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UAS noise certification

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ABSTRACT

With the expected increase in UAS operations and resulting noise, FAA's Office of Environment and Energy (AEE) sees potential issues with the application of current noise certification procedures to UAS. The only completed regulation that covers UAS is 14 CFR part 107 for small UAS (sUAS) with takeoff weights less than 55 pounds. Under Part 107, small UAS are exempt from noise certification. Current noise certification requirements for fixed- and rotary-wing aircraft may not adequately capture the noise effects of UAS vehicles operating in urban environments. This paper presents the existing certification methods and efforts to date, and discusses potential methods of future certification of UAS which more closely align with their unique noise and operational characteristics.

1 INTRODUCTION

In addition to its primary purpose of ensuring aviation safety in the U.S. National Airspace System (NAS), the FAA is also responsible for ensuring that aircraft comply with noise certification requirements. These noise certification requirements are intended to help mitigate the adverse environmental effects from aircraft operations by ensuring that aircraft comply with the appropriate standards. Although the noise certification system is intended to work with crewed aircraft, it is equally applicable to unmanned aerial systems (UAS), when those UAS are comparable to crewed aircraft.

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The FAA has determined that small (less than 25 kilograms) unmanned aerial systems (sUAS) that meet the requirements of flight under Part107[1] do not require noise certification. UAS that weigh more than 25 kilograms, or otherwise don't meet the Part 107 requirements, do currently require noise certification. FAA introduced Part 107 regulations to mitigate risk; the rule limits sUAS to non-nighttime operations, confined areas of operation, and visual-line-of-sight operations. This rule also addresses airspace restrictions, remote pilot certification, visual observer requirements, and operational limits in order to maintain the safety of the NAS.

The requirement that UAS need to be certificated in the same manner as crewed aircraft may be problematic for the manufacturers, the regulators, and the public. The manufacturers may find the current system burdensome and costly relative to the value of the vehicles. The regulators may find that the certification levels do not correlate to the noise during operations – possibly because certification tests may not represent the in-service operation of these vehicles. The public may find that certification levels do not provide a meaningful comparison against crewed aircraft, and that the metrics used in certification do not represent their perception of this new type of noise source.

2 CURRENT CERTIFICATION REQUIREMENTS

2.1 Fixed-wing Aircraft

In the U.S., propeller-driven fixed-wing aircraft that have a maximum takeoff weight less than 8,618 kg (19,000 pounds) are required to pass the noise limits defined in the U.S. Code of Federal Regulation (CFR). These noise limits are defined in Title 14, Part 36, Appendix G[2]; the noise limits are based on the takeoff weight of the aircraft as shown in Figure 1 below. Appendix G is a takeoff noise level test. The noise metric used in the test is the A-weighted slow-response maximum noise level (L_{Amax}). The conditions for the test include ambient atmospheric conditions test window which could affect the sound propagation. The test plan must be approved by the FAA or a designated engineering representative. The noise levels during the test are captured by an inverted 12.7 mm (0.5in) pressure response microphone mounted 7 mm above a specifically designed surface plate. A surface plate is used in place of the 4 foot pole-mounted microphones used in turbofan aircraft noise certification. The intention of the surface plate and the inverted mounting is to avoid issues due to constructive and destructive interference between the direct and reflected sound paths for the blade passage frequencies.

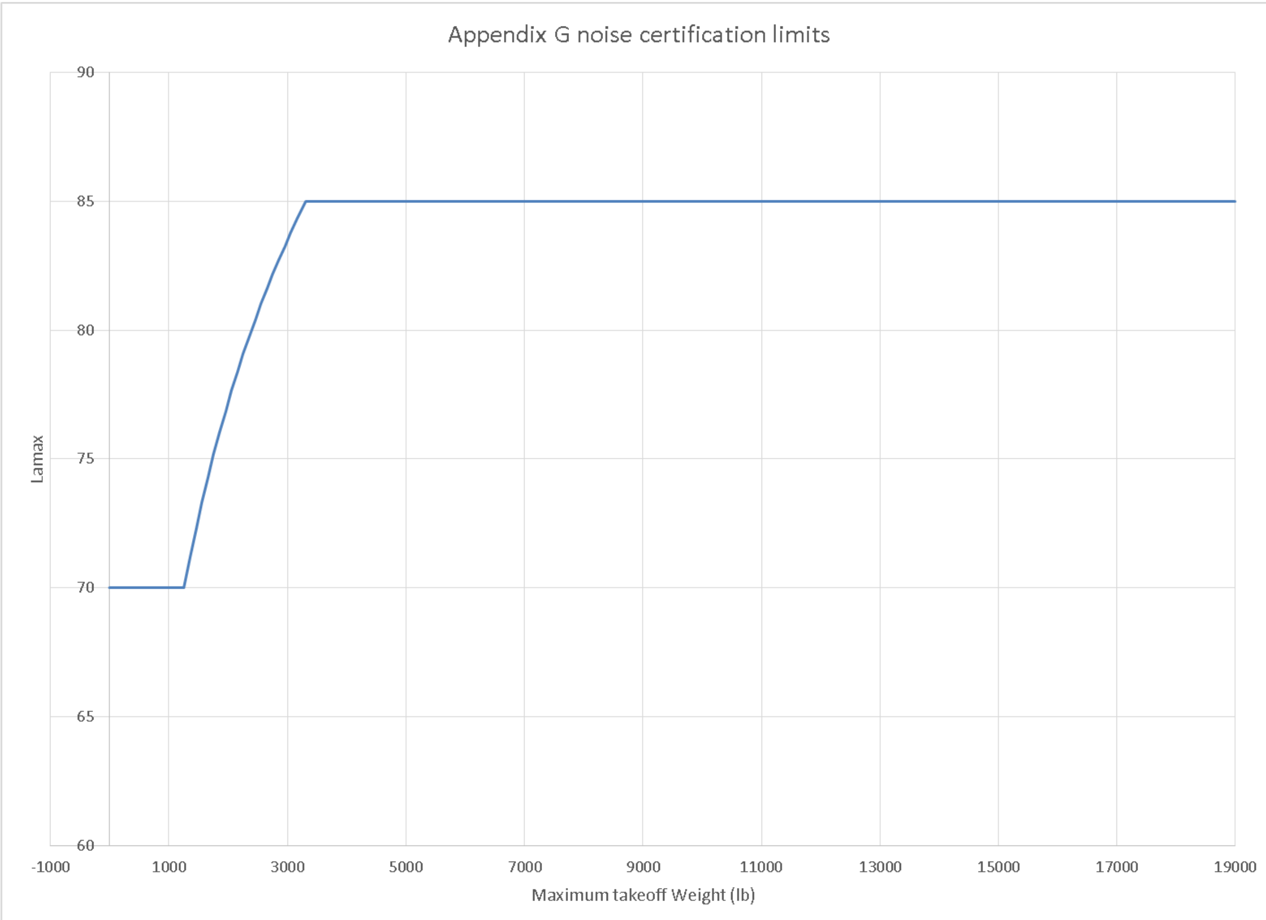

Fig. 1 - CFR Title 14, Part 36, Appendix G noise limits for light propeller-driven airplanes

2.2 Rotary-wing Aircraft

In the U.S., rotary-wing aircraft (i.e. helicopters) that have a maximum takeoff weight less than 3,175 kg (7,000 pounds) are required to pass the noise limits defined in CFR Title 14, Part 36, Appendix J; the noise limits are based on the takeoff weight of the helicopter as shown in Figure 2 below. Unlike Appendix G, Appendix J is a level-flyover noise test, with a set height of 150 meters (492 feet) over the microphone. The noise metric used in the test is the A-weighted slow-response sound exposure level (SEL). Like Appendix G, the conditions for the Appendix J test include ambient atmospheric conditions test window and the test must be approved by the FAA or a designated engineering representative. The noise levels during the test are captured by a 4 foot pole-mounted microphones similar to those used in turbofan aircraft noise certification. Note that helicopters, unlike propeller-driven small airplanes discussed above, have blade passage frequencies which are unlikely to fall into the frequency range of the first constructive/destructive interference of the 4 foot microphone.

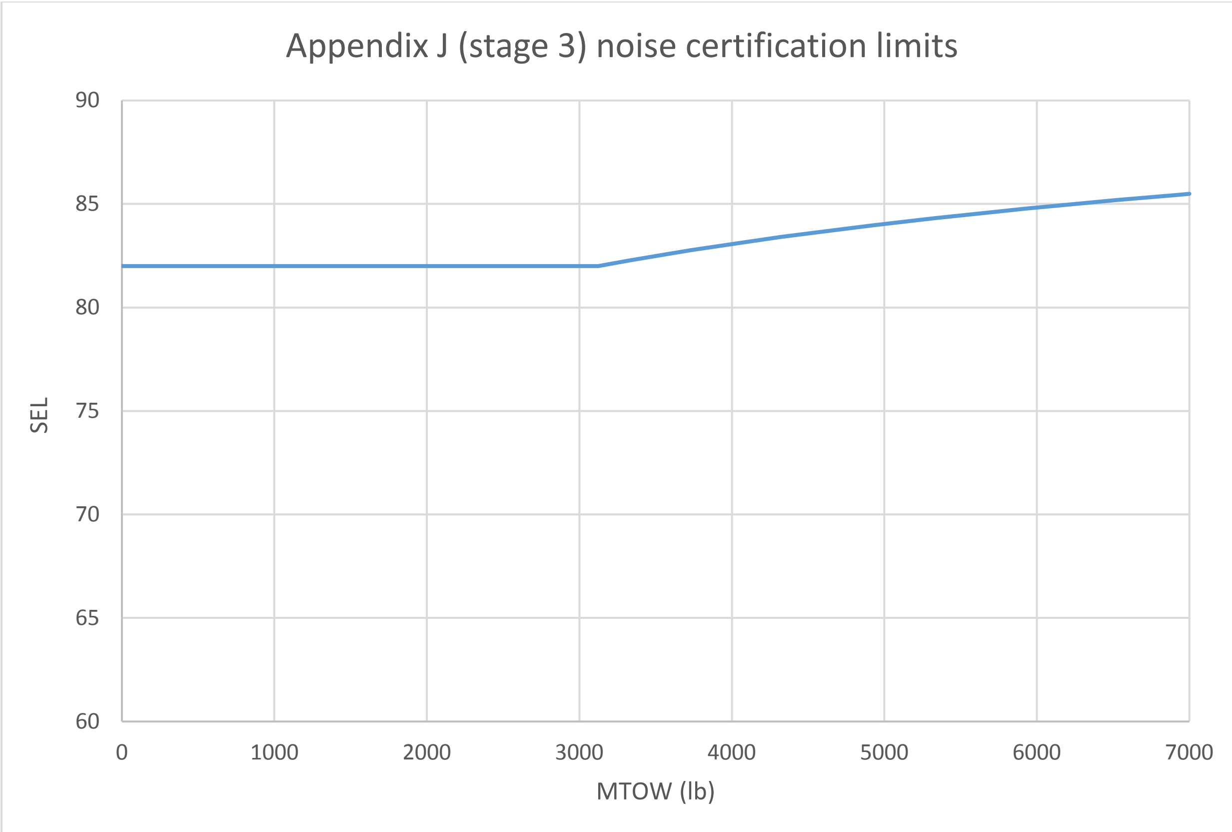

Fig. 2 - CFR Title 14, Part 36, Appendix J Stage 3 noise limits for light helicopters

3 UAS CERTIFICATION ISSUES

This section discusses some of the issues related to noise certification of UAS vehicles under the current system.

3.1 UAS certification under the current system

A number of UAS vehicles have undergone certification or certification-like tests in the U.S. Table 1 below shows some of the data from these tests. The two columns on the left indicate the UAS and the type of vehicle. The third column is the weight of the vehicle in pounds. The fourth column indicates the operation type conducted during the particular noise test. “Takeoff” indicates that a Part 36 Appendix G test was used. “Level overflight” indicates a standard straight-and-level pass over the microphone was used. The fifth column indicates the type of microphone mounting used in the test. “IGPM” is an Inverted Ground Plane Microphone – this is the type of microphone mounting explicitly required in Appendix G. “Pole” indicates that a microphone on a four foot tripod was used. “MOP” indicates a microphone on a plate was used. Only the Navmar Tigershark had a test with more than a single operation and microphone type. The penultimate column represents the A-weighted maximum noise level normalized to a distance of 400 feet. Only spherical spreading was used in the normalization. The seventh and final column contains information on the quality of the test data. “Cert” indicates that the data were collected in an actual noise certification. “Cert Quality” indicates that the procedures of Part 36 Appendix G were followed in the test. "Research" indicates that the data are useful for research purposes; the data were not collected with the intention of being certification quality.

Table 1 - Comparison of UAS noise test data

UAS vehicle	UAS type	Weight (lb)	Operation	Microphone configuration	Lamax @ 400'	Data quality
AeroVironment PUMA	Fixed wing	13.4	Takeoff	IGPM	37.9[1]	Cert
Insitu Scan Eagle	Fixed wing	46	Takeoff	IGPM	57.8[1]	Cert
Navmar TigerShark	Fixed wing	397	Takeoff	IGPM	90.8[1]	Cert Quality
Navmar TigerShark	Fixed wing	397	Level overflight	Pole	84.9	Cert Quality
Edge 540	Fixed wing	25	Level overflight	MOP	53.4	Research
DJI Phantom 2	Quadcopter	3.5	Level overflight	MOP	44.9	Research
Prioria Hex	Hexcopter	5.5	Level overflight	MOP	45.9	Research

[1] Actual reference profile for certified noise levels are much lower. Certified levels were readjusted to 400 feet for demonstration purposes

IGPM: Inverted Ground Plane Microphone
MOP: Microphone on a Plate
Pole: Tripod supported Pole Microphone at 4 foot

Of the three vehicles – all fixed-wing – which have undergone certification or certification quality tests, two are below the certified noise limits for their weight, while one is not.

3.2 Limitations of the current system

The current noise certification system serves a number of functions. The system:

- provides a method of measuring improvements in noise-reduction technology as they become available and are applied to the aircraft,
- provides an objective method of comparing noise from different aircraft of the same class, and
- provides the public with information on aircraft noise.

The current system functions well for its intended purpose with heavier aircraft, but may not work well for all UAS vehicles. The sections below discuss limitations in the noise metric and operations used in the current certification methods.

3.2.1 Noise metric limitations

Crewed helicopters generally control vertical speed by adjusting the pitch of the main rotor blades and control rotations about the lateral and longitudinal axes by adjusting the plane of rotation of the main rotor. In rotary-wing UAS which use fixed-pitch propellers, vertical speed is controlled by varying the speed of the rotors to adjust lift, while rotation about the vertical axis is controlled by varying the torque (via differential speed changes) of the rotors. The consequence of this is that UAS must vary thrust to effect maneuvers. Since thrust, in turn, influences noise, this means that the noise of rotary-wing UAS is inherently unstable during maneuvering operations. When different rotors operate at different speeds, the phase differences of the rotors may also contribute to the noise generation. Metrics which assume a relatively constant noise source may not capture the perception of noise which is rapidly fluctuation due to control inputs[3,4]. Figure 3 below shows the different noise signatures for a common commercially available sUAS operating in a steady state (hovering), compared to maneuvering flight.

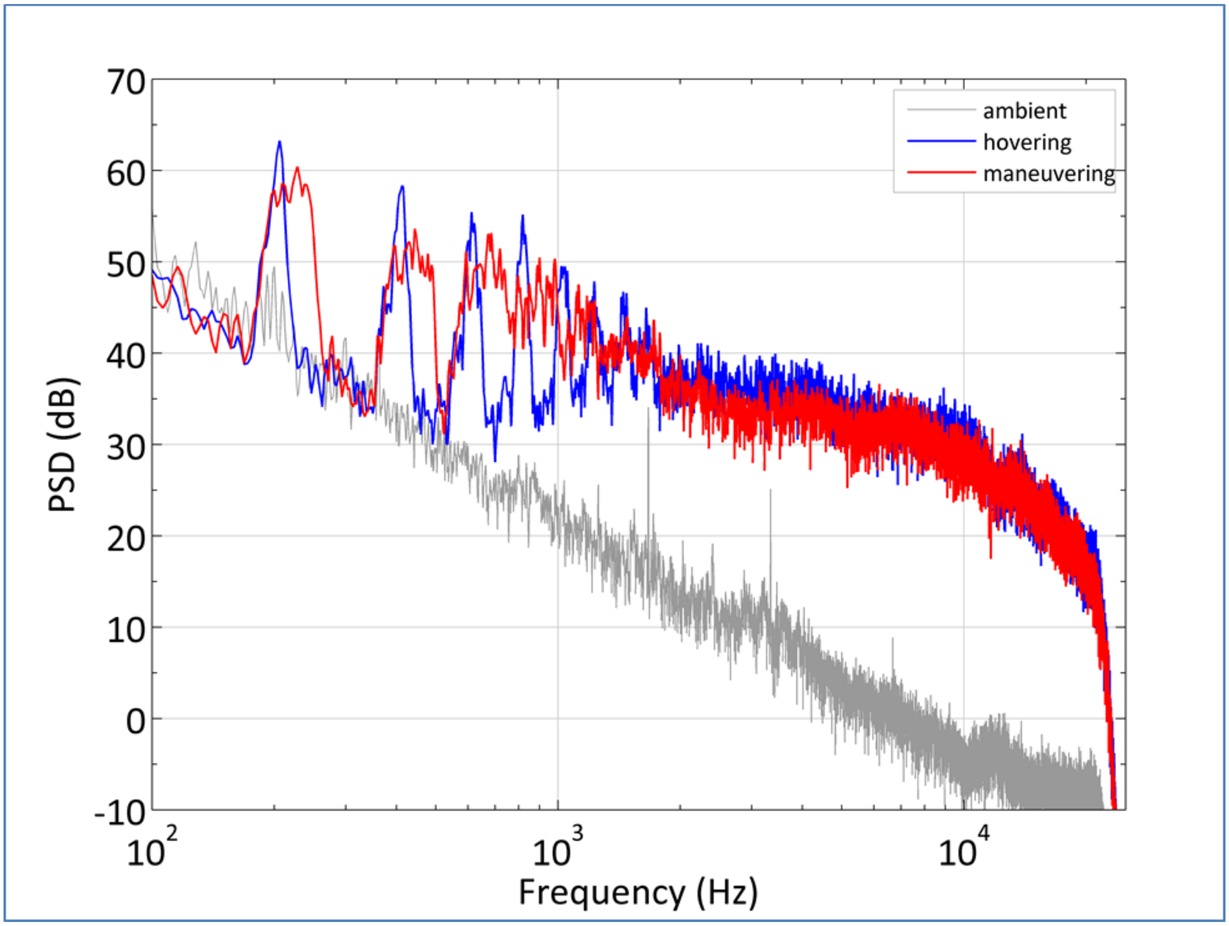

Fig. 3 - Power Spectral Density of an example sUAS during hovering and maneuvering flight

3.2.2 Operational limitations

The fixed-wing Appendix G test, by definition, is a takeoff noise test. This is reasonable for vehicles which have their primary noise effects close to the airport; fixed-wing aircraft are generally not considered to be a noise issue during en-route operations. That may not be the case for UAS vehicles which will potentially be operating in closer proximity to people during normal operations than crewed aircraft normally fly. The Appendix G test is based on a distance from the start of the take-off roll that may have little meaning for UAS vehicles which have substantially different thrust-to-weight ratios compared with crewed aircraft.

Helicopter certification tests may be closer to the expected operations of UAS, but the test itself is still problematic due to the relatively long distance from the aircraft flight altitude to the microphone. We note that the Appendix J fly-over altitude for helicopter noise certification is currently greater than the altitude small UAS vehicles are allowed to fly under Part 107.

In order to measure UAS with an adequate signal-to-noise ratio (SNR), the distance between the vehicle and the microphones may have to be reduced. The SNR is determined by the ambient noise levels during the test.

4 POTENTIAL FUTURE UAS CERTIFICATION OPTIONS

This section discusses possible options which could make noise certification of UAS more meaningful and appropriate than the current methods.

4.1 Measurement systems

Noise metrics have yet to be decided. Note that the Appendix G test uses one of the simplest possible noise metrics; it will be hard to justify using a more complex metric for vehicles which are substantially less expensive than crewed aircraft.

The inverted ground plate microphone used in Appendix G noise certification flight tests is designed to remove the issue of constructive/destructive interference of directed and reflected sound from the aircraft. Two other methods of achieving this end are 1) a microphone mounted directly in the ground plate so that the microphone diaphragm is pointed up, and 2) a microphone placed flat on plate, so that the microphone diaphragm is pointed horizontally. In Figure 4 below, the left picture shows a microphone mounted directly in the plate, the middle picture shows an Appendix G inverted microphone (an IGPM in the parlance of Table 1), and the right picture shows a microphone on a plate (MOP). Note that all three microphone set-ups include hemispherical windscreens.

Preliminary investigation with a sUAS showed that the noise levels for sUAS overflights were similar for the three configurations, while the IGPM had less scatter in the measurements than the other two configurations. The initial experiment was conducted in an acoustically poor environment - Volpe and FAA staff plan further investigations in an area with lower ambient noise levels.

Fig. 4 - Ground plane and microphone configurations during an sUAS flight test

4.2 Operations

Any new certification methods for UAS vehicles should capture the expected actual operational noise to which people would be exposed. An optimal case would be one where we could use a certification metric which corresponds with nuisance caused by UAS operations, but knowing which metric to use may not be possible until people are actually exposed to UAS noise[5]. Current certification methods focus on takeoffs, where it is anticipated the most UAS operations will be fly-overs or level fly-overs at a higher altitude than where UAS would operate, which may lead existing methods to not be appropriate.

As a starting point for discussions on operational procedures for certification, the distance from the vehicle to the microphone in the certification test should approximate the distances from the vehicle to the receptor during actual operations. These distances may be close enough to the microphones so that the error in the position of the vehicle relative to the microphone becomes a concern. As an example, based just on spherical spreading, an error of one meter when the slant distance between the vehicle and receptor is 10 meters leads to error in the measurement of 0.4 dB for a maximum level compared to the same one meter error during a 100 meter slant distance leading to 0.04 dB measurement error. Volpe and FAA have developed a GPS-based system to provide precise vehicle tracking in a package small enough to be carried on vehicles as light as 2 kg. Distance measurements of this type during noise certification tests would likely be of much higher accuracy than the photo-scaling methods of SAE-AIR-902A[6].

5 CONCLUSIONS

While existing noise certification methods for crewed aircraft have been used to certificate UAS, those methods are not optimal and may not represent the best methods for certificating UAS vehicles in the future. FAA continues to investigate which noise metrics correlate best with potential UAS annoyance and which noise certification flight operations best represent expected actual operations.

6 REFERENCES

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