Assessment of Noise from Emerging Technology Aircraft

By D. Josephson & R. Naru (Joby Aviation) and J. Caillet (Airbus)

Introduction

Since the development of the first practical helicopter in the 1940s, concepts have been proposed to make vertical takeoff and landing aircraft a part of daily life, bringing air transport into cities, suburbs, and remote areas without the requirement for airport runways. Despite their utility for applications such as medical emergency transport, obstacles have always emerged making helicopters impractical for general use. Noise is one of the most significant problems. During the last decade, aircraft have been proposed eliminating many of these obstacles, including high cost, mechanical complexity, and high noise emissions. Millions of small quadcopters have been sold as toys, camera drones and for agriculture -- these aircraft would not have been possible without the combination of battery, magnet and automation technology that has emerged in recent years. Several hundred of these designs[1] have been launched as commercial development efforts for cargo transport and passenger aircraft, and at least ten have reached Technology Readiness Level (TRL) 6 or greater at commercially useful payload, range, and speed[2], most of which have type certification procedures underway with the Federal Aviation Administration (FAA) of the USA.

In some jurisdictions, any aircraft used commercially requires type certification for airworthiness and noise emissions. Civil aviation authorities in several countries have begun considering the requirements, and at least one has published a certification basis including noise certification[3] based on modified light helicopter procedures. The International Civil Aviation Organization (ICAO) Annex 16, Volume I, Chapter 11 procedures were used with significant modifications as there is no existing noise standard that can be applied. The ICAO Committee on Aviation Environmental Protection (CAEP) Working Group 1 (WG1) has adopted[4] the name "Emerging Technology Aircraft" (ETA) to mean "those aircraft that are not covered by existing categories in current Annex 16 Volume 1 Certification Procedures." The definition does not include supersonic aircraft and may not cover all new aircraft configurations in the future. This article describes some of those aircraft, the challenges preventing the use of existing noise certification procedures, and a new CAEP WG1 subgroup formed to track and report on developments across member states' civil aviation authorities for noise certification and operational noise assessment of ETA, leading potentially to new Standards and Recommended Practices (SARPs).

Reducing Environmental Footprint

Most Emerging Technology Aircraft (ETA) projects focus on enabling air transportation for short trips in areas of high congestion, at reduced environmental and economic cost compared with helicopters. Uber Elevate described an integrated ground/air ridesharing ecosystem[5] that proposed to reduce car traffic by providing a low-cost, quiet airborne alternative to driving. Most projects propose operation with zero local carbon emissions, being enabled by rechargeable batteries. An underlying premise of most ETA proposals

1 https://evtol.news/aircraft
2 ICAO E-HAPI https://www.icao.int/environmental-protection/Pages/electric-aircraft.aspx
3 Matternet NPRM, https://www.govinfo.gov/content/pkg/FR-2020-11-20/pdf/2020-25664.pdf
4 CAEP.12.WP.037
5 https://evtol.news/__media/PDFs/UberElevateWhitePaperOct2016.pdf

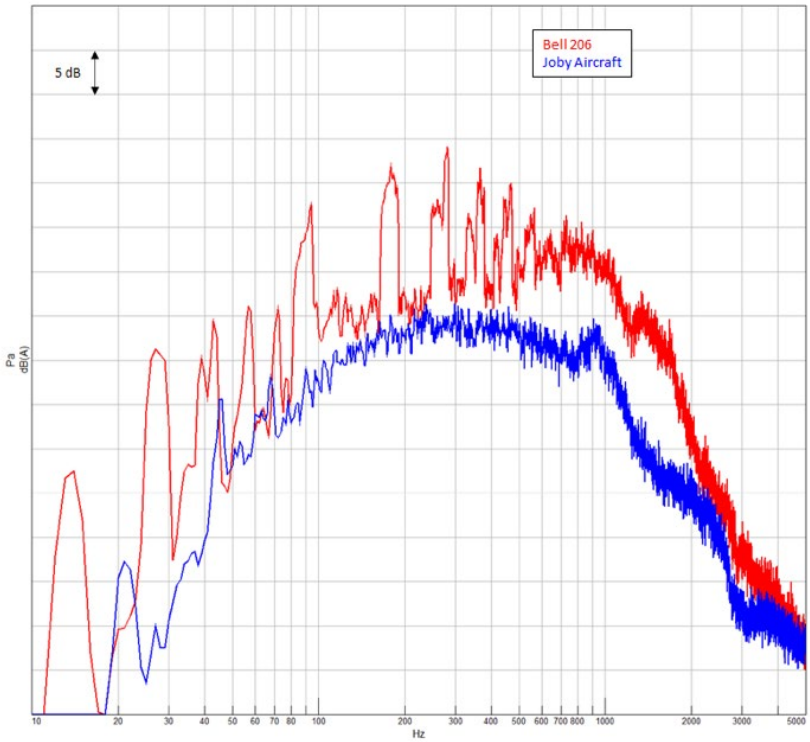

FIGURE 1: Comparison of spectra from the Joby JAS4-1 aircraft and a common helicopter of similar weight.

FIGURE 2: Diagram of the microphone array deployed by NASA for the Joby JAS4-1 acoustic tests[8].

is greatly reduced noise compared with helicopters and tiltrotors, generally acknowledging that legacy Vertical Takeoff and Landing (VTOL) aircraft would be too noisy to be accepted for mass market use in communities.

Some ETA projects have identified a target of 15 to 20 dB reduction in noise emissions compared with helicopters of similar weight. In simplified terms, a reduction in noise emission of 20 dB results in the distance to any given sound level contour being 1/10 as far away, covering an area 1/100 as large. Given uniform population density, this can result in a similar reduction in the number of people experiencing a given level of noise. This kind of potential for change suggests that work will be required to determine appropriate metrics for assessing human impact of this noise.

Joby Aviation is one of the ETA efforts that has advanced to flying a near-production version of its aircraft, having reached stage 4 of the G-1 issue paper process with the USA FAA in 2020[6]. In 2021 the company conducted joint acoustic tests with NASA[7] confirming the company's measurements of around 45 dB(A) in overflight at 500

6 https://www.compositesworld.com/news/joby-aviation-advances-toward-faa-certification-highlights-toray-prepreg-and-coriolis-afp-machines
7 https://www.businesswire.com/news/home/20220510005429/en/Joby-Confirms-Revolutionary-Low-Noise-Footprint-Following-NASA-Testing

meters, and less than 65 dB(A) in takeoff at 100 meters (see Figures 1 and 2).

Emerging Technology Aircraft (ETA) Topologies

Current ETA VTOL projects are distinguished by the use of multiple electrically driven propulsors (rotors, propellers, or fans) to achieve vertical takeoff and landing using Distributed Electric Propulsion (DEP). DEP replaces the mechanical complexity of helicopters and tiltrotors with processor-controlled parameters that are varied automatically. In addition to noise and performance improvements, DEP can provide a high degree of fault tolerance through the elimination of single points of failure. Some of the concepts are all-electric, using batteries, while some are hybrid using a combustion engine to provide power.

ETA include multicopters, which use the same means for lift and forward translation through differential thrust, and aircraft that employ a wing to improve enroute speed and efficiency. Forward flight of wing-based ETA may be principally driven by distinct cruise propulsors or may be achieved by vectoring thrust from the same propulsors used for vertical flight. Unlike helicopters, the propulsors sometimes employ relatively slow changes in blade pitch (if the pitch is changed at all) and there is typically no cyclic pitch. No counter-torque thrust is used. Instead, the relative speed, blade pitch and/or tilt angle of the propulsors are modulated to effect stability and control. The simplest example of this is the quadrotor, first demonstrated in France in 1907, where two pairs of rotors, turning in opposite directions, can achieve hover, climb and descent. Slight variations in speed, pitch or tilt shift the direction of thrust, and differences in ratio of clockwise and counterclockwise rotation produce yaw.

Noise Certification Procedures

Some Emerging Technology Aircraft (ETA) seemed sufficiently similar to propeller-driven aeroplanes that initial proposals suggested using light propeller noise certification procedures, under the premise that the landing and takeoff phase was a small proportion of total flight time. This approach was generally discounted because of the need to capture the noise characteristics of all relevant operating conditions to allow assessment of their potential community impact.

Helicopter and tiltrotor procedures were also considered because many ETAs have some characteristics of helicopters such as the ability to hover. However, the existing procedures were developed to permit comparison of the noisiest operating conditions of rotorcraft with cyclic and collective pitch control and require precise control of rotor speed and descent angle to maintain uniform test conditions. Most ETA cannot maintain locked rotor speed because it is constantly varied to achieve stability and control.

The only ETA noise certification basis published to date is the United States FAA's Notice of Proposed Rulemaking for the Matternet small package delivery Unmanned Aircraft Systems (UAS). It requires the use of a subset of FAA procedures that are initially equivalent to ICAO Annex 16, Volume 1, Subchapter 8, using the Rules of Particular Applicability concept permitted in the USA. A level flyover is required at 250 feet, with the certification metric and limit value being taken from the light helicopter procedures. Supplemental tests are also required (although no certification limit is stated) in hover, as public exposure to the Matternet aircraft is expected to be at close range in near hover conditions.

During the next three years of the ICAO CAEP/13 cycle (2022-2025), the authors anticipate that additional special procedures will be defined by certifying civil aviation authorities (CAAs), with adjustments to existing rules for early certification of ETA. The new ETA subgroup will track these developments and provide regular updates to the ICAO CAEP WG1 until enough has been learned that work can begin on procedures for general applicability. The subgroup hopes to build a general understanding of ETA noise, to enable development of new standards as a data-driven process, and to explore the need for noise measurement guidelines and adjustment formulas for ETA.

8 Pascioni, Kyle et al, "Acoustic Flight Test of the Joby Aviation Advanced Air Mobility Vehicle" presented at Aeroacoustics 2022 in Glasgow

Community Noise Assessment

Besides development of measurement protocols for noise certification, a major question remains as to the community tolerance of noise from ETA operations, given that while their individual noise footprints may be greatly reduced, there may be many more flights in close proximity to the community than has ever been possible. Existing CAEP WG2 tasks O.01 and O.11 are being refined to incorporate not only unmanned aircraft operations on and around airports, but other considerations on community engagement in assessing environmental impact of ETA. The WG1 ETA subgroup will monitor, and members may also participate in these activities.

Many ETAs are designed from the outset for low acoustic emissions, not only in terms of traditional noise metrics such as sound exposure level (SEL) and effective perceived noise level (EPNL), but for the ability to blend in with or be masked by urban ambient conditions. Significant developments have been made since EPNL was developed, in metrics for assessing the audibility, prominence and annoyance of complex sounds in the presence of background noise conditions. Research is ongoing on the best methods for quantifying these impacts, which may influence how noise emissions are measured for certification.

ICAO CAEP WG1 Subgroup on ETA

The ICAO CAEP/12 Meeting in February 2022 agreed on a new task for the CAEP WG1, in order to track and coordinate future work on noise certification of ETA. The effort will focus on tracking progress made by Member States in developing noise certification procedures for the range of ETA that require certification.