Overview of European Union Guidelines and Regulatory Framework for Drones in Aviation in the Context of the Introduction of Automatic and Autonomous Flight Operations in Urban Air Mobility

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***Abstract*—Over the past years, Unmanned Aircraft Systems (UAS) operations surged exponentially. Due to new air mobility concepts, industries tend to use more advanced technology to build the UASs. So, it is essential to develop regulations in the new and rapidly evolving contexts in which these new technologies are imposed. The European Union drone regulation is in the transition period, in which the existing regulations in individual European member states are replaced with a unified regulation framework across the European Union. However, this European regulatory framework is very young and will be subject to further development. In this sense, efforts must be made in the scientific literature focusing on the regulatory framework of Europe. This paper provides a solid understanding of the drone's legal framework in the European Union.**

Keywords- Unmanned Aircraft Systems (UAS), Drones, Urban Air Mobility (UAM), EU regulation, Regulatory framework.

I. Introduction

Unmanned Aircraft Systems (UAS) are becoming popular. In recent years, drones have been used in various sectors such as agriculture, inspection, media, and entertainment. It is imaginable that remotely piloted aircraft will enter the area of commercial flights, in the near future [1]. Over the last years, new operational concepts based on innovative technologies, such as UAS and Vertical Take-Off and Landing (VTOL) aircrafts, have led to creating new air mobility concepts [2]. Although UAS's operational and technological capabilities have matured to the point where UASs are expected to gain greater freedom, most civil operations of UAS are conducted in low-level uncontrolled areas or in segregated controlled airspace due to safety concerns [1].

A wide range of literature is published around the world, trying to answer the research question of how to adapt UAS with Urban Air Mobility (UAM) and regulations. Clarke [3] investigated the impacts of civilian drones' regulation on behavioral privacy. He also presented the impacts of the civilian drones' regulation on public safety [4]. Thomasen [5] considered the robots (including drones) and robot regulation impact on public spaces. This paper highlights the importance to regulate robotic systems that operate in public spaces. She also presented a feminist perspective on drone privacy regulation. This article contributes to drone privacy literature to examine the technology's impacts on women's privacy and related regulations [6]. Li and Kim [7] examined the dynamics of local drone policy adoption in the largest registered drone population in the United States, California. West et al. [8] reviewed the public's opinions about drone policy, and its fluctuation over time. In the work done by Merkert, Beck, and Bushell [9], they adopt the theoretical road pricing framework to investigate the willingness of drone operators to pay for Low-Altitude Airspace Management (LAAM). Winkler, Zeadally, and Evans [10] highlighted the concerns and needs of privacy and operation of civilian drone regulations. Nelson and Gorichanaz [11] analyzed the emergence of drones and the evolving regulation in 20 cities in southern California, and they suggested trust as an ethical value in emerging technology governance.

While the aviation industry is subjected to an international framework, it is fair to state that efforts must be made to achieve the same framework for civil drones [12]. In the available literature and the official aviation organizations and regulatory authorities' documents in Europe and worldwide, there is no agreed and consolidated definition of the notion of UAM. However, European Union Aviation Safety Agency

(EASA) recently introduced the UAM concept for the purpose of standardizing communication in the European Union, and for future requirement developments: " The safe, secure and sustainable air mobility of passengers and cargo enabled by new generation technologies integrated into a multimodal transportation system conducted in to, within or out of urban environments" [2]. There is also a need to establish a comprehensive regulatory framework addressing the safety, security and environmental aspects of this new form of mobility of people and cargo by air in order to ensure its adequate acceptance and adoption by European citizens. Some elements of this regulatory framework have already been established with the adoption of Commission Implementing Regulation (EU) 2019/947, Commission Delegated Regulation (EU) 2019/945, and Commission Implementing Regulation (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space [2].

It is fair to state that there are no efforts in the scientific literature focusing specifically on the regulatory framework of Europe, so far. One of the reasons is that the drone European Union (EU) regulatory framework is currently under transition, and it was fragmented before 2020. So, this paper provides a comprehensive overview of the developed UAS regulation in the European Union considering the regulations provided by the European Aviation Safety Agency (EASA) to develop a reliable basis for future studies of drones' EU regulatory framework. The structure of the paper is as follows: Section II introduces the existing and upcoming European regulatory framework for UASs. Section III defines the UAS operational categories developed by the EASA. Section IV briefly discusses the existing and upcoming European regulatory framework and standards regarding Artificial Intelligence (AI) and autonomous flights. Section V explains how the regulations apply to drones according to the risk assessments. Section VI discusses the potentials and challenges before presenting the conclusion in Section VII.

II. EUROPEAN UNION REGULATORY FRAMEWORK TRANSITION

Before 2020, the drone EU regulatory framework was fragmented. The member states regulated civil drones with less than 150 kg operating mass, while the EASA regulated civil drones with over 150 kg operating mass. The difference in extent, content, and level of detail of national regulations led to unreached conditions for mutual recognition of operational authorization between the EU Member States [2].

Since 2020, the European Union drones' legal framework officially subjected to a uniform regulation by European Union Aviation Safety Agency (EASA) under the Regulation 2019/947 and 2019/945. Regulation 2019/947 was expected to be implemented on 1 July 2020; however, due to the COVID-19 crisis, it was delayed to 31 December 2020 [13]. Aircraft airworthiness concerns the safety standards in all construction aspects such as structural strength, safeguard provisions, and design requirements relating to aerodynamics, performance, electrical and hydraulic systems [14].

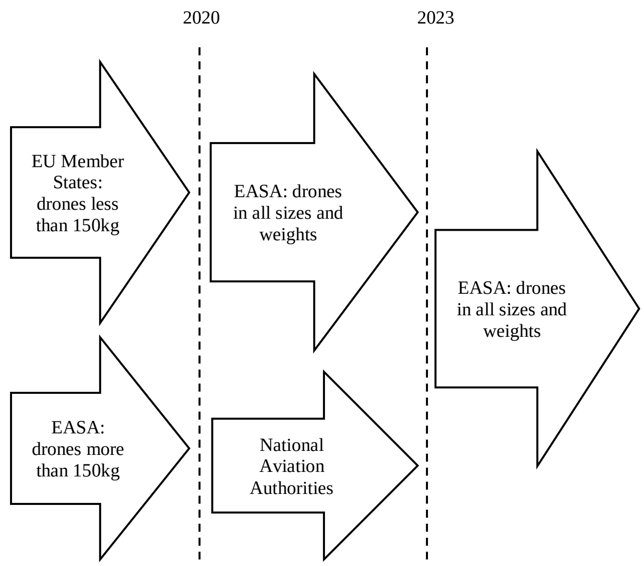

Figure 1. European Union regulatory framework transition

Easy Access Rules for Airworthiness and Environmental Certification (Regulation (EU) No 748/2012) contains the applicable rules for Airworthiness and Environmental Certification of aircraft and related products, parts, and appliances, as well as for the certification of design and production organizations [15]. In general, international and national regulations are focused on safety. Nevertheless, small drones avoid many of these requirements, as they pose fewer risks to people [12]. Figure 1 presents an overview of European Union regulatory framework transition.

III. CIVIL DRONE OPERATIONS CATEGORIES IN THE EUROPEAN UNION REGULATORY FRAMEWORK

Civil drones' operational framework in the European Union (EU) is Regulations 2019/947 and 2019/945. These regulations conduct a risk-based approach considering the weight, the specifications, and the intended operation of the civil drone. Regulation 2019/947 defines three categories for civil drone operations: the open, the specific, and the certified category [16], as shown in Figure 2.

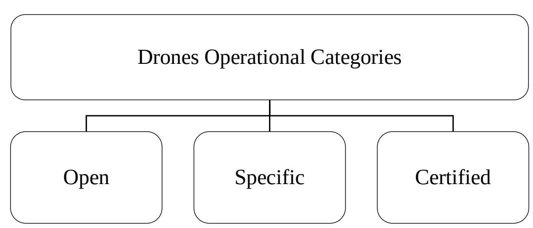

Figure 2. Drone categories in the European Union regulatory framework

A. *The open category (low risk)*

Drones in low-risk operations (e.g., leisure drone activities and low-risk commercial activities) are categorized as the open category. This category has three sub-categories:

- A1: fly over people but not over assemblies of people
- A2: fly close to people
- A3: fly far from people

Each sub-category comes with its own requirements, depending on the drone's weight. The maximum operational weight in this category is 25 kg [17].

B. *The specific category (medium risk)*

Riskier drone operations, which fall out of the open category's scope, are in the specific category. Based on the risk assessment outcome conducted under Article 11 of Regulation (EU) 2019/947, operational authorization (issued by the competent authority of registration) is required in this category, unless the operation is covered by a Standard Scenario (STS) that is a predefined operation described in the appendix of EU regulation 2019/947 [18].

C. *The certified category (high risk)*

The highest level of risk in drone operations and future drones onboard passenger flights (e.g., air taxis) are covered in the certified category. Based on the outcome of risk assessment conducted under Article 11 of Regulation (EU) 2019/947, drones can also be classified in the certified category. These aircraft will always need to be certified. The UAS operator will need an air operator approval issued by the competent authority, and the remote pilot is required to hold a pilot license. In the longer term, drone automation development is expected to reach a level to have fully autonomous drones without remote pilot intervention. The approach used to ensure the safety of these flights will be very similar to the one used for manned aviation, and almost all the aviation regulations will need to be amended. So this will be a major task, and EASA is decided to conduct this activity in multiple phases [19].

Overall, if drone operations contain any of the below conductions, they are certainly classified in the certified category:

- The UAS has a dimension of 3 m or more in the operation involves flying over assemblies of people (flying over assemblies of people with a UAS that has a dimension less than 3 m may be in the specific category unless the risk assessment concludes that it is in the certified category)
- The operation involved transport of people
- The operation involved transport of dangerous goods if the payload is not in a crash-protected container [20].

IV. AUTONOMOUS AND AUTOMATIC UAS

With the advancement of technology, autonomous and automatic UASs are expected to conduct safe operations in Urban Air Mobility (UAM); major differences are between autonomous and automatic concepts. With the help of artificial intelligence, autonomous UAS must cope with unforeseen conditions and unpredictable emergencies to conduct a safe flight without the pilot's intervention. However, the automatic UAS flies on pre-determined routes, and the remote pilot intervenes in case of unforeseen events not programmed in pre-determined operation. While automatic drones are allowed in all categories, autonomous drones are not allowed in the open category. Instead, they can operate in the specific category and the certified category, where the Regulation includes more flexible tools to verify requirements and level of robustness. [22].

The key research question is how autonomy can be safely used in UAM [23]. In 2020, EASA published the first guidance, EASA AI roadmap, for the safe use of artificial intelligence in aviation [21] in several domains such as aircraft design and operation, aircraft production and maintenance, drones, open-air mobility, safety risk management, and cybersecurity [24]. Figure 3 presents the definition of the trustworthy AI building block, which is one of the important contributions of this document [21]. The schedule presented in the EASA AI roadmap document foresees the first approvals of AI starting in 2025 [24].

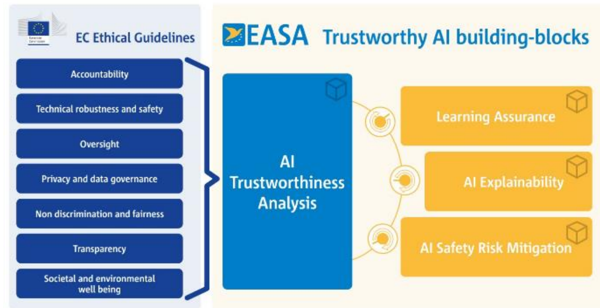

Figure 3. EASA trustworthy AI building-blocks: : AI trustworthiness analysis, learning assurance, AI explainability, and AI safety risk mitigation [21]

V. OPERATIONAL RISK ASSESSMENT FOR DRONES IN SPECIFIC CATEGORY

The volume and scope of drone operations have increased in Europe. To ensure safety, particularly in operations conducted in populated areas, the design verification of the drone by EASA is needed depending on the operation’s level of risk [25]:

- In drone operations classified as high risk operations (i.e., Specific Assurance and Integrity Level (SAIL) V and VI according to Specific Operation Risk Assessment (SORA)), EASA will issue a type certificate according to Part 21 (Regulation (EU) 748/2012) [15].
- In drones operation classified as medium risk operations (i.e., SAIL III and IV according to SORA),

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a more proportionate approach, leading to a design verification report, will be applied [25].

The work in [20] describes the operational risk assessment for drones in detailed steps, and this paper presents an overview of these steps. Overall, there are three categories in the operational risk assessment. The first lower risk category is the operations in Standard Scenarios (STS), and the second category is Predefined Risk Assessment (PDRA). This category also tends to cover some deviations from STS. When the operation is not subject to STS or PDRA, it will be categorized as Specific Operation Risk Assessment (SORA), the last category.

A. *Standard scenario (STS)*

Due to the lower risks in UAS operations when complying with STSs listed in TABLE I, a declaration may be submitted.

B. *Predefined risk assessment (PDRA)*

EASA intends to publish several PDRAs considering the most common operations in Europe. Instead of conducting a full risk assessment, a request for authorization may be submitted based on the mitigations and provisions described in the PDRA when the UAS operation meets the operational characterization described in TABLE II.

While STSs are described in a detailed way, PDRAs are described in a rather generic way to provide flexibility. Two types of PDRAs are provided: the first category is derived from STSs, which allow the UAS operator to conduct similar operations without the UAS class label that is mandated by the STS; and the other category is the more generic PDRAs. The codification of a PDRA includes the letter 'G' (used for generic PDRAs) or 'S' (used for PDRAs that are derived from an STS) [20].

TABLE I. LIST OF THE STANDARD SCENARIOS (STS) PUBLISHED [20]

STS#	**Edition/date**	**UAS characteristics**	**BVLOS/ VLOS****	**Overflown area**	**Maximum range from remote pilot**	**Maximum height**	**Airspace**
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	120 m	Controlled or uncontrolled, with low risk of encounter with manned aircraft
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	2 km with an AO*** 1 km, if no AO	120 m	Controlled or uncontrolled, with low risk of encounter with manned aircraft

* Maximum TakeOff Mass
** Beyond Visual Line of Sight / Visual Line of Sight
*** Airspace Observer

TABLE II. LIST OF THE PREDEFINED RISK ASSESSMENTS (PDRA) PUBLISHED [20]

PDRA#	**Edition/date**	**UAS characteristics**	**BVLOS/ VLOS**	**Overflown area**	**Maximum range from remote pilot**	**Maximum height**	**Airspace**	**AMC#* to Article 11**
PDRA-S01	1.0/July 2020	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	120 m	Controlled or uncontrolled, with low risk of encounter with manned aircraft	AMC4
PDRA-S02	1.0/July 2020	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	2 km with an AO 1 km, if no AO	120 m	Controlled or uncontrolled, with low risk of encounter with manned aircraft	AMC5
PDRA-G01	1.1/July 2020	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	150 m (operational volume)	Uncontrolled, with low risk of encounter with manned aircraft	AMC2
PDRA-G02	1.0/July 2020	Maximum characteristic dimension of up to 3 m and typical kinetic energy of up to 34 kJ	BVLOS	Sparsely populated area	N/a	As established for the reserved airspace	As reserved for the operation	AMC3

* Acceptable Means of Compliance

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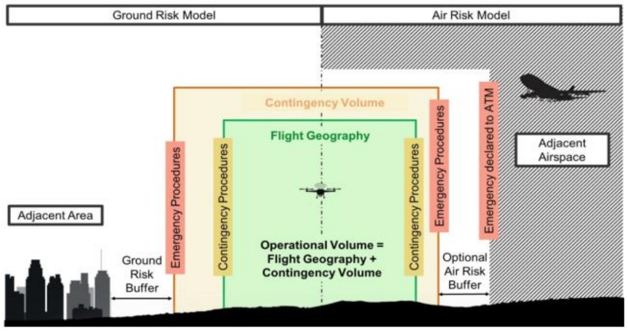

Figure 4. Graphical representation of the SORA semantic model [20]

C. *Specific operation risk assessment (SORA)*

SORA evaluates the safety risks in the UAS operation considering any UAS class and size, or type of operation [20]. Figure 4 provides a visual reference to the SORA methodology. Robustness is one of the concepts to account for when conducting SORA. SORA presents three robustness levels: low, medium, and high. Risk mitigations and Operational Safety Objectives (OSO) can be demonstrated at different robustness levels. Risk is another key concept. Many works of literature exist to define risk. SORA defines risk as: 'the combination of the frequency (probability) of an occurrence and its associated level of severity'. SORA focuses on the assessment of air and ground risks. Figure 5 outlines the needed ten steps to support the SORA methodology. If UAS operates in different environments, some steps may need to be repeated [20].

Before starting the SORA process, it is important to verify the operational feasibility. If the operation is not categorized as the open category or the certified category, not covered by a standard scenario or by a predefined risk assessment, and not subjected to a specific NO-GO from the competent authority, the SORA can be applied [20].

VI. DISCUSSION

One of the distinctive features of the future cities in science fiction movies and novels is flying cars and transport systems. This is one of the basic concepts accepted by society when imagining the future. The technological advances make us wonder if we are a few steps away from having safe automatic and autonomous air transport systems for urban areas in the near future. UAS are becoming popular and it is only a matter of time before they will enter UAM as a way of transporting goods and even individuals. For this vision to become feasible, it is essential to develop a regulatory framework accepted by society. As presented in Figure 1, the European Union regulatory framework for UASs was fragmented before 2020 and each EU Member states were in charge of drones with a Maximum Take-Off Mass (MTOM) of less than 150 Kg and EASA was responsible for drones with MTOM of more than 150 Kg. In 2020, the regulation transition started and EASA has become responsible for drones of all sizes and weights. This young regulatory framework is still under further development. So, the national aviation authority of each country will help this regulation to

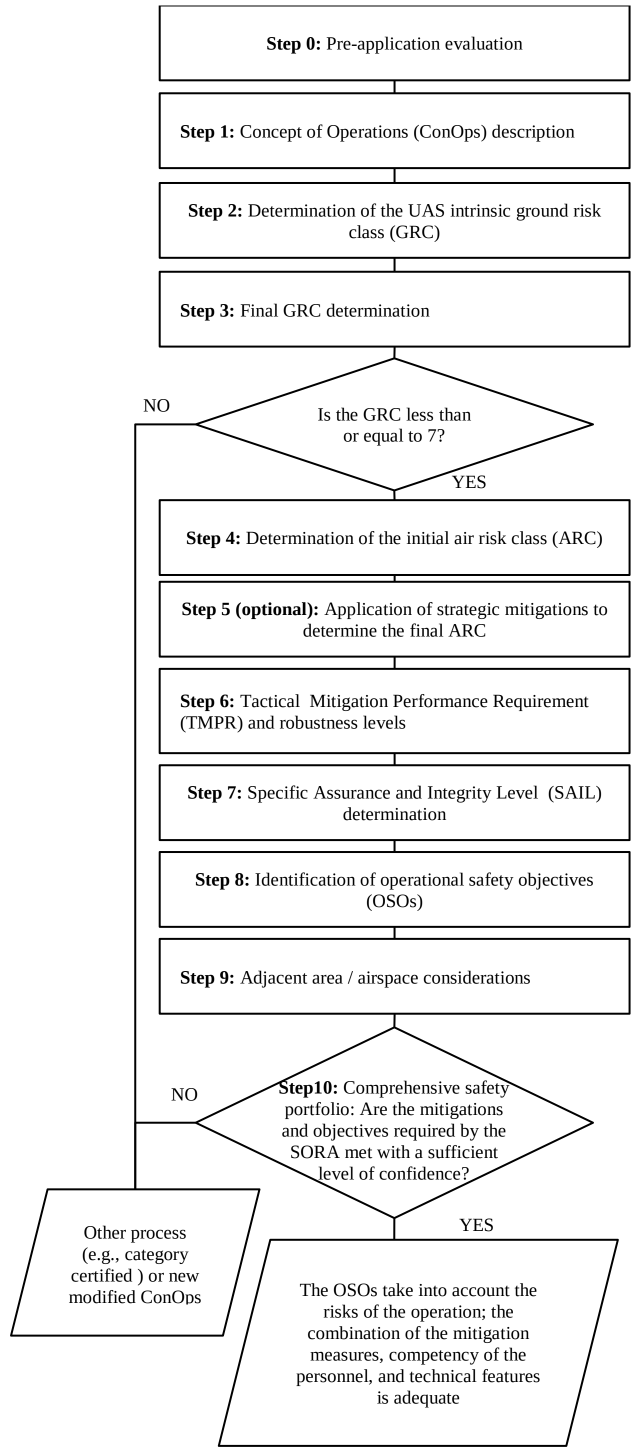

Figure 5. Determination of robustness level [20]

fill its gaps until the year 2023 when this regulatory framework becomes fully developed.

Autonomous and automatic UASs are expected to conduct safe operations in UAM. With the help of artificial intelligence, the autonomous UAS conducts a safe flight without the pilot's intervention, while the automatic UAS flies on pre-determined routes, and the remote pilot can intervene in unforeseen events. With a quick comparison between autonomous and automatic flights, it can be concluded that there is no human safety net in case of unforeseen events when conducting an autonomous flight. So, precise regulations have to be developed in the context of artificial intelligence to make sure of conducting a safe autonomous flight. In 2020, EASA also published the first guidance, the EASA AI roadmap, for the safe use of artificial intelligence in aviation in several domains. However, it is still a long way for the dream of having Science fiction flying transport systems to come true as the schedule presented in the EASA AI roadmap document foresees the first approvals of AI in 2025.

A wide range of literature is published around the world, trying to answer the research question of how to adapt UAS with UAM and regulations. However, there is not much literature effort in the context of the drone EU regulatory framework since this regulatory framework is currently under transition, and it was fragmented before 2020. As mentioned, the concept of drone regulation in the context of the European Union regulation and UAM adaptation to carry cargo and individuals is young. While the devoted regulations for this type of operation, mainly the certified category, are still in the development phase, even in the specific category, lots of factors and parameters need to be considered for the determination of robustness level, as presented in Figure 4, to ensure a safe flight without any complications. For instance, preparing ConOps and calculating the GRC and ARC requires operating conditions data. Moreover, UAS autonomous flights are not currently conducted in most European countries due to safety reasons and uncompleted regulation development. When a new concept is arising, the lack of literature and documents is inevitable in the early stages. So, the first and most important challenge at this moment is to keep track of the developments and changes of the regulation.

VII. CONCLUSION

The popularity of UAS operations increased over the past years and new air mobility concepts have been created. It is essential to develop regulations in this new technological context. The European Union drone regulation is in the transition period and this young regulatory framework will be subject to further development. This causes a scientific literature gap of no efforts focusing on the regulatory framework of Europe. In this paper, we provide a comprehensive overview of the developed UAS regulation in the European Union to fill this gap and to provide a solid understanding of the drone's legal framework in the European Union for future studies.

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