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Regulatory Needs for the Implementation of Urban Air Mobility In Spain. Innovative Air Mobility Noise Impact in Urban Areas - Regulatory Proposal.

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SUMARY: 1. EUROPEAN STRATEGIES TO ADDRESS NOISE AND OTHER HARMFUL EFFECTS OF INNOVATIVE AIR MOBILITY. 2. CURRENT REGULATION IN SPAIN. 3. NOTES ON THE REGULATORY NEEDS FOR THE IMPLEMENTATION OF URBAN AIR MOBILITY IN SPAIN. 4. NOISE IMPACT OF INNOVATIVE AIR MOBILITY IN URBAN AREAS. 4.1. Noise emissions from aircraft and their infrastructure (aerodromes). 4.2. Specific aspects of UAS/UAM noise and future challenges. 4.3. EASA actions. A) Consultation document: Environmental Protection Technical Specification (EPTS) applicable to eVTOL powered by multiple, vertical, non-tilting, evenly distributed rotors | EASA. B) Environmental research - rotorcraft noise | EASA. C) Technical specifications of the vertiports prototype PTS-VPT-DSN. *D)* Guidelines on noise measurement of unmanned aircraft systems of less than 600 kg operating in the specific category (low and medium risk) - EASA. 4.4. From the generation to the reception (or immission) of noise by the UAS. 4.5. Digital models of the urban environment. 4.6. Digital UAS Models. 4.7. Conclusions.

1. EUROPEAN STRATEGIES TO ADDRESS NOISE AND OTHER HARMFUL EFFECTS OF INNOVATIVE AIR MOBILITY

The transport system is vital for European businesses and global supply chains. Transport contributes around 5% of EU GDP and employs more than 10 million people in Europe, but it is not without costs to our society: greenhouse gases and pollutant emissions, noise, road accidents and congestion[1]. Indeed, climate change is a global challenge,

[1] Today, transport emissions account for about a quarter of the EU's total GHG emissions, European Commision "Mobility Strategy", https://transport.ec.europa.eu/transport-themes/mobility-strategy_en . Whilst mobility brings many benefits

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as it clearly affects the whole planet and requires global cooperation[2]. Within this general framework of the fight against climate change, the aviation sector must undoubtedly bincluded since air pollution affects the aviation sector by negatively affecting air quality[3]. Therefore, while the aviation sector provides economic benefits, connectivity and stimulates innovation, European citizens are increasingly aware of the impact of aviation activities on their quality of life through climate change, noise and air quality[4]. Noise pollution is no less annoying than air quality pollution, as it can ultimately affect health. This problem is not alien to the Community institutions, to the extent that sustainable urban mobility is promoted[5]. Let us look at the ITER in this context.

There is a long tradition within the European Union regarding the importance of the transport sector in general, dating back to the pre-Treaty of Rome period[6]. For its part, the European Commission, in its Communication of May 2018: "Towards automated mobility: an EU strategy for the mobility of the future". The European Parliament welcomed this new direction in its resolution of 15 January 2019 on autonomous driving[7]. In this text, the European Parliament highlighted the efforts of the Commission and the Member States in this field and decided to support the approach that the EU should take the global lead in the deployment of safe automated mobility systems, both

for its users, it is not without costs for our society. These include greenhouse gas emissions, air, noise and water pollution, but also accidents and road crashes, congestion, and biodiversity loss - all of which affect our health and wellbein. Past efforts and strategic actions have not yet sufficiently addressed these costs. Greenhouse gas emissions from the transport sector have increased over time and now account for no less than a quarter of the EU total, European Commission Communication "Sustainable and Intelligent Mobility Strategy: Harnessing Europe's transport for the future" (ST 14012/20 + ADD 1), available at https://eur-lex.europa.eu/legal-content/ES/TXT/?uri=CELEX%3A52020DC0789.

[2] SANZ RUBIALES, I (Coord,): *"Cambio climático y Unión Europea (Presente y futuro del mercado europeo de emisiones)".* Tirant lo Blanch. Valencia. 2014.

[3] In the Report from the Commission to the European Parliament and the Council entitled: "Updated analysis of the non-CO2 climate effects of aviation and possible policy measures under Article 30(4) of the EU Emissions Trading Directive" (COM (2020) 747 final), aviation emissions of nitrogen oxide, soot, sulfur oxides and water vapor are denounced as climate-damaging.

[4] European Aviation Environmental Report 2022: Sustainability crucial for long-term viability of the sector, https://www.easa.europa.eu/eco/eaer/executive-summary.

[5] Santandreu Capón, F.: "Desarrollo turístico y medidas medioambientales en el sector aéreo: el ejemplo de Canarias", *Revista Española de Derecho Aeronáutico y Espacial,* 2023, No. 3, in press, and more extensively on this issue can be found in his work "Problemas jurídico-medioambientales en relación con el aeropuerto de Barajas". *Revista Española de Derecho Aeronáutico y Espacial,* 2023, 2 (September 2022). pp.215-236.

[6] In spite of the possible initial doubts about the inclusion of maritime and air transport in the *common transport policy,* after the STJCE of 22 May 1985, the different action programs in this field have been focused on improving safety and the organization of the market in its triple typology of land, air and maritime transport. Even so, of all these modalities, air transport currently occupies a privileged place in terms of the Community regulatory impulse provided and visible through a vast regulatory framework, of direct and obligatory compliance, as we will report throughout this work The legal basis of the EU is Article 100, paragraph 2, of the Treaty on the Functioning of the European Union. According to Article 4(2) of the Treaty, shared competence between the EU and the Member States applies in the field of transport. In addition, Article 114 TFEU provides a legal basis for harmonization measures relating to the EU internal market, as stated in *Drone strategy 2.0 for Europe to foster sustainable and smart mobility*, *Roadmap - Ares* (2021) 3664195, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13046-A-Drone-strategy-20-for-Europe-to-foster-sustainable-and-smart-mobility_en. More extensively on this development, Gómez Diaz, A.B. : (2022): "La política del transporte en la UE (especial referencia al transporte ferroviario", *Economist And Jurist*. 2022, pp. 1-14.

[7] European Parliament Resolution of 15 January 2019 on autonomous driving in European transport, (2018/2089(INI), hereinafter European Parliament Resolution on autonomous driving, available at https://eur-lex.europa.eu/legal-content/ES/TXT/PDF/?uri=CELEX:52019IP0005&from=EN.

in terms of cooperative intelligent transport systems and the development of "autonomous" vehicles. For this reason, it urged these public authorities to take the lead in this area.

Subsequently, on December 11, 2020, the Commission presented the Communication "Sustainable and Intelligent Mobility Strategy: Harnessing Europe's Transport for the Future", hereafter CEM[8]. Its aim is to set the EU on the path towards a sustainable, intelligent, and resilient mobility system of the future and to introduce the fundamental changes needed to achieve the objectives of the European Green Deal, as confirmed in the Council Conclusions on the Commission's Sustainable and Intelligent Mobility Strategy[9].

Within the framework of this intention and in the field of multimodal logistics, CEM refers to sustainable urban mobility planning, which "includes the freight dimension through specific sustainable urban logistics plans. Such plans will accelerate the deployment of already available zero-emission solutions, such as delivery bikes, automated deliveries and drones (unmanned aerial vehicles), and better use of inland waterways to cities". In addition, the EMF highlights the need to reduce accidents and congestion, as well as the external costs of freight delivery, which are rising sharply with the growth of e-commerce[10].

In turn, Regulation (EU) 2021/694 of the European Parliament and of the Council of 29 April 2021 establishing the Digital Europe Program (hereinafter Regulation (EU) 2021/694, Digital Europe Program) . This Community text includes, within the fifth specific objective ("Deployment and better use of digital capacity and interoperability"), projects of common interest in areas of public interest related to automated and connected driving, intelligent mobility concepts and unmanned aerial systems. Finally, and in continuity with this EU urban mobility strategy, it is worth mentioning the Drone Strategy 2.0 for Europe to promote sustainable and intelligent mobility, whose main objective is to further develop the EU drone strategy in the light of the European Green Pact, the Intelligent and Sustainable Mobility Strategy, the Digital Strategy and other EU policies[11].

Considering the above, there is no doubt that drones will play an essential role in smart cities. The creation of sustainable transportation alternatives in major cities is getting closer every day. Congestion will be reduced, certain locations will be more quickly accessible and carbon emissions will be reduced, but there are several

[8] Commission Communication "Sustainable and Intelligent Mobility Strategy: Harnessing Europe's transport for the future" (ST 14012/20 + ADD 1), available at https://eur-lex.europa.eu/legal-content/ES/TXT/?uri=CELEX%3A52020DC0789.

[9] The European Green Pact presented by the European Commission in December 2019 (COM/2019/640 final) as a response to climate and environmental challenges, states the need to accelerate the transition to sustainable and smart mobility. Specifically, it states that "achieving sustainable transport means putting users first and providing them with alternatives to their current mobility habits that are more affordable, accessible, healthy and clean", as stated in the explanatory memorandum of the Preliminary Draft SML. Council Conclusions on the Commission's Sustainable and Intelligent Mobility Strategy, Report of the General Secretariat of the Council, n. 86252/21, available at https://data.consilium.europa.eu/doc/document/ST-8824-2021-INIT/es/pdf

[10] As aptly noted in App. 41 CEM, "multimodal logistics must be part of this transformation, within urban areas and beyond. The growth of e-commerce has significantly changed consumer habits, but the external costs of millions of deliveries, including the reduction of unladen and unnecessary journeys, must be taken into account."

[11] Available at https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13046-A-Drone-strategy-20-for-Europe-to-foster-sustainable-and-smart-mobility_en
The Commission's Sustainable and Intelligent Mobility Strategy7 adopted in December 2020 provides an ambitious roadmap to put European transport firmly on track towards a sustainable, smart and resilient future.

challenges to be solved from a regulatory, safety and citizen acceptance point of view. As part of the preparation of an appropriate regulatory framework for innovative air mobility, EASA conducted a comprehensive study on social acceptance in Europe[12]. However, the study identified some major concerns related to the social acceptance of urban air mobility, with noise and safety issues being the most important, followed by privacy, environmental issues, and physical security.

In fact, today's society tends to associate UAS with a negative impact of being visibly overflown by these small automated systems. It is inevitable that the foreseeable increase in the number of unmanned aircraft operating at low altitudes will also inevitably increase the nuisance and interference with the use and enjoyment of public or private property. It is expected that UAS will cause discomfort, mental and emotional distress to people because of the feeling of being watched. In addition, it is possible that they will be annoyed by aircraft noise and visual pollution[13]. This might be considered intrusive at a certain level. The issue here is to delimit the reasonable parameter for measuring the reasonableness of these disturbances in relation to the rights of people on the surface.

Focusing on noise pollution, to the extent that this type of noise significantly affects our quality of life and well-being, a balance must be found between the right of overflight, which implies that citizens must endure such nuisances, and the protection of their human rights (art. 8 ECHR STEDH 9 -12-1994) [14].

2. CURRENT REGULATION IN SPAIN

From the point of view of the citizen in the urban environment, as a matter of principle, we can point out that "no one can oppose, on the basis of a property right, the passage of an aircraft carried out in accordance with the regulations in force. However, if damage is caused, he/she shall be entitled to compensation", as stated in the proposed Aeronautical Code of the Latin American Association of Aeronautical and Space Law (ALADA)[15].

Article 4 of the Spanish Aeronautical Law (LNA), as amended by Law 5/2010 of March 17, establishes that the owners or occupiers of the underlying property have the right to be compensated for damages caused to them as a result of their obligation to support air navigation, in accordance with Chapters IX (Aeronautical Easements) and XIII (Liability in the event of accidents) of this Law, Law 37/2003 of November 17, on Noise, International Treaties and Community Law[16]. This refers to damages caused by the mere fact of the passage of aircraft through the

[12] Ap 50 Drone Strategy 2.0, *op. cit.,* p. 13-14:
[13] As noted at https://www.rpas-drones.com/retos-de-la-integracion-de-drones-en-las-smart-cities/
[14] The aim is to protect the rights enshrined, for example, in Art. 8 of the ECHR as interpreted by the ECtHR in the Lopez Ostra v. Spain judgment of December 9, 1994, which states that «serious damage to the environment may affect a person's well-being and deprive him of the enjoyment of his home in a way that harms his private and family life, without seriously endangering his health».
[15] Draft Aeronautical Code, Latin American Association of Aeronautic and Space Law (ALADA), Version 2022. Unanimously approved at the XXXVIIth. General Assembly of ALADA, held on 27 October 2022.
[16] Noise pollution is defined in the Noise Law as «the presence in the environment of noise, vibrations, whatever the acoustic emitter that originates them, which imply a nuisance, risk or damage for people, for the development of their activities or for goods of any nature, or which cause significant effects on the environment».

airspace, based on the obligation to bear the noise levels, overflights, frequencies, and environmental impact generated by air navigation.

The interpretation of Art. 4 LNA can be somewhat confusing[17]. In principle, this provision generally recognizes the right of persons overflown to be compensated in accordance with Chapters IX and XIII of this law, law 37/2003 of 17 November, international treaties and Community law. Chapter XIII "Liability in the event of an accident" (articles 115 to 125 LNA), unsuited to the reality of drones[18], is reserved for damages caused to third parties, directly due to the action of the aircraft, not for those which, indirectly, are due to the "mere fact of the passage of the aircraft", expressly excluded by art. 1.1. CR, art. 3 CRG . Unfortunately, when the damage is caused by the direct action of UAS, there is no adequate and complete legal regime applicable from the point of view of compensation. The European Commission expressed its willingness to initiate a harmonization process in its Roadmap for the integration of civil remotely piloted aircraft systems into the European aviation system, from the European RPAS Steering Group, June 2013. This intention did not culminate in a Community regulatory text due to a lack of support from EU Member States, which opted to apply their national regulations designed for traditional aircraft, i.e. manned aircraft, with some legal exceptions that can be found in the study Civil liability regime for artificial intelligence, European Parliament, September 2020.

The current scenario is certainly not very protective for possible injured parties, among other reasons due to the inadequacy of compensation limits (or insurance coverage) for the diversity of UAS: from model airplanes or toys to the most sophisticated and highest MTOM, with a clearly outdated criterion in view of recent (EU) regulations based on the level of risk assumed by these drones. At the same time, the possibility of cross-border accidents (in which the nationality of the operator and the place of the harmful event do not coincide) will highlight the legal uncertainty caused by the lack of a supranational regulatory framework.

From another perspective, it should be noted that both Art. 4 LNA and Chapter IX "aeronautical easements" LNA are basically designed for one of the cases that gives rise to the most claims in other laws: damages resulting from abnormal noise generated by aircraft, the compensation of which has been rejected by the courts of other countries, according to the classical interpretation of Art. 1.1 Rome Convention, since the leading case "Causby vs. US Supreme Court of USA May 27, 1946"; and this despite the criticism of the doctrine that considers that it should be included in the scope of application of the aforementioned international instrument.

In Spain, to date, the obligation to comply with the noise levels, overflights, frequencies, and environmental impacts generated by air navigation, in accordance with the regulations governing air traffic, has been of particular

[17] On such interpretation, Bustos Moreno, Y.: "El transporte y la navegación aérea", in *Responsabilidad civil en el ámbito del transporte y la navegación aérea (Natalia Álvarez Lata, Yolanda B. Bustos Moreno), Tratado de responsabilidad civil (*coord. por L. F. Reglero Campos, J. M. Busto Lago*, Vol. 2, 2014,* pp. 1072-1073 and "La irrupción de los drones (unmanned aircraft systems, UAS) y la responsabilidad civil: El futuro de los UAS autónomos", *Cuestiones clásicas y actuales del Derecho de daños: estudios en homenaje al profesor Dr. Roca Guillamón*, (coord. por J. Ataz López, J. A. Cobacho Gómez; Juan Roca Guillamón (hom.), pp. 900-901.

[18] In the Spanish case, the basic regulation is Law 48/1960, of 21 July, on Air Navigation, which has been reformed (insufficiently, in our opinion), in order to adapt it to the reality of drones (through Law 18/2014, of 15 October and the recent Royal Decree-Law 26/2020, of 7 July, on economic reactivation measures to deal with the impact of COVID-19, in the fields of transport and housing).

importance in the vicinity of airports, due to the acoustic impact caused by aircraft. Furthermore, in the context of rescue operations or assistance to aircraft in distress, the owners or possessors of property may not oppose the entry or passage of their property (art. 153 LNA), with the possibility of compensation for damages caused by such actions, or in the case of property affected by the easements of art. 151 LNA, as provided for in art. 154 LNA.

Regarding Art. 4 LNA, we understand that the regulation was intended for noise nuisance caused by manned aircraft to the population in the vicinity of airports, but not for UAS. It should be noted that aerodromes, which would currently include airports according to the current definition of Law 48/1960 on Air Navigation (art. 39), must be subject to the environmental impact assessment procedure of the project, as provided for in Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment and in the national regulation, Law 21/2013, of 9 December, on Environmental Impact Assessment. It is in this procedure that noise is assessed for the first time in the permit. The noise regulation, derived from Directive 2002/49 on Environmental Noise, defines immission values for both indoor and outdoor areas. Large infrastructures of public interest (public use airports) have the tools to define protection zones (acoustic easements) where both targets and limits can be exceeded in the defined area[19]. Urban development may be restricted in these zones, which will impose costs on the operator for corrective and compensatory measures. Restricted use aerodromes do not have these privileges[20].

Regarding drones, regulation is currently scarce and insufficient. Thus, in terms of Community regulations applicable to drones, basically the Commission Delegated Regulation (EU) 2019/945, of March 12, 2019, the Commission Implementing Regulation (EU) 2019/947, of May 24, 2019, and the Commission Implementing Regulation (EU) 2021/664, of April 22, 2021) on U-Space (together with those that amend them, 2020/639, 2020/746), it is noted that they basically aim to cover issues related to safety and security and, in particular, address the preventive prism of drone operations and requirements in the production chain. This regulation, of successive articulation in the short term, favors the identification of the civil liable party, which falls on the figure of the UAS operator and establishes three operational categories (open, specific and certified), depending on the different factors that determine the degree of risk assumed with respect to third parties on the ground, as well as in relation to other manned aircraft.

This European regulatory framework, in relation to the issue at hand, focuses on aspects related to aviation safety, including the will to establish requirements to try to mitigate risks related not only to flight safety, but also to privacy, environmental protection and noise at unacceptable levels, among other aspects. For example, in the "specific" category, in order for the competent authority to carry out a risk assessment, the operator must submit a "declaration", Art. 12.2 c) Regulation 947, confirming that the intended operation complies with all applicable Union and national rules, in particular with regard to privacy, data protection, liability, insurance, security in the sense of protection against attacks, most likely cyber-attacks (security) and the environment. Classes C0, C1, C2 and C4 may only be powered by electricity.

[19] Articles 7 and 11, Royal Decree 1367/2007, of 19 October, which implements Law 37/2003, of 17 November, on Noise, with regard to acoustic zoning, quality objectives and acoustic emissions.
[20] *Vid*. Ap. 4.1

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However, it remains to be satisfactorily regulated the means of assessment (and thus indirectly the determination of the best protection) in relation to noise with respect to drone overflights in urban areas, which is discussed in section four.2. CURRENT REGULATION IN SPAIN

From the point of view of the citizen in the urban environment, as a matter of principle, we can point out that "no one can oppose, on the basis of a property right, the passage of an aircraft carried out in accordance with the regulations in force. However, if damage is caused, he/she shall be entitled to compensation", as stated in the proposed Aeronautical Code of the Latin American Association of Aeronautical and Space Law (ALADA).

Article 4 of the Spanish Aeronautical Law (LNA), as amended by Law 5/2010 of March 17, establishes that the owners or occupiers of the underlying property have the right to be compensated for damages caused to them as a result of their obligation to support air navigation, in accordance with Chapters IX (Aeronautical Easements) and XIII (Liability in the event of accidents) of this Law, Law 37/2003 of November 17, on Noise, International Treaties and Community Law. This refers to damages caused by the mere fact of the passage of aircraft through the airspace, based on the obligation to bear the noise levels, overflights, frequencies, and environmental impact generated by air navigation.

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The current scenario is certainly not very protective for possible injured parties, among other reasons due to the inadequacy of compensation limits (or insurance coverage) for the diversity of UAS: from model airplanes or toys to the most sophisticated and highest MTOM, with a clearly outdated criterion in view of recent (EU) regulations based on the level of risk assumed by these drones. At the same time, the possibility of cross-border accidents (in which the nationality of the operator and the place of the harmful event do not coincide) will highlight the legal uncertainty caused by the lack of a supranational regulatory framework.

From another perspective, it should be noted that both Art. 4 LNA and Chapter IX "aeronautical easements" LNA are basically designed for one of the cases that gives rise to the most claims in other laws: damages resulting from abnormal noise generated by aircraft, the compensation of which has been rejected by the courts of other countries,

according to the classical interpretation of Art. 1.1 Rome Convention, since the leading case "Causby vs. US Supreme Court of USA May 27, 1946"; and this despite the criticism of the doctrine that considers that it should be included in the scope of application of the aforementioned international instrument.

In Spain, to date, the obligation to comply with the noise levels, overflights, frequencies, and environmental impacts generated by air navigation, in accordance with the regulations governing air traffic, has been of particular importance in the vicinity of airports, due to the acoustic impact caused by aircraft. Furthermore, in the context of rescue operations or assistance to aircraft in distress, the owners or possessors of property may not oppose the entry or passage of their property (art. 153 LNA), with the possibility of compensation for damages caused by such actions, or in the case of property affected by the easements of art. 151 LNA, as provided for in art. 154 LNA.

Regarding Art. 4 LNA, we understand that the regulation was intended for noise nuisance caused by manned aircraft to the population in the vicinity of airports, but not for UAS. It should be noted that aerodromes, which would currently include airports according to the current definition of Law 48/1960 on Air Navigation, must be subject to the environmental impact assessment procedure of the project, as provided for in Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment and in the national regulation, Law 21/2013, of 9 December, on Environmental Impact Assessment. It is in this procedure that noise is assessed for the first time in the permit. The noise regulation, derived from Directive 2002/49 on Environmental Noise, defines immission values for both indoor and outdoor areas. Large infrastructures of public interest (public use airports) have the tools to define protection zones (acoustic easements) where both targets and limits can be exceeded in the defined area. Urban development may be restricted in these zones, which will impose costs on the operator for corrective and compensatory measures. Restricted use aerodromes do not have these privileges.

Regarding drones, regulation is currently scarce and insufficient. Thus, in terms of Community regulations applicable to drones, basically the Commission Delegated Regulation (EU) 2019/945, of March 12, 2019, the Commission Implementing Regulation (EU) 2019/947, of May 24, 2019, and the Commission Implementing Regulation (EU) 2021/664, of April 22, 2021) on U-Space (together with those that amend them, 2020/639, 2020/746), it is noted that they basically aim to cover issues related to safety and security and, in particular, address the preventive prism of drone operations and requirements in the production chain. This regulation, of successive articulation in the short term, favors the identification of the civil liable party, which falls on the figure of the UAS operator and establishes three operational categories (open, specific and certified), depending on the different factors that determine the degree of risk assumed with respect to third parties on the ground, as well as in relation to other manned aircraft.

This European regulatory framework, in relation to the issue at hand, focuses on aspects related to aviation safety, including the will to establish requirements to try to mitigate risks related not only to flight safety, but also to privacy, environmental protection and noise at unacceptable levels, among other aspects[21]. For example, in the

[21] Such provision of U-space services may facilitate the definition of areas with respect to acceptable noise levels in time and space and which can support foreseen planning of flights through these areas (e.g. geo-fencing services to protect

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"specific" category, in order for the competent authority to carry out a risk assessment, the operator must submit a "declaration", Art. 12.2 c) Regulation 947, confirming that the intended operation complies with all applicable Union and national rules, in particular with regard to privacy, data protection, liability, insurance, security in the sense of protection against attacks, most likely cyber-attacks (security) and the environment. Classes C0, C1, C2 and C4 may only be powered by electricity.

However, it remains to be satisfactorily regulated the means of assessment (and thus indirectly the determination of the best protection) in relation to noise with respect to drone overflights in urban areas, which is discussed in section four[22].

3.- NOTES ON THE REGULATORY NEEDS FOR THE IMPLEMENTATION OF URBAN AIR MOBILITY IN SPAIN

In the medium term, transport will be provided by electric aircraft with vertical take-off and landing, controlled remotely or with a pilot on board. By 2030, 340 million people are expected to live in EU cities and experience UAM. Specifically, commercial operations in EU cities are expected to start around 2025 with the delivery of goods by drones as well as passenger transport by unmanned aircraft[23]. Therefore, as warned in the report "Drone Strategy 2.0 for Europe to foster sustainable and smart mobility"[24], the role of municipalities will be crucial in terms of regional planning in urban and rural areas and the creation of specific infrastructures to host landing sites or take-off and landing areas. Local administrations must be involved and able to convey a message of certainty and transparency to society about what, how, when, and where innovative air mobility will be deployed. The participation of citizens in controlled test areas, living laboratories and demonstrations should be encouraged to include local and regional aspects in the final decision on the deployment of innovative air mobility.

At the Spanish level, in line with the aforementioned EU policy of promoting multimodal logistics and sustainable mobility, the so-called smart mobility is one of the main axes within the Strategy for Safe, Sustainable and Connected Mobility 2030, approved by the Council of Ministers on December 10, 2021[25]. Focusing on the section dedicated to the promotion of the "use of drones", we highlight the measures aimed at continuing the work to make authorizations for drone flights more flexible and faster, facilitating tests and trials for innovation projects in the field of drones, the plan for the deployment and operation of the common infrastructure for the implementation of U-Space, measures aimed at developing projects to promote the use of drones in cities and the plan for the

privacy as well as environmentally sensitive areas such as bird protection zones, etc.) EASA Opinion n. 01/2020 EASA, pp. 39-40.

[22] US Supreme Court of USA 27 May 1946" has planned to establish the limits on the ability of drone operators to fly over private property and the factors for determining what would or would not be *substantial interference*, where there was no negligence in the act, KURTZ, Paul M., "Memorandum Uniform Tort Law relating to Drones Act", *Uniform Law Commission*, 2019.

[23] According to the forecasts in EMC App. 9, which also covers hydrogen powered aircraft, electric personal air vehicles and electric waterborne transport, EMC App. 64 and in the report provided by EASA available at https://www.easa.europa.eu/what-is-uam.

[24] Drone Strategy 2.0, *op. cit.*

[25] https://esmovilidad.mitma.es/ejes-estrategicos/movilidad-inteligente

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protection of airports against the malicious use of drones. Directly related to the objectives described above, another field of action is the "Promotion of Research, Development and Innovation in Mobility", where measures will be taken to promote actions to support start-ups and innovative developments in the field of mobility and the creation of a regulatory sandbox.

Urban Air Mobility (UAM), which is part of the European Digital Strategy and the Smart Cities policy - embodied in Spain in the National Smart Cities Plan - contributes to this policy with sustainable and alternative transport in large cities, with the aim of reducing road congestion, as well as faster access to certain places and reducing carbon emissions. In March 2022, the government approved the Strategic Project for Aerospace Economic Recovery and Transformation (PERTE), which aims to strengthen aerospace capabilities and promote the green and digital transition of the sector through R&D&I[26].

Finally, and as the most important milestone from a legal point of view, it should be noted that MITMA's Intelligent Mobility Strategy was mainly supported by a forthcoming legal regulatory instrument, namely the draft Sustainable Mobility Law, dated 27 January 2023, which, however, lapsed with the dissolution of the Spanish Parliament[27]. Nor did it address specific issues related to the UAM, whose articles were essentially programmatic, with the exception of the appropriate regulation of regulatory sandboxes or controlled test areas, necessary prior to the implementation and integration of automated vehicles in cities in general, whose analysis we have studied in detail in other works already published[28].

Therefore, the current situation in Spain is that there is a starting deficit for the integration of drones in urban spaces under the new paradigm of sustainable mobility since the regulation that would govern this new model of sustainable mobility has not yet been approved. Current drone regulations are made up of several European regulations (basically the Commission Delegated Regulation (EU) 2019/945 of March 12, 2019, the Commission

[26] Aerospace is a strategic sector in Spain, accounting for almost 1.2% of national GDP and 5.4% of industrial GDP. The PERTE Aerospace plans to mobilise around 4,533 million euros between 2021 and 2025, with a public sector contribution of around 2,193 million euros and a private investment of around 2,340 million euros, source: https://www.ciencia.gob.es/Noticias/2022/Marzo/El-Gobierno-aprueba-el-PERTE-Aeroespacial--que-prev--movilizar-cerca-de-4.500-M--para-impulsar-la-I-D-I-en-el-sector-aeron-utico-y-del-espacio.html

[27] Yolanda B. Bustos Moreno: "La responsabilidad civil en los espacios controlados de pruebas (regulatory sandboxes) sobre movilidad aérea urbana y la futura Ley de movilidad sostenible", *Cuadernos de derecho privado*, Nº. 2, 2022, págs. 8-49, https://cdp.editorialbercal.es/index.php/cuadernos/article/view/16/12; Yolanda B. Bustos Moreno: "Análisis sobre las medidas de apoyo legal a la experimentación en tecnologías innovadoras", *Revista Española de Derecho Aeronáutico y Espacial*, N.º 2 (Septiembre), 2022 (Ejemplar dedicado a: In memoriam excmo.sr.d. Rodolfo A. González-Lebrero), págs. 319-346, https://aedae-aeroespacial.org/wp-content/uploads/2022/09/Revista-AEDAE_2022_digital-27-09.pdf

[28] C hapter II, entitled "automated vehicle", began with a legal precision of a *programmatic nature* applicable in principle to any type of automated vehicle. Thus, the explanatory memorandum stated that: "innovation in unmanned, connected or automated vehicles is constant, including in this field both drones or unmanned aircraft (UAS) and automated road vehicles, trains and autonomous nautical vessels". It stated that, from a safety point of view, each type of vehicle has a sectoral regulatory framework, both at European and sometimes at national level. Therefore, it was not the purpose of this law to regulate the operation of vehicles and their safety conditions. Furthermore, 2.3 ALMS, segregated the concept of "automated vehicle" to refer to motor vehicles on public roads or roads for public use referred to in Chapter II of Title V.

Implementing Regulation (EU) 2019/947 of May 24, 2019, and the Commission Implementing Regulation (EU), with a separate mention of the U-space regulation). At the regulatory level, Royal Decree 1036/2017 of 15 December is still in force in Spain, although partially and tacitly repealed, pending the approval of the Royal Decree that replaces it as an adaptation of the EU regulations to regulate mainly non-EASA operations.

Regarding the implementation of U-space in Spain, it is necessary to start from its European regulatory framework, articulated in the Implementing Regulations (EU) 2021/664, (EU) 2021/665 and (EU) 2021/666. Its deployment at national level, established by MITMA, is materialized through the PANDU (National Action Plan for the Deployment of U-space)[29]. PANDU can be considered as a roadmap for urban development - which includes Urban Air Mobility (UAM) - and the necessary harmonization between public administrations, such as city councils, together with all actors of the sector, where the lines of action and the necessary coordination for the implementation of this new system during the period 2022-2025 are defined[30].

Despite the above-mentioned National Action Plan for the deployment of UAS, in short, sharing the opinion expressed by Silvia del Saz, it can be said that we have a regulatory framework that, despite its youth, is already inefficient to address the integration and implementation of drones in urban environments[31]. Precisely for this reason, she emphasizes that the regulatory authority must first develop the desired regulatory model; for example, it must decide whether and how to allow or prohibit aerial operations with passengers or the transport of goods in urban environments. If so, it must be determined under what model and under what circumstances. Only then, once the model has been conceived, should the regulation that gives it life be enacted, because without it, without that model, it is unlikely that there will be an effective - and full - development of UAM.

In fact, although, as is well known, the normative regulation, planning and management of airspace is an exclusive competence of the State, the necessary cooperation of the various public administrations in the implementation of the of U-SPACE, it follows that the Community regulatory framework assigns a participatory role to EASA in spatial risk assessment, in requesting additional U-SPACE services, as well as in participating in the establishment of

[29] MITMA's National Action Plan for the Deployment of U-Space has been establishing general protocols with autonomous communities to carry out joint projects that contribute to digital and technological development in the provision of aeronautical services, as well as with certain municipalities.

[30] For more information on these actions, see Portal for the Coordination of U-space in Spain - Ministry of Transport, Mobility and Urban Agenda (https://www.mitma.gob.es/aviacion-civil/politica-espacio-aereo/portal-para-la-coordinacion-del-u-space-en-España); https://www.europapress.es/turismo/transportes/aeropuertos/noticia-enaire-invierte-mas-13-millones-euros-plataforma-gestion-automatizada-digital-drones-20210826134510.html ;220208_plan_de_de_de_deployment_u-space_vfinal_acordada.pdf (mitma.gob.es). Victoria González, representative of ENAIRE, informed us about the importance of participating in European projects, such as the U-ELCOME | EUROCONTROL project that will be carried out in 8 Spanish Autonomous Communities, demonstrating a complete U-space ecosystem with all the necessary actors (USSPs, CISP, UAS operators, administrations...). Projects such as this and others in Europe are the path that ENAIRE is following for its certification as a CISP and USSP. All of this is focused on U-space deployment, thus giving impetus to the development of the UAM, *Innovative Air Mobility Noise Impact in the Urban Areas – Regulatory Proposal* Workshop IV Legaldrone Congress**/**EXPODRÓNICA. Airspace Integration Week Madrid, AEDAE, dir. Yolanda Bustos, 28/09/2023.

[31] Silvia del Saz, Of Counsel of Andersen in the area of Public and Regulatory Law and Professor of Administrative Law, at *Innovative Air Mobility Noise Impact in the Urban Areas – Regulatory Proposal* Workshop IV Legaldrone Congress**/**EXPODRÓNICA. Airspace Integration Week Madrid, AEDAE, dir. Yolanda Bustos, 28/09/2023.

airspace restrictions. It responds to the recently adopted Sustainable Mobility Decree of Madrid[32]. It will be essential for the implementation of the U-Space and, in addition, from a broader and more integrative perspective, the set of competences of the municipalities, in order to integrate the development of urban air mobility within the urban mobility as a whole, in a way fully compatible with the guarantee of the rights of the citizens and the general interests, whose promotion is legally attributed to the City Council of Madrid[33].

Finally, we would like to make one more point in this section. The legislator has not yet resolved this issue. And is that, if we assume that they are of general interest for the Member State and have priority in terms of urban, the question we can ask ourselves is whether they have priority for U-space ports and corridors over development and urban noise maps[34]. Similarly, it will be necessary to clarify whether future U-space corridors/routes and vertiports will be considered according to their use (sanitary, logistic, public services), as today there are exceptions for Heliports for health and public services (e.g., police) [35]. It seems, after that ENAIRE, in the development of its digital platform U-Space, has taken into account the non-EASA operations, such as police or emergency operations, will be privileged as users. Privileged for all that their role in society entails in terms of public safety[36].

However, one of the biggest obstacles to the new Air Mobility is the noisy environment, which means introducing the new aircraft to a place where there have been no aircraft, except for emergency or public services (e.g., police).

Although there are other scenarios, such as Sao Paulo (Brazil), where hundreds of helicopters fly over the city, in Spain we have the assessment of the environmental noise generated by drones in the urban environment is a pending issue. In the urban environment, this is a problem that will be described in the following section.

4.- NOISE IMPACT OF INNOVATIVE AIR MOBILITY IN URBAN AREAS

Of all the issues identified as problematic for the implementation of Innovative Air Mobility (IAM), the most problematic and unresolved is undoubtedly the impact of noise in urban areas. In the following pages, we will

[32] This is not really an ordinance, but the creation of the Urban Aerial Mobility Commission of the Madrid City Council, a pioneer in Spain, along with some other cities. This Air Mobility Commission Urbana will be aimed at articulating dialogue and institutional collaboration with the rest of the Public Administrations involved. https://sede.madrid.es/portal/site/tramites/menuitem.b4c91589e7f6a5d829da39e5a8a409a0/?vgnextoid=28c005d7307ba810VgnVCM1000001d4a900aRCRD&vgnextchannel=741d814231ede410VgnVCM1000000b205a0aRCRD&vgnextfmt=pd

[33] Measures explained by Federico Jiménez de Parga Maseda, General Coordinator of Mobility of the Madrid City Council, who also pointed out the municipal interest of the possible urban taxes, at *Innovative Air Mobility Noise Impact in the Urban Areas – Regulatory Proposal* Workshop IV Legaldrone Congress**/**EXPODRÓNICA. Airspace Integration Week Madrid, dir. Yolanda Bustos, 28/09/2023.

[34] U-Space airspaces'will be established as geographical UAS areas designated by Member States, where drone operations will only be allowed to be conducted with the support of U-Space services (Art. 2.1 Regulation (EU) 2021/664).

[35] Questions raised by the sector, Marta Cejuela, Safety and Regulatory Consultant of Abionica, at *Innovative Air Mobility Noise Impact in the Urban Areas – Regulatory Proposal* Workshop IV Legaldrone Congress**/**EXPODRÓNICA. Airspace Integration Week Madrid, AEDAE, dir. Yolanda Bustos, 28/09/2023.

[36] Victoria González Otón, Director of Strategy and Innovation, Drones Business Development Department,) at *Innovative Air Mobility Noise Impact in the Urban Areas – Regulatory Proposal* Workshop IV Legaldrone Congress**/**EXPODRÓNICA. Airspace Integration Week Madrid, AEDAE, dir. Yolanda Bustos, 28/09/2023.

analyse the specific aspects required for the assessment of aircraft noise and, in particular, the noise emitted by UASs, the consultation documents drawn up for this purpose by certain EU bodies, such as the EASA, and certain technical projects. Ultimately, we will present some conclusions in the form of recommended lines of action by experts in the field[37].

4.1. Noise emissions from aircraft and their infrastructure (aerodromes)[38].

From the technical point of view of the regulations on the assessment of environmental noise and, in particular, aircraft noise, the following points and considerations must be taken into account, which EVA SANTOS presents in detail. Firstly, the difference between emission and immission (art. 12 Law 37/2003) [39]. Emissions are regulated in a sectoral manner, i.e., it is the aeronautical standard that must define the methods for measuring the noise emitted by vehicles, as well as the limits for each type of aircraft, similar to what is currently done in Annex 16 of the ICAO. On the other hand, immissions refers to noise levels at receptors (people or buildings)[40]. It is regulated by environmental noise legislation, the European Directive 2002/49/EC. Noise indicators, methods for assessing environmental noise and the obligations of authorities to protect the public and to try to reduce these levels have been defined in a common way in Europe. Each European Member State has set its own acceptable levels, based on international recommendations on the effects of noise levels on human health.

As we have already explained, aerodromes, which would include vertiports according to the current definition of art. 39 of Law 48/1960 on Air Navigation, must undergo the project's environmental impact procedure, in accordance with the provisions of the Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment, and in our national regulations, Law 21/2013 of 9 December, on Environmental Impact Assessment. It is in this procedure that noise is assessed for the first time as part of the authorisation process.

The noise regulations[41], derived from the Environmental Noise Directive 2002/49, define immission values for both indoor and outdoor areas. Aircraft noise, including jet aircraft, helicopters and now UAS, and their

[37] Most of the materials and documents on display have been provided by the participants at *Innovative Air Mobility Noise Impact in the Urban Areas – Regulatory Proposal* Workshop IV Legaldrone Congress**/**EXPODRÓNICA. Airspace Integration Week Madrid, AEDAE, dir. Yolanda Bustos, 28/09/2023, https://airspaceintegrationweekmadrid.com/wp-content/uploads/sites/53/2023/09/AI23-PROGRAM-SKELETON-9.pdf;

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[38] It should be noted that throughout this section, the statements made by this specialist, Eva Santos Gónzalez, *Project Coordinator. Environmental and Aeronautical Noise Advisor. SENASA*, at *Innovative Air Mobility Noise Impact in the Urban Areas – Regulatory Proposal* Workshop IV Legaldrone Congress**/**EXPODRÓNICA. Airspace Integration Week Madrid, AEDAE, dir. Yolanda Bustos, 28/09/2023.

[39] *Annex 16 - Environmental protection - Volume I - aircraft noise. 8th Edition, July 2017. ICAO - International Civil Aviation Conference.*

[40] *Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise. Revision in force since 29 July 2021. DOUEL no. 189 of 18 July 2002.*

[41] According to art. 14 of Royal Decree 1367/2007, of 19 October, which implements Law 37/2003, of 17 November, on Noise, with regard to acoustic zoning, quality objectives and acoustic emissions, a distinction is made between noise quality objectives and limit values. Large infrastructures of General State Interest (airports for public use) have

infrastructure ("aerodromes"[42]) are mobile emitters and therefore generate noise events, not continuous noise. Their immissions need to be assessed not only for the single passage of an aircraft, but for the aggregation of noise events from different aircraft over a period of time (assessment period). Currently, the approval of new aerodromes is subject to the Environmental Impact Assessment (EIA) procedure for projects, which assesses, among other environmental impacts, the noise in the vicinity of the infrastructure by means of predictions prior to approval. However, operations/infrastructure for emergency health and fire-fighting purposes, as well as those of the State Security and Military Forces and Corps, are exempted from compliance with noise quality objectives.

The routes established for the operation are also a concentration of noise events, but unlike other transport infrastructure, the level of immission level at the receptors decrease with increasing distance to the ground infrastructure with increasing altitude. Preventive or corrective measures in the transmission medium are not considered feasible, i.e., aircraft noise cannot be shielded by barriers. The most effective corrective measure when outdoor levels are exceeded is the insulation of buildings, but this is a very costly measure that does not solve the outdoor levels. It should also be noted that the psychological factor of perception is particularly important. There are psychosocial (non-acoustic) factors that make aircraft noise more annoying than other modes of transport at the same measured levels[43].

4.2. Specific aspects of UAS/UAM noise and future challenges

Firstly, the variability and diversity of the type of UAM systems/vehicles and their mode of operation is well known, while only a few systems have been acoustically characterised[44]. A standard for acoustic certification being developed and will be reported later, although ICAO proposes that the index should be similar to those already in Annex 16 Vol 1[45].

From a technical point of view, there is a need to establish assessment index that correspond to the annoyance[46]. The assessment methods should be predictive. At the same time, these methods need to be based on noise

mechanisms to define protection zones (acoustic easements) in which both objectives and limits can be exceeded in the delimited area. In these zones, urban development can be restricted, which implies costs for the airport operator in terms of corrective and compensatory measures. Restricted-use aerodromes do not enjoy these privileges, as referred to in the NOTE

[42] The infrastructures for their operation are places of concentration of noise events and therefore of the noise accumulated in the period. According to current regulations, all of them (including landfills) are considered aerodromes.

[43] Brink, M., Schäffer, B., Vienneau, D., Foraster, M., Pieren, R., Eze, I. C., Cajochen, C., Probst-Hensch, N., Röösli, M., & Wunderli, J. M. (2019). A survey on exposure-response relationships for road, rail, and aircraft noise Annoyance: Differences between continuous and intermittent noise. Environment International, 125, 277-290. https://doi.org/10.1016/j.envint.2019.01.043

[44] Rizzi, S. A. (2020, 1 October). Urban Air mobility noise: Current practice, gaps, and recommendations. NASA Technical Reports Server (NTRS). https://ntrs.nasa.gov/citations/20205007433

[45] Guidelines on noise measurement of unmanned aircraft systems lighter than 600 kg operating in the specific category (Low and Medium Risk) | EASA. (2023, 11 September). EASA. https://www.easa.europa.eu/en/document-library/product-certification-consultations/guidelines-noise-measurement-unmanned-aircraft

[46] For auralisation projects and further psychoacoustic studies, see: Alkmim, M., Cardenuto, J., Tengan, E., Dietzen, T., Van Waterschoot, T., Cuenca, J., De Ryck, L., & Desmet, W. (2022). Drone noise directivity and psychoacoustic evaluation

emission and performance databases of the UAS to be modelled, which differ from the certification values in terms of the method for obtaining them[47].

It is well known that UAS have to comply with height restrictions in corridors or routes in an urban environment so as not to interfere with the airspace of other types of air transport, which makes it difficult to keep them away from ground receptors (people at ground level or buildings at height) and thus potential high levels along the entire route. It follows from the above that different noise assessment heights may be required for ground (Vertiport) and air (Corridor) infrastructure due to possible receptors at different heights, which is not the case for any other transport infrastructure. This will, with some degree of certainty, mean that it will be difficult to set restrictions on urban development or exemptions from meeting noise quality objectives if there is no public interest in the infrastructure. Therefore, it is very likely that the public will reject the project based on two elements to devaluate. Both the added psychological factor in the UAM on the perception of the receivers due to the uncertainty of the new technology, and that UAM´s private use cases would not necessarily be a public service benefiting all[48]. Awareness-raising and sensitisation activities may need to be considered for those involved in the design, construction, management and operation of airports and aircraft, as well as for users and the general public[49].

In view of the challenges outlined above, there are several issues that need to be taken in the specific noise regulations for UAM, as well as in the technical adaptation of environmental regulations. These include coordination and cooperation between the various administrations responsible for noise, aviation, urban planning, and the environment at national, European, and international levels. The articulation of specific assessment mechanisms in the initial authorisation of Vertiports, different from what is currently established in the legislation on environmental assessment of aerodrome projects, both in terms of environmental impact assessment and their specific method of noise prediction/assessment and control, considering whether they should be included as a new group of projects in the regulations. The most appropriate assessment metrics for UAM noise should be defined, including how UAM noise will be included in existing strategic noise maps of cities. Finally, it may be necessary to redefine the cases of exemption from the noise quality objectives, in addition to health emergencies, fire-fighting, etc., to include other cases where the UAM can provide a public service.

4.3. EASA actions

Aircraft noise certification is an important process to ensure that the latest available safe and airworthy noise abatement technology is incorporated into aircraft design. In this respect, the European Aviation Safety Agency

using a hemispherical microphone array. Journal of the Acoustical Society of America, 152(5), 2735-2745. https://doi.org/10.1121/10.0014957

[47] Kapoor, R., Kloet, N., Gardi, A., Abdel-Rohman, M., & Sabatini, R. (2021). Sound Propagation Modelling for Manned and Unmanned Aircraft Noise Assessment and Mitigation: A review. Atmosphere, 12(11), 1424. https://doi.org/10.3390/atmos12111424

[48] Study on the societal acceptance of Urban Air Mobility in Europe. EASA (2021, 19 May). https://www.easa.europa.eu/sites/default/files/dfu/uam-full-report.pdf

[49] As concluded by Eva Santos, who also raises the various unresolved questions that we set out in the text below, *op. cit*.

(EASA) plays an important role in the certification process. EASA certification noise levels are approved as part of the aircraft certification process and are established in accordance with the applicable noise standards defined in ICAO Annex 16, Volume I. These noise levels serve as the basis for the National Aviation Authorities of the EASA Member States to issue individual noise certificates to aircraft on their register using EASA Form 45. As mentioned above, when EASA conducted a Europe-wide survey on Urban Air Mobility at the end of 2021, noise was highlighted as one of the main concerns of participants regarding air taxis, along with environmental concerns and safety in general. Hence, EASA has published the first global proposal for the assessment of noise emitted by air taxis (4th May 2023) and guidelines for the determination of noise levels for drones below 600 kg, which aim to provide harmonised procedures for the measurement of noise emitted by drones used in low and medium risk operations in the "specific" category.

Regarding to noise from vertiports, in the name of subsidiarity, it does not fall within EASA´s competence and is therefore the prerogative of the NPAs or local authorities. However, EASA is involved in supporting local authorities in this task. Regarding noise from drones or eVTOLs, EASA has a project to collect noise data (hemispheres) around such vehicles, which can then be used to support the development of local noise maps. These consultation documents are summarised below.

A) Consultation document: Environmental Protection Technical Specification (EPTS) applicable to eVTOL powered by multiple, vertical, non-tilting, evenly distributed rotors | EASA[50]*.*

The noise technical specifications were inspired by the content of ICAO Annex 16, Volume I, Chapter 8 and the associated assessment method in Appendix 2, and the ICAO Environmental Technical Manual (ETM) guidance material applicable to heavy helicopters, to allow for a level playing field and comparability of technology.

The procedures are expected to be adapted to the characteristics of eVTOL aircraft with multiple vertical, non-tilting and evenly distributed rotors where necessary, e.g., by extending the lower test height limit to anticipate the lower acoustic signature of such designs, or by allowing a more refined source noise correction than for classic helicopters. In addition, a stationary flight noise assessment has been developed to facilitate the noise assessment of operations in the vicinity of vertiports. The maximum permissible noise levels remain identical to the latest International Civil Aviation Organisation (ICAO) limits for heavy helicopters (ICAO Annex 16, Volume I, Chapter 8.4.2), while EASA is collecting more noise data on such designs through certification projects.

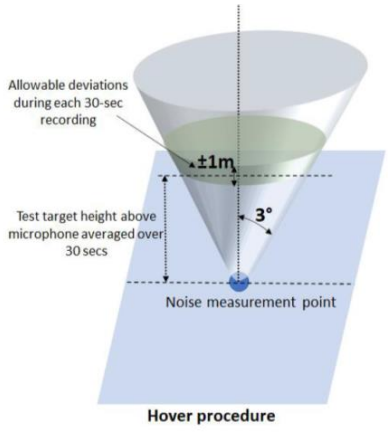


Figure 5: depiction of allowable flight boundaries for the hover procedure

[50] The analysis of this consultation document reflected in the text comes from Marta Cejuela, *op. cit.* https://www.easa.europa.eu/en/document-library/product-certification-consultations/consultation-paper-environmental-protection

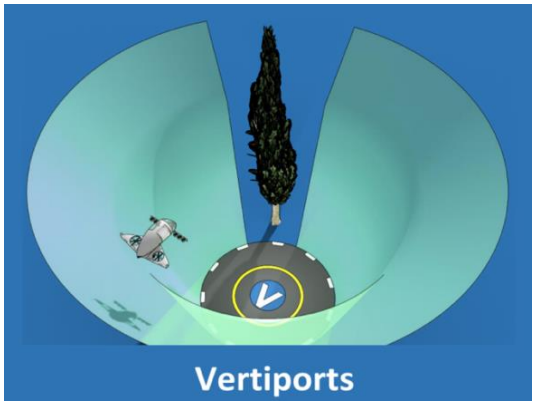
B) Environmental research - rotorcraft noise | EASA[51].

The objective of this study was to conduct a psychoacoustic study of annoyance caused by helicopters and rotor drones. A single-event laboratory dose-response analysis was conducted with participants rating UAM sounds by self-reporting an annoyance score per event. Participants were seated in front of a computer that played the sound events and listened to the events through headphones.

The study presents dose-response relationships for a new class of aircraft, namely four drones and an air taxi. A small fixed-wing aircraft and two helicopters were also included as reference measurements. The A-weighted sound exposure level (SEL) was used to determine the input sound levels ("doses") of the stimuli. The measurement results show higher predicted annoyance rates for each vehicle as the SEL values increase. Differences are observed between the high annoyance ratings of the helicopters (lower) and the other vehicles (higher), especially at SEL values above 70 dB(A). The fixed-wing aircraft also scored similarly to the drones but was also equipped with electric motors similar to those of the drones, which produced similar noise. The annoyance ratings of the air taxis were similar to those of the drones and were rated as more annoying than the helicopters at the higher SEL values. The greater annoyance may be related to the unfamiliarity of the drones and air taxis compared to the helicopters, although this was not investigated.

c) Technical specifications of the vertiports prototype PTS-VPT-DSN[52] .

EASA has also published the first guidelines for the design of spillways to provide new and innovative solutions specifically for congested urban environments, such as the concept of a funnel-shaped area above the spillway designated as an obstacle-free volume.



This concept is adapted to the operational capabilities of the new VTOL aircraft, which can perform landings and take-offs with a significant vertical segment. Depending on the urban environment and the performance of certain VTOL-capable aircraft, omnidirectional approaches to vertiports will also be possible. Such approaches can more easily take into account environmental and acoustic constraints and are therefore better suited to an urban environment than conventional heliport

[51] The analysis of this consultation document reflected in the text comes from Marta Cejuela, *op. cit.* https://www.easa.europa.eu/en/research-projects/environmental-research-rotorcraft-noise
[52] The analysis of this consultation document reflected in the text comes from Marta Cejuela, *op. cit.* https://www.easa.europa.eu/en/document-library/general-publications/prototype-technical-design-specifications-vertiports

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operations, which are more limited in the approaches that can be safely implemented.

D) Guidelines on noise measurement of unmanned aircraft systems of less than 600 kg operating in the specific category (low and medium risk) - EASA[53].

This document is important because it provides UAS manufacturers and designers with the first guidelines towards which the regulator is guiding the process of standardising the measurement of noise generated by UAS, although manufacturers or operators may voluntarily measure noise in accordance with these guidelines and submit the data to EASA.

The procedure is technically complete and requires a great deal of preparation: it underlines the need for positioning by satellite positioning or photogrammetry, takes into account the effect of atmospheric conditions on sound propagation, specifies appropriate correction factors, etc. It also requires the declaration of a series of very interesting data, such as maximum take-off weight (MTOW), dimensions, number of propellers or rotors, rotor orientation, number of blades, blade diameter, engine power, speed... as well as the model or designation of the UAS, engine and propellers.

Although it is a technically robust document, it focuses exclusively on obtaining the sound level. Nonetheless, there is a fundamental difference between sound level and noise. The former is a physical property, mathematically, and technically quantifiable, of any sound. Noise, on the other hand, is defined as "inarticulate sound, generally unpleasant"[54]. In other words, it is a fundamentally *qualitative* definition, not a *quantitative one*.

Despite decades of psychoacoustic research, it is still not possible to determine with certainty what physical parameters define when a sound becomes noise. All that remains is to conduct auditions to determine how unpleasant a sound is. In the specific case of UAS, we have the recent *Urban Air Mobility Survey* by EASA[55], which includes a section on annoyance caused by UAS noise. Listening was carried out with panels in various cities, scoring from 1 to 10 how annoying the sound of various means of transport (cars, bicycles, motorcycles, airplanes, helicopters...) and UAS of different sizes was. It is important to emphasize that the sounds were reproduced at the same sound level (80 dBA). Nevertheless, the sound of the UAS was twice as annoying as, for example, that of a city bus. This is a very relevant result, with profound implications for the "acceptability" of urban UAS operations.

If we analyze the flight physics of a typical UAS, for example a quadcopter, we get clues as to why they are so unpleasant[56]. Their fundamental source of noise is the propellers. Two factors come into play: frequency, and variability. The typical size of UAS propellers requires a rotational speed that, together with the usual number of

[53] The analysis of this consultation document, reflected in the text, comes from Jorge García Tíscar CMT - Clean Mobility & Thermofluids, Universitat Politècnica de València, *Innovative Air Mobility Noise Impact in the Urban Areas – Regulatory Proposal* Workshop IV Legaldrone Congress**/**EXPODRÓNICA. Airspace Integration Week Madrid, AEDAE, dir. Yolanda Bustos, 28/09/2023. https://www.easa.europa.eu/en/document-library/product-certification-consultations/guidelines-noise-measurement-unmanned-aircraft

[54] Dictionary of the Royal Spanish Academy (RAE)

[55] https://www.easa.europa.eu/sites/default/files/dfu/uam_detailed_survey_evaluation.pdf

[56] Christian, A. W., & Cabell, R. (2017). Initial investigation into the psychoacoustic properties of small unmanned aerial system noise. In *23rd AIAA/CEAS aeroacoustics conference*

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blades (mainly 2, but sometimes 3 or 4), leads to frequencies of the order of the kilohertz, which are in a particularly sensitive range for the human ear. In addition, multicopter UASs have a fundamental difference from propeller planes or helicopters. Attitude control is performed, not through the variation of the propeller pitch, but directly through small variations in the rotational speed of the different motors[57]. This means that the sound frequency of these devices is not constant, but varies slightly and continuously around the equilibrium point, a quality that instinctively reminds us of the sound produced by the flight of insects, and which is related to the popular nickname of "drone" for these aircraft.

In any case, given that the same sound may be perceived as unpleasant or not, or unpleasant by different people, the legislator has generally chosen to reduce noise levels to levels considered acceptable by the public. This can be seen from the results of the survey mentioned above: the same air taxi reduces its perceived annoyance level from 8 to 3 when moving from a noise level of 80 dBA to a level of 60 dBA. It is therefore questionable whether it is justified to focus only on the noise level, as the EASA guidelines do, and not on the frequency components of the noise. However, it remains to be determined what level of noise from UAS can be considered acceptable to the public, which will be different from what is considered acceptable from a bus or a car.

4.4. From the generation to the reception (or immission) of noise by the UAS.

So far, the starting point has been the generation or emission of noise by the UAS. However, we have just seen that it is not this that is critical from the point of view of the annoyance caused to citizens, but rather the reception (or immission) of the noise that causes the annoyance. It is therefore necessary to study the relationship between the generation and reception, i.e., the propagation, of noise in urban environments[58]. The final objective is to obtain the so-called noise maps, which show the level of noise generated by a given source (a road, a railway, an airport or, in this case, a landfill or an airstrip) in its surroundings.

Without going into detail about the complex physics of sound transmission, let us discuss some basic aspects that influence it:

- Frequency: low-frequency (low-pitched) sounds are less attenuated as they propagate than higher-pitched sounds (something most people have experienced when walking up to a concert: first you hear the bass and then gradually the rest of the music). Therefore, the fewer blades and the lower the rotation speed (and therefore the lower the bass), the greater the distance at which the UAS will be audible.

- Reflections and scattering: Sound waves bounce off hard surfaces and also scattered around corners. This is critical in the urban environment: as UAS fly between buildings to avoid entering the airspace used by manned aircraft, bouncing and scattering will occur in the complex three-dimensional geometry that defines modern cities.

[57] Torija, A. J., Self, R. H., & Lawrence, J. L. (2019). Psychoacoustic characterisation of a small fixed-pitch quadcopter. In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings* (Vol. 259, No. 8)
[58] Siguiendo el estudio que realiza Jorge García, *op. cit*.

We can no longer assume that the propagation problem is two-dimensional, on one plane, but that we have to solve a complex three-dimensional problem.

- Absorption: Different materials absorb sound to a greater or lesser extend. Rigid surfaces such as concrete, asphalt, glass, steel, etc., reflect sound without absorbing much energy, while other materials found in the urban environment such as vegetation (bushes, trees, grass), soil, etc., contribute to its attenuation.

- Refraction: When a sound wave encounters differences in the atmosphere, it can change its path. This can be due to changes in temperature and humidity (an effect exacerbated by the heat island effect of modern cities), or wind speed at different heights or behind building wakes. The same effect can be seen in the way a straw appears to bend when inserted into a glass of liquid. In reality, it is the path of the light that bends.

4.5. Digital Models of the urban environment

In principle, the physical effects described in the previous section would have to be taken into account to produce noise maps for, say, the operation of a particular UAS route. Nevertheless, this would require immense computing power. Given the scarcity of scientific literature on the analysis of this problem, work is currently being carried out on the evaluation of each of these parameters, taking the city of Benidorm as a reference to clarify which are essential to take into account and which are secondary and can be ignored in a first approach[59]

. For example: should the wind pattern be taken into account, should the absorption coefficient of the different surfaces be taken into account, should temperature changes due to heat islands be taken into account, and if so, which ones?

The first step of building these *digital twins* consists of taking advantage of the Spanish data infrastructure, such as the National Aerial Orthophotography Plan, in its LiDAR variant (PNOA-LiDAR)[60], framed in the National Plan for Territory Observation (PNOT), which offers as a result a complete 3D scan of the national territory. In addition, the National Center for Geographic Information (CNIG), which depends on the DG of the National Geographic Institute, has used this data to build different Digital Surface Models[61], separated into terrain, buildings, and vegetation. There are also other sources of 3D building data such as the Cadastre[62], as well as various regional initiatives. As for atmospheric variables, the data bank of the National Meteorological Agency (AEMET) is available[63]. Thus, thanks to these efforts, raw information is available to tackle the three-dimensional problem.

Once the physical effects essential for modelling the propagation have been identified, it is proposed to study different numerical techniques to assess which is optimal in terms of accuracy and computational requirements.

[59] Project *Digital models for the evaluation and reduction of acoustic pollution generated by UAS in urban environments (MODERA)*, TED2021-131087A-I00, funded by MCIN/AEI/10.13039/501100011033
[60] https://pnoa.ign.es/pnoa-lidar/presentacion
[61] https://centrodedescargas.cnig.es/CentroDescargas/index.jsp
[62] https://www.catastro.minhap.es/webinspire/index.html
[63] https://www.aemet.es/es/datos_abiertos

There is also the problem of the complex wind pattern in the urban environment, if current research indicates that it is essential to take this into account, as detailed fluid dynamic simulations require the use of supercomputers, which would be prohibitive (expensive?) if the goal is to achieve a functional tool for everyday use. Hence, work is being done to obtain reduced-order models that allow wind patterns to be interpolated at any height and in any direction from a small number of reference simulations.

4.6. Digital UAS Models

However, to feed this digital twin of the urban environment, it may not be enought to assume that the UAS is a point source of noise. It is necessary to determine the directivity of the emission, i.e., what is the spatial pattern of the acoustic emission (we can imagine a sphere around the UAS, coloured according to the sound intensity at each coordinate of this sphere)[64]. Again, a reliable numerical simulation of this emission pattern requires the use of supercomputers (such a simulation carried out by NASA in 2019 required 801600 CPU hours, i.e., the equivalent of an office computer working continuously for 23 years). Therefore, it is necessary to investigate reduced models that can capture the acoustics of a UAS sufficiently well. One could start with simulations in which only the propellers are present, although initial results indicate that the presence of the fuselage can significantly increase the noise level in certain directions[65].

4.7. Conclusions[66].

While the IAM concept is still in the development phase and despite significant technological advancements in recent years, it still hasn't been introduced to large cities on a big scale, noise impact is one of the most burdensome problems of the conventional aviation – a problem that must be addressed as soon as possible and comprehensively to ensure the successful widespread introduction of UAS (Unmanned Aerial Systems) and IAM to the industry.

One of the main and initial points of the discussion was the analysis of noise abatement procedures and existing regulation. The participants agreed that the noise is a serious nuisance in urban areas, which is why it triggers numerous complaints and protests, inevitably forcing local and international authorities to take radical steps. While today's problems concern mainly jet-driven aircraft, which generate most of the urban aviation noise, IAM concept is more about rotor-driven aircraft which today operate on a much smaller scale and whose noise generation will

[64] *Yunus et al., Efficient prediction of urban air mobility noise in a vertiport environment,DOI 10.1016/j.ast.2023.108410*
[65] L. M. García-Cuevas, J. García-tíscar, P. Varela, F. N. Ramírez, Design of unmanned air vehicles with distributed electric propulsion: range improvement and noise emission, in: Proceedings of the Aerospace Europe Conference - EUCASS - CEAS, 2023. doi:10.13009/EUCASS2023-143.
[66] Conclusions reflected by Joanna Wieczorek, *Drone Alliance Europe Innovative Air Mobility Noise Impact in the Urban Areas – Regulatory Proposal* Workshop IV Legaldrone Congress**/**EXPODRÓNICA. Airspace Integration Week Madrid, AEDAE, dir. Yolanda Bustos, 28/09/2023

have to be carefully studied in terms of annoyance and possible intensity, especially IAM is expected to to undergo rapid development and become an integral part of urban life.

The participants highlighted that current local regulations generally emphasize the noise limitations, e.g., by defining a minimum cruise altitude over cities, departure and arrival procedure and air operators' operational procedure guidelines, as well as technological trends and requirements that determine the design of the newly-developed aircraft and engines. Taking into consideration the main objective of IAM, the participants agreed that with the IAM dynamic and functioning model, the issue of air traffic management will be problematic, and the field that may be the most efficient in minimizing noise emissions will most likely be technology.

Although scheduled air traffic currently accounts for the majority of noise emissions, some aviation sectors are excluded from the abatement requirements, including most vital services such as medical transportation or police. And while there's a big chance that a part of future IAM traffic will also fall into this category, according to the main objectives of IAM most of it would supply the non-critical services, which is why it will be restricted with strict noise abatement requirements.

The participants discussed the problem of noise that can realistically be generated by IAM in the future, also in terms of urban noise generated by non-aviation-related sources such as road traffic or industry. One of the comparasions given outlines Spanish vertiports (aerodromes dedicated for IAM) generate noise comparable to that of a bus station. Another example indicates that the noise generated by a typical unmanned aircraft representing IAM is comparable with a noise generated by a garbage truck.

The central point of the noise discussion focused on legal aspects accompanying the introduction of IAM into European industry. It was a subject to a debate who shall be responsible for environmental jurisdiction over the IAM-generated noise – whether it shall be local, State, or international authorities, and in the case of the latter – whether it would be regulated in terms of international law or just executive guidelines for contracting States. Existing regulations and guidelines were cited, such as the directive 2002/49/WE regarding noise assessment.

During the discussion, several completed projects and guidelines were outlined, including Prorotype Technical Specifications for the design of vertiports dedicated for VTOL, or Guidelines on Noise Level Measurements for Drones below 600 kg. The guideline addresses two main aspects: hover and cruise flight and takes into account numerous external factors affecting the noise, notably the environmental factors. EASA suggested that the guideline, should it be implemented by State authorities, may give a green light for a positive decision regarding wide-scale implementation of IAM in contracting States. EASA recommends the contracting States to perform measurements of noise and share them with EASA to improve knowledge on IAM environmental impact.

One of the projects that was discussed in detail was Jorge Garcia Tiscar's contribution 'Digital models for UAS noise assessment in the urban environment' that analyzes the EASA's abovementioned guideline. It points out that the terms noise and sound level should be considered separately, as the sound level is a physical quantity, while noise is understood in much wider, non-measurable context, including impact on human physiology and psychology. The work indicates that the level of noise is not as important as the type of noise, as different sounds may affect people differently due to specific component frequencies. Dr. García listed the following aspects that influence sound

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transmission and that should be subject of further analysis: frequencies, reflections and scattering, absorption, and refraction. He also emphasizes developing urban noise maps for UAS operations, but selecting only certain aspects due to the number and complexity of contributing factors, as well as limited computing or knowledge resources.

The discussion also addressed the newest proposal world-wide for the assessment of the noise generated by air taxis, issued in May and known as the Environmental Protection Technical Specifications (EPTS). It shall act as a guideline not only for designing e-VTOL, but also the vertiports, analogically to environmental analysis conducted prior to building traditional airports.

The participants also addressed the secondary issues, not directly associated with noise, e.g., concerns regarding air traffic and safety, privacy violations, air pollution and other environmental aspects, visual pollution, or the impact of future air traffic on the value of properties. These topics were not profoundly discussed, as they are not directly connected to the main topic of the panel.

In conclusion, the participants agreed that the problem of noise emissions generated by IAM aircraft is only one of many that the still new concept must face. It was noted that unlike the conventional aviation, IAM will have to overcome barriers of totally new and unseen challenges, as a new flying model and appropriate regulation and procedure design will have to be developed. No one is surprised that the IAM will mainly have to overcome the social barrier, whether it comes down to an interest in services offered by IAM or to safety, security, or privacy measures. Nonetheless, noise remains one of the most urgent issues to be addressed, as its high level can be one of the obstacles to the development of IAM. Hence, special emphasis is placed on both technological advances and regulating acts relating to noise limitation.