR TRAN COMMITTEE, "Unmanned Aircraft Systems integration into European airspace and operation over populated areas", Final Report. https://www.europarl.europa.eu/RegData/etudes/STUD/2023/733124/IPOL_STU(2023)733124_EN.pdf, May 2023.

[79] FAA. FAA AC 431.35-1, "EXPECTED CASUALTY CALCULATIONS FOR COMMERCIAL SPACE LAUNCH AND REENTRY MISSIONS". https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/Ac4311fn.pdf, 2002.

[80] Air Force. RQ-170 Sentinel. https://www.af.mil/About-Us/Fact-Sheets/Display/Article/2796993/rq-170-sentinel/, Consulted in July 2023.

[81] Northrop Grumman. Fire Scout. https://www.northropgrumman.com/what-we-do/air/fire-scout, Consulted in July 2023.

[82] Northrop Grumman. Global hawk. https://www.northropgrumman.com/what-we-do/air/global-hawk, 2023.

[83] Leonardo Helicopters. AWHero. https://unmanned.leonardo.com/it/products/awhero, Consulted in July 2023.

[84] Leonardo Helicopters. Falco Xplorer. https://unmanned.leonardo.com/it/products/falco-xplorer, Consulted in July 2023.

[85] IAI. Heron. https://www.iai.co.il/p/heron-tp, Consulted in July 2023.

[86] ICAO. "About ICAO", ICAO. https://www.icao.int/about-icao/Pages/default.aspx, Consulted in July 2023.

[87] ICAO. APPENDIX SARPs “NOTIFICATION OF DIFFERENCES” PROCEDURES AND PANS STATUS. https://www.icao.int/Meetings/AMC/MA/Eleventh%20Air%20Navigation%20Conference%20(ANConf11)/anconf11_wp142_app_en.pdf, number = AN-Conf/11-WP/142, Consulted in August 2023.

[88] ICAO. Cir 328 AN/190, "Unmanned Aircraft Systems (UAS)". https://www.icao.int/meetings/uas/documents/circular%20328_en.pdf, 2011.

[89] ICAO. "Convention on International Civil Aviation", Aerostandart. https://standart.aero/en/icao/book/doc-7300-convention-on-international-civil-aviation-ed-9-en-8774, Doc 7300. Edition 9 2006.

[90] ICAO. Doc. 7030 5th Edition, "EUR Regional Supplementary Procedures (SUPPS)". https://www.icao.int/EURNAT/Other%20Meetings%20Seminars%20and%20Workshops/PBN%20TF/PBN%20TF2/PBN%20TF2%20WP04%20-draft%20Doc7030-5%20EUR.pdf, 2008.

[91] ICAO. Doc 9854, "Global Air Traffic Management Operational Concept". https://www.icao.int/Meetings/anconf12/Document%20Archive/9854_cons_en%5B1%5D.pdf, 2005.

[92] ICAO. ICAO Council. https://www.icao.int/about-icao/Council/Pages/council.aspx, Consulted in July 2023.

[93] ICAO. ICAO Secretariat. https://www.icao.int/secretariat/Pages/default.aspx, Consulted in July 2023.

[94] ICAO. Riga Declaration on Remotely Piloted Aircraft (drones) "FRAMING THE FUTURE OF AVIATION". https://eu2015.lv/images/news/2016_03_06_RPAS_Riga_Declaration.pdf, 2015.

[95] ICAO. "Strategic Objectives ", ICAO. https://www.icao.int/about-icao/Council/Pages/Strategic-Objectives.aspx, consulted in July 2023.

[96] ICAO. "THE HISTORY OF ICAO AND CHICAGO CONVENTION", ICAO75. https://www4.icao.int/icao75/History/ICAOAndChicagoConvention#:~:text=The%20Convention%20on%20International%20Civil,and%20peoples%20of%20the%20world.%E2%80%9D, consulted in July 2023.

[97] ICAO. The ICAO Council. https://applications.icao.int/postalhistory/the_icao_council.htm, Consulted in August 2023.

[98] Eißfeldt Innerk and Biella Marcus. The public acceptance of drones–Challenges for advanced aerial mobility (AAM). *Transportation Research Procedia*, 66:80–88, 2022.

[99] Insitu. ScanEagle. https://www.insitu.com/products/scaneagle, Consulted in July 2023.

[100] JARUS. Doc. No. :SC-RPAS.1309-01 Issue 2,"SPECIAL CONDITION Equipment, systems, and installations". https://www.easa.europa.eu/sites/default/files/dfu/SC-RPAS.1309-01_Iss02.pdf, 2015.

[101] JARUS. Doc.JAR-DEL-WG6-D.04 "Specific Operation Risk Assessment (SORA)" Version 2.0, Main Body. http://jarus-rpas.org/publications/, 2019.

[102] JARUS. Doc.JAR-DEL-WG6-D.04_A Annex A, "JARUS guidelines on SORA - Annex A – Guidelines on collecting and presenting system and operation information for a specific UAS operation", Version 2.0. http://jarus-rpas.org/publications/, 2019.

[103] JARUS. Doc.JAR-DEL-WG6-D.04_B Annex B, "JARUS guidelines on SORA - Annex B - Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class", Version 2.0. http://jarus-rpas.org/publications/, 2019.

[104] JARUS. Doc.JAR-DEL-WG6-D.04_C Annex C, "JARUS guidelines on SORA - Annex C - Strategic Mitigation Collision Risk Assessment", Version 2.0. http://jarus-rpas.org/publications/, 2019.

[105] JARUS. Doc.JAR-DEL-WG6-D.04_D Annex D , "JARUS guidelines on SORA - Annex D - Tactical Mitigation Collision Risk Assessment", Version 2.0. http://jarus-rpas.org/publications/, 2019.

[106] JARUS. Doc.JAR-DEL-WG6-D.04_E Annex E, "JARUS guidelines on SORA - Annex E - Integrity and assurance levels for the Operation Safety Objectives (OSO)", Version 2.0. http://jarus-rpas.org/publications/, 2019.

[107] JARUS. Doc.JAR-DEL-WG6-D.04_I Annex I , "JARUS guidelines on SORA - Annex I - Glossary of Terms", Version 2.0. http://jarus-rpas.org/publications/, 2019.

[108] JARUS. JARUS ToR v8.1.2022, "Terms of Refenece". http://jarus-rpas.org/about-us/terms-of-reference/, 2022.

[109] JARUS. Publications. http://jarus-rpas.org/publications/, 2023.

[110] JARUS. SORA Workshop: from version 2.0 to 2.5 "Summary of changes SORA". https://www.easa.europa.eu/en/newsroom-and-events/events/sora-workshop-version-20-25, February 2023.

[111] JARUS. Doc. JAR-DEL-WG6-D.04 "JARUS SORA 2.5 Explanatory notes", Version 1.0. Draft, JARUS, 2022.

[112] JARUS. "JARUS guidelines on SORA, Annex B, Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, JARUS, 2022.

[113] JARUS. "JARUS guidelines on SORA, Annex E, Integrity and assurance levels for the Operational Safety Objectives (OSO)" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, JARUS, 2022.

[114] JARUS. "JARUS guidelines on SORA, Annex F, Theoretical Basis for Ground Risk Classification" Edition 0.3. Draft for external consultation JAR-DEL-WG6-D.04, JARUS, 2022.

[115] JARUS. "JARUS guidelines on SORA, Annex I, Glossary of Terms" Edition 2.5. Draft for external consultation JAR-DEL-WG6-D.04, JARUS, 2022.

[116] JARUS. "JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.5". Draft for external consultation JAR-DEL-WG6-D.04, JARUS, 2022.

[117] John E. Mayer. State of art of airworthiness certification. STO-MP-AVT-273, NATO, 2017.

[118] Hassanalian Mostafa and Abdelkefi Abdessattar. "Classifications, applications, and design challenges of drones: A review", Elsevier. https://www.sciencedirect.com/science/article/abs/pii/S0376042116301348, 2017.

[119] NATO. Allied Command Operations (ACO). https://www.nato.int/cps/en/natohq/topics_52091.htm, Consulted in Septemeber 2023.

[120] NATO. Allied Command Transformation (ACT). https://www.nato.int/cps/en/natohq/topics_52092.htm, Consulted in Septemeber 2023.

[121] NATO. NATO Standardization Office. https://www.nato.int/cps/en/natohq/topics_124879.htm, Consulted in October 2023.

[122] NATO. Standardization. https://www.nato.int/cps/en/natohq/topics_69269.htm, Consulted in October 2023.

[123] NATO. What is NATO? https://www.nato.int/nato-welcome/index.html, Consulted in Septemeber 2023.

[124] NATO. AEP-80,"Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements", Ed.B. NATO Standard, NATO, 2016.

[125] NATO. STANAG 4702, "Rotary Wing Unmanned Aircraft Systems Airwothiness Requirements", Ed.2. Standardization Agreement, NATO, 2016.

[126] NATO. AEP-4671, "Unmanned Aircraft Systems Airwothiness Requirements (USAR)", Ed.B Ver.1. NATO Standard, NATO, 2019.

[127] NATO. STANAG 4671, "Unmanned Aircraft Systems Airwothiness Requirements (USAR)" Ed.3. Standardization Agreement, NATO, 2019.

[128] NATO. AEP-83 "Light Unmanned Aircraft Systems Airworthiness Requirement", Ed.C Ver.1. NATO Standard, NATO, 2023.

[129] NATO. STANAG 4703, "Light Unmanned Aircraft Systems Airworthiness Requirements", Ed.3. Standardization Agreement, NATO, 2023.

[130] Office of Secretary of Defense. "Unmanned Aircraft Systems Roadmap 2005-2030". https://irp.fas.org/program/collect/uav_roadmap2005.pdf, 2005.

[131] European Parliament and the Counci. REGULATION (EU) 2018/1139 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency,. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1139, 2018.

[132] European Parliament and the Council. REGULATION (EC) No 1592/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 July 2002 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002R1592, 2002.

[133] Louisa Brooke-Holland UK Parliament. "Overview of military drones used by the UK Armed Forces". https://commonslibrary.parliament.uk/research-briefings/sn06493/#:~:text=The%20UK%20operates%20five%20different,Royal%20Navy%20operates%20Scan%20Eagle., September 2015.

[134] La Repubblica. "Droni in crescita il mercato italiano: nel 2022 vale 118 milioni (+20%)". https://finanza.repubblica.it/Pages/News/Item.aspx?ID=57_2023-02-21_TLB, 2023, Consulted in July 2023.

[135] RTCA. "POWERFUL PROGRESS, COMMON GROUND". https://www.rtca.org/about/, Consulted in November 2023.

[136] Therese Skrzypietz. BIGS Policy Paper No. 1, "Unmanned Aircraft Systems for Civilian Missions". https://www.bigs-potsdam.org/app/uploads/2020/06/PolicyPaper-No.1_Civil-Use-of-UAS_Bildschirmversion-interaktiv.pdf, 2012.

[137] BAE Systems. Taranis. https://www.baesystems.com/en/product/taranis, Consulted in July 2023.

[138] Elbit Systems. Skylark I. https://elbitsystems.com/product/skylark-i-lex/, Consulted in September 2023.

[139] Thales. Watchkeeper. https://www.thalesgroup.com/en/countries/europe/united-kingdom/markets-we-operate/defence/air-systems-uk/isr-air/watchkeeper, Consulted in July 2023.

[140] Thejapantimes. "Suzuki and SkyDrive to jointly start producing flying cars in 2024. https://www.japantimes.co.jp/news/2023/06/20/business/corporate-business/suzuki-skydrive-joint-flying-cars/, 2023, Consulted in July 2023.

[141] European Union. "Consolidated version of the Treaty on the Functioning of the European Union". https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:12012E/TXT:en:PDF, 2012.

[142] Illinois State University. University Policies and Procedures. https://policy.illinoisstate.edu/facilities/6-1-40/, 2017, Consulted in August 2023.

[143] Western Michigan University. Unoccupied Aircraft System (Drone) Policy. https://wmich.edu/policies/drones, Consulted in August 2023.

[144] Defence Update. Black Widdow Micro UAV. https://defense-update.com/20040604_black-widdow.html, Consulted in July 2023.

[145] Kimon P Valavanis and George J Vachtsevanos. *Handbook of unmanned aerial vehicles*, volume 1. Springer, 2015.

[146] Volocopter. "volocity the air taxi that's a cut above". https://www.volocopter.com/en/solutions/volocity, Consulted in July 2023.

[147] Roland Weibel and R John Hansman. "Safety considerations for operation of different classes of UAVs in the NAS". https://www.researchgate.net/publication/37995753_Safety_Considerations_for_Operation_of_Different_Classes_of_UAVs_in_the_NAS, 2004.

[148] Wikipedia. Black Hornet Nano. https://en.wikipedia.org/wiki/Black_Hornet_Nano, Consulted in July 2023.

[149] Wikipedia. Northrop Grumman MQ-8 Fire Scout. https://en.wikipedia.org/wiki/Northrop_Grumman_MQ-8_Fire_Scout, Consulted in July 2023.

[150] WING. "Learn about how Wing delivery works". https://wing.com/about-delivery/#:~:text=What%20can%20the%20aircraft%20carry,find%20useful%20in%20the%20future., consulted in Novermber 2023.

[151] Wing. Wing. https://wing.com/, Consulted in July 2023.

[152] Wisk. Wisk Unveils World's First Self-Flying, Four-Seat, All-Electric, Vertical Takeoff and Landing Air Taxi. https://wisk.aero/news/press-release/generation6/, Consulted in August 2023.

[153] Adoni W.Y.H. Classification of Uncrewed Aerial Vehicles. https://encyclopedia.pub/entry/43656, Consulted in July 2023.