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Research to Support New Entrants to Public Airspace and Aircraft Noise Certification

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Summary
This paper identifies some of the reasons why existing aircraft noise certification methods might not fully address the integration of new entrants to public airspace, and describes ongoing research measurement programs to obtain data that can inform future noise policy and methodologies for noise certification of such aircraft.

1. Introduction
Aircraft noise certification is a mechanism promulgated by civil aviation authorities such as the U.S. Federal Aviation Administration (FAA) to fulfil statutory requirements including those in the United States under U.S.C. 49, section 44715, “Controlling aircraft noise and sonic boom”. When such requirements were first introduced, the purpose was to control aircraft noise at its source (the aircraft) where it had the greatest potential to impact the public the most: in the vicinity of airports, during typical operations, such as take-offs and landings. (Figure 1)

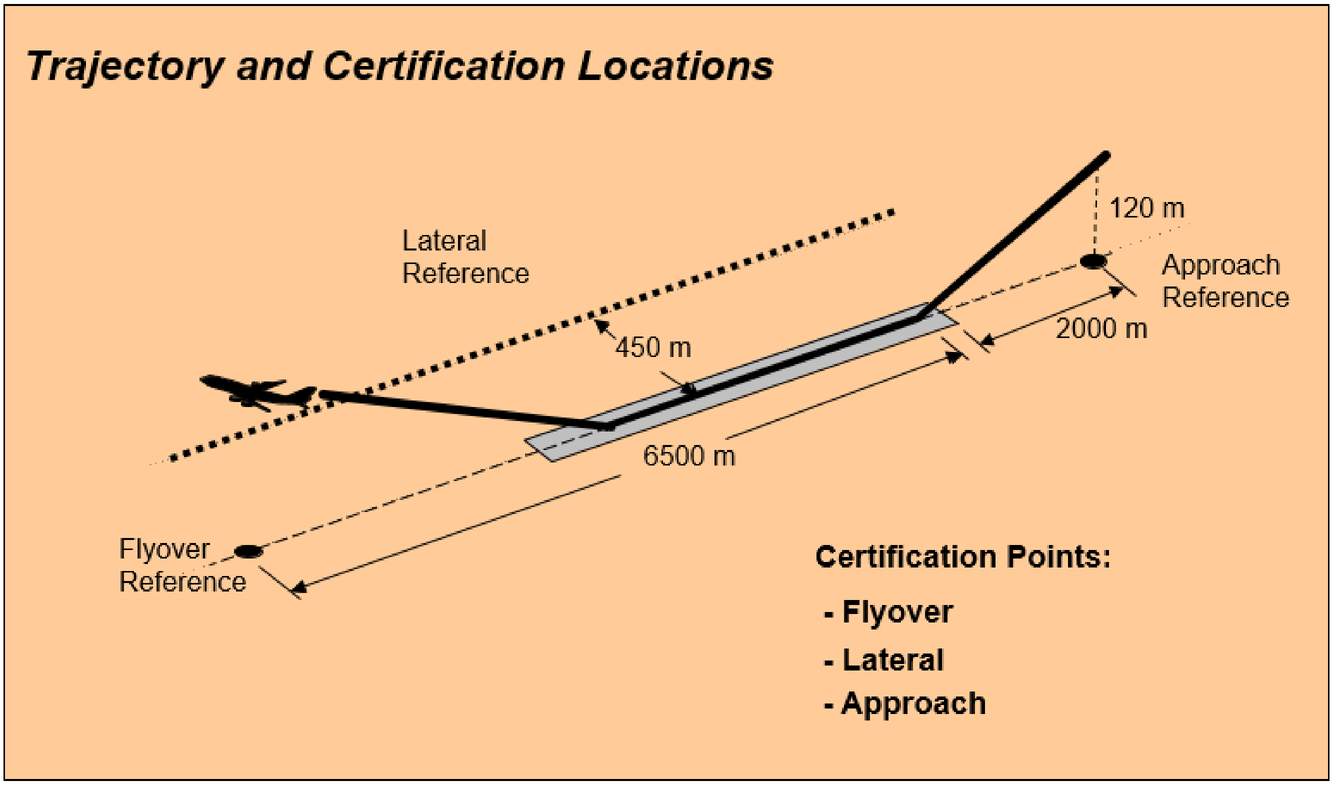

Figure 1 - Aircraft Noise Certification - Flight Operations for Transport Category Aircraft evaluated under 14 CFR Part 36, Appendix 1 (FAA Office of Environment & Energy)

Today, technology improvements are allowing previously unavailable flexibility in aircraft configuration, size, propulsion, and control mechanisms; and the missions and typical operations of such aircraft have the potential to affect the environment in previously unanticipated ways: Noise from some of these aircraft is likely to extend to communities beyond the vicinity of an airport into areas not previously experiencing aircraft noise. The qualities of such noise may cause public reaction in a variety of ways not anticipated by conventional aircraft noise regulation. In addition, due to the novel design techniques being employed, and the operational capabilities enabled by those designs, the ability of conventional noise metrics to reliably represent the effects of noise from these aircraft may not be a certainly.

2. The role of aircraft noise certification

Currently, certification is the primary mechanism used to regulate and reduce aircraft source noise. The process, developed and agreed to internationally[1], is managed on a national level by aircraft authorities. The underlying philosophy is to motivate manufacturers and operators to employ current best-practices in design – and to operate aircraft featuring these design elements - in order to meet increasingly stringent noise level limits based on existing aircraft categories: small propeller-driven aircraft; small helicopters; and “transport-category” aircraft such as jets, large propeller-driven aircraft, helicopters, and tilt-rotors, using takeoff mass as the primary correlating

[1] The United States Government is a member-state of the United Nations (UN), and participates in the UN’s International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) Working Group 1 – Noise Technical. ICAO Noise Standards are documented in Annex 16 Volume 1.

element. Other than stringency increases (quieter noise limits) associated with various “stages” or “chapters”, and small updates to the details regarding technical procedures and methodology for noise measurement and analysis, the rules – and noise metrics - have remained mostly the same as when first introduced in the mid-to-late 1960’s (in the US) and early 1970’s (for ICAO member states).

2.1 Unwritten assumptions behind existing aircraft noise certification requirements and specifications

When the standards for noise certification were established, it was impossible, for example, for an aircraft to be piloted entirely by computer control. Also, it was impractical to design for exclusively electrical propulsion systems, or for an aircraft (other than toys or model replicas) to be small enough to be operated within a community from areas other than aerodromes or airports.

All of these aircraft functional concepts have either already been implemented or are entirely plausible, and represent issues being introduced by the consideration of new entrants to the public airspace. None of them were addressed in the formulation of noise certification procedures because they did not exist at the time. Improvements in computer-processing power and software-aided simulation and design techniques, in combination with the development of new materials and construction methods; as well as developments in electrical energy storage technology, have converged to make the current moment possible. Previously impossible aircraft are now a reality. These new entrants and novel aircraft designs will enable previously impossible missions and flight profiles, in places where aircraft operations were never anticipated.

2.2 Unique characteristics of noise from new entrants

Some of the new aircraft design and operational differences may result in the introduction of community noise with substantially different qualities than that from conventional aircraft. For example, electric propulsion systems currently available exhibit different spectral content from conventional internal-combustion or jet-powered aircraft.

Observations have been made that aircraft with electrical propulsion may actually result in lower noise levels, than from conventionally-powered aircraft when quantified using conventional noise metrics. In contrast, multi-rotor eVTOL aircraft that make use of computer-controlled, differential-thrust for manoeuvring have raised public awareness of a characteristic sound that some have compared to the sound of swarming bees – due perhaps to the presence of multiple, dynamic, enharmonic tones.

Additionally, operations in and around neighbourhoods - such as package delivery or infrastructure inspections – could result in relatively short sound propagation paths, which could minimize or negate any beneficial effects of high-frequency atmospheric absorption of sound. (Such absorption is typical for high-altitude aircraft overflights.) The proximity of aircraft operations in itself, may be a contributing factor to human annoyance, and the unattenuated high-frequency content may be perceived as characteristic of such proximity.

Abrupt onsets and cut-offs of the sound may be more likely, due to intermittent line-of-sight blockage by local objects and structures, as the aircraft travel through neighbourhoods. The absence of human occupants on an aircraft may allow for performance profiles that would not be otherwise acceptable, but may also contribute to the dynamic, time-variant nature of this noise.

Long-term operations involving sustained hovering, where an aircraft may be performing a local survey (weather conditions, surface traffic volume, insect population estimates, mapping, etc.) or reconnaissance (automobile license plate capture, census-taking, fugitive searches, etc.), or may be providing temporary access to Wi-Fi or cellular radio service, may also create new noise characteristics that the public are not accustomed to.

2.3 Aircraft noise metrics

Traditionally, broadband frequency-weighted noise levels in various forms are used to characterize noise in communities. For aircraft certification, several such metrics are used, including the maximum, slow (1-second time-constant) time-averaged, A-weighted Level (L_{Asmx}), for small propeller-driven aircraft under 19,000 lbs (8618 kg). This value is provided in decibels re: 20 micro-Pascals, and is directly available as an output from any calibrated, class 1 sound level meter (SLM). A-weighted Sound Exposure Level (ASEL or L_{Ae}), also referenced in decibels re: 20 micro-Pascals, is used for small helicopters under 7,000 lbs. (3175 kg). This ASEL is a time-integrated metric, and so it not only includes the maximum broadband noise level, but also reflects the duration effect of the noise by integrating the noise energy over the 10 dB-down duration in reference to the standard duration of 1 second. This metric is available as a direct output from any calibrated, class 1, *integrating* SLM.

The Effective tone-corrected Perceived Noise Level (EPNL) is specifically used for noise certification of any jet-powered aircraft, large, propeller-driven aircraft, helicopter or tilt-rotor. Similar to SEL, EPNL is another time-integrated, broadband metric, but is derived from one-third octave band (OTOB) spectral analysis at one-half second increments of the time-varying pressure signal from a calibrated, class 1 measurement microphone system. EPNL is similar in nature to SEL, in that it integrates the noise energy over time, but in this case, the reference duration is 10 seconds, and the time-integration is performed using Tone-corrected Perceived Noise Level (PNLT), which is a broadband metric representing the spectral and tonal content at any one-half second instant in time. Rather than applying a simple frequency-weighting to the noise energy, each OTOB sound pressure level (SPL) in a particular spectrum is converted to Noys – an indicator of perceived loudness, based on amplitude and frequency – then summed together to obtain Perceived Noise Level (PNL). The maximum tonal content in each spectrum is identified and quantified to determine the Tone-corrected Perceived Noise Level (PNLT) for that spectrum, and then the time-history of PNLT is integrated to obtain EPNL. Current noise certification regulations only require that OTOB analysis be evaluated over the range of bands having nominal center frequencies of 50 Hz to 10 kHz. It should be noted that tonal content is only evaluated to identify the *maximum single tone correction* within a given spectrum. (Figure 2)

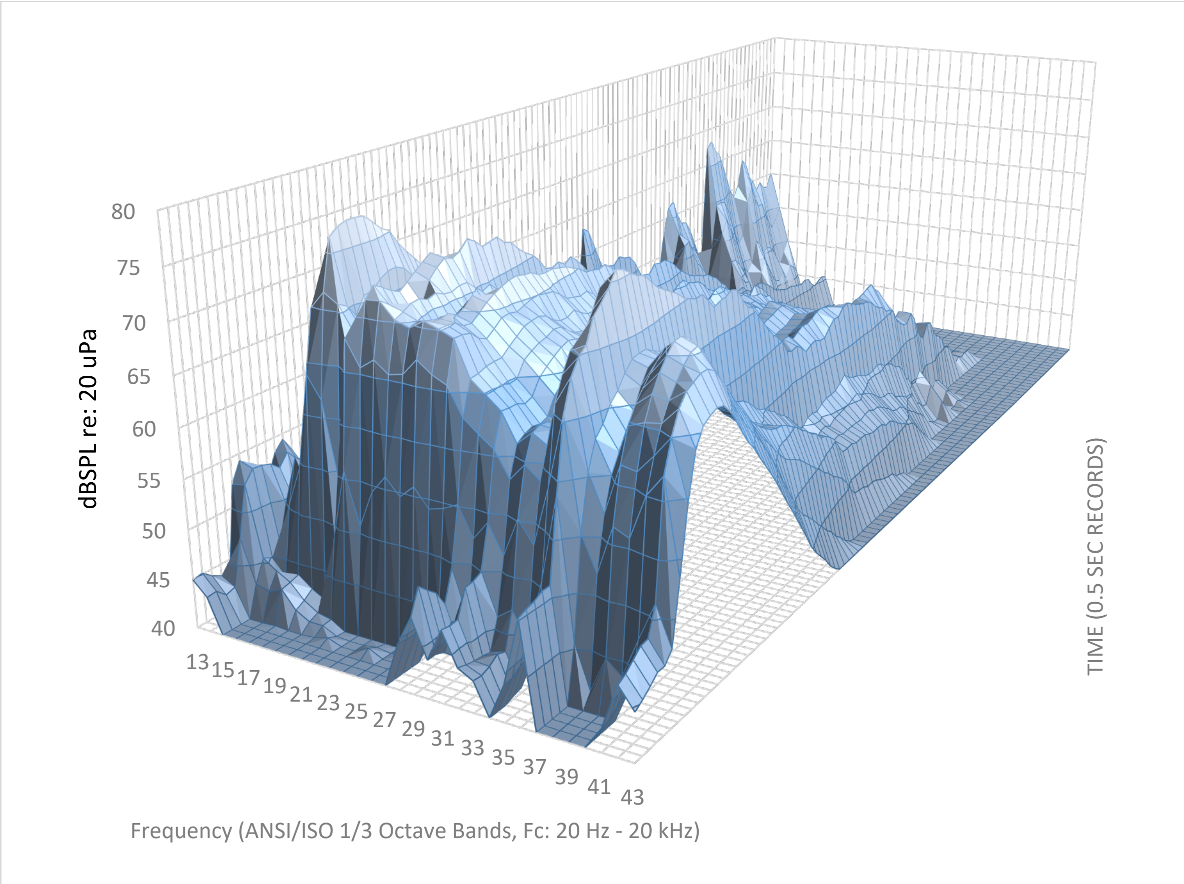

Figure 2- OTOB SPL time history (slow time-weighting response): octocopter vertical take-off, ground plane microphone illustrating energy above 10 kHz and presence of multiple tones (Volpe)

Noise metrics used in the modelling and prediction of aircraft noise in communities are also primarily based on broadband frequency-weighted levels and include some of the metrics already mentioned, but also – for cases such as Day-Night Average Sound Level (DNL) and Community Noise Equivalent Level (CNEL), the metrics are intended to represent cumulative noise during 24-hour periods – with “penalty” offsets applied to account for the intrusive effects for sounds occurring during evening or night-time hours - and may present specific challenges when used to manage operational noise from novel aircraft.

2.4 Exploring additional metrics for noise certification

As noted previously, there are indications that the new entrants being discussed may exhibit noise signatures that contain substantial energy in the high-frequency region beyond 10 kHz (between 10 kHz and 20 kHz) due to the noise generating mechanisms involved, as well as due to the lack of attenuation of higher frequencies from atmospheric absorption, since propagation distances may be very short. The EPNL metric used for many types of aircraft considers noise within the 50 Hz to 10 kHz OTOB range, thus potentially excluding a portion of the sound energy that may be found to be typical of these new entrants. Substantial work might be required to modify the existing EPNL calculation procedures to adapt this metric to accommodate these higher-frequency bands. SEL (A-weighted, or with other frequency-weightings) could accommodate the higher frequency content because for each weighting curve the response vs. frequency is expressed as a continuous function (whereas the PNL and Tone-correction frequency-dependencies used for EPNL are defined in the form of OTOB constants for the previously identified range of bands only) but may have other weaknesses in representing noise effects from these aircraft.

Additionally, it is anticipated that much of the noise energy from such aircraft – especially electrically-powered and/or multirotor - could be in the form of multiple, dynamic tones, which are likely to be important in possible future human-response evaluations. None of the metrics currently in use for aircraft noise certification address perceived annoyance related to the presence of multiple tones.

Furthermore, close operating distances in urban or suburban environments - in combination with near-instantaneous, computer-controlled manoeuvring systems, and the potential absence of human occupants - suggest that, in addition to sudden onsets and cut-offs of the sound, there are likely to be rapid fluctuations of the noise energy content over time, which would likely not be captured using any of the current noise metrics.

Although initial noise rules and specifications for such aircraft are likely to be based on conventional metrics, new metrics employing finer resolution in both time and frequency – as well as the ability to track and quantify multiple simultaneous tones - might be needed for future noise regulations for noise certification, as well as for quantifying contribution of noise from these aircraft in the community..

3. FAA-Sponsored noise measurements & research related to new entrants

In order to prepare for noise certification or other noise-related evaluations of these new entrants and novel aircraft, FAA's Office of Environment & Energy (AEE) is funding noise measurement research by the US DOT Volpe Center (Volpe) to obtain operational noise data and audio recordings from production models of existing aircraft and prototypes of future aircraft, such as drones, UAVs, Air Taxis, UAMs, etc.

3.1 Noise data collection and measurement methodology

Volpe's Unconventional Aircraft Noise Team is undertaking noise measurement campaigns through various avenues using high-quality audio recording to capture the fundamental noise data. Rugged, multichannel audio recorders with high sample rates and frequency bandwidth beyond 20 kHz are used to store the audio pressure time waveform from the microphone signals and time-synchronize them using GPS-based Universal Coordinated Time (UTC). (Figure 3)

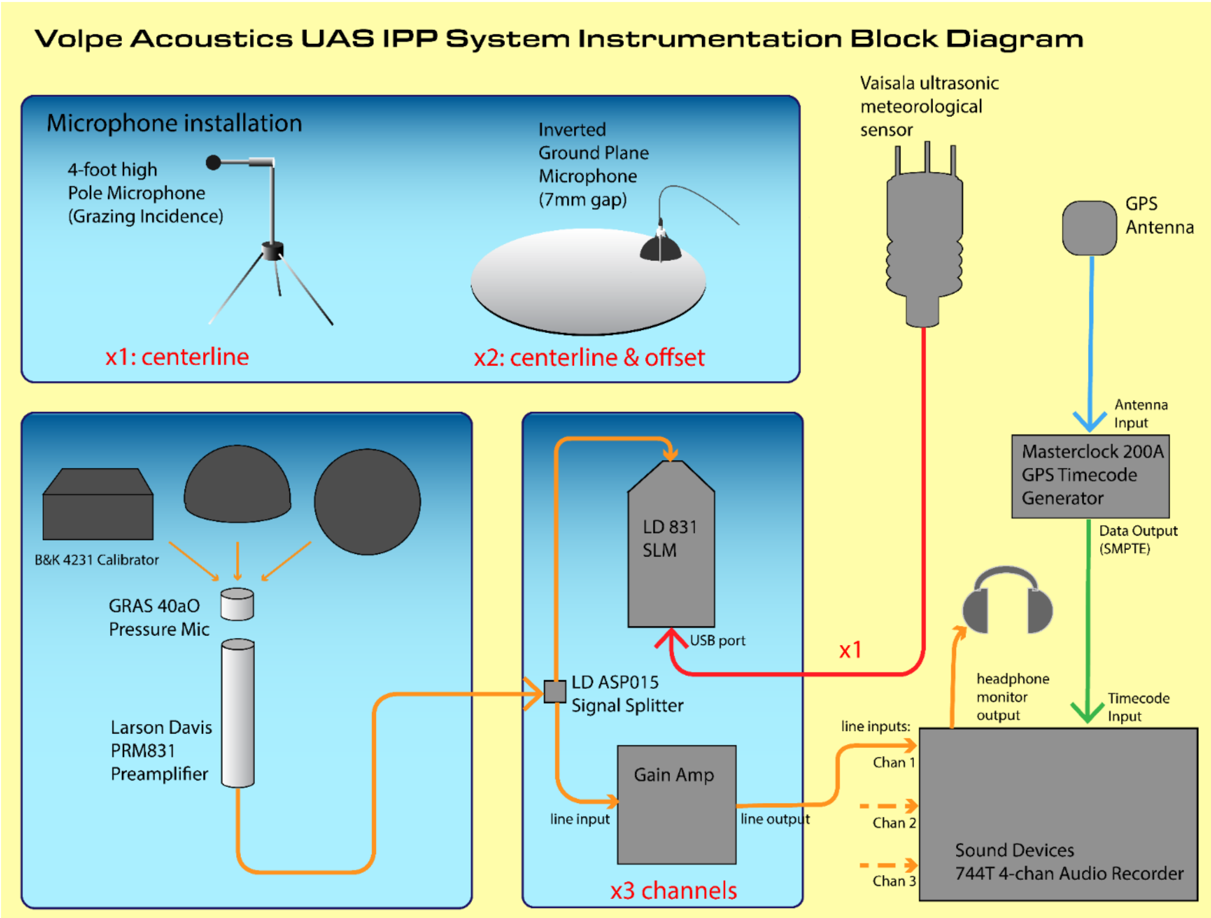

Figure 3 - Volpe UA Noise Team Instrumentation (Volpe)

Microphones are deployed in both 4-foot-high pole-mount and ground-plane configurations, directly under a notional flight path, with a second ground plane microphone positioned about 20' off to one side of the flight path. (Figure 4)

The microphones are all class 1, one-half inch diameter measurement microphones with predominantly flat pressure response from ~10 Hz to ~ 20 kHz. The pole mic is mounted for primarily grazing incidence relative to the aircraft flight path, while the ground plane microphones are installed in an inverted position, parallel to and 7mm above a flat aluminium disc, 14 cm in diameter and 2.5 mm in thickness, which has been installed into the local ground surface in a manner intended to minimize edge effects caused by the impedance boundary between the plate and the local ground material. (Figure 5)

Figure 4 - Microphone deployment for IPP (Volpe)

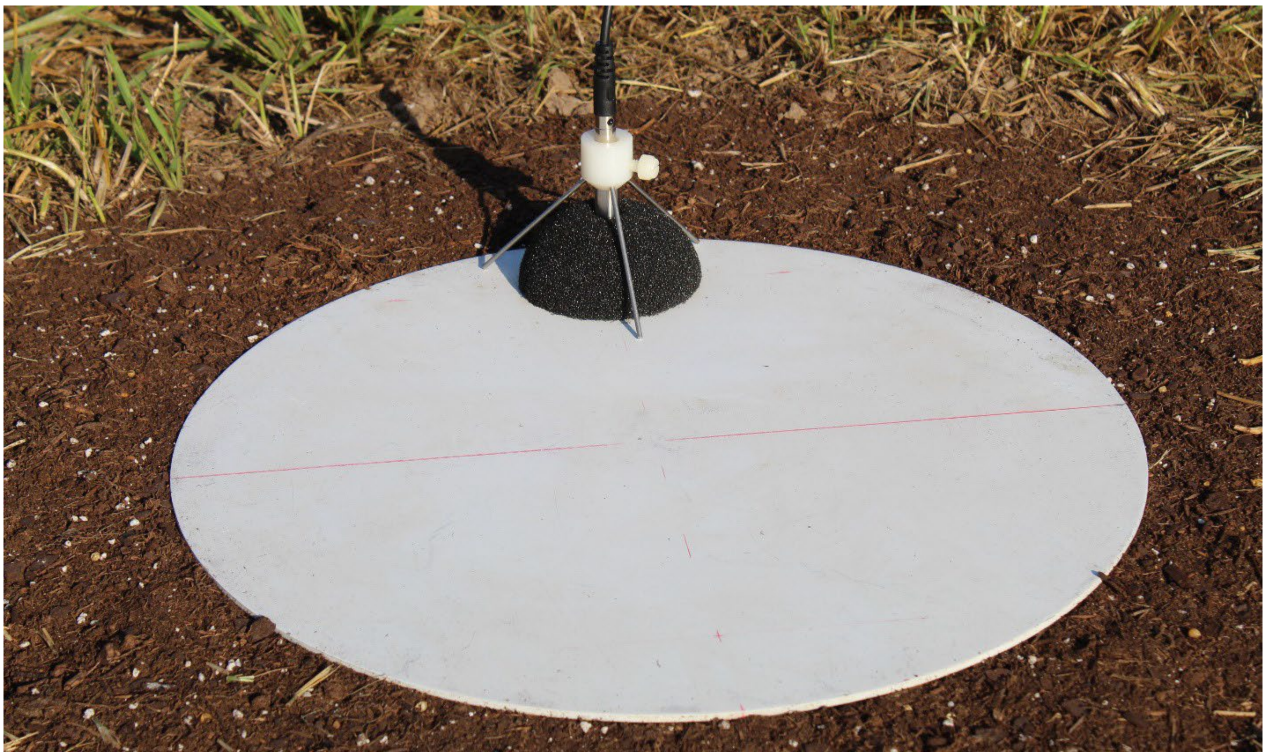

Figure 5 - Inverted ground-plane microphone: ground plate installation in local surface (Volpe)

Edge effects can introduce irregularities into the higher-frequency response of the system, which otherwise substantially provides a uniform pressure-doubling effect in the microphone response to sound pressure. The pressure-doubling effect becomes less uniform with lower sound incidence angles, such as when the source is at a low elevation or a very long distance relative to the microphone location. The frequency bandwidth of the effective pressure zone varies with the physical size of the microphone and of the gap between the microphone and the plate. (Note: Members of the Volpe Team are also actively participating in ICAO technical efforts that include evaluation and comparison of conventional aircraft noise measured using ground plane microphones vs. the pole-mounted microphones specified for noise certification.)

During testing, the subject aircraft is flown past the microphones in a series of operations intended to characterize typical flights that might occur in a neighborhood: ideally a variety of higher-speed ("dash") and lower-speed ("cruise") level overflights are completed, at a variety of heights above the ground, with the aircraft maintaining stable flight conditions. Overflights are performed in both directions in order to minimize influences of measurement site topology, and prevailing wind, as well as to provide data from both sides of the aircraft to the "sideline" microphone. These operations also allow for comparison to the level overflights required for conventional noise certification for large and small rotorcraft and tilt-rotors.

For any fixed-wing aircraft evaluated during these programs, simulated takeoffs are also performed for comparison to the noise certification requirements for small and large propeller-driven aircraft.

For each individual aircraft evaluated during these programs, an effort is made to identify typical missions and modes of operation, such as package-delivery, infrastructure inspection, hovering surveys, etc. Test flight procedures are then established to simulate the noise effects of such typical operations.

In most cases for rotorcraft, a takeoff/landing target is identified, and specific flight operations are performed in relation to this location, which is typically close to the measurement microphones. Horizontal approaches, followed by complete vertical or near-vertical landings are not unusual for many such aircraft, as are complete vertical takeoffs, followed by horizontal departures from the measurement area. In some cases, hovers or orbits are included, as appropriate. For delivery missions where a parcel is lowered to the local ground while the aircraft hovers over the target, such operations – or appropriate simulations - will be included in these tests. (Figure 6)

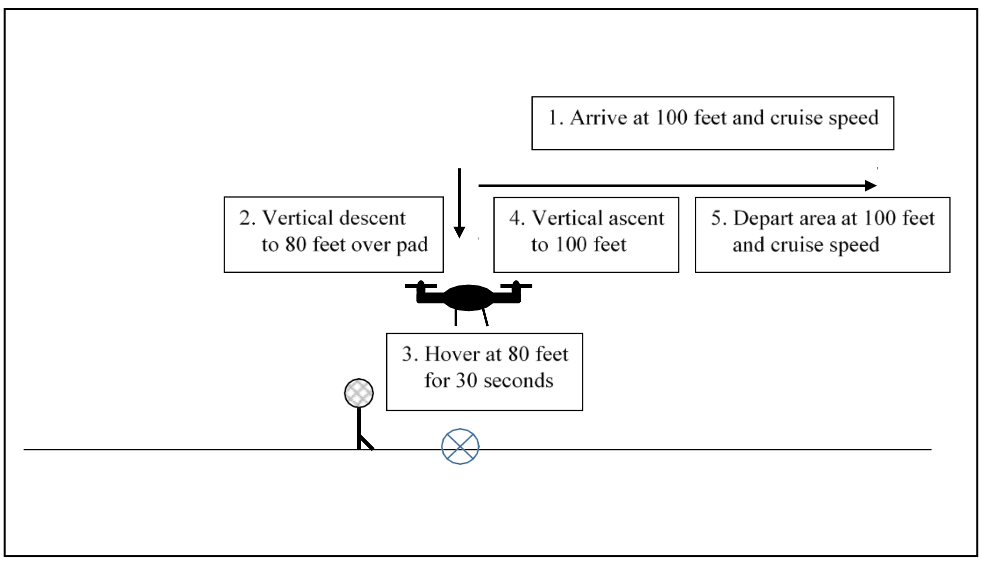

Figure 6 - Schematic for Infrastructure inspection operation specific to a particular multirotor (Volpe)

In most cases, prior to noise flight testing, aircraft are fitted with miniature, independent, Volpe-developed, RTK GPS instrumentation system (Figure 7), comprised of components that capture and record high resolution, time-synchronized aircraft position data. The time-space-position-information (TSPI) datasets obtained from this system are then used in coordination with the time-synchronized audio recordings and local meteorological data to characterize the aircraft noise appropriately.

Figure 7 - Installation of Volpe miniature tracking system components on hexcopter sUAS (Volpe)

Test reports primarily include as-measured data sets, using conventional noise metrics, with some distance-normalized levels also provided. The availability of time-synchronized audio recordings allows for a variety of future analyses and re-analyses to be performed as needed. It is anticipated that such analyses will include finer time and frequency resolutions than are currently required for noise certification purposes.

The audio recordings may also prove useful for auralization experiments, where representative sounds for a particular aircraft type or configuration may be synthesized or modified from the recorded audio for use in human perception evaluations.

As additional data are collected, they may also be used to evaluate scalability factors, such as identifying characteristics of UAV noise that might apply to air-taxis as well. The database may also be useful for development of noise modelling procedures and methodologies, as the models currently in use may not otherwise effectively represent the community noise effects from new entrants.

3.2 Opportunities for data collection

AEE and Volpe are leveraging various existing and new relationships with the National Aeronautics and Space Administration (NASA), industry, local governments and other FAA programs and activities in order to maximize data collection opportunities. The scheduling and logistical preparations for such noise measurement programs can be difficult, and optimal opportunities can be hard to find, due to various limitations – including:

- legal restrictions on commercial or institutional operation of such aircraft within the U.S. National Airspace (NAS);
- preferred measurement site conditions that are crucial for smaller and quieter aircraft, such as low ambient background noise levels, and calm wind conditions;
- obtaining cooperation from owners /operators of such aircraft, who are willing to allow a such noise measurements to be made – and who have the appropriate clearances and authorizations;

The situation has become especially problematic during the current pandemic environment, due to travel restrictions, and quarantining conventions.

Some of the avenues and opportunities for noise data-collection being considered are listed below:

3.2.1 FAA's UAS National Airspace Integration Pilot Program (IPP)

With nine lead participants at various locations around the US, the IPP offers a variety of aircraft and applications. As of this writing, a small assortment of UAVs were measured at the Oklahoma site. Measurements were in planning stages for multiple UAVs at several additional sites around the country, but the program ended on 30 September, 2020. Additional opportunities may be available during future programs.

3.2.2 Other programs

AEE and Volpe's relationships with NASA have enabled various collaborative research measurement programs including ones that address noise from new entrants and should continue to allow for these in the future.

Industry-sponsored events such as the GoFly Personal Flight Competition FlyOffs, held at Moffett Federal Airfield in February, 2020 (Figures 8 & 9), may provide opportunities to capture sound from experimental, prototype aircraft, and NASA's Advanced Air Mobility (AAM) National Campaign (Formerly Urban Air Mobility Grand Challenge) may make available some larger aircraft, designed for passenger flights.

Figure 8- Team Verticycle - GoFly FlyOffs Finalist (Volpe)

Figure 9 - Team Tetra - GoFly FlyOffs Finalist (Volpe)

Volpe is also in discussion with various manufacturers, and operators, some of which are open to the idea of supporting this work by allowing Volpe to perform side-by-side noise measurements during in-house flight testing.

3.2.3 Individual Noise Certification projects

Volpe is supporting FAA/AEE and the various aircraft directorate Noise Certification Specialists (NCSs) in the development of noise certification procedures for new entrants, including the potential for supplemental flight operations that do not currently have associated noise limits, but may help provide needed noise data for future decision-making. Volpe is also involved in discussions with FAA technical specialists regarding development of long-term approaches to aircraft noise certification for new entrants.

4. Other activities related to noise from new entrants

AEE and Volpe are also engaging in other activities related to new entrants, including participation in public discussions, working groups and technical committees, such as the following:

- NASA's UAM Noise Working Group (UAMNWG or UNWG) to develop guidance and flight-testing standards for noise related to Urban Air Mobility – now included under the newly-named Advanced Air Mobility (AAM) vehicles;
- The Vertical Flight Society (VFS) and General Aviation Manufacturers' Association (GAMA) have joined efforts to form a VTOL Noise Assessment Working Group (NAWG), which has similar goals to the NASA group, but from an Industry-centric perspective;
- INCE-USA (and I-INCE, and INCE-Europe) Workshops and symposiums on drone noise;
- SAE International's A-21 Subcommittee on Aircraft Noise is supporting development in cooperation with ANSI and ASA of the noise section of the ANSI Unmanned Aircraft Systems Standardization Collaborative (UASSC)'s Standardization Roadmap for Unmanned Aircraft

Systems, now available as version 2, and has established a Project Working Team to address UAM noise;

- ICAO Working Group 1- Volpe has been supporting FAA by bringing reports of activities related to noise from new entrants in the US to the international arena, as well as engaging in brainstorming and idea exchange discussions with noise certification experts from other nations (including EASA, DGAC France, CAA UK, Transport Canada, ANAC Brazil, and Australian CASA, among others) in order to help find meaningful solutions to the issues being presented by such aircraft.

Additionally, Volpe team members serve as advisors to many of FAA's ASCENT Center Of Excellence projects, including current and coming projects related to UAS/UAM noise modelling, testing and noise certification. Volpe has continuously supported FAA's Office of Environment & Energy in efforts related to Aircraft Noise Certification for over 40 years.

5. Considerations for Future Research and Analyses

Volpe's Unconventional Aircraft Noise Team has identified some unique noise characteristics and analysis approaches we think could be most valuable for moving research and understanding forward. The following are recommendations are based on opinions, but those opinions are based on discussions with various organizational and individual stakeholders and on first-hand experiences with our own noise measurements and those we've participated in or have observed.

It should be noted that the opinions expressed herein do not necessarily reflect the opinions of FAA.

5.1 High-quality noise data collection

The need for real noise measurement data related to typical flight operations of these aircraft cannot be overstated: prevailing business and legal concerns have created an environment where it is extremely difficult to obtain noise data suitable for research purposes – due not only to the particular physical requirements for research-quality noise measurements, such as calm wind conditions and low background noise levels – but also due to the competitive nature of the industry and the concern for protecting what may be proprietary information, while opportunities for performing noise measurement flight testing is hampered by concerns about operational approvals by authorities at various levels. There is a fundamental need for "research-quality" data: wide frequency bandwidth, high-dynamic range audio recordings of typical flight operations at locations representing typical sound propagation distances, time-synchronized to high-resolution position information, at sites with suitable environments as described above. Careful capture and clear field documentation of the data collection efforts are also needed. Such recordings could be used to analyse and re-analyze noise data using various metrics and methodologies, as well as provide source material (time-pressure waveforms) for human-response testing and public awareness sessions via auralization techniques.

Currently, the scarcity of such data is considered the primary gap in moving forward with research related to the noise from new entrants.

Since there is a scarcity of measurement data, the following characteristics have been identified as priorities in the selection of test subject aircraft to be considered for research-quality noise measurements:

- Larger – and heavier – aircraft – among the new entrants, these seem to be most problematic in terms of measurement scheduling availability; also, most likely to exhibit any unique noise characteristics associated with novel propulsion systems, or physical configurations;
- Unique physical configurations – to broaden knowledge of potential noise-generating mechanisms;
- Common physical configurations – such as put forward by organizations anticipating high levels of market infiltration (Major package delivery firms, popular hobbyist models, etc.) – to better represent typical community noise source-composition;
- Differential-thrust designs – especially for larger numbers of rotors/propulsors, since these have already been identified as having characteristic noise signatures AND seem to be extremely popular;
- Hybrid designs that combine vertical lift and fixed-wing/forward propulsion – due to potential acoustic interaction effects that might result from such unusual design;
- Hybrid propulsion systems, such as electric motors with on-board internal-combustion or turbine-based electrical generators that may run on limited duty-cycle schedules – or at reduced output - during flight operations – such designs seem likely to prevail for larger aircraft, at least until better battery capacity technology arrives;
- Any design incorporating intentional noise-reduction technology – these may provide insight into potential areas and methods, and might also be helpful in revealing possible weaknesses in conventional noise metrics;
- Aircraft capable of – or designed specifically for – unique operations such as long-term station-keeping, or local package delivery, or herding of livestock – such operations may introduce noise having unique characteristics into the community;
- Aircraft intended to operate within close proximity of humans or wildlife – useful in evaluation of extended high-frequency bandwidth for instrumentation and metrics;

5.2 In-situ noise data from existing operations in their intended environment

Although less useful for research purposes due to potentially suboptimal measurement conditions and constraints, noise data from new entrants measured during actual flight operations will likely be needed in order to monitor community noise levels and to validate any noise modelling, prediction, or correction methodologies.

5.3 Exploration and evaluation of current aircraft noise certification approaches, metrics, and methodologies to address noise from new entrants

Initial impressions regarding the typical characteristics of noise from new entrants suggest that conventional methods of quantifying such noise – including metrics, noise limits and certification procedures – could benefit from exploratory experimentation to evaluate their effectiveness in addressing the noise from new entrants, but until additional data are available for such aircraft, specific recommendations cannot be made.

5.4 Experimentation to identify potential benefits of increased “granularity” in methods, techniques and metrics for characterization of noise in the community from new entrants

As noted, the variation of noise over time from some of these new entrants will be more dynamic than for conventional aircraft noise, due to control system concepts – like differential thrust – and potentially abrupt onset and cutoff of sound due to line-of-sight blockages. Additionally, close proximity to sensitive receivers may result in shorter-duration "events", where the entire 10 dB-down "envelope" may have a duration of only a few seconds – or even less – in contrast to noise envelopes from conventional aircraft flyovers, where such duration can stretch out to 30 seconds or more. In the frequency domain, closely-spaced tones, or other spectral irregularities may result in characteristic noise signatures that differ substantially from conventional aircraft. All of these elements may require analyses of the sound with substantially higher time and frequency resolution – or granularity – than is currently applied. (OTOB frequency analysis, and one-half second time samples are the current "granules" used for aircraft noise certification.)

5.5 Development of noise generation source modelling and prediction techniques

In order to begin consideration of potential noise-reduction technologies, source prediction methodologies will need to be developed and optimized to address the unique characteristics of new entrants and novel aircraft designs, some of which have been identified in other sections of this paper. The variety of proposed designs and missions suggests that this modelling effort may need to be considered as an ongoing task, as technology and conceptual innovations continue to be introduced in the fleet.

5.6 Evaluation of important considerations for – and development of methodologies specific to - prediction and modelling of noise in the community from new entrants

Current state-of-practice aircraft noise modelling methods need to be evaluated for applicability to noise from new entrants, and innovative techniques and considerations for successfully predicting community noise effects for the introduction of these aircraft to the public airspace may be needed. The sheer number and anticipated variability of flight operations, combined with the introduction of such operations into an acoustically complex environment, close to the ground, where structures and terrain features may influence the perceived noise in a substantial manner, suggest that such modelling may need to be profoundly different from the current state of practice.

6. Conclusions

New entrants to public airspace and novel aircraft are becoming a reality and in the U.S. the FAA is already working through a list of Applications for noise certification for such aircraft. Noise from these aircraft may be substantially different from what the public has previously experienced. The variety of configurations, propulsion systems, flight controls, physical size, and potential mission objectives may require an entirely new framework for classifying similar groups of aircraft, and for determining appropriate noise certification procedures and specifications. New methods, rules, limits, procedures and even metrics may be required to address community noise from such aircraft, and while research is ongoing in various arenas, the greatest gap seems to be the scarcity of representative noise data sets. Evaluating these data sets will be the next step in determining whether any updates are needed to the existing noise certification paradigm.

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