Remotely Piloted Aircraft Systems (RPAS) noise in an urban environment

Mark Latimore[1], Clyton Moyo[1], Belinda Fenner[1] and Paul Zissermann[1]

1. Environment and Community Branch, Air Navigation Services Group, Airservices Australia, Canberra, Australia.

ABSTRACT

Disturbance from Remotely Piloted Aircraft Systems (RPAS) will become more prevalent as their recreational and commercial use increases in urban environments. Noise from RPAS can be very distinct, with tonal qualities that sensitive individuals can find particularly annoying. This is an issue faced both within Australia and worldwide. In 2018, the Australian Government's Department of Infrastructure, Transport, Cities and Regional Development (the Department) provided approval to a commercial operator to perform a trial of drone deliveries of food and household items at specific locations in the south of Canberra. In 2019, the delivery services were approved for four northern Canberra suburbs and two suburbs in South Brisbane. The trial in south Canberra in 2018 had mixed reviews from the community and prompted the need to implement quieter drone technologies in an urban environment. A review of noise regulations has been initiated by the Department that addresses both RPAS and the new concept of urban air mobility (UAM) systems. This paper explores the existing regulatory framework in Australia and discusses appropriate noise certification standards and noise metrics. Noise modelling results are also presented for a hypothetical UAM operating scenario in the Melbourne central business district (CBD).

1 INTRODUCTION

Disturbance from Remotely Piloted Aircraft Systems (RPAS) will become more prevalent as their recreational and commercial use increases in urban environments. Noise from RPAS can be very distinct, with tonal qualities that sensitive individuals can find particularly annoying. This is an issue faced both within Australia and worldwide.

In early 2019, Australia's Federal Department of Infrastructure, Transport, Cities and Regional Development (the Department) provided approval to a commercial operator to perform a trial of drone deliveries of food and household items in three northern Canberra suburbs. Commercial deliveries are now being undertaken in these three suburbs and will be extended to a fourth. A trial has also been approved for South Brisbane (Logan) to two suburbs. In 2018, a previous trial in south Canberra had mixed reviews from the community and prompted the need to implement quieter drone technologies in an urban environment.

The Department has used the term urban air mobility (UAM) to describe on-demand and automated passenger and cargo air transportation services, with or without a pilot, operating within an urban area (DITRCD, 2019). This type of passenger transport technology is expected to rapidly grow and be used in major cities around the world. RPAS and UAMs are currently the fastest growing sector in civil aviation and this technology is expected to play an increasingly significant role in the aviation industry over the next 20 years. Current aviation regulation and policies need to be updated to allow the emerging technology to grow, while adequately managing the potential aircraft noise impacts from these operations.

2 AIR NAVIGATION (AIRCRAFT NOISE) REGULATIONS 2018 REVIEW

Towards the end of 2019, the Department initiated a review of the Air Navigation (Aircraft Noise) Regulations 2018. The purpose of the review is to help determine the appropriate scope and breadth of future noise regulation, primarily for RPAS and UAM aircraft. The following sections of this paper discuss some of the potential noise regulation amendments, including noise certification standards for RPAS and UAMs, and the concept of using typical noise metrics used in Australia including the Australian Noise Exposure Forecast (ANEF) for managing noise from these aircraft types. The ANEF is a single number index for predicting the cumulative exposure of aircraft noise in communities near aerodromes during a specified time period (AS 2021; 2015).

3 RELEVANT STAKEHOLDERS

The table below describes the relevant stakeholders in RPAS and UAM operations in Australia, and their general area of responsibility regarding the introduction of this new technology into Australia.

Table 1: Stakeholders

Stakeholder	Area of Responsibility
Airservices	• Management of airspace and integration of RPAS and UAM into air traffic management systems. • Noise certification of aircraft in accordance with the Air Navigation (Aircraft Noise) Regulations 2018. • Management of noise impacts from aircraft operations including a national Noise Complaint and Information Service (NCIS). • Management of a national aircraft Noise and Flight Path Management System (NFPMS), covering 8 major airports.
The Department	• Oversee government legislation and policy relating to airports and aviation. • Implementation and review of the Air Navigation (Aircraft Noise) Regulations 2018.
CASA	• Safety regulator for civil air operations. • Airspace regulation, aircraft and pilot licensing. • Safety education through training programs.
Commercial Industry and Operators	• Technology development and implementation. • Operation of RPAS and UAMs in accordance with regulatory requirements.
Local Council and State Governments	• Infrastructure development. • Enforcement of local (state and territory) noise regulations relating to ground-based ‘nuisance’ noise sources in urban and rural areas.
Community	• End user of some commercial RPAS and UAM services. • Potentially affected by noise impacts from RPAS and UAM operations.

One area of responsibility omitted above is the enforcement of RPAS and UAM operations against noise legislation. This responsibility may sit at a Commonwealth (federal) level through the Department, or at a local/state government level, depending on the outcome of the regulatory review.

4 AIRSPACE CHALLENGES FOR AIRSERVICES

Within Australia, airspace is designated as ‘controlled’ or ‘uncontrolled’. Controlled airspace is actively managed by Airservices’ air traffic controllers and is broken up into a number of different classes or classifications. To enter controlled airspace, an aircraft must first gain a clearance from air traffic control (ATC). In contrast, no clearance (or supervision by ATC) is required to operate in uncontrolled airspace. The large majority of light aircraft and helicopters operate in uncontrolled airspace, outside or underneath controlled airspace.

Airservices currently has an RPAS Operational Concept which describes the level of integration required between the RPAS operator and ATC. This is dependent on the location of the operation, the RPAS avionics equipment levels and the operational capability of the RPAS. A concept of RPAS Fly Zones that are typically located within 5.56 km (3 nm) of a controlled aerodrome has also been developed (Airservices, 2018).

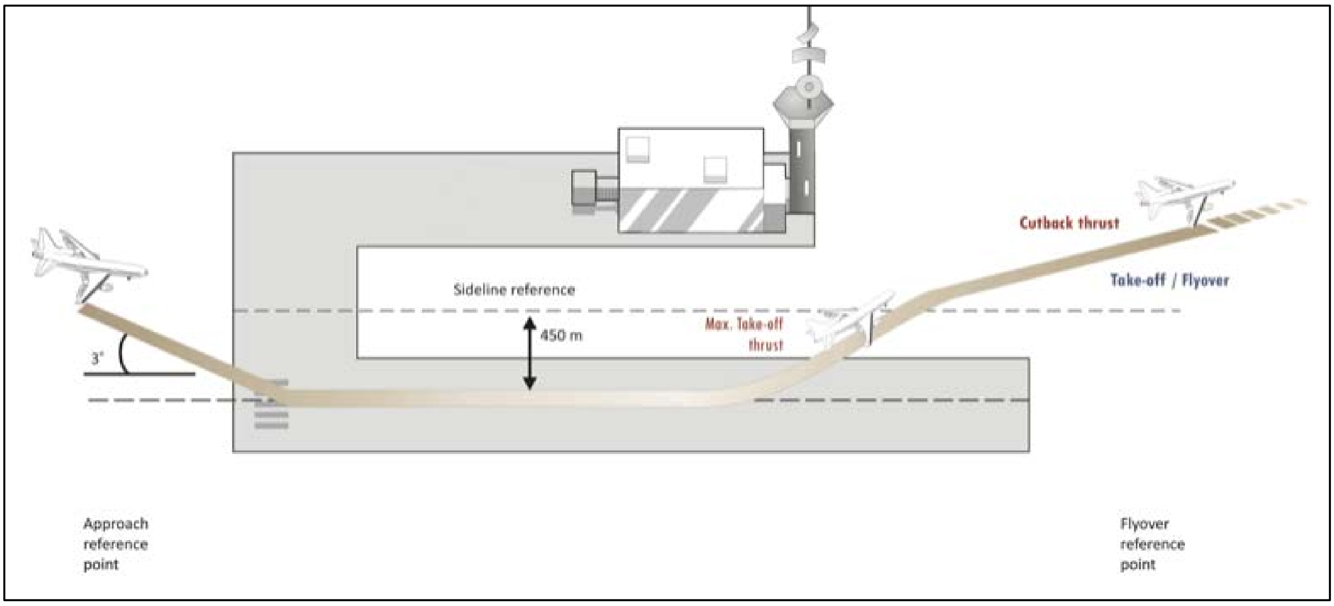
It is expected that RPAS and UAM may largely operate within uncontrolled airspace, typically up to levels below 400ft, or possibly in controlled airspace outside of the RPAS Fly Zones. They will also likely operate under an

Unmanned Traffic Management system (UTM). The challenge for Airservices will be to successfully integrate the UTMs into its Air Traffic Management (ATM) systems safely and with minimal impact. Airservices will continue to work with future airspace users and other stakeholders to develop approaches to low level airspace management that supports the safe introduction of these new technologies.

5 RPAS AND UAM NOISE CERTIFICATION STANDARDS

It has recently been determined by the Department that RPAS and UAMs should be subject to the existing national aircraft noise regulatory regime (DITCRD, n.d.). Australia is a member state of the International Civil Aviation Organisation (ICAO) and therefore, noise regulation for conventional aircraft is largely established through compliance with the relevant chapters of ICAO Annex 16, Volume 1 Aircraft Noise. This poses an issue, as current ICAO standards do not prescribe noise standards for RPAS and UAM aircraft types.

Historically the ICAO aircraft noise certification standards were developed to address communities concerns about aircraft noise in the vicinity of airports. Each ICAO chapter describes a test reference procedure that represents aircraft operations arriving to and departing from an airport.



Source (ICAO, n.d.)
Figure 1: Aircraft noise certification reference measurement points

The concept of UAM operations is not specifically limited to areas in the vicinity of airports and noise exposure issues will likely extend deep in to urban areas, at considerable distances from traditional airport operations. Therefore the maximum allowable noise limits defined in the relevant chapters of ICAO Annex 16, Volume 1 may not be directly applicable to UAM operations. Because of the way UAMs will potentially operate over large urban areas at low altitudes (and sometimes within close proximity to people), lower maximum allowable noise limits need to be considered.

5.1 Noise Standards For UAMs

It is expected that a UAM will operate similarly to a light helicopter, and therefore the closest relevant standard is ICAO Annex 16, Volume 1, Chapter 11, *Helicopters Not Exceeding 3,175kg Maximum Certificated Take-Off Mass* (ICAO, 2017). This standard specifies that the maximum noise levels should not exceed 82 dB SEL for an applicable helicopter up to 788 kg, increasing linearly with the logarithm of the helicopter mass (at a rate of 3 dB per doubling of mass thereafter).

A representative helicopter that complies with this standard is the Robinson 44 (R44). The R44 is a four seater aircraft powered by Lycoming's IO-540 fuel injected engine. It has a Maximum Take-off Weight (MTOW) of 1,089 kg and a certificated noise level of 81.9 dB SEL, in accordance with ICAO Annex 16, Volume 1, Chapter 11 (European Union Aviation Safety Agency (EASA), 2017).

To comply with the ICAO standard, noise levels are measured while the subject aircraft performs a reference procedure. For ICAO Annex 16, Volume 1, Chapter 11, the reference procedure includes:

- Stabilised level flight overhead a noise measurement point at 150m (492ft) +/- 15m (50ft).
- Constant speed, generally corresponding to 90% of the speed under maximum continuous power conditions.
- Stabilized rotor speed at the maximum normal revolutions per minute (rpm) certificated for level flight.
- Aircraft in cruise configuration with aircraft mass equal to its MTOW.

It is possible that the general UAM operating conditions will be similar to the ICAO reference conditions, particularly the operating altitudes of UAMs up to 500ft in uncontrolled airspace. In which case the maximum allowable noise levels of ICAO Annex 16, Volume 1, Chapter 11 may be of some relevance. It is important to note that the concepts of rotor rpm and maximum continuous power may not be applicable to UAMs, which will be typically electric vehicles with different rotor rpm conditions. Adjustments to the allowable maximum noise levels should be considered for these factors.

It is also possible that aspects of ICAO Annex 16, Volume1, Chapter 13, *Tilt-Rotors,* may be applicable to UAMs. Chapter 13 was recently published and is applicable to tilt-rotor aircraft type certificated from 1 January 2018. This chapter specifies take-off, overflight and approach reference procedures and provides maximum Effective Perceived Noise levels (EPNdB). The maximum allowable EPNdB varies according to the aircraft MTOW. As an example, an aircraft with an MTOW of 1,089kg would have maximum allowable limits of 90.4 EPNdB for take-off, 89.9 EPNdB for overflight and 91.4 EPNdB for approach. Aircraft with these noise levels would likely cause significant noise impacts in urban areas, particularly in built-up, commercial districts.

5.2 Noise Standards For RPAS

RPAS (or drones) for commercial household deliveries typically operate in urban areas at altitudes much lower than the ICAO test reference conditions. Cruising altitudes may be around 40m (130ft) to 50m (164ft). Therefore testing RPAS against the current ICAO standards and using ICAO maximum allowable noise levels would likely not be appropriate.

Noise levels from RPAS in an urban environment may be better controlled by the use of international standards for drones using sound power limits. For RPAS, there are two relevant regulatory documents from EASA:

- Commission Delegated Regulation (EU) 2019/945 of 12 March 2019, on unmanned aircraft systems and on third-country operator of unmanned aircraft systems (EASA, 2019a), and
- Commission Implementing Regulation (EU) 2019/947 of 24 May 2019, on the rules and procedures for the operation of unmanned aircraft (EASA, 2019b).

These documents define RPAS categories of operation and class levels depending on the relevant MTOW (or MTOM – maximum take-off mass). Part 13 of (EU) 2019/945 defines a noise test code for RPAS, and describes the methods of measurement of airborne noise that should be used to determine the A-weighted sound power levels. The document also provides maximum sound power limits for Class 1 and Class 2 systems, as defined in the following table.

Table 2: Drone Noise Limits

Source (EASA, 2019a)

UA class	MTOM m in gram	Maximum sound power level L_{WA} in dB(A) as from entry into force	as from 2 years after entry into force	as from 4 years after entry into force
C1	250 ≤ m < 900	85	83	81
C2	900 ≤ m < 4000	$85 + 18{,}5 \lg \frac{m}{900}$	$83 + 18{,}5 \lg \frac{m}{900}$	$81 + 18{,}5 \lg \frac{m}{900}$

where 'lg' is the base 10 logarithm.

RPAS delivery systems are likely to have an MTOM greater than 4kg, and carry additional payload. The maximum sound power levels defined above can be used as a guide, however, may not be directly applicable to specific RPAS delivery operations.

6 URBAN AIR MOBILITY (UAM) EXAMPLE TEST CASE

Many future operators are developing technology to introduce UAM vehicles into major cities around the world including operations in Australia. Large scale UAM operations will likely be possible through the development of "sky ports" or launch pads atop buildings. One of the potential operators of UAMs includes Uber Elevate who have published the white paper *Fast-Forwarding to a Future of On Demand Urban Air Transportation October 27, 2016*. (Uber, 2016). The white paper addresses future noise issues and states:

> *VTOL aircraft will make use of electric propulsion so they have zero operational emissions and will likely be quiet enough to operate in cities without disturbing the neighbors. At flying altitude, noise from advanced electric vehicles will be barely audible. Even during take-off and landing, the noise will be comparable to existing background noise* (Uber, 2016).

The white paper also indicates that these vertical take-off and landing vehicles (VTOL) will initially be 15 dB quieter than existing helicopters and references similarities in vehicle size to the Robinson 44 light helicopter aircraft. To help explore the noise exposure from UAM operations in Australia and test their integration into typical noise modelling tools, a theoretical noise model has been created for this paper as a hypothetical test case. Note that the test case is completely fictitious and is not associated in anyway with any current developments or with Uber Elevate.

The hypothetical test case models noise exposure from a theoretical "sky port" on a Melbourne CBD roof top. The purpose of the modelling exercise is to explore the potential noise exposure from future hypothetical UAM operations in regards to current noise metrics used in Australia, including the ANEF system for land use planning and 'number above' noise metrics. The exercise also tested how current aviation noise modelling software programs, such as the United States Federal Aviation Administration (US FAA) Airport Environmental Design Tool (AEDT), could be adapted to include UAMs.

6.1 Noise Modelling Software

The UAM test case noise model was generated using AEDT. AEDT is a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality impacts. It is a comprehensive tool that provides information to US FAA stakeholders on each of these specific environmental impacts (US FAA, n.d.).

6.2 Modelled Site and Flight Tracks

To represent a potential "sky port", an AEDT model was built with two representative helipads on top of a building at 570 Bourke Street, Melbourne, Victoria. The building height of 390ft was sourced through Butler (n.d.). Each helipad was created with two departure and two arrival tracks to represent potential UAM traffic between Melbourne International Airport and the Melbourne CBD. Hypothetical flight tracks were modelled generally along current transport infrastructure routes, such as railways and major arterial roads. On each track, a total of 10 movements were allocated during daytime hours, representing a total of 80 UAM movements on a single day. The hypothetical flight tracks can be seen in Figure 2 below, with departures in green and arrivals in blue.

Source background image (Google Earth 2019)
Figure 2: Hypothetical UAM test case flight tracks in the Melbourne CBD.

6.3 Aircraft Adjustments

Within AEDT, each aircraft type is represented with a Noise-Power-Distance (NPD) curve, which is used to calculate noise exposure. To represent UAM aircraft, the Robinson 44 (R44) light helicopter was used with NPD curves reduced by 15dB. The 15dB has been used here to represent the assumed noise reduction described in Uber's 2016 white paper.

Aircraft arrival and departure profiles also have a heavy influence over the calculated noise exposure. To represent UAM operations to the hypothetical roof top "sky port", the aircraft profiles were adjusted as shown in Figure 3 below. Each profile was maintained at around 500ft to represent the potential flight profiles of UAMs.

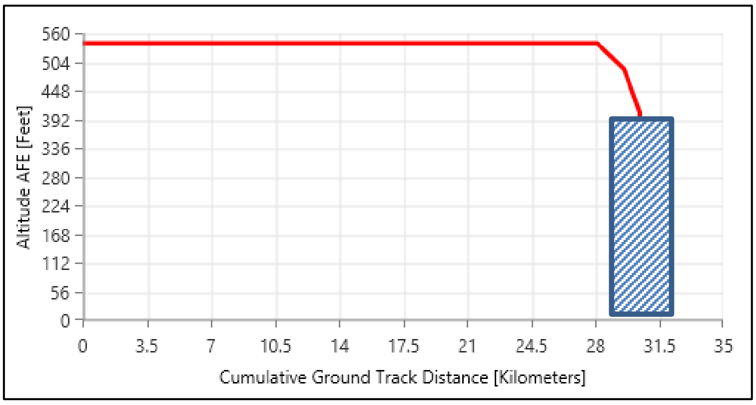


Figure 3: Hypothetical UAM test case arrival profile

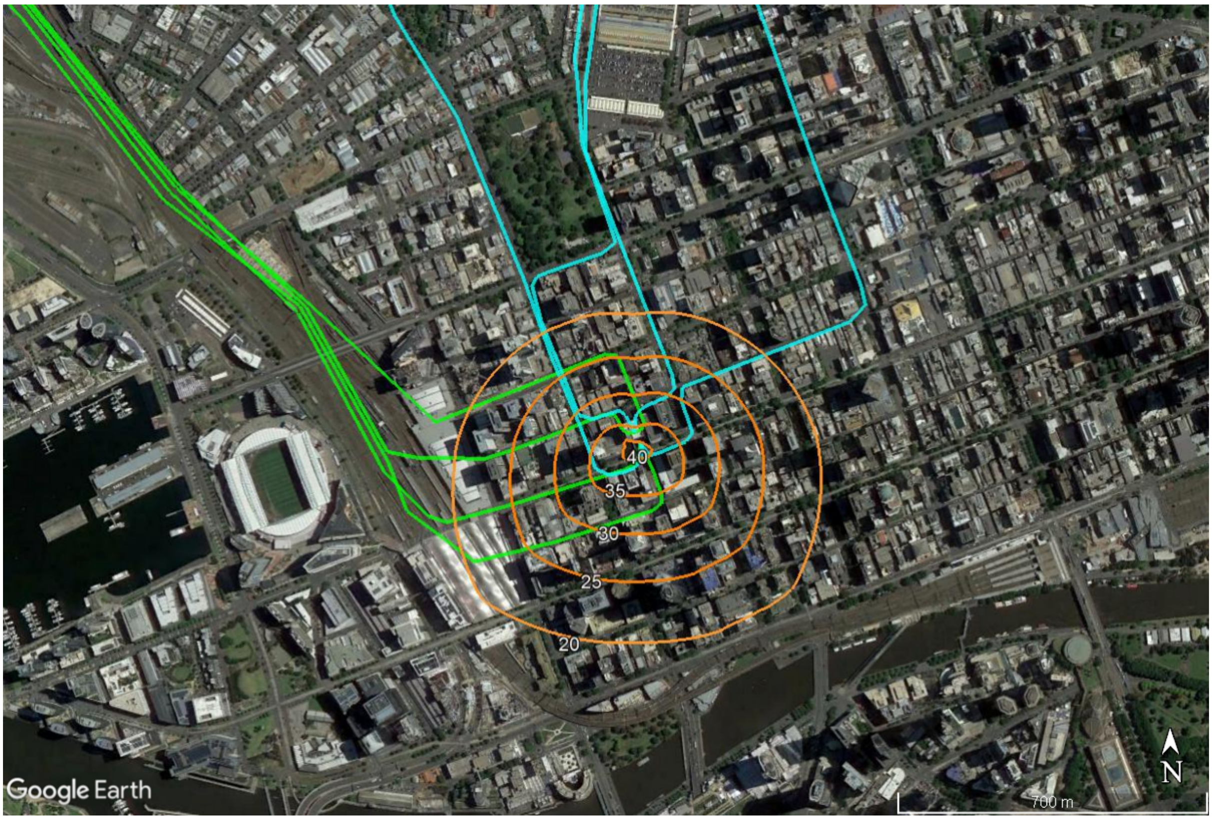
Note that in the profile image above, the representative aircraft arrives to a hypothetical "sky port" on top of a building at a height of 390ft above ground level.

6.4 Model Limitations

Due to time limitations in the preparation of this paper, a terrain model was not used within AEDT. The AEDT calculation grid was located at ground level with the modelled "sky port" at a height of 390ft. It is expected that a detailed terrain model of the CBD would greatly affect the noise results. It is also understood that the AEDT model adjusts noise levels due to ground reflections, however not building reflections or shielding. Other modelling packages (or a combination of models) may be better suited to modelling UAM operations in urban CBD environments, to account for noise from building facade reflections.

6.5 Noise Modelling Results

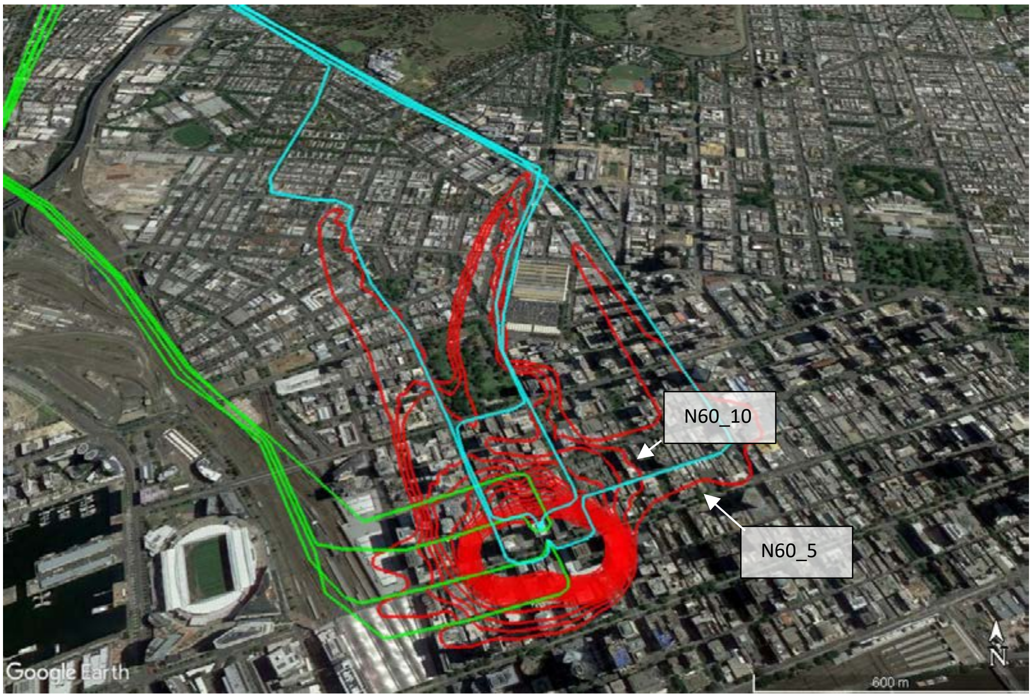
The ANEF modelling results are shown in Figure 4. The typical ANEF contour values used for airports (ANEF 20 to 40) are shown. The results follow a particular pattern, forming concentric rings around the hypothetical "sky port". This is typical of helicopter operations modelled in this way, due to the most noise exposure being experienced from flight segments close to or over the helipad.



Source background image (Google Earth 2019)
Figure 4: Hypothetical UAM test case ANEF result

The ANEF results above are somewhat larger than expected, despite the modelled UAM aircraft type being 15dB less than a typical R44 aircraft. This is likely due to the significant number of movements modelled per day and adjustments made to the operational profile. The ANEF contours are at ground level, without the effects of terrain or building facade reflection.

"Noise above" (or N-above) metrics are typically used in Australia to help show noise impacts from aircraft operations around airports. They usually extend much further than ANEF contours and combine the number of aircraft overflights with predicted noise levels. The results below show N60 noise contours for the hypothetical UAM test case. N60 contours are shown in red ranging from 5 to 75 noise events above 60dB(A) during the day, in increments of 5.



Source background image (Google Earth 2019)
Figure 5: Hypothetical UAM test case in Melbourne CBD - N60 contours.

Source background image (Google Earth 2019)
Figure 6: Hypothetical UAM test case in Melbourne CBD - N60 contours (close up).

The N60 noise contours shown above typically follow the arrival paths and are concentrated around the hypothetical "sky port". Close to the "sky port", each UAM movement would create noise levels above 60dBA. The N60 contours shown above are at ground level and do not include the effects of terrain or building facade reflections. A detailed terrain model would heavily influence the results.

In a busy CBD environment, background noise levels can vary greatly. The hypothetical noise event levels of around 60dBA from UAM shown above would likely blend into the background and not cause disturbance in a busy CBD environment. However, the potential locations of future UAM "sky ports" should be carefully considered to minimise noise impacts on sensitive receivers (such as residential buildings, hospitals and educational facilities). Additional factors that consider any particularly annoying aspects of UAM noise (including tonal content, visual noticeability and frequency and time of operations), should also be considered when assessing potential "sky port" locations.

The results above for ANEF and N60 contours show that is possible to model UAM operations and predict noise exposure on communities. This work will help inform the Department's current regulatory review, including the limitations of the noise modelling software identified above. Also, the accuracy of the noise exposure prediction will largely rely on accurate source data regarding UAM vehicle noise levels rather than the hypothetical levels used in this study.

7 CONCLUSION

It is certain that use of RPAS and UAM systems will rapidly grow in the future and that these new technologies will drive changes to existing legislation. It has been shown that current ICAO noise certification standards may provide useful guidance for UAM noise certification, however they are not directly applicable. Likewise, maximum sound power levels within the current European standards for RPAS provide a useful guide, but may not directly apply, particularly for RPAS delivery systems operating in an urban environment.

A hypothetical UAM test case noise model was developed that showed it is possible to generate typical aircraft noise metrics used in Australia, such as ANEF and N-above contours. However, there are still many limitations with the conventional aircraft noise modelling software used, including its limited ability to accommodate noise reflections from building facades in an urban CBD environment.

REFERENCES

Air Navigation (Aircraft Noise) Regulations 2018 (Cth), https://www.legislation.gov.au/Details/F2018L00448.

Airservices, 2018. *Management of Remotely Piloted Aircraft Systems (RPAS) in ATM Operations.* http://www.airservicesaustralia.com/wp-content/uploads/AIR575_RPAS_ATM_Operations_d3a1.pdf.

Airservices, 2018. *Guide to Our Operations*. http://www.airservicesaustralia.com/wp-content/uploads/12-058BKT_Guide-to-our-operations_WEB-1.pdf.

Australian Standard AS2021:2015. *Acoustics—Aircraft noise intrusion—Building siting and construction.*

Butler, Luke. n.d. *Melbourne Building Heights. Accessed*, September 12 2019. http://lbutler.github.io/MelbBuildingHeights.

Department of Infrastructure, Transport, Cities and Regional Development (DITCRD). 2019. *Review of the Air Navigation (Aircraft Noise) Regulation 2018. Issues Paper. https://www.infrastructure.gov.au/aviation/environmental/aircraft-noise/files/Issues_Paper-Review_of_Air_Navigation-Aircraft_Noise_Regulations_2018-RPA.pdf*

Department of Infrastructure, Transport, Cities and Regional Development (DITCRD). n.d. *Noise Regulation for Remotely Piloted Aircraft (RPA)—Drones,* Accessed 3 October 2019. *https://www.infrastructure.gov.au/aviation/environmental/aircraft-noise/noise_regulation_for_rpa_drones.aspx*

EASA. European Union Aviation Safety Agency. 2017. *Type Certification Data Sheet for Noise (TCDSN) EASA.IM.R.121. Robinson R44.* https://www.easa.europa.eu/sites/default/files/dfu/EASA.IM_.R.121%20Issue4.pdf

EASA. European Union Aviation Safety Agency. 2019a. Commission Delegated Regulation (EU) 2019/945 *unmanned aircraft systems and on third-country operators of unmanned aircraft systems. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R0945.*

EASA. European Union Aviation Safety Agency. 2019b. Commission Implementing Regulation (EU) 2019/947 *the rules and procedures for the operation of unmanned aircraft. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R0947.*

International Civil Aviation Organisation. 2017. ICAO, Annex 16, Volume 1, Seventh Edition July 2017, *Environmental Protection, Aircraft Noise.*

International Civil Aviation Organisation. n.d. *Environmental Protection, Reduction of Noise at Source*, Accessed 3 October 2019, https://www.icao.int/environmental-protection/pages/Reduction-of-Noise-at-Source.aspx.

Uber Elevate. October 27, 2016. *Fast-Forwarding to a Future of On-Demand Urban Air Transportation. https://www.uber.com/elevate.pdf/.*

United States Federal Aviation Administration, n.d. *Aviation Environmental Design Tool*, Accessed 3 October 2019, https://aedt.faa.gov/