Airbase Auckland: Whenuapai

Noise From Aircraft Engine Testing

Noise Predictions & Assessment

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Prepared For:

New Zealand DEFENCE FORCE
Te Ope Kātua O Aotearoa
NAVY NZ ARMY AIR FORCE

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Acoustic Terminology

dB[A] A weighted Decibel. A measurement of sound which has its frequency characteristics modified by a filter [A-weighted] so as to more closely approximate the frequency bias of the human ear.

L_{Aeq} dB The time-averaged sound level [or equivalent sound level] that has the same mean square sound pressure level as the time-varying sound level under consideration. Commonly referred to as an "energy average" measure of sound exposure. The L_{Aeq} is an A weighted sound pressure level over the measurement period.

$$L_{Aeq(t_3)} = 10 \lg \left(\frac{1}{t_3} \int_{t_1}^{t_2} p_A{}^2(t)\, dt / p_0{}^2 \right) \text{dB}$$

where:

t_3 is the measurement time interval between start and finish times t_1 and t_2

$L_{Aeq(t_3)}$ is the LEQ over time period t_3

$p_A{}^2(t)$ is the square of the A-frequency-weighted sound pressure as a function of time

p_0 is the reference value of 20 μPa

L_{AFmax} dB A weighted sound pressure level. The single highest sampled level of sound over the measurement period.

L_{A10} dB The level of sound exceeded for 10% of the monitoring period. This level of sound equates to an average maximum sound level. **L_{A10}** Usually measures within 1 to 3 dB of the LAeq level, for the same sound. Prior to 2008 most District Plan noise emission limits were stipulated using the **L_{A10}** adopted since the 1970's which although being reasonable predictor of noise annoyance was difficult to predict and scientifically calculate compared to the recently adopted LAeq unit.

L_{A90} dB The level of sound exceeded for 90% of the monitoring period. This level of sound equates to an average background sound level, and is influenced by constant sources. Noise emission limits are not generally specified in terms of an L_{90} level, but it is used as a guide to the general background sound level. The L_{A90} is widely accepted as reflecting human perception of ambient background noise and generally reflects the noise level in the lulls between individual noise events, for example noise present during car by pass or someone yelling. The L_{A90} is an A weighted sound pressure level over the measurement period.

Ldn dB The day-night average sound level (Ldn or DNL) is the average LAeq sound level over a 24-hour period. Noise events taking place between the hours of 10pm and 7am is artificially increased by 10 dB to take into account the increase in sensitivity to noise occurring during night time.

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1 Scope of Assessment

The purpose of this report is to quantify aircraft ground run-up noise received within areas surrounding RNZAF Airbase Auckland (Whenuapai), prepared for the purposes of informing land use planning decisions within the affected areas.

Whenuapai is the home of the Fixed Wing Transport Force of New Zealand which provides strategic air transport to the government. This involves air services to support the government's needs in relation to overseas deployments of NZ troops, ministerial travel, disaster relief and humanitarian operations, the NZ Antarctic Programme, etc. involving all manner of flights undertaken internationally and within New Zealand air space.

The testing of aircraft engines is a noise generating activity that is essential to NZDF's operations at Whenuapai. This is because the aviation industry has very strict procedures regarding the need to run an engine after engine maintenance, before it can be used for flight. Routine or unplanned work on an engine will often require a period of idling or a short full power run of the engine.

The testing of aircraft engines at Whenuapai is a known source of local noise for neighbours to Whenuapai. Sound levels could be measured to assess areas affected, however the assessment over wide areas would require many hundreds of field measurements for each test variant or aircraft type. Providing valid input sound levels are adopted and operational variables are accurately reflected within acoustic calculations, the project is most efficiently undertaken as a desktop exercise using predicted noise contours (lines of equal sound pressure) to denote the areas affected.

This investigation utilises the best available aircraft engine noise data and information on engine test procedures adopted at Whenuapai[1]. While the methodology is based on a desktop prediction of noise-affected areas (as opposed to field monitoring), concerted efforts have been made to ensure the accuracy and reliability of information proposed to be used within calculations to identify the areas affected by aircraft engine testing noise around Whenuapai Airbase.

This study does not include the noise from aircraft operations (arrivals or departures), taxiing, ground equipment, APU's, etc. The noise being assessed is solely the noise emitted from the aircraft during engine running on the ground when under-going engine testing. The greatest noise arises when the

[1] The precautions and methods in place that control aircraft engine testing at Whenuapai are embedded within 'standing orders' and established aviation requirements as apply to the operation of military aircraft. This results in engine testing undertaken in a relatively uniform manner for the type of high power or low power test being undertaken.

pilot in command advances the throttles to ensure engines operating correctly at higher engine revolutions, including some high-power tests where it is necessary to test the engines are capable of producing take-off thrust, although not all run-up procedures involve such checks.

This assessment seeks to identify those areas which, due to the current and expected levels of aircraft engine testing typically carried out at Whenuapai are likely to receive levels of engine testing noise that would be incompatible with development of the affected land for noise-sensitive uses. This report includes diagrams showing noise contours which depict the geographical extent of areas affected by cumulative engine testing noise.

This study focuses on noise from the largest aircraft operated from Whenuapai, namely engine testing noise emitted by the Boeing B757, Hercules C130H and P-3K2 Orion aircraft. As these aircraft are operated (cumulatively) for many thousands of hours per year, a comprehensive aircraft maintenance and testing regime is in place to maintain the fleet. Characteristics surrounding the duration, aircraft location and orientation and power settings used during typical engine testing[2] have been based on the results of a 2016 survey of engine testing carried over a 60 day period at Whenuapai.

In summary, this report sets out the background, methods, procedures and assumptions involved in estimating noise exposure in the vicinity of the Whenuapai airbase due to testing of aircraft engines on the B757, C130H and P-3K2 Orion aircraft. The data and information collected locally and, where necessary, on information sourced offshore, is considered reliable and a useful basis to proceed to the actual predictions. This document has been prepared as a discussion document to establish an appropriate basis to undertake the actual predictions.

2 New Zealand Standards

There are no New Zealand Standards that are specifically intended to apply to noise from aircraft engine testing. As the study is based on published noise data, no field readings have been taken using NZ Standard NZS6801:2008 *Acoustics – Measurement of Sound*. However, below we refer to engine test noise data acquired by field measurements, using methods we believe to be generally consistent with the requirements of this Standard.

The recommendations of NZ Standard NZS6802:2008 *Acoustics – Environmental Noise*, although not considered wholly appropriate (on its own) for the assessment of effects of aircraft engine testing noise, many of the generic corrections or adjustments will be taken into account in the assessments to be undertaken.

3 Noise Units or Metrics

Multiple metrics will be employed to assess noise exposure at far field receiver sites. All are measured in decibel units, mostly "A" frequency weighted. Sound levels are calculated, modelled and assessed

[2] The term 'engine testing' in this report refers to testing of aircraft engines fitted to an airframe, as opposed to bench testing an aircraft engine within a specialist test facility.

in each octave band 63 Hz to 8,000 Hz in order to accurately emulate sound as it propagates through the air (and across what is assumed as a soft, relatively flat, open area.

Thus, this study explores the noise exposure values using LAeq values calculated over various time periods. This study is based on the energy average sound level measured on a 24 hour basis, in units expressed as LAeq(24 hour). As aircraft engine testing is conducted almost exclusively between 7am and 10pm (unless an emergency arises which can only be authorised by the Officer in Command at the base and is a very rare event). On the basis that testing is conducted during daytime only, the LAeq(24 hour) value is synonymous with 'Level Day Night' Leq level (Ldn) which is the unit of noise measurement adopted for the control of noise from aircraft engine testing at other airports in the region under Policy 4.3.3 (c) of the Auckland Unitary Plan.

4 Aircraft Types

This assessment focusses on noise emitted by high power engine runs from the largest aircraft based at Whenuapai, namely:

- Twin engine Boeing 757 large jet with 2 x Rolls Royce RB211535E4/4B power units; and
- Four turboprop Allison T56-A-15 engine Lockheed C-130H Hercules aircraft.
- P-3K2 Orion aircraft fitted with 4 x Allison T56-A 14 turboprop engines.

The dominant source of noise emissions from aircraft when ground run are the propulsion systems. These comprise the engines themselves for both jet and turboprop aircraft, with the former including the enclosed fans, and the exposed propellers in the case of turboprop aircraft. The following summarises the approach taken;

The only available sound power level data in 'polar plot' format for the C130 aircraft was for the C130J model. The C130 model based at Whenuapai is the C130H model. Whereas the C130H is fitted with four Allison T56-A-15 turboprop engines developing 4,591prop shaft horsepower, the newer C130J (known as the Super Hercules) are fitted with Rolls-Royce AE 2100D3 turboprop engines, driving six-bladed scimitar propellers. There are four blades on each propeller on the C130H models flown at Whenuapai.

Although the C-130J has a quieter propeller it has more powerful engines which means a higher top speed carrying "maximum normal payload" (which is greater than the C130H). The assessment below has adopted the noise data for engine testing of the C130J aircraft as being reasonably representative of the older C130H model that has less horsepower. Full details of the source of the C130J noise data are set out in the following section of this report.

No. 5 Squadron RNZAF based at Whenuapai are equipped with a total of six Orion aircraft, each having undergone various airframe and mission system upgrades. The P-3K2 provides airborne surveillance and reconnaissance of New Zealand's areas of economic interest, exclusive economic zone, the South Pacific, and the Southern Ocean including Antarctica in support of the Commission for the Conservation of Antarctic Marine Living Resources.

The C-130H Hercules aircraft based at Whenuapai are fitted with the Allison T56-A-<u>15</u> engine, the P-3K2 Orion aircraft are fitted with a very similar Allison T56-A <u>14</u>. Although some minor acoustic differences are inevitable, for the purposes of this study engine testing emissions for the P-3K2 Orion have been set at the same sound power level (and spectrum)a s the C130H aircraft.

Testing of aircraft engines usually requires testing across a range of typical power settings (including frequent testing at low power or idle runs). Engine power settings included within the acoustic calculations are based on the data provided by the representative 2016 engine testing survey.

To ensure adequate assessment the frequency content of engine testing noise at Whenuapai, sound power levels in the bands 63 Hz to 8,000 Hz have been adopted within the noise predictions. Sound power levels in a 'polar plot' format have been used within the analysis below so that directivity of the noise sources is fully accounted for.

Source data for engine sound power levels in 'polar plot' format are however not easily sourced. A literature review revealed a published report[3] of noise associated with testing of aircraft engines at Cambridge Airport (UK) undertaken by Hoare Lea Consultants on behalf of Marshalls Aerospace and Defence Group, the airport operator. Polar plots for several aircraft were published as part of the base information upon which acoustic attenuation due to a proposed engine noise-reducing Ground Run-up Enclosure. This study references the International Civil Aviation Organisation's (ICAO) Aircraft Noise and Performance (ANP) database[4].

The published sound levels measured at 100metrs from the aircraft under high power test have been converted into sound power levels for use in noise modelling. The derived sound power levels for each octave band (63 Hz to 8,000 Hz) and each 10° directivity step are summarised in the tables below.

The conversion from the measured sound pressure levels to sound power levels has been based on the assumption that noise is emitted from an aggregate position on the centre line of the aircraft and in line with the engines. This assumption is valid, since the sound power data is for use in a point source model. The correction from sound pressure to sound power was based on hard ground between the source and the measurement location. Nosie contour predictions however are all based on soft ground which is the predominant surface considering the wider environment around the airbase.

The basis of aircraft noise emission data (for high power engine testing) is described in detail below for both aircraft types. For all aircraft types the sound power levels adopted for testing under low power have been set at 10 dB below the sound power levels adopted for the high power setting.

4.1 C310 Hercules

The source data for the C-130J aircraft has been obtained from measurements of engine tests taken by Hoare Lea Consultants at RAF Brize Norton 2012 and published within the Cambridge Airport study. The measurements undertaken relate to a C-130J aircraft with all four engines running, two running

[3] Appendix R Noise: Noise Emission Data, Hoare Lea Consultants, *Cambridge Airport Engine Ground Run-Up Enclosure - Environmental Statement*, Marshall Group Properties Limited, December 2016.

[4] The Aircraft Noise and Performance database is hosted and maintained by EUROCONTROL on behalf of ICAO. It provides the noise and performance characteristics of a wide range of aircraft types, which are required to compute noise contours around airports using datasets supplied by aircraft manufacturers for specific airframe-engine types.

at the highest power setting and the remaining two engines operating at low power. This is the highest power setting that can be used during ground running of the aircraft engines without risking damage to the airframe. As such this test data is considered conservative compared to testing undertaken at Whenuapai.

Measurements were obtained in each octave band and for 10° steps around the aircraft to ensure the sound levels were accurately captured along with frequency content and the directivity of the sound source(s). The published overall LAeq sound level of high power engine testing of the C130J measured at 100 metres is presented in Figure 1 below.

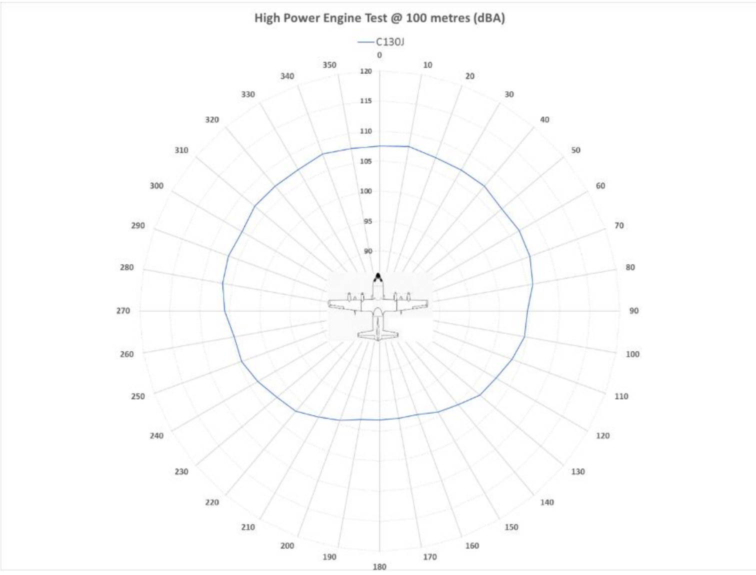

Figure 1 C130J High power engine test noise, measured at 100 metres.

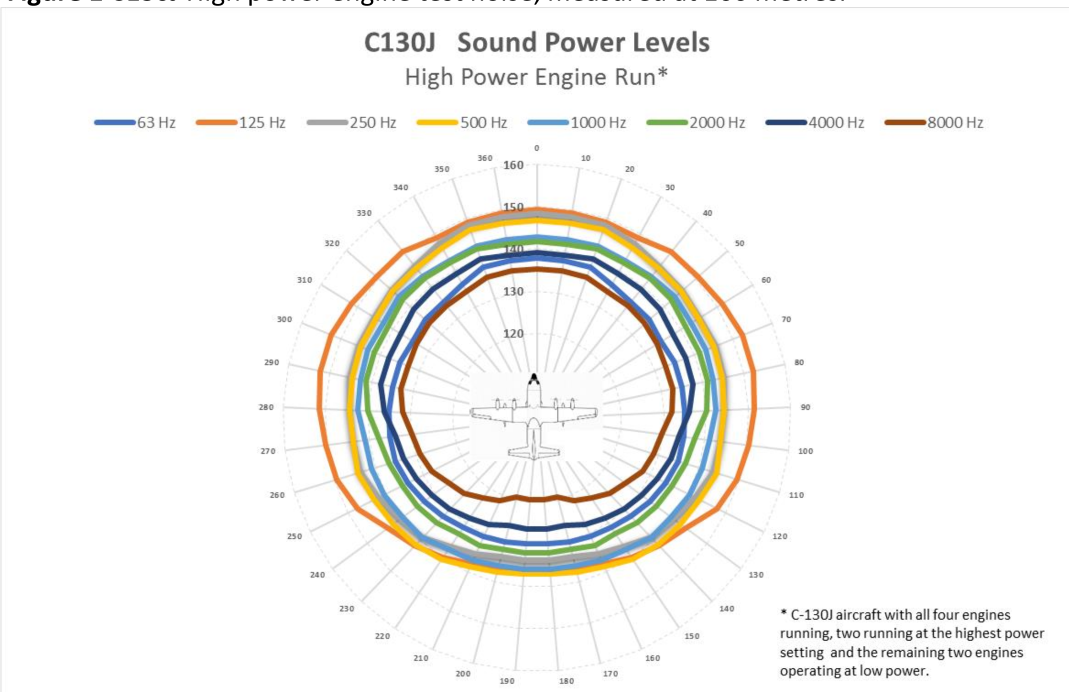

Figure 2 Calculated C130 sound power engine test noise, in octave bands 63 Hz to 8,000 Hz, based on sound levels measured at 100 metres (summarised in Figure 1).

The sound power levels depicted within **Figure 2** are reproduced in the sound power values in each octave band and for each 10 degrees are presented below in Table 1.

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	dBA
0	137.8	149.3	148.5	146.7	142.7	141.7	139.1	135.3	**107.4**
10	137.8	149.1	148.3	146.7	142.7	141.7	139.1	135.3	**107.4**
20	137.8	149.1	148.3	147.1	143.0	142.4	139.8	135.3	**107.7**
30	136.2	148.8	147.2	146.1	142.7	142.0	139.1	134.3	**107.1**
40	135.2	150.5	146.0	145.5	143.0	142.4	139.1	134.2	**107.2**
50	135.2	150.5	145.6	145.5	143.4	142.4	138.8	133.9	**106.5**
60	134.5	151.4	145.1	144.8	142.7	141.4	137.8	133.4	**106.8**
70	135.0	152.4	145.5	145.1	143.1	141.4	137.8	132.9	**106.6**
80	135.0	152.4	145.3	144.8	142.7	141.4	137.8	132.9	**105.9**
90	135.0	151.4	144.3	144.4	142.4	140.1	136.1	131.9	**104.6**
100	135.0	150.4	143.7	143.8	141.0	137.7	133.8	129.9	**104.5**
110	135.0	149.5	143.6	144.4	140.8	136.7	133.1	128.9	**103.5**
120	134.1	147.6	141.9	143.1	140.4	135.7	131.8	127.9	**102.3**
130	133.1	143.7	140.0	142.2	139.4	135.1	130.8	125.9	**101.7**
140	132.1	141.9	139.0	141.4	139.2	134.4	129.8	124.9	**100.3**
150	131.3	139.9	136.7	140.4	137.6	133.1	128.6	122.9	**99.4**
160	130.8	137.9	135.3	138.7	137.0	133.1	127.6	121.4	**98.3**
170	130.2	136.8	133.9	137.7	136.0	132.1	126.3	119.4	**98.1**
180	129.8	136.8	133.9	137.0	136.0	132.1	126.3	119.4	**98.1**
190	129.8	136.8	133.9	137.0	136.0	132.1	126.3	119.4	**98.3**
200	130.2	136.8	133.9	137.7	136.0	132.1	126.3	119.4	**99.4**
210	130.8	137.9	135.3	138.7	137.0	133.1	127.6	121.4	**100.3**
220	131.3	139.9	136.7	140.4	137.6	133.1	128.6	122.9	**101.7**
230	132.1	141.9	139.0	141.4	139.2	134.4	129.8	124.9	**102.3**
240	133.1	143.7	140.0	142.2	139.4	135.1	130.8	125.9	**103.5**
250	134.1	147.6	141.9	143.1	140.4	135.7	131.8	127.9	**104.5**
260	135.0	149.5	143.6	144.4	140.8	136.7	133.1	128.9	**104.6**
270	135.0	150.4	143.7	143.8	141.0	137.7	133.8	129.9	**105.9**
280	135.0	151.4	144.3	144.4	142.4	140.1	136.1	131.9	**106.6**
290	135.0	152.4	145.3	144.8	142.7	141.4	137.8	132.9	**106.8**
300	135.0	152.4	145.5	145.1	143.1	141.4	137.8	132.9	**106.5**
310	134.5	151.4	145.1	144.8	142.7	141.4	137.8	133.4	**107.2**
320	135.2	150.5	145.6	145.5	143.4	142.4	138.8	133.9	**107.1**
330	135.2	150.5	146.0	145.5	143.0	142.4	139.1	134.2	**107.2**
340	136.2	148.8	147.2	146.1	142.7	142.0	139.1	134.3	**107.8**
350	137.8	149.1	148.3	147.1	143.0	142.4	139.8	135.3	**107.4**

Table 1 C130 Sound power levels in each octave band, for each 10 degree direction from source, as shown above in Figure 2. Yellow highlighting indicates the 'worst case' directionality of engine test noise for the C130. These sound power values have also been adopted for the P-3K2 Orion aircraft engine tests.

4.2 Boeing B757

Squadron 40 operate two Boeing B757 aircraft. These aircraft are similar to their civil counterpart except they are fitted with an upper deck cargo door to facilitate an 11-pallet cargo capability, internal air stairs, upgraded engines and flight deck enhancements including full compliance with current global air navigation specifications and standards.

The B757 aircraft are the largest jet aircraft operated by NZDF for the foreseeable future and are not likely to be upgraded or replaced in the near future. This is confirmed within the 2016 NZ Defence 'White Paper' which sets out the plans for the Ministry of Defence to deliver significant projects planned out to 2030. While this includes replacement of three major capabilities that will reach the end of their life during this period (the Hercules transport aircraft, the Orion air surveillance fleet and bringing on stream of the frigates HMNZS Te Kaha and HMNZS Te Man), there are no plans to replace the B757 aircraft in the current planning timeframe. The B757 therefore reasonably represents the largest aircraft likely to be regularly engine-tested at Whenuapai for the foreseeable future.

The B757's are fitted with Rolls Royce engines (RB211535E4/4B). As above, approaches to the aircraft or engine manufacturer for aircraft engine noise level data in polar plot format proved fruitless, as has approaches to airline operators using the B757 and other agencies. The above Cambridge Airport (UK) engine testing noise study also found B757 polar plot engine test noise data difficult to obtain. However, this UK report includes high power engine test noise data for the Rolls Royce RB211 engine fitted to a B747[5]. The RB211 engine is an earlier, slightly more noisy version of the RB211535E4/4B engine fitted to the B757. The more recent B757 Rolls Royce engine has a fourth compressor stage and is known to be a quiet engine, however the available noise data relates to the noisier RB211 engine under high power test. This will build in a certain level of conservancy in the predictions of B757 engine test noise.

Figure 3 below sets out an excerpt from Appendix 2 of the aircraft engine test noise report used in the Cambridge Airport (UK) study. The data for the RB211 engine test are found within the following diagram extracted from the UK report.

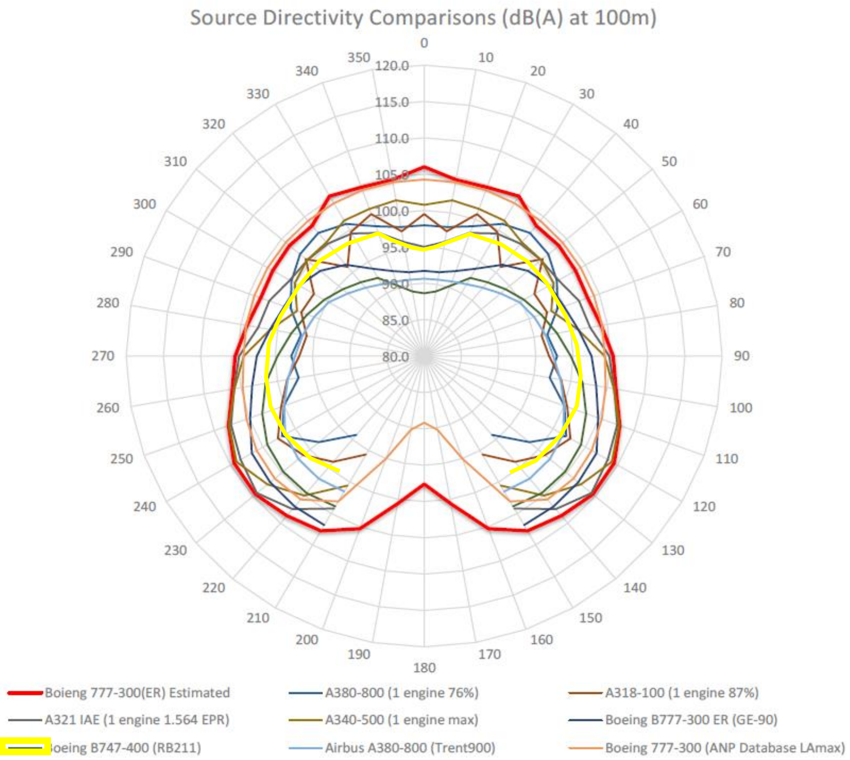

Figure 3 Polar plot of LAeq sound levels measured at 100 metres from various jet aircraft operating under high power test conditions (ref Appendix 2 of Cambridge UK report).

[5] Although the B747 is a four-engined aircraft, the test results are for only two engines operating under high power.

While this data provides a basis to calculate sound power levels around the aircraft under high power test, the sound levels are available in overall LAeq levels only, with no frequency content information provided for the RB211 engine. To surmount this problem, the published octave band sound levels for the B777-ER (GE engine) were adopted for the purposes of this study. The B777-ER represents a modern high bypass jet engine which has a fourth stage compressor and therefore sound similar to the Rolls Royce engines fitted to the B757's. As above, conversions from sound level to sound power assumed a hard ground surface to account for testing typically undertaken on hardstand areas.

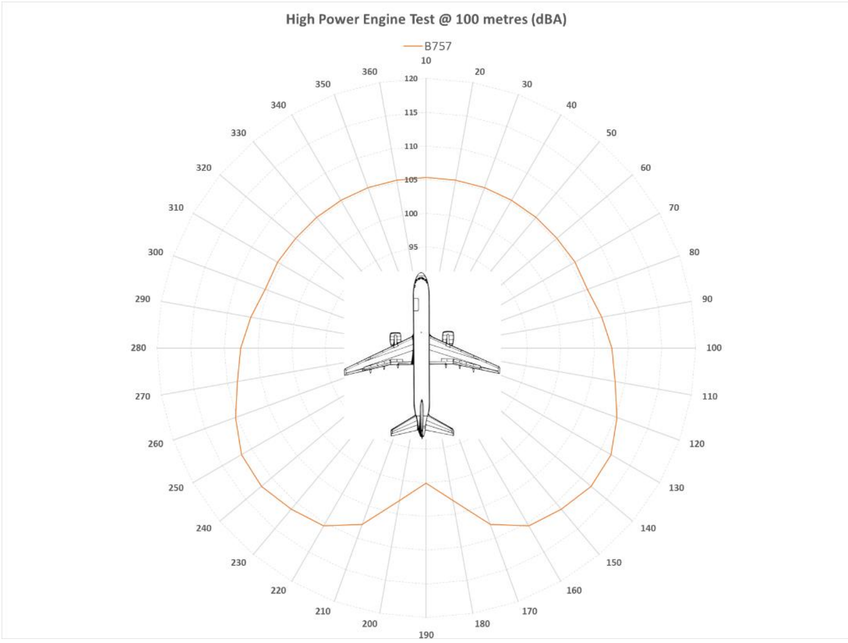

Figure 4 B757 High power engine test noise, measured at 100 metres, based on RB211 engines with B777-ER frequency content.

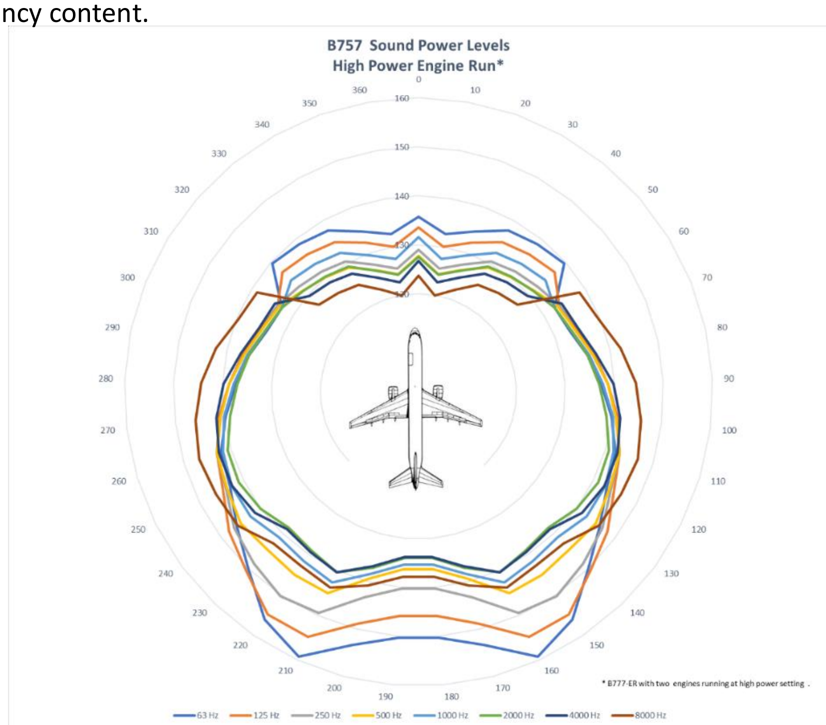

Figure 5 Calculated B757 sound power engine test noise levels, in octave bands 63 Hz to 8,000 Hz, based on sound levels measured at 100 metres (summarised in Figure 4).

The sound power levels depicted within **Figure 5** are reproduced in the sound power values in each octave band and for each 10 degrees are presented below in **Table 2**.

Degrees	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	dBA
0	135.7	133.5	129.0	127.8	131.6	127.5	126.7	123.7	**105.3**
10	132.7	130.0	125.5	124.4	127.6	124.2	122.7	120.0	**105.3**
20	134.7	132.3	127.5	126.4	129.6	126.2	124.7	122.1	**105.3**
30	137.7	135.0	130.5	129.1	132.6	129.2	127.7	125.0	**105.3**
40	138.7	136.0	131.5	130.1	133.6	130.2	128.7	126.0	**105.3**
50	139.7	137.0	132.5	131.4	134.6	131.2	129.7	127.0	**105.3**
60	132.7	133.7	133.7	133.4	132.7	132.7	134.4	138.7	**105.5**
70	133.4	134.7	134.4	134.4	133.7	133.7	135.1	139.7	**105.5**
80	135.4	136.7	136.4	136.4	135.7	135.4	137.1	142.3	**106.5**
90	137.4	138.7	138.7	138.7	137.7	137.0	139.8	144.4	**107.6**
100	139.7	141.0	140.7	140.7	140.0	138.7	141.5	145.8	**108.5**
110	142.1	143.0	143.0	143.0	141.7	140.7	142.5	146.8	**110.2**
120	143.1	144.7	144.0	143.7	142.7	141.1	142.5	146.3	**111.7**
130	146.1	148.0	146.7	145.1	142.7	140.1	141.5	145.8	**112.0**
140	150.1	150.7	148.5	144.5	141.1	138.4	138.8	142.8	**111.2**
150	156.1	154.8	150.3	145.1	141.7	139.1	139.4	142.8	**110.5**
160	159.3	154.8	149.5	145.1	142.7	140.4	140.4	143.8	**107.8**
170	153.3	148.8	143.3	139.4	138.4	137.1	136.8	140.8	**103.0**
180	150.3	145.8	140.3	136.4	135.4	134.1	133.8	137.8	**100.0**
190	150.3	145.8	140.3	136.4	135.4	134.1	133.8	137.8	**103.0**
200	153.3	148.8	143.3	139.4	138.4	137.1	136.8	140.8	**107.8**
210	159.3	154.8	149.5	145.1	142.7	140.4	140.4	143.8	**110.5**
220	156.1	154.8	150.3	145.1	141.7	139.1	139.4	142.8	**111.2**
230	146.1	148.0	146.7	145.1	142.7	140.1	141.5	145.8	**112.0**
240	143.1	144.7	144.0	143.7	142.7	141.1	142.5	146.3	**111.7**
250	142.1	143.0	143.0	143.0	141.7	140.7	142.5	146.8	**110.2**
260	139.7	141.0	140.7	140.7	140.0	138.7	141.5	145.8	**108.5**
270	137.4	138.7	138.7	138.7	137.7	137.0	139.8	144.4	**107.6**
280	135.4	136.7	136.4	136.4	135.7	135.4	137.1	142.3	**106.5**
290	133.4	134.7	134.4	134.4	133.7	133.7	135.1	139.7	**105.5**
300	132.7	133.7	133.7	133.4	132.7	132.7	134.4	138.7	**105.5**
310	139.7	137.0	132.5	131.4	134.6	131.2	129.7	127.0	**105.3**
320	138.7	136.0	131.5	130.1	133.6	130.2	128.7	126.0	**105.3**
330	137.7	135.0	130.5	129.1	132.6	129.2	127.7	125.0	**105.3**
340	134.7	132.3	127.5	126.4	129.6	126.2	124.7	122.1	**105.3**
350	132.7	130.0	125.5	124.4	127.6	124.2	122.7	120.0	**105.3**

Table 2 B757 Sound power levels in each octave band, for each 10 degree direction from source, as shown above in Figure 5. Yellow highlighting indicates the 'worst case' directionality of engine test noise for the B757.

In summary, the LAeq sound levels from the B757 under high power test have been based on a B747 aircraft operating 2 x RB211 Rolls Royce engines under high power. The frequency content of this sound (not the overall sound level) has been based on the frequency content of the sound of two modern GE engines fitted to a B777-ER operating under high power. As the RB211 engine is a slightly older version of the Rolls Royce engine, there will be a level of over-prediction in the results which will cause the results to be conservative.

4.3 Engine Test Noise Levels

The above LAeq sound pressure levels measured at 100 metres depicted above in **Figure 1** and **Figure 4** are combined in the same polar plot shown below in **Figure 6**

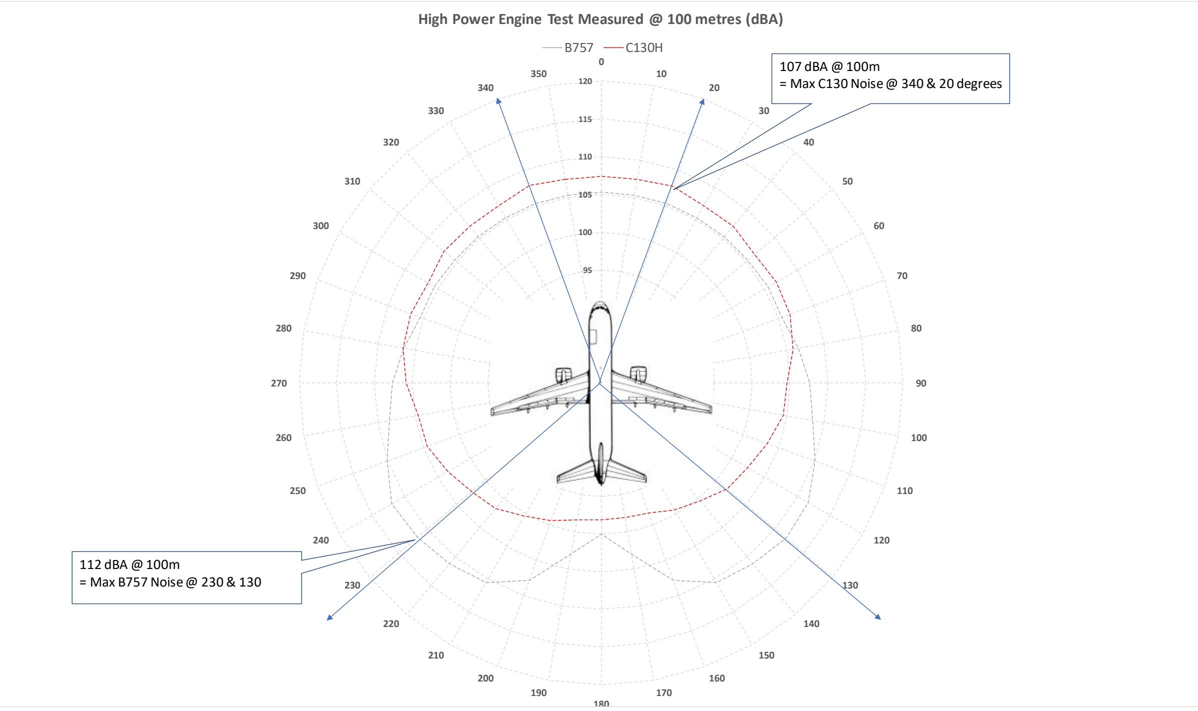

Figure 6 LAeq sound pressure levels measured at 100 metres depicted above in **Figure 1** and **Figure 4** combined in the same polar plot shown below in.

This comparison shows the B757 to generate higher sound levels, particularly in directs aft of the wings. The C130 on the other hand emits more noise forward of the wing consistent with the high levels of induction noise characteristic of turboprop engines.

The directivity of engine test noise varies as a function of wind direction. In all cases the pilot in command orients the aircraft into the wind for all testing. The NZDF 60 day survey of engine testing shows the aircraft heading varies considerably, even for testing conducted at the same location ion the same day. In order to cater for the 'worse case' maximum sound emission due to directivity of the source(s), the sound power at source was based on the maximum noise emission levels found anywhere between zero and 360 degrees. **Figure 6** indicates the directions at which the highest noise output occurs, with these values highlighted in **Table 1** and **Table 2** above.

Figure 7 sets out the 'worse case' sound power levels identified in this manner, for both the B757 and the C130 aircraft. Owing to the similarity in engines, the C130 values shown in Figure 7 have also been adopted for the P-3K2 Orion aircraft engine tests.

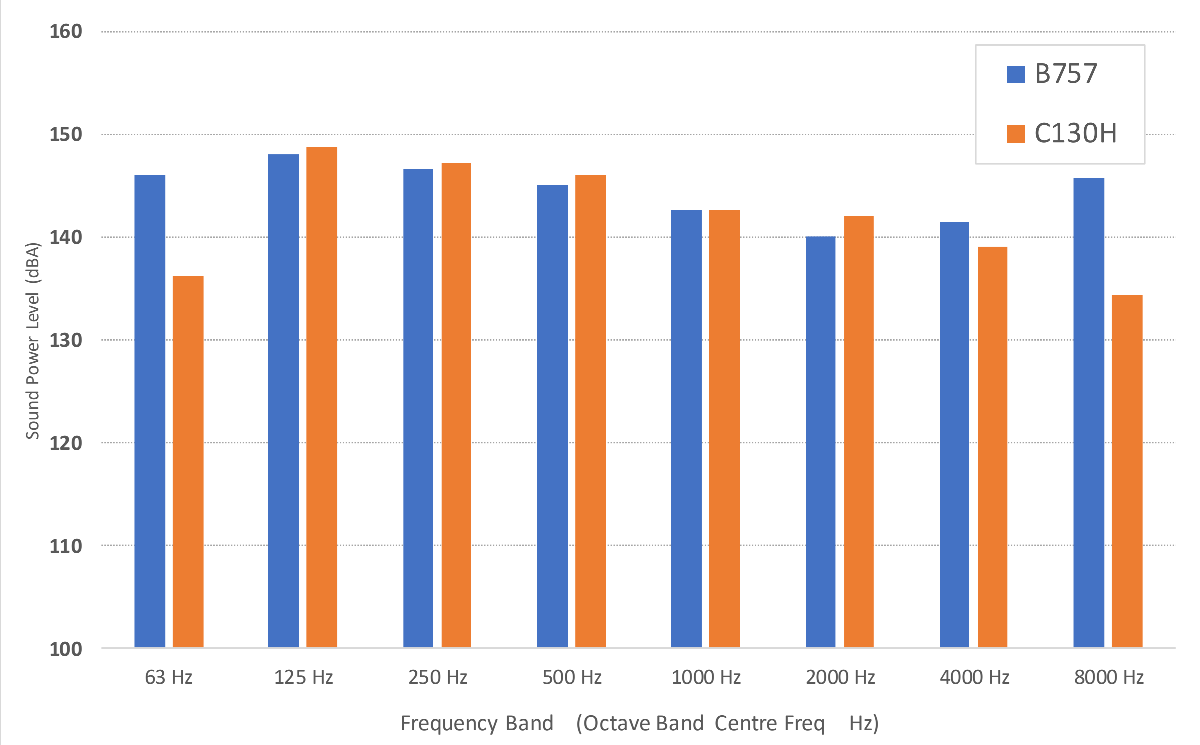

Figure 7 Maximum LAeq sound power levels for each octave band from 63 Hz to 8,000 Hz adopted within the engine test noise predictions for the B757 and C130 aircraft (as above the C130 values have also been adopted for the P-3K2 Orion aircraft engine tests).

5 Whenuapai Engine Testing Attributes

In 2016 Whenuapai Airbase conducted a survey of all aircraft engine testing undertaken at the base over a 60 day period from 25 May 2016 to 25 July 2016. The survey involved recording, for each engine test, the aircraft type, time and date of test, high power or low power test, the duration of test (minutes), aircraft test location and wind direction & speed.

The survey revealed a total of 96 engine tests conducted over a 60 day period. Of these, 37 engine tests were “High Power” (>85% of full power) while the remainder of tests were under taken a lower power settings (including test with engines at idle). For the purposes of acoustic modelling, all ‘Low Power” tests were set at a sound power level 10 dB below that of the high power noise level for each aircraft type. As above, owing to the similarity in engine types the sound power levels and directivity pattern of the C130 have also been adopted .

In terms of testing frequency, ***APPENDIX B*** (Engine Testing Frequency - NZDF Survey Results) sets out the dates on which actual tests took place, including on days when two or more were conducted. The records reveal only two tests were carried out at night (after 10pm). Under standing orders, any aircraft engine testing after 10 pm must be individually authorised by the Whenuapai base commander and are only requested under exceptional circumstances. **Figure 8** sets out the frequency of testing over ‘days of the week’ reported via the 2016 survey which shows few tests conducted on weekend days, with no high power runs taking place on a weekend day.

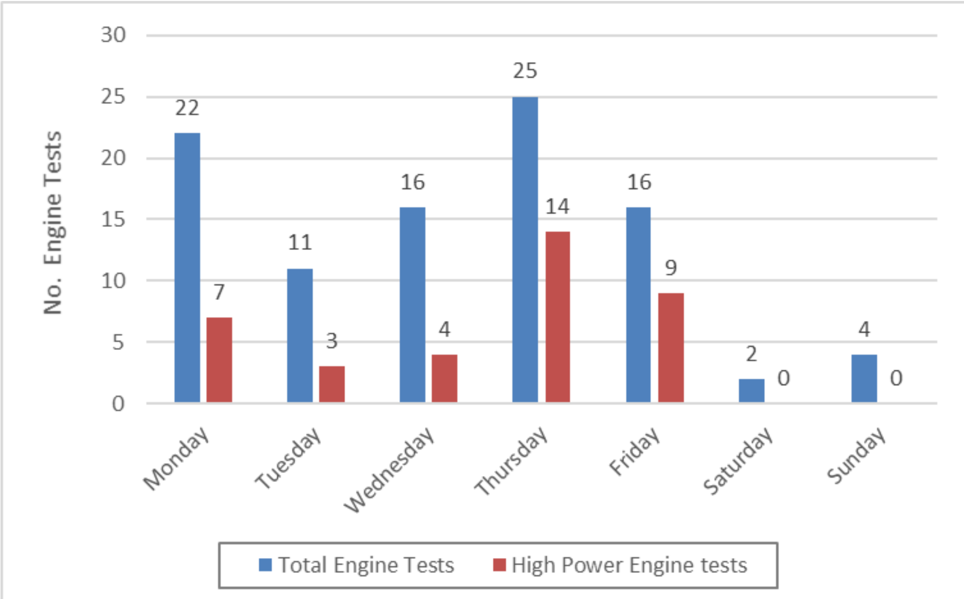

Figure 8 Number of High Power / Low Power Engine Tests for Each Day Of The Week.

The average duration of a high power engine test was found to be 75 minutes, however fewer of these tests take place (one high power test every 2.5 days). For a Low Power engine test the average duration was found to be 27 minutes, with one such test every day and half. Combined, this results, on average, to one test every day with a typical duration of 34 minutes.

Regarding the duration of engine tests, analysis of the survey results returned the following distribution of engine test durations across all testing (high and low power) for the three main fixed wing aircraft types operating from Whenuapai;

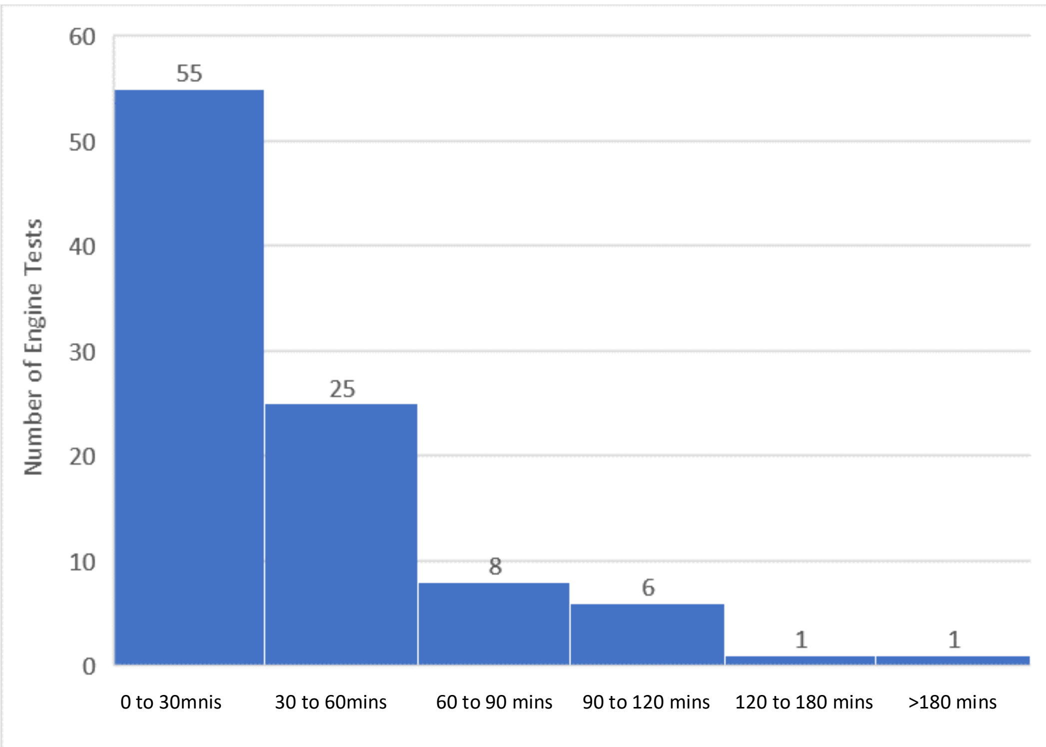

Figure 9 Distribution of engine test duration (All aircraft types, high and low power tests).

Looking in more detail at the duration of engine testing noise for each aircraft type/power settings, the following table sets out total test duration, the average test duration on days on which the given aircraft type /power setting tests took place, and an average duration across the entire survey period (60 days) are set out in the following table;

	Total Duration Engine Of Engine Tests Over 60 Days (minutes)	**Average Duration On Days When Stated Aircraft Tests Were Carried Out** (minutes)	**Av Duration Over 60 Days** (Total duration divided by 60 days) (minutes)
B757 High Power	80	40.0	0.9
B757 Low Power	210	21.0	2.3
C130 High Power	950	105.6	10.6
C130 Low Power	710	29.6	7.9
P3 High Power	972	97.2	10.8
P3 Low Power	165	18.3	1.8

Table 4 Description of test durations for each main aircraft type (operating at high / low power settings

The above durations and averages have formed the basis of the noise level predictions and have a role in determining the impact of engine testing noise.

6 Test Locations

The survey records indicate >95% of all engine testing takes place at the following designated engine test locations:

Test Location	**Description**
A	Site 08
B	Taxiway D
C	Taxiway F
D	Area 13
E	Area 11
F	Area 15

Table 3 Description of Engine Test Locations – see Figure 11 below.

The amount of testing conducted at each of the nominated test sites is set out in the following graph;

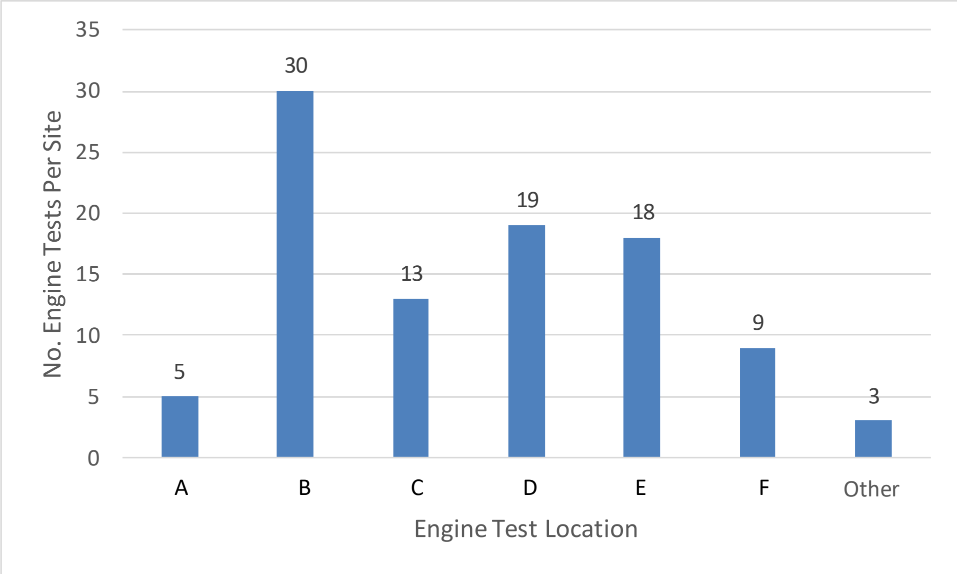

Figure 10 Number of engine tests carried out at each test site (Refer Figure 11).

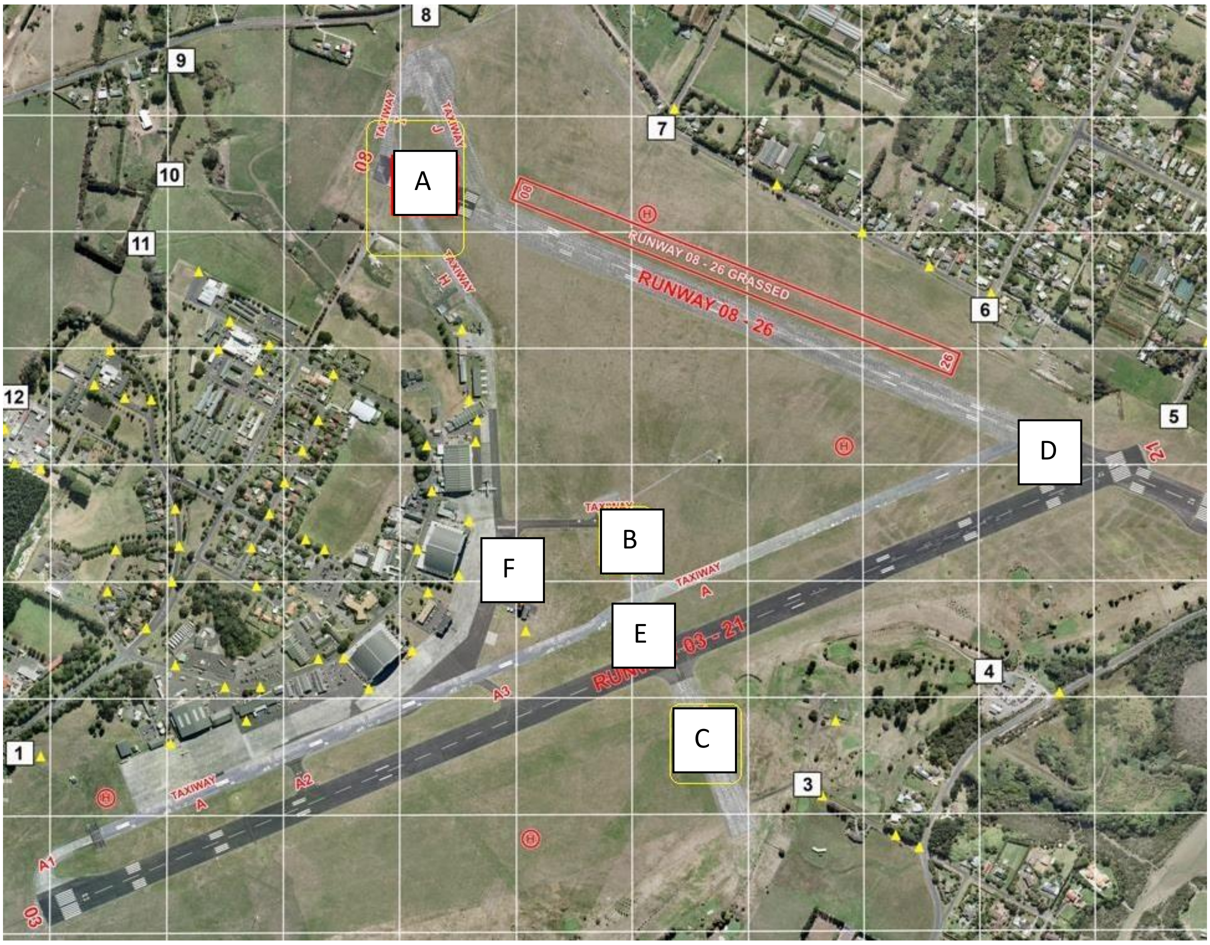

Figure 11 Location of nominated engine test sites at Whenuapai Airbase.

The use of each test location by each aircraft type is set out in the following table;

Test Type	Percentage Of Tests At Each Location			
B757 High Power	1=100%			
P3 Low Power	2 = 68%	5=12%	1 = 10%	Other = 10%
P3 High Power	2 = 98%	3 = 2%		
C130 High Power	3 =95%	2 = 5%		
B757 Low Power	4 = 85%	6 = 5%	2= 5%	Other = 5%
C130 Low Power	5 = 75%	4 = 20%	6 = 5%	

Table 3 Distribution Of Engine Testing By Test Type.

The predictions of aircraft engine testing takes into account the type of test conducted at each location, together with the duration and source strength. As above, the same source strength adopted for the C130 is the same as the P3 Orion.

7 Predictions

The above data is proposed to be used within calculations of far field high-power engine test noise levels for noise receiver locations. AS above, the calculations will take account of;

- Aircraft type
- Power setting
- Orientation
- Location

Calculations are proposed to be made in accordance with the algorithm detailed in ISO9613-2: 1996- *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation* (ISO9613). ISO9613 considers a range of frequency dependent attenuation factors, including hemi-spherical divergence, atmospheric absorption, ground effect, and directivity effects. ISO9613 assumes meteorological conditions favourable to propagation from sources (downwind at wind speeds 1 -5 m/s in all directions), and as such, calculates conservative sound levels. The predictions take account of the undulating terrain found in the area surrounding Whenuapai airbase.

The calculations will be carried out within each octave band, aggregated together and A weighted to determine the received sound level. As above, the prediction results will be assessed using various LAeq reference time intervals in order to cover a range of sound exposure metrics.

8 Prediction Area

The instructions for this study indicated the potential noise effects of aircraft engine testing were confined to an area referred to as "Whenuapai Plan Change Area'. This the map forming part of this plan change has formed the base map over which predicted noise contours have been projected. The area over which predicted aircraft engine test noise effects have been assessed are set out in **Figure 12** below.

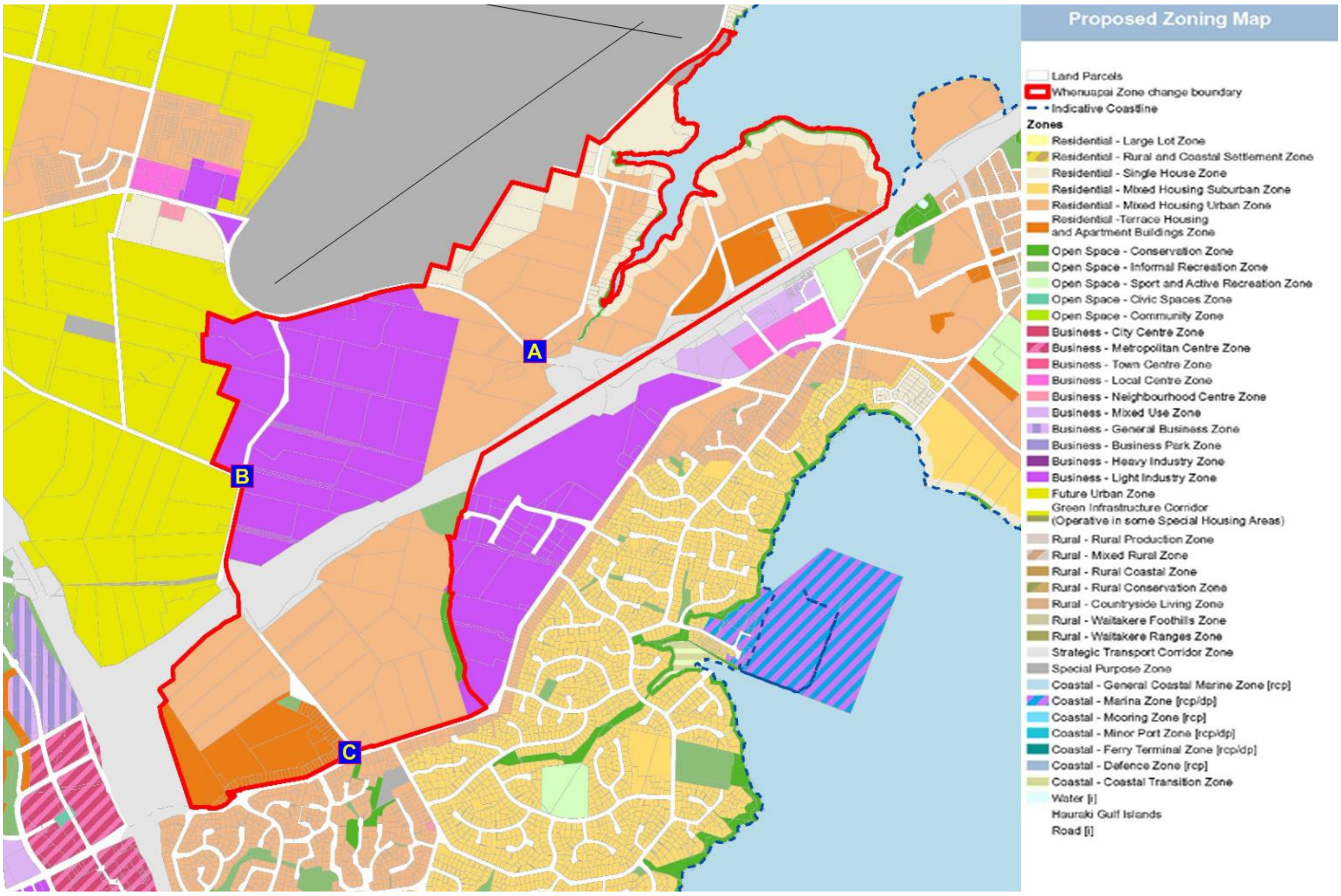

Figure 12 Map showing 'Whenuapai Plan Change Area within which noise effects of aircraft engine testing noise from Whenuapai Airbase has been assed. Also shown are receiver sites A, B and C which feature within the analysis below.

For the purposes of assessing aircraft engine noise at representative receiver locations in the area, the assessment below includes noise levels received at THREE representative receiver locations as described within the following table;

Location	Description	Zoning
A	Corner of Brigham Creek Road and Kauri Road	*'Residential - Mixed Housing Urban Zone'*
B	Corner of Spedding Road and Trig Road	The zoning to the north, east and south is '*Business – Light Industry Zone*'. The zoning to the west is '*Residential – Future Urban Zone*'.
C	Corner of Hobsonville Road and Trig Road	The zoning to the north is '*Business – Light Industry Zone*'. The zoning to the east and south is '*Residential – Mixed Housing Suburban Zone*'. The zoning to the west is '*Residential - Mixed Housing Urban Zone'*

Table 4 Description of representative receiver locations adopted within the assessment below.

9 Prediction Results

9.1 Noise Contour Results

The sound power levels have been calculated for each test location based upon the fore-going descriptions.

The base assessment unit is the LAeq(24 hour) measured in dB[6]. The LAeq(24 hr) 57 dB and 65 dB contours have been predicted based on the 'worse case' rolling seven day engine testing undertaken by all THREE aircraft types (high and low power tests). This turns out to be the period 9-15 June inclusive as shown in Appendix 2. The prediction calculations are based on a receiver height of 4.2 metres which is designed to cater for receivers located on the upper storey of a two storey dwelling.

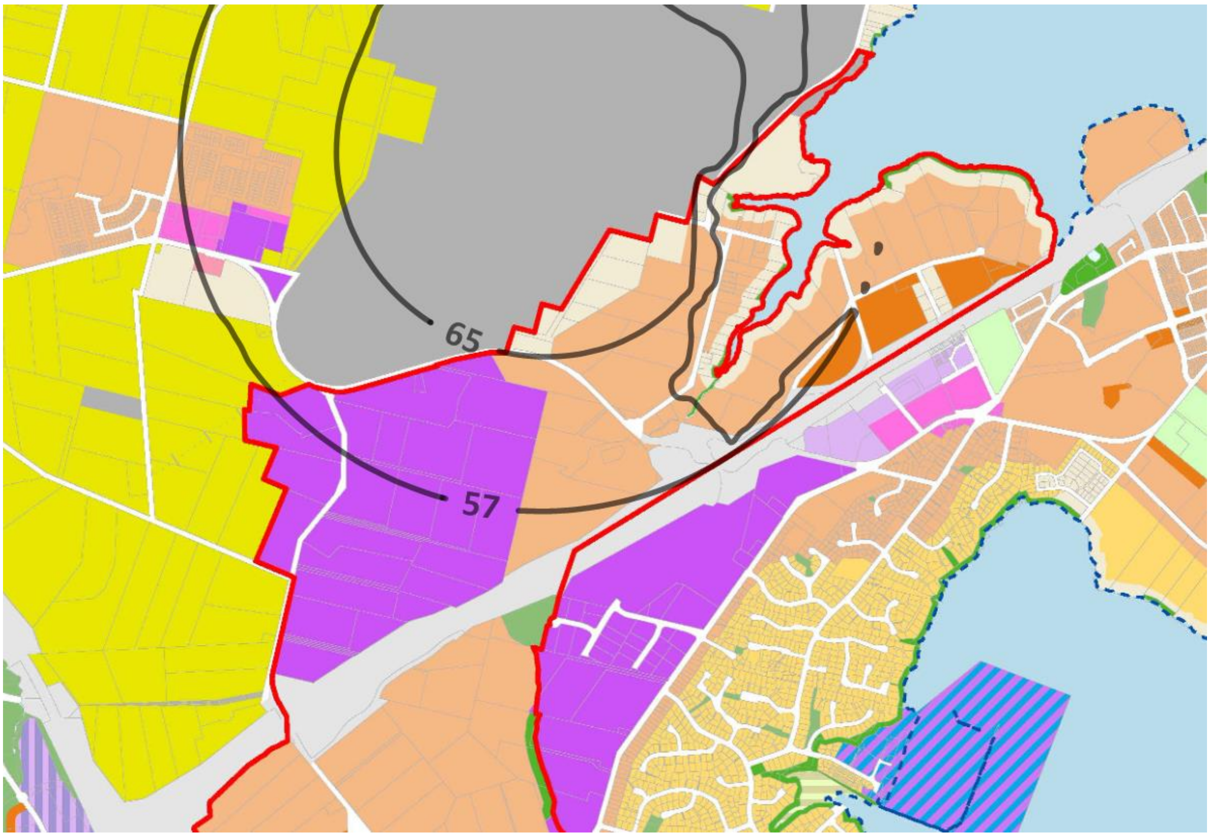

Figure 13 Map showing LAeq(24 hr) 57 dB and 65 dB contours for cumulative noise from engine testing of the B757, C130 and P3 aircraft conducted at Whenuapai Airbase over a 'worse case' seven day rolling time period recorded during the 60 day survey of engine testing conducted in 2016.

LAeq(24 hour) values are set out below for receiver sites A, B and C (as shown in **Figure 12**) in the following table

Location	LAeq(24 hr)
A	60.6 dB
B	51.4 dB
C	42.1 dB

Table 5 Calculated LAeq (cumulative) engine test noise levels for the three representative receiver locations shown in **Figure 12**.

[6] As described above in Section 3, this is considered the equivalent to the "Ldn" unit.

10 Assessment

The noise-related provisions of the Auckland Unitary Plan guide the assessment of engine testing noise. The Unitary Plan contains a condition on the designation for Whenuapai Airbase which limits noise from flying activities received in areas around the airbase. The current assessment is usefully informed by a comparison of the above engine test noise contour with the Unitary Plan controls over noise from flying activities undertaken at Whenuapai.

The following diagram overlays the Ldn 55 dB "operational" aircraft noise contour over the area affected by engine testing noise.

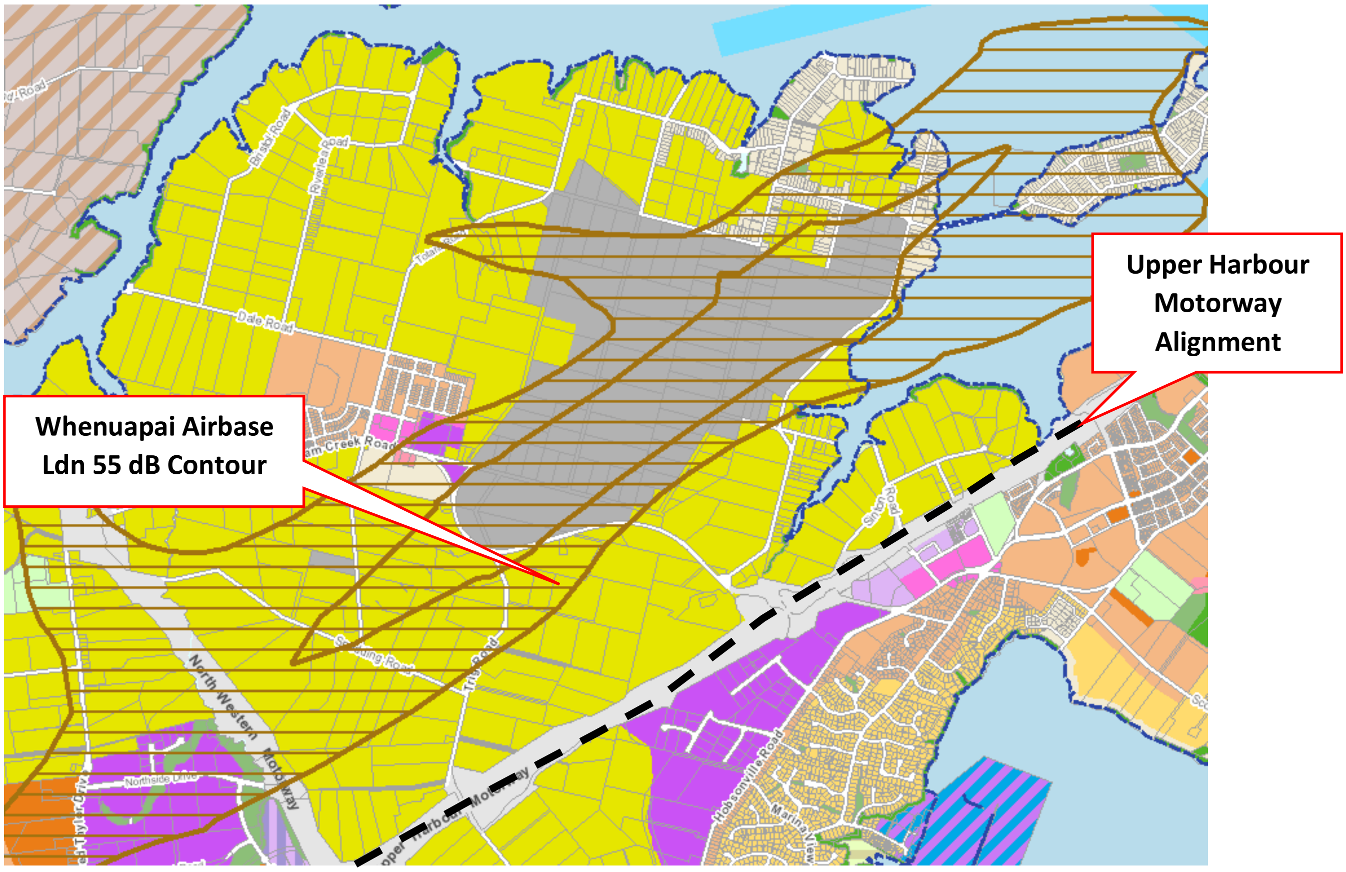

Figure 14 Map showing 'Whenuapai Plan Change Area' with the Ldn 55 dB aircraft noise contour shown (as extracted from the Unitary Plan designation for the site).

The Ldn 55 dB noise contour for aircraft operating from Whenuapai covers a wide area, however in relation to this study area, the Ldn 55 "operational noise" contour is exceeded in some areas by cumulative engine test noise reaching Ldn 57 dB for a typical busy day, as shown in **Figure 13**. This is generally because the noise effects of aircraft arrivals and departures are short duration sounds whereas sounds from engine testing can occur for periods of up to 60 to 120 minutes.

Limits on generic environmental noise experienced within residential receiving environments in Auckland arising from activities within zones are set out within Section E25.6.2 of the Auckland Unitary

Plan (E25.6.2. Maximum noise levels in residential zones). The following table summarises the noise (rating) levels and maximum noise level arising from any activity in residential areas (Large Lot Zone, Residential – Rural and Coastal Settlement Zone, Residential – Single House Zone, Residential – Mixed Housing Suburban Zone, Residential – Mixed Housing Urban Zone and the Residential – Terrace Housing and Apartment Buildings Zone measured within the boundary of an adjacent site in these residential zones.

Time	Noise level
Monday to Saturday 7am-10pm	50dB L_{Aeq}
Sunday 9am-6pm	
All other times	40dB L_{Aeq} 75dB L_{AFmax}

Table 7 Recommended LAeq daytime noise levels received within residential zones (Ref. Table E25.6.2.1 Auckland Unitary Plan).

Section E25.6.2 of the Unitary Plan does however state that the levels for the daytime hours in Table E25.6.2.1 zones *"…may be exceeded by intermittent noise for reasonable periods where that noise is associated with normal household activities, such as lawn mowing or home handyman work"*.

It is worth noting that the Unitary Plan includes specific controls over daytime engine testing noise at Auckland International Airport

Any use of the designated area for the testing of engines which are in situ on an aircraft ("in situ aircraft engines") shall not exceed the following noise limits within the Identified Area shown on Figure 5 attached to this designation:

7 day rolling average	55 dB L_{dn}

The map included at Figure 5 of the designation provisions of the Unitary Plan indicate that engine noise is to be controlled based on the levels of this sound received within nearby residential zones, the nearest of which is many hundreds of metres away from the aircraft engine test locations used at Auckland Airport.

The important aspect of this rule specific to aircraft engine testing is to recognise the importance of time averaging received engine testing noise which the Unitary Plan has adopted in terms of;

(a) A 24 hour reference time interval as used within the Ldn unit which is consistent with the LAeq(24 hr) units adopted within the above analysis; and

(b) The averaging of these daily 24 hour values over several days to ensure the quantification of noise effects is able to take into account the variations between quiet and busy test days.

10.1 LAFMax Sound levels

LAmax represents the maximum sound level occurring during a measurement period or a noise event. NZ Standard NZS6802:2008 states that assessment of night-time noise exposure should include consideration of the maximum noise level (LAFmax). This Standard recommends district plans include LAFMax night time noise limits to protect the majority of people from disturbance to sleep and from being woken during the night.

The testing of aircraft engines at Whenuapai is managed so that testing during evening and night time hours is avoided as far as possible. If testing is required during night time hours, this is due to an urgent NZDF requirement as Standing Orders normally require all testing to be undertaken during normal daytime hours. During the 2016 sixty day survey of engine testing only 2% of tests were conducted after 10pm or before 7am. We understand that this authorised test was undertaken at this time due to extenuating circumstances.

Nevertheless, it is indicative to assess LAFMax noise levels that are associated with engine testing noise undertaken during daytime. Typical engine testing noise from both jet and turbo prop aircraft results in a relatively stable noise level, once the desired throttle setting is achieved. Leaving aside the effect of altering the engine power setting via the throttle position, fluctuations in the sound received from engine testing are usually due to atmospheric effects of the engine test sound during propagation from source to receiver. This effect is shown in the examples of engine testing noise provided in **APPENDIX A**. Generally speaking, for a given engine test power setting, the LAFMax sound level recorded during the test will be within 5 to 8 dB of the LAeq values recorded for the test undertaken at a given power setting. Night time LAFMax controls adopted into District Plans and the Auckland Unitary Plan are set at levels generally 25 to 30 dB higher than the LAeq limit applying at night time. Therefore controls on engine testing noise based on the LAeq (or Ldn) unit are considered adequate to also protect noise sensitive uses at night time (if required) from the adverse effects of engine testing noise.

11 Summary & Recommendation

This report sets out information (incomplete at this stage) used as a basis for predicting noise emitted by high power engine runs from the largest aircraft based at Whenuapai, namely:

- Boeing 757; and
- Lockheed C-130 Hercules turboprop
- Lockheed P-3K2 Orion turboprop

The aim has been to quantify noise generated by aircraft engine testing undertaken on the ground at various locations on the Whenuapai Airbase in accordance with established practice and standing orders.

Noise from aircraft engine testing on the airbase has been predicted for receiver locations mainly to the south of Airbase Auckland (Whenuapai) for the purposes of informing land use planning decisions within the Whenuapai Plan Change Area. Representative calculations of overall LAeq noise levels have been made using published engine test noise data. Information and assumptions employed within the predictions are set out above. Importantly, attributes of the engine testing such as the power settings, duration and location of the engine testing as may affect the acoustic calculations have been based on the results of a NZDF survey of engine testing practices undertaken over a 60 day period in 2016. The predictions are inherently conservative as they assume the worst-case aircraft directivity (noisiest angle assumed to apply to all receivers) with the prediction algorithm (ISO 9613 Part 2) assuming downwind conditions favouring the propagation of sound. This ‘downwind’ effect is assumed to occur in all directions around the compass even though, in reality, there would be both upwind and downwind effects on sound propagation.

The results of acoustic predictions indicate extensive areas to the west and south of the airbase are affected, at times, by significant levels of noise.

Considering the levels of engine testing noise emission from the Airbase (including its intensity, duration and character) the above analysis indicates potentially unacceptable noise effects may occur (at times) during daytime for noise sensitive residential sites in that part of the Whenuapai plan change area located to the south of the Airbase and to the north / west of the Upper Harbour Motorway alignment. At greater distances, lower levels of this noise would generally result in little or no adverse effects for future residential uses.

Owing to the frequent occurrence of elevated levels of aircraft engine testing noise, land use planning controls are recommended to be included into the Auckland Unitary Plan. **Figure 13** above indicates areas affected by current and future levels of engine testing noise. Areas likely to receive noise above Ldn 65 dB are considered unsuitable for new residential or noise sensitive uses. Noise effects will remain significant for sites located between the Ldn 65 dB and Ldn 57 dB however indoor areas can be suitably protected by inserting measures to require habitable rooms or teaching spaces to be protected from outdoor noise by inserting requirements within the Unitary Plan for new or altered noise sensitive developments (including new residential uses). Such uses establishing on sites located outside the Ldn 57 dB contour shown in **Figure 13** are likely to receive acceptable levels of engine testing noise without any targeted mitigation measures and will result in the land being suitable for noise-sensitive development (at least in terms of noise from aircraft engine testing carried out at Whenuapai airbase).

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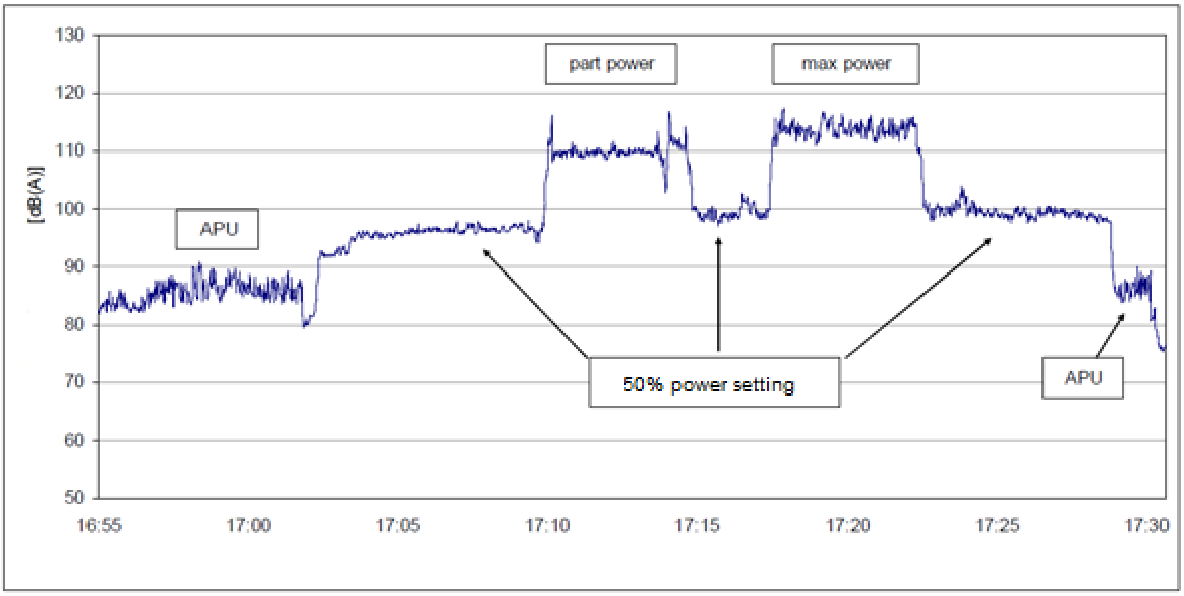
B.Sc, M.E.(mech) Dip Public Health

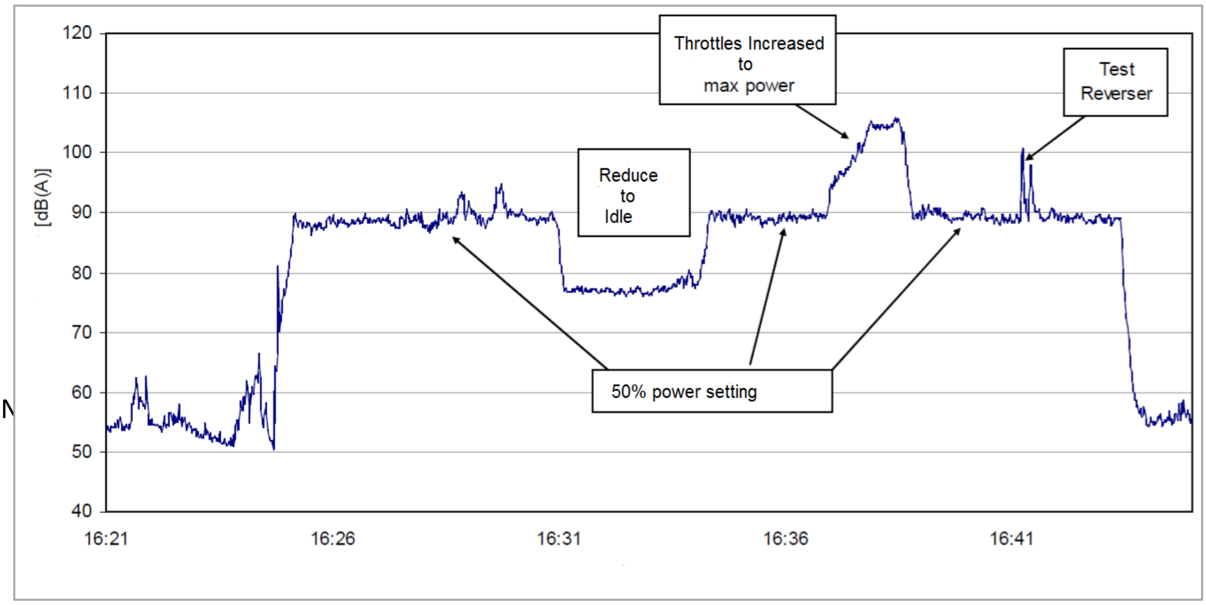
APPENDIX A: Typical Engine Test Runs

Typical aircraft engine test noise measured at 200 metres showing variations in noise output with throttle settings.

TEST A



TEST B



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APPENDIX B: Engine Testing Frequency

NZDF Survey Results 25 May 2016 to July 2016