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COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION (CAEP)

STEERING GROUP MEETING

Takamatsu, Japan, 16 to 20 October 2023

Agenda Item 9: Noise Technical (WG1)

NOISE CERTIFICATION FOR NEW ENTRANTS TO PUBLIC AIRSPACE – U.S. ACTIVITY UPDATE

(Presented by the United States of America)

SUMMARY

This working paper presents U.S. progress in the area of noise from Emerging Technology Aircraft. An overview of various activities and efforts is provided.

Action by the CAEP-SG is in paragraph 7.

1. INTRODUCTION

1.1 This paper provides updates on developments regarding Emerging Technology Aircraft (ETA) in the United States, including current ETA noise certification approaches and recent research activities to understand noise from these aircraft. It summarizes U.S. activities supporting the ICAO Working Group 1 Task N.06: ETA noise measurement procedures and noise standard development, identifies non-domestic rulemaking and standard-setting activities of interest to the United States, and makes recommendations for activities that may inform the development of future noise standards and recommended practices (SARPs) in the next CAEP cycle.

2. BACKGROUND

2.1 Aircraft noise certification is a mechanism promulgated by civil aviation authorities to fulfill national statutory requirements for controlling aircraft noise. When such requirements were first introduced, the purpose was to control this noise at its source (the aircraft) where it had the greatest potential to impact the public most: in the vicinity of airports, during typical operations, such as take-offs and landings, while considering technical feasibility, economic reasonableness, and environmental benefit to be achieved and the potential interdependence of measures taken to control noise and control engine emissions. So far, SARPs have been developed for jets, propeller driven aircraft, helicopters, and tilt-rotors.

2.2 ETA, by definition, are not covered by existing categories in the current Annex 16, Volume I certification procedures. ETA include both uncrewed aircraft (e.g., Unmanned Aircraft Systems

(UAS) for deliveries, remote-sensing, or infrastructure inspections), and crewed aircraft (e.g., Urban Air Mobility (UAM) aircraft). The flight profiles and reference conditions included in Annex 16 procedures that have been specifically developed for conventional aircraft categories may not be appropriate for ETA, which exhibit potentially disqualifying characteristics such as: distributed propulsion, automated controls, and capabilities for vertical take-off, hovering and landing.

2.3 Further, ETA may exhibit new noise characteristics during flight and may operate near communities as part of their mission design. The new and unique noise sources coupled with novel flight operations in formerly little-utilized portions of the U.S. National Airspace System (NAS) prompt uncertainty regarding the ability of conventional noise metrics to reliably represent the effects of noise from ETA.

2.4 It is necessary to obtain better understanding of ETA noise generation processes including relationships to aircraft weight, configuration, and other design and operational parameters, and to gauge how ETA noise is perceived by humans (including both those participating and not participating in or benefitting from the new services and benefits provided by ETA). A wide range of research and noise data collection efforts will be needed to fully understand ETA noise. As the ETA industry is rapidly developing, it is also necessary to monitor and engage in the development of measurement procedures and certification approaches to inform future Annex 16 standard(s) development for these aircraft.

3. CURRENT NOISE CERTIFICATION APPROACHES FOR ETA IN THE UNITED STATES

3.1 The U.S. Federal Aviation Administration (FAA) authorizes small UAS weighing no more than 55 pounds (25 kg) to operate commercially under Title 14, Part 107, *Small Unmanned Aircraft Systems*, of the Code of Federal Regulations (CFR), and other commercial operations under 14 CFR Part 135, *Operating Requirements: Commuter and on Demand Operations and Rules Governing Persons on Board Such Aircraft*. Pertinent to Part 107, the FAA has allowed limited operations outside the rule through a special waiver request program. The FAA published a new rule in January of 2021 that relieved some of the Part 107 restrictions, allowing small UAS operation over people and at night under certain conditions. Since 2017, the FAA's UAS Integration Pilot Program (IPP) and subsequently the BEYOND Program have brought state, local, and tribal governments together with private sector entities, such as UAS operators and manufacturers, to test and evaluate the integration of civil and public drone/UAS operations into the NAS. There is no noise certification requirement for UAS operating under Part 107.

3.2 The FAA has been actively developing a certification basis for ETA seeking a type certificate from the United States (for example, when an ETA applicant seeks Air Carrier and Operator Certification under 14 CFR Part 135). At the early phase of the noise certification process, the FAA's noise certification team considers and evaluates the aircraft design and performance characteristics as well as operational concepts and mission flight profiles through technical familiarization sessions and via interactions with the applicants. If the aircraft design and its operational characteristics fit into the existing noise measurement procedures, the FAA will use the current noise standards (found in 14 CFR Part 36 *Noise Standards: Aircraft Type and Airworthiness Certification*) as the certification basis.

3.3 Many ETA, however, do not align well with 14 CFR Part 36 due to their novel design and operating concepts. In such cases, the FAA develops a rule of particular applicability (RPA) for each aircraft model as the FAA builds its noise database for these aircraft types. To that end, the FAA published the final RPA for the Matternet Model M2 aircraft in September of 2022: https://www.federalregister.gov/documents/2022/09/12/2022-19639/noise-certification-standards-matternet-model-m2-aircraft. In this RPA, the light-weight helicopter noise standard (Appendix J of Part 36) was modified to fit the specific aircraft model design and operating concepts. A level flight noise testing procedure was prescribed for noise compliance measurement. In addition to the noise compliance test, the RPA includes supplemental testing to measure noise for hover positions with no noise limit imposed. Data from such supplemental testing may help the FAA to develop general noise certification procedures and specifications in the future.

3.4 Subsequently, when a noise certification applicant presents an ETA for certification and the FAA finds that the appropriate noise certification basis is essentially the same as the standard adopted previously for another ETA that was adopted through notice and comment rulemaking, the FAA may adopt the same standard for another applicant only as a final RPA. The following site includes information on aircraft models for which the FAA has adopted a noise certification standard as a final rule, with a link to each rule:

https://www.faa.gov/about/office_org/headquarters_offices/apl/aee/noise/uas_noise_certification.

3.5 The United States sees the development and publication of RPAs as an interim solution that would lead—together with research programs and other databases—to the development of a Standard or Standards for ETA noise certification to enable harmonization of these certification activities worldwide.

4. U.S. ETA NOISE RESEARCH

4.1 The United States continues to invest in further understanding the noise characteristics of ETA in the form of research programs, working groups, symposiums, workshops, technical committee meetings, and data measurement campaigns. An overview of these activities is provided in **Appendix A.** The United States expects to be able to share some results of these measurements and research efforts in future WG1 meetings.

5. NON-DOMESTIC NOISE STANDARD DEVELOPMENT OF INTEREST TO THE UNITED STATES

5.1 The United States continues to monitor noise standards developed worldwide on ETA. For example, the European Union (EU) Easy Access Rules for Unmanned Aircraft Systems (EU regulation 2019/947 and 2019/945) contain noise standards and limits for very light-weight drones: https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulations-eu.

5.2 In June of 2023, the European Union Safety Agency (EASA) published Guidelines on Noise Measurement of Unmanned Aircraft Systems Lighter than 600 kg Operating in the Specific Category (Low and Medium Risk). The final rule's Comments Response Document (CRD) contains EASA's responses to comments submitted by the FAA and other organizations and companies in the United States: https://www.easa.europa.eu/en/document-library/product-certification-consultations/guidelines-noise-measurement-unmanned-aircraft.

5.2.1 The measurement guidelines are similar to the FAA's RPAs in many ways. EASA has included many noise measurement elements that are similar to those, for example, used in the RPA for the Matternet M2 model in the United States. There are some differences, however. For example, the EASA guideline did not include noise limits. This is understandable because the EASA guidelines are considered on a voluntary basis and not intended to be used by itself for type certification. This is different from the RPAs that are used by the FAA in the United States.

5.3 In May of 2023, EASA published a consultation paper: "Environmental Protection Technical Specification (EPTS) applicable to eVTOL powered by multiple, vertical, non-tilting, evenly distributed rotors": https://www.easa.europa.eu/en/document-library/product-certification-consultations/consultation-paper-environmental-protection. The FAA submitted comments to the EASA proposal.

5.4 The FAA is actively participating in the development of consensus noise standards related to ETA, including: The International Standard Organization (ISO)'s draft ISO/FDIS 5305: Noise Measurements for UAS (Unmanned Aircraft Systems), and the SAE International, A-21 technical committee's ongoing efforts to update and revise Aerospace Recommended Practice ARP 4721/1: Monitoring Aircraft Noise and Operations in the Vicinity of Airports: System Description, Acquisition, and Operation, to include guidance on monitoring ETA noise.

5.5 The United States is pleased to see robust international interest and efforts to better understand and address noise from ETA.

6. RECOMMENDATIONS TO CAEP-SG

6.1 The United States recommends that CAEP begin preparations to develop Standards for certain ETA during the CAEP/14 cycle. Given the activities of various manufacturers and certificating authorities in the ETA domain, the United States sees substantial risk in the creation of disharmonized noise certification regulations throughout the world. Initiating development of international standards is a necessary and prudent step for CAEP to take to ensure certification requirements are harmonized. Such harmonization will enable industry to develop ETA technologies with confidence that their aircraft will be measured against a common set of requirements.

6.2 The United States recommends that CAEP task WG1 to begin exploring which ETA technologies may be mature enough for CAEP to address via new Standards in Annex 16, Volume 1, (e.g., certain UA or AAM technologies). WG1 should consider recent RPAs published by the United States, standards published by EASA, and other recently published requirements. WG1 should bring initial thoughts on potential Standards to CAEP/13 SG3.

7. ACTIONS FOR CAEP-SG

7.1 The CAEP-SG is invited to:

a) acknowledge the research and data collection activities (outlined in Appendix A) in the United States;

b) acknowledge the noise certification approaches published by the United States and EASA;

c) note the views of the United States that there is a risk of regulatory disharmonization without action from CAEP in the near future; and

d) agree to task WG1 to begin exploring which ETA technologies may be mature enough for CAEP to address via new Standards in Annex 16, Volume 1, during the CAEP/14 cycle, as discussed in Section 6.

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APPENDIX A

U.S. ETA NOISE RESEARCH OVERVIEW

1. The United States continues to invest in further understanding the noise characteristics of ETA in the form of research programs, working groups, symposiums, workshops, technical committee meetings, and data measurement campaigns. Some highlights are provided in this Appendix.

2. ASCENT

2.1 The Center of Excellence for Alternative Jet Fuels and Environment (ASCENT) is a cooperative aviation research organization co-led by Washington State University and the Massachusetts Institute of Technology, in collaboration with FAA, the National Aeronautics and Space Administration (NASA), the Department of Defense, the Environmental Protection Agency, and Transport Canada. The center works to create science-based solutions for the aviation industry's biggest challenges: https://ascent.aero/. The knowledge and capabilities gained from this research provide the aviation industry, governmental agencies, communities, and policy-makers with new scientific understanding and data, with which they can continue to address environmental issues and the future of aviation. Each project requires close coordination, working with industry partners who provide matching contributions to augment FAA research grants. Through these long-term cost-sharing activities, the government and university-industry teams leverage resources to advance the technological future of the nation's aviation industry. Additionally, students gain hands-on experience applicable to the aviation and aerospace workplace.

2.2 Several ASCENT research projects have been funded to support quantification and mitigation of ETA noise. The design-space for ETA is very large, with a wide variety of combinations of technological features and the associated mission capabilities resulting from those technologies. Even so, it is reasonable to anticipate that at least some of those features and technologies would be practically and efficiently scalable and could be assumed to apply to groups of diverse aircraft types, with varying dependencies on characteristics such as size, mass, physical configuration, or mission goals. Initial approaches to noise certification of such aircraft should include focus on identifying important noise characteristics and consistent—if flexible—means of addressing them through noise flight testing and numerical modelling.

2.3 For example, ASCENT project A77, led by Professor Eric Greenwood of the Penn State University (PSU), is developing methods to reliably characterize noise from UAS and UAM aircraft and applying them to generate an extensive noise measurement database: https://ascent.aero/project/measurements-to-support-noise-certification-for-uas-uam-vehicles-and-identify-noise-reduction-opportunities/. To date, methods have been developed to isolate the individual sources from measured noise of multirotor aircraft, with the aim of reducing uncertainty in their noise characterization. To assist in the development of experimental procedures, the UAM/eVTOL computational modelling tools developed under ASCENT project A49 led by Professor Ken Brentner of PSU are being used to simulate and predict physical experiments: https://ascent.aero/project/modeling-of-urban-air-mobility-noise-to-enable-innovative-means-of-noise-reduction/. Using insight gained from these predictions, focused experiments have been conducted to better understand the acoustic far-field of multirotor aircraft and how variability in the flight state of the aircraft correlates with changes in the measured noise. More recently, the A77 research team has demonstrated the noise reduction potential of synchrophasing the motors and rotors to reduce noise in specified directions under laboratory conditions.

In the near future, research will explore how other changes to the flight control system of ETA could reduce noise generation during realistic routine operations.

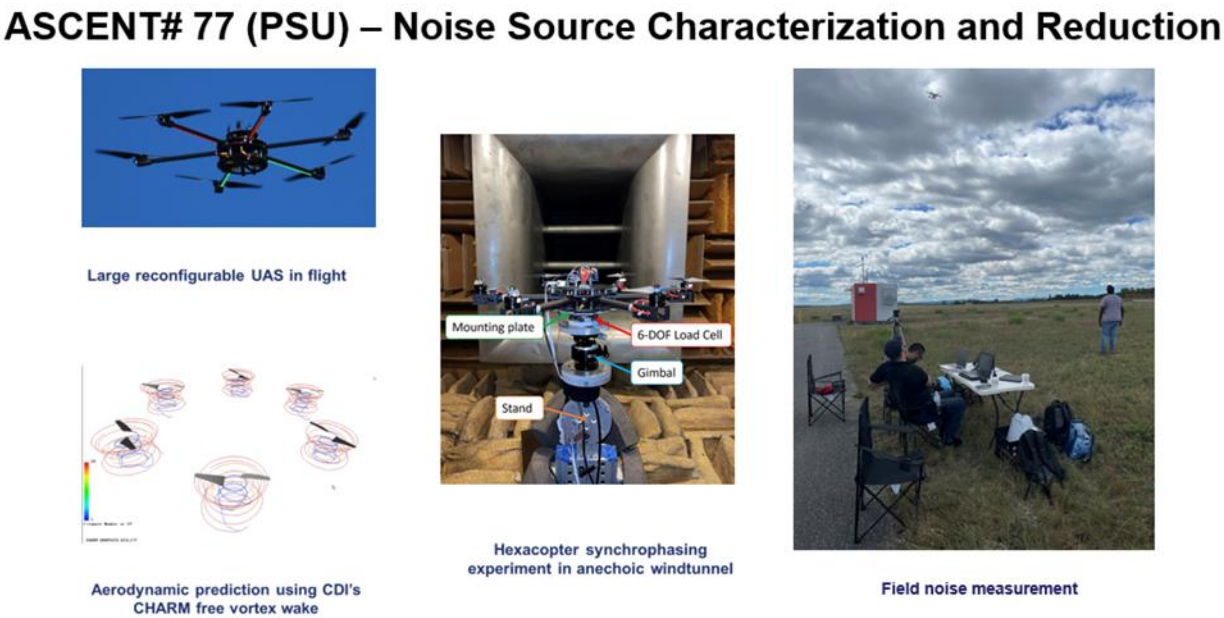

Figure 1 - Examples of ASCENT #77 ETA Noise Research efforts

3. FAA / Volpe

The FAA and The U.S. Department of Transportation Volpe Center have conducted measurement campaigns of ETA in an effort to characterize their noise emissions. This work promotes a better understanding of how these vehicles might impact the environment and informs the creation of noise certification compatible procedures. The analysis of data from large microphone arrays with elevated microphones deployed for these campaigns has been used to understand the directivity of noise from these complex sources. By measuring ETA across their flight envelope, the analyses will lead to understanding the relationships between the vehicle's operation and the resulting noise measured on the ground. With these relationships, it is hoped to inform rulemaking akin to what is in Part 36 regulations and the Annex 16 standards for conventional aircraft. Many uses of the data from these measurements have been made, including ASCENT project(s) and environmental analyses.

Figure 2 – Measurement of hexcopter drone by microphones suspended from a crane and along the ground with the noise directivity pattern superimposed on drone location shown by the colour contours on the transparent sphere.

Additional efforts include:
Presentation at Spring 2022 SAE A-21 Committee Meeting, "UAS Noise Measurements Repeatability Analysis," Barzach. Presentation for meeting in Atlanta, hosted by Georgia Tech.

Paper/Presentation for I-INCE Quiet Drones Symposium 27-30 June 2022, "Estimating Unmanned Aircraft Takeoff Noise Using Hover Measurement Data," Cutler-Wood, Hobbs, Downs, Shirayama, and Barzach: https://rosap.ntl.bts.gov/view/dot/64152.

4. NASA

4.1 As part of its Advanced Air Mobility (AAM) Mission, NASA has conducted extensive laboratory, ground and flight noise testing, noise modelling, tool research, and auralization studies to understand human perception of ETA noise: https://www.nasa.gov/aam. Further, NASA has created and supported a community of acoustic experts from industry, academia, and government agencies to identify, discuss, and address noise issues associated with UAM vehicles and their operations. The NASA UAM Noise Working Group (UNWG) published a white paper on UAM Noise: "Current Practice, Gaps and Recommendations" in 2020 and continues the research and collaborative efforts to address the topics outlined in the white paper through four subgroups: Tools and Technology, Ground and Flight Testing, Human Response and Metrics, Regulation and Policy: https://ntrs.nasa.gov/citations/20205007433.

4.2 In Spring of 2023, the NASA UAM Noise Working Group organized a manufacturer industry panel on UAM noise: https://www.youtube.com/watch?v=WPODSoaESTw. A second such panel will be held at the Fall 2023 meeting.

4.3 The Advanced Air Mobility (AAM) National Campaign (formerly the UAM Grand Challenge) seeks to promote public confidence and to accelerate the realization of emerging aviation markets for passenger and cargo transportation in urban, suburban, rural, and regional environments: https://www.nasa.gov/centers/armstrong/features/science-of-sound-aam-noise.html. The program encompasses developing and deploying aviation in transformative and innovative manners in order to provide aerial mobility in ways not typically seen today. To help make AAM a reality for the United States, NASA started hosting a series of activities called the AAM National Campaign. NASA's Mobile Acoustics Facility and an array of more than 50 microphones helped the agency's researchers measure the acoustic profile of Joby's aircraft during a test in September of 2021. Data from this measurement campaign were documented in two recent conference papers:

Thai, A., Bain, J., Mikic, G., and Stoll, A., "Flyover Noise Computations of the Joby Aviation Aircraft," Vertical Flight Society's 79th Annual Forum & Technology Display, West Palm Beach, FL, May 2023: https://www.nasa.gov/centers/armstrong/features/science-of-sound-aam-noise.html; and

Pascioni, K.A., Watts, M.E., Houston, M., Lind, A., Stephenson, J.H., and Bain, J., "Acoustic Flight Test of the Joby Aviation Advanced Air Mobility Prototype Vehicle," 28th AIAA/CEAS Aeroacoustics Conference, Southampton, UK, June 2022: https://doi.org/10.2514/6.2022-3036.

4.4 The FAA and NASA have initiated preliminary planning of UAM community noise test(s) to be conducted in the United States in the late 2020s. A draft set of candidate test objectives was shared, and comments were solicited at the Spring 2022 UNWG and the Fall 2022 Acoustical Society of America meetings: https://doi.org/10.1121/10.0015626.

4.5 Over the last year, NASA has conducted psychoacoustic studies on the effects of sound quality, duration and the number of events, and masking on annoyance to UAM. Additionally, NASA has developed a remote psychoacoustic test platform (tests conducted over the internet) and demonstrated its ability to replicate findings from a laboratory study on annoyance to small UAS noise. A more widespread test on annoyance to UAM noise is being planned for 2024. These efforts will be reported on at a future WG1 meeting.

5. Data from FAA Noise Certification Measurements

5.1 The FAA is also currently analyzing ETA noise data collected during noise certification from various programs. The FAA plans to plot the noise level versus ETA weights and then compare the data with EASA plots shared to the ETA subgroup in 2023.

5.2 In order to compare noise level data obtained using different microphone installations (i.e., ground-plane vs. 4-foot pole), the FAA is continuing to investigate differences in noise level for aircraft where measurements have been made with both types of microphone installations. Analysis of currently available A-weighted Sound Exposure Level (ASEL, or simply SEL – symbol: L_{AE} – a metric that accounts for noise duration effects) data from level flyovers for UAS and UAM suggests a relationship where ground microphone SELs will be approximately 3 dB higher than those for a similarly-located 4-foot (1.2 m) pole microphone. A larger population of comparison data will need to be evaluated before this relationship is established.

5.3 In order to compare level flyover data measured at different aircraft altitudes, the FAA has analyzed several data sets of ETA overflight SELs. The data examined so far seems to follow the 10_{log} scaling rule for adjusting SEL for differences in height. This differs from the 12.5_{log} scaling currently used in Appendix J of Part 36 regulations and Annex Chapter 11 standards for light helicopters and which is also being used in many UAS/UAM noise studies. The U.S. study is going to evaluate more data sets to reach more solid conclusions and recommendations. In the meantime, the FAA team encourages other organizations to look at their data on this topic. FAA suggests that for reporting ETA SEL noise levels, the SEL height scaling rule value used be reported in order to track "normalization" of SELs to a specific height.

6. Industry Groups and Engineering Societies

6.1 Industry groups and engineering societies in the United States have organized conferences and workshops as well. For example, the Vertical Flight Society (VFS) organizes an annual Electric Vertical Take-off and Landing (eVTOL) forum with sessions on eVTOL acoustics: https://vtol.org/annual-forum/forum-79. The Institute of Noise Control Engineering (INCE) USA has organized two workshops on ETA as part of the Technology for a Quieter America workshop series: https://www.inceusa.org/publications/technology-for-a-quieter-america/.

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