SOUNDIN

BRISBANE AIRPORT

SUMMARISING THE CALIBRATED AIRCRAFT NOISE MODEL FOR BRISBANE AIRPORT

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1 INTRODUCTION

This report outlines the development of a calibrated aircraft noise model for Brisbane Airport, which was used in preparing the recent ANEF.

Creating a best-practice calibrated noise model is essential for accurate noise predictions. Calibration ensures that modelled noise levels closely match actual measurements; without it, predictions can be misleading, resulting in unrealistic expectations and compromising decisions made on the basis of modelling results.

Following the opening of its new runway, Brisbane Airport has acted on community and stakeholder feedback by adopting advanced noise modelling techniques; embracing technological advancements and increased capabilities in aircraft noise modelling. SoundIN considers Brisbane Airport's approach to represent current best practice, incorporating every effort to accurately reflect both existing and future aircraft noise levels.

1.1 Aircraft Noise Modelling Overview

Aircraft noise modelling allows for noise to be calculated for existing and forecast future operating scenarios. Inputs and assumptions are selected so that the model approximates reality as closely as possible. The objective of best practice modelling is to consider the impact of any assumptions or approximations, as well as the fidelity of input data, so that modelling outputs are not compromised by any assumptions or approximations.

1.1.1 Outline of the Calculation Procedures

Detailed calculation of aircraft noise levels at any airport requires details of actual or forecast operations, as indicated in **Figure 1-1**.

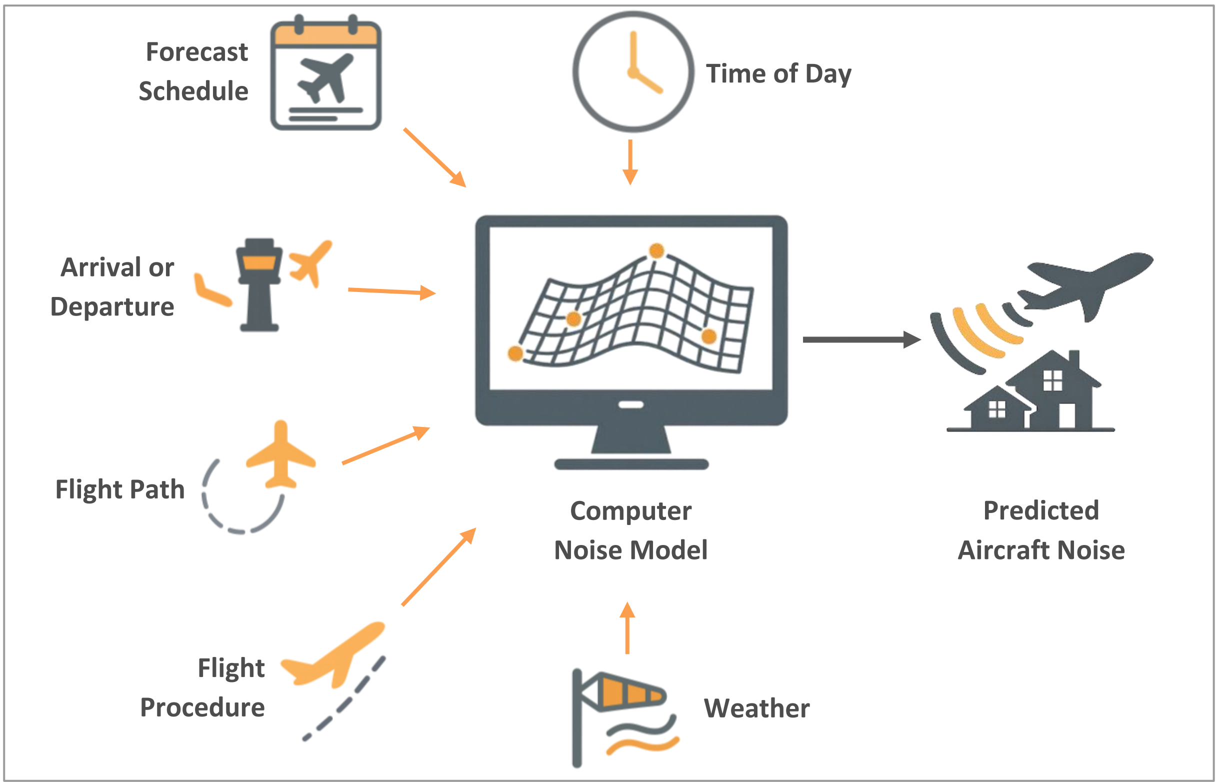
Where long-term (i.e., several or many years) trends impact noise modelling, those inputs are informed by long-term data. Forecast schedules are informed by decades of historical data, derived trends, as well as current and forecast conditions. The potential impact of short-term trends in meteorological conditions is mitigated by considering 10-years of historical meteorological conditions.

The decision tree analysis is applied to more than 3,600 days (i.e., 10-years of historical meteorological conditions), including all of the variables identified – the recorded meteorological conditions, variations in aircraft performance, and operating rules to mimic ATC behaviour. The resulting forecasts are complex – for each scenario comprising noise level calculations for millions of operations.

Through this rigorous approach, more realistic variations in each aspect of the noise forecasting are able to be incorporated – e.g., airport and ATC operations including possible vectoring or selecting between multiple available SIDs/STARs; and aircraft performance and noise emissions considering varying meteorological and operating conditions.

This approach contrasts with other forecasting methods that calculate average operations as an input to the noise calculation, thus precluding the full impact of the variables on the resulting noise metrics from being considered.

Figure 1-1 Aircraft Noise Modelling



1.1.2 Aviation Environmental Design Tool (AEDT)

The Aviation Environmental Design Tool (AEDT) aircraft noise and emissions prediction program, produced by the United States Federal Aviation Administration (FAA), is the industry-standard tool for the calculation of aircraft noise, and other environmental emissions, from aircraft operations.

The AEDT program is a computer model that calculates aircraft noise exposure in the vicinity of airports. It was developed based on the algorithm and framework from SAE-AIR-1845 *Procedure for the Calculation of Airplane Noise in the Vicinity of Airports* (Society of Automotive Engineers (SAE), 1986), which used noise-power-distance (NPD) data to estimate noise accounting for specific operation modes, thrust settings, source-receiver geometry, acoustic directivity and other environmental factors.

2 CALIBRATION PROCESS

2.1 NFPMS Data

Airservices Australia's (Airservices) Noise and Flight Path Monitoring System (NFPMS) collects noise and flight path data at numerous major Australian airports – currently Brisbane, Cairns, Canberra, Gold Coast, Sydney, Melbourne, Essendon, Adelaide and Perth airports. This system operates 24-hours-a-day, seven-days-a-week, collecting data from every aircraft operating to and from the airport.

Calibration has been progressively refined based on NFPMS data obtained from 2019 onwards. Throughout that process, NFPMS data has been obtained for 31 noise monitoring terminals (NMTs) around Brisbane Airport.

The most recent calibration is based on data for calendar year 2023, which includes data for 23 NMTs. All NMTs used in the analysis are shown in **Figure 2-1**.

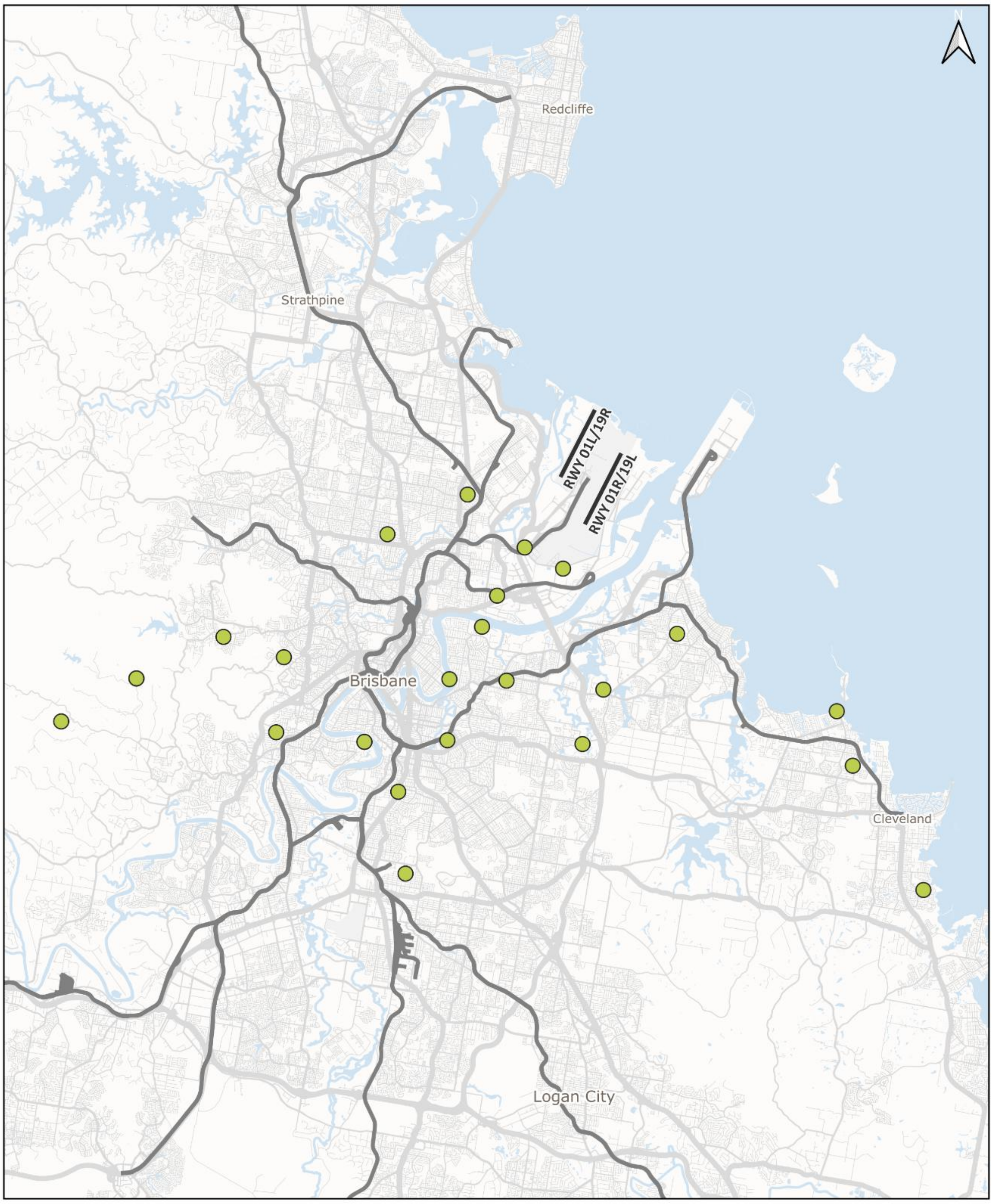
The NFPMS data includes surveillance data – i.e., a sequence of points indicating the aircraft's latitude, longitude and flight level / altitude through the flight. Noise data is provided for both L_{Amax} and sound exposure level (SEL) noise descriptors.

Data from 102,340 flights was included in the analysis, with over 229,000 noise measurements (i.e., measurements at multiple NMTs for most flights).

The significance and magnitude of data included in the calibration must not be understated. The 100-thousand flights and 229-thousand noise measurements included is comprehensive and provides ample data to account for and quantify the calibration measures that were derived from the process. This comprehensive dataset also provided sufficient resolution to derive a modelling approach that accounts for much of the observed variations in aircraft noise levels.

Furthermore, though the most recent calibration exercise considered one complete year of data, the calibration measures have been incrementally developed and improved over several iterations of this exercise, with data from 2019 to 2023 (inclusive).

Figure 2-1 NFPMS Noise Monitoring Terminals



NOISE AND FLIGHT PATH MONITORING SYSTEM

NOISE MONITORING TERMINALS

LEGEND

Noise monitoring terminals

0 2 4 6 8 10 km

Note: Locations of features are indicative only and are shown solely to demonstrate features pertinent to the noise assessment.

2.2 Calibration Process Overview

Calibration was undertaken by modelling each of the operations in the NFPMS data (i.e., 100+ thousand operations) and determining the "best-fit" for each operation. In this way, each of the flights with NFPMS data can be modelled using the "best-fit" parameters. For flights without NFPMS data or for modelling of future scenarios, a calibration profile can be applied – i.e., the proportional allocation of profiles, stage lengths, and meteorological (met) classes based on the actual or forecast operation.

It is noteworthy that aircraft performance and related noise emissions will vary from flight-to-flight, most notably due to meteorological conditions, but also due to differences in airline and pilot behaviour and tendencies. In general, changes in meteorological conditions mean that aircraft efficiency varies. In turn, this affects climb rates and thrust requirements, and consequently noise levels on the ground. Therefore, it is important to consider these variations in aircraft performance and noise emissions as part of the calibration process.

Figure 2-2 demonstrates the process of modelling aircraft performance and noise emissions and evaluating the available options to determine the "best-fit" for each operation in the data.

The process consists of the following steps.

1. Generation of a database of AEDT-calculated trajectories and noise levels for all available aircraft, operations, profiles / procedures, and met classes on single, generic flight path.
2. Screening each flight against the available AEDT-trajectories to determine viable options for detailed modelling.
3. Modelling each of the viable options on the actual flown path and calculating modelled noise levels at each of the NMTs.
4. Selection of the "best-fit" modelling option based on a weighted score consisting of the difference in L_{Amax} and SEL between measurements and modelling at each NMT and the agreement between the modelled and measured trajectories.

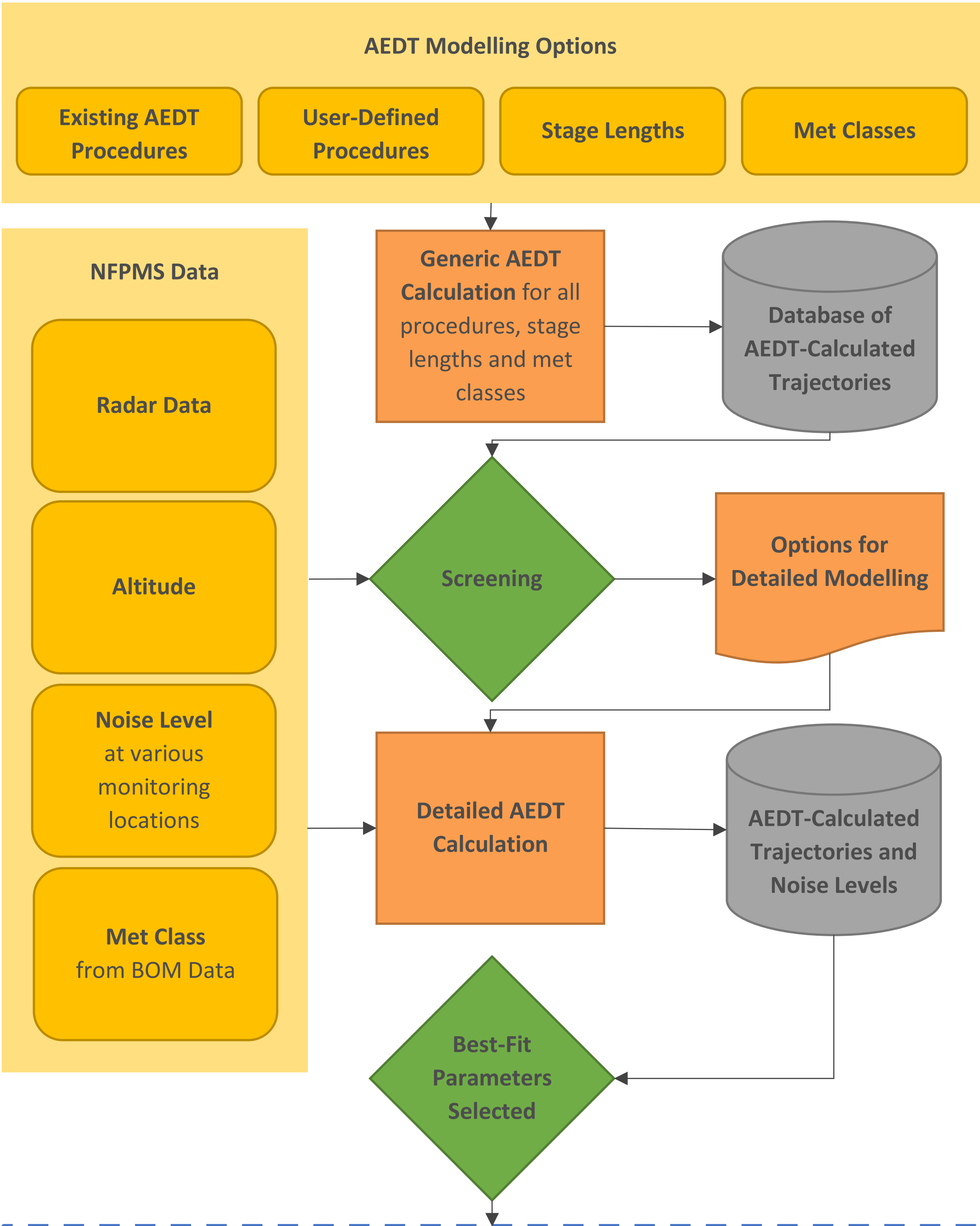
In the screening process, a minimum of 50 options for each flight proceeded to detailed modelling – in many cases several hundred options were considered viable and proceeded to be modelled.

Trajectories were evaluated along the flight path, between 3,000 m and 30,000 m from the end of the runway. The magnitude of the difference in altitude was determined at each point and given a score indicating the level of agreement between the measured and modelled trajectory.

The difference between measured and modelled L_{Amax} and SEL noise levels was evaluated at each NMT with noise level data for the flight being analysed. The "aggregated noise score" was determined by applying a weighting to the SEL and L_{Amax} component scores.

The overall score for each option was determined by summing the absolute values of the "aggregated noise score" and the "weighted trajectory score". The "best-fit" was determined based on this combined score.

Figure 2-2 Determining the Best-Fit Parameters for Each Flight



"Best-Fit" Parameters for Each Flight

The combination of met class, stage length and procedure with the best correlation of both profile and noise levels is selected and subsequently used in noise modelling

Figure 2-3 presents an example calibration report for a single operation – an Airbus A320 departure flying a distance that is classified as stage length 2, in conditions that classify as met class “D92”.

The top graph shows the difference in trajectories between the model prediction and actual real-world observations. The baseline (model prediction) is shown in red, actual data in yellow, and the “best fit” option in black. The grey lines show the range of options that were considered. In this example, A320 aircraft were observed to follow a shallower climb angle than the model predicted, so aircraft noise was underpredicted at ground level. This is supported by the smaller graphs that compare predicted noise and actual noise, which show actual noise levels were higher than predicted.

The “best-fit” option demonstrates improved agreement between the modelled and actual trajectories, and greatly reduces the error in the modelled noise levels for this flight.

The example is just one of over 100,000 flights that were analysed in this manner.

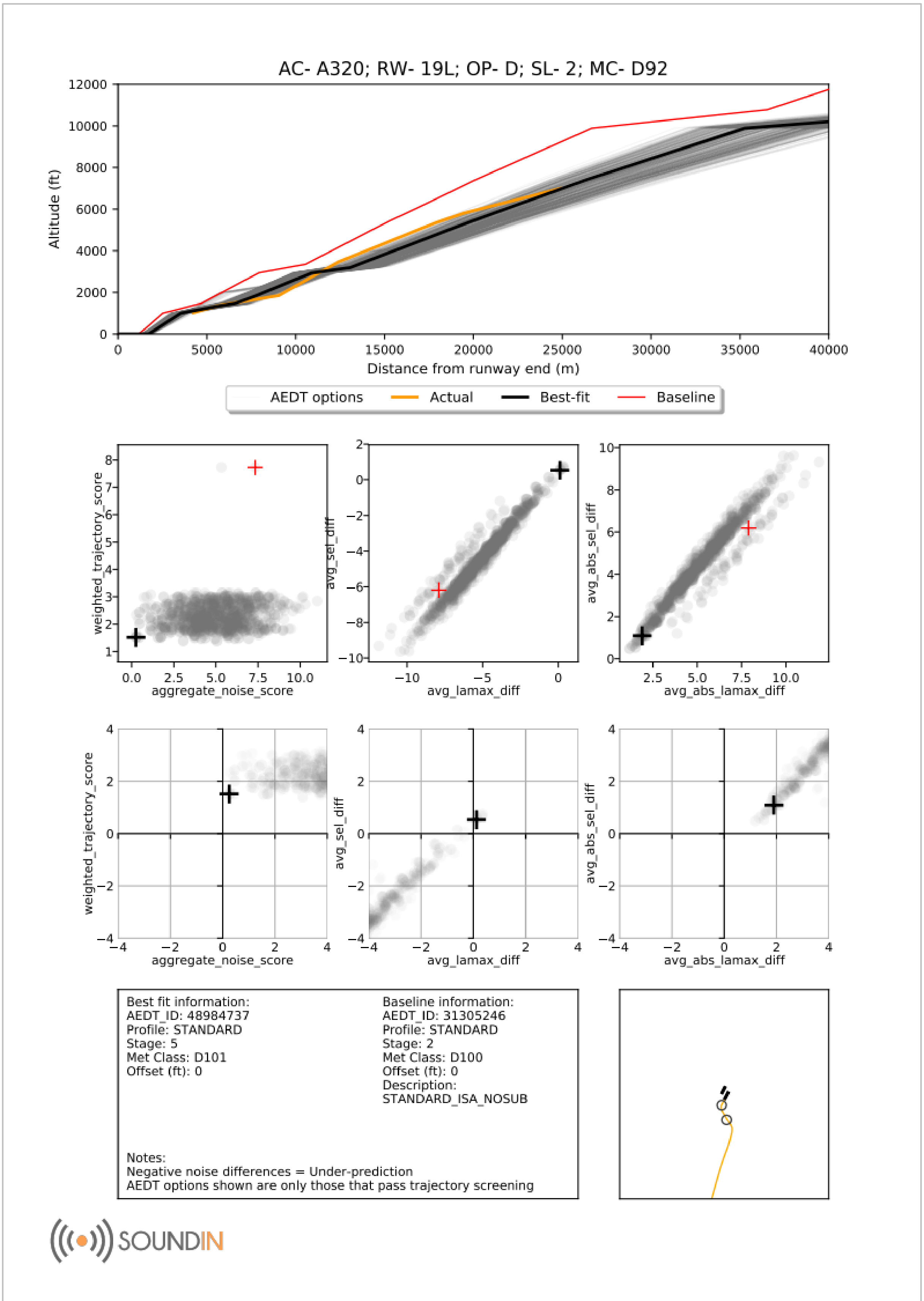
2.2.1 Scale of the Calibration Exercise

Data from 102,340 flights was included in the analysis, with 229,769 noise measurements (i.e., measurements at multiple NMTs for most flights).

The options considered for “best-fit” selection ranged between 50 and several thousand for each flight – 50 being the minimum number of options that were advanced through screening to the detailed AEDT calculation, and more than 3,000 demonstrating that in some instances many options were considered viable through screening.

A total of 59 million options were modelled in AEDT, producing 3.4 billion noise level predictions across the various NMTs (L_{Amax} and SEL).

Figure 2-3 Example Calibration Report for a Single A320 Departure



3 CALIBRATION MEASURES

3.1 User-Defined Profiles and Procedures

Some operations exhibited different profile characteristics to the default-AEDT procedures. To accommodate these operations, SoundIN has augmented the default-AEDT procedures through the creation of user-defined procedures.

3.2 User-Defined Aircraft

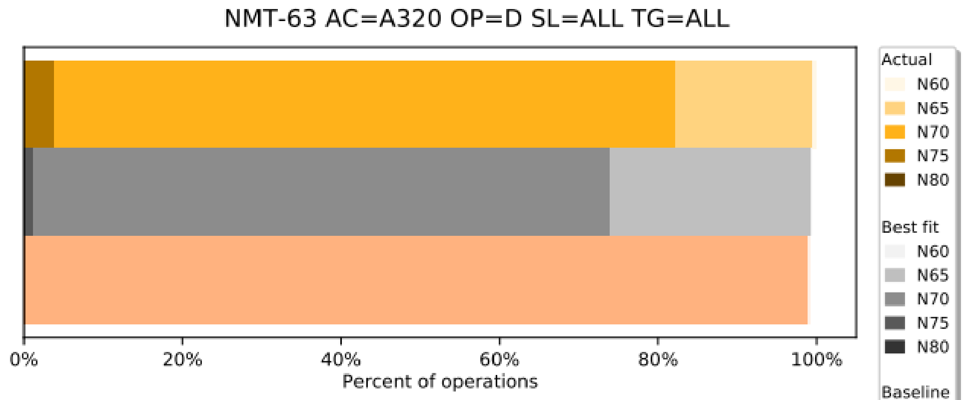
In some circumstances, calibration without the application of user-defined aircraft produced poor correlation between the measured and modelled data. User-defined aircraft use standard AEDT aircraft as their basis, with the base noise level data (noise-power-distance curves) adjusted to better align with measured noise levels at Brisbane Airport.

Figure 3-1 presents an analysis of A320 (a prolific jet aircraft) departures at a single NMT. Differences between measured and modelled noise levels are presented for both the L_{Amax} and SEL in the form of histograms (third row). Above these (second row), the actual measured (yellow) and modelled (red) noise levels are shown on histograms, similar to the difference plots.

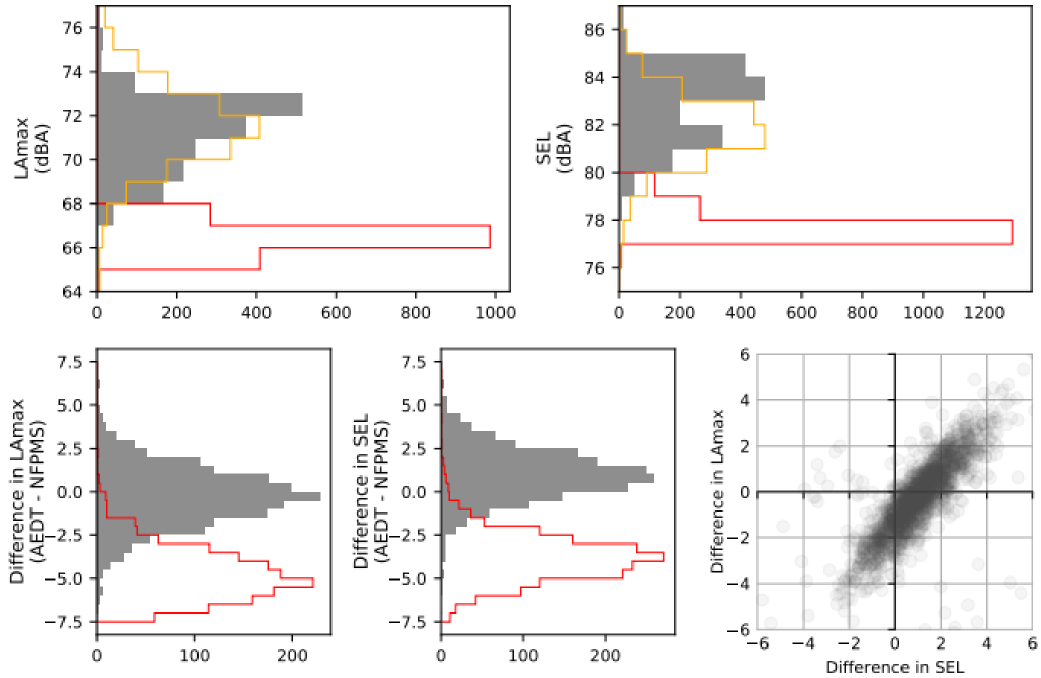
The resulting N-above for those operations at the subject NMT is shown on at the top of the figure as a bar-plot and also tabulated data. N-above determined from the actual measured data are shown at the top with a yellow palette whilst N-above determined from the modelled noise levels are shown at the bottom of the plot using an orange / red palette.

The baseline condition presents a substantial underprediction of noise levels, with very few flights demonstrating good calibration. The results with the calibration are greatly improved – the median modelled L_{Amax} is only 0.2 dB above the median of measured L_{Amax}, the median error in L_{Amax} is -0.2 dB, N-above shows good agreement, and the number of flights demonstrating good calibration is increased to 77 per cent.

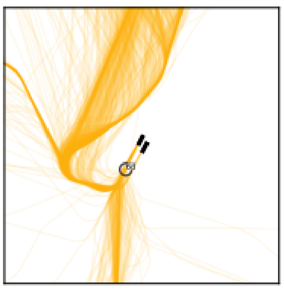
Figure 3-1 A320 Departures at NMT-63 Modelled with User-Defined Aircraft "A320_vBNE3"



	N60	N65	N70	N75	N80
Actual	100	99	82	4	0
Best fit	99	99	74	1	0
Baseline	99	99	0	0	0



	Mean	Median	10th %	90th %	% <2dB
NFPMS LAmax	71.5	71.5	69.2	73.9	-
AEDT LAmax	71.2 (66.4)	71.7 (66.5)	68.9 (65.8)	72.9 (67.2)	-
NFPMS SEL	81.7	81.8	80.0	83.6	-
AEDT SEL	82.7 (77.9)	83.1 (78.0)	80.9 (77.5)	84.2 (78.4)	-
Error in LAmax	-0.3 (-5.1)	-0.2 (-5.1)	-2.4 (-7.4)	1.8 (-2.9)	77.1 (4.3)
Error in SEL	1.0 (-3.8)	1.0 (-3.8)	-0.7 (-5.6)	2.9 (-2.1)	74.5 (8.4)



Notes:
Number of measurements: 1700 (1700)
Negative noise differences = Under-prediction
Baseline shown in brackets (table) and red (plots)
Baseline: STD_ISA_NOSUB

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4 CALIBRATION RESULTS

Most aircraft exhibit a greater proportion of good calibration for departures, where multiple stage lengths and procedures provide some flexibility for the calibration process to select a "best-fit" condition that satisfies noise levels at multiple NMTs. For many aircraft, the improvement is substantial (e.g., B738, A320, DH8D, B712).

For arrivals, some aircraft exhibit a far greater proportion of good calibration with the inclusion of the selected calibration measures (e.g., DH8D, BE20, SW4, B350, B463, B763, AT75, and DH8A). For the remainder of aircraft, the change in the proportion of good calibration compared to the baseline condition is more marginal. In general, fewer options exist for the calibration process to determine a "best-fit" condition that satisfies multiple NMTs. Often, in order to reduce the error at one NMT, the calibration must compromise by increasing the error at another NMT.

It must be noted that it is not possible, using the calibration measures and methods described in this report, to achieve good calibration for all flights at all NMTs. The primary reason is the existence of noise measurement data at multiple NMTs for many flights. The selection of a "best-fit" option for each flight must consider the noise levels at each NMT. Inevitably this process requires some compromise between the noise levels at each NMT.

In reality, the aircraft operates in four dimensions, with thrust and other parameters varying in time and space, as well as noise then propagating through conditions that again vary through time and space. The aircraft noise model approximates this behaviour, but no model can ever predict noise levels for every operation, at every point on the ground. In short, fully satisfying the noise level at every NMT for every flight is beyond even the 59 million options and 3.4 billion noise level data considered in the calibration process described herein.

Table 4-1 Summary of Calibration Results by Aircraft and Operation

Acrft	Arrivals					Departures				
	# Flts	# Meas.	L_{Amax} Δ	SEL Δ	% < 2 dB	# Flts	# Meas.	L_{Amax} Δ	SEL Δ	% < 2 dB
B738	16932	43355	0.0 (-1.2)	1.1 (-0.0)	67.0 (62.7)	19701	36526	-0.2 (-1.6)	0.4 (-0.3)	84.7 (53.1)
DH8D	5454	18951	-0.2 (-7.5)	2.1 (-7.4)	62.3 (0.1)	3918	4176	0.1 (-8.5)	2.3 (-6.2)	83.2 (0.1)
A320	3654	10198	0.1 (-2.6)	1.6 (-1.2)	41.3 (44.4)	3975	9015	-0.5 (-5.8)	0.4 (-4.4)	69.4 (3.7)
E190	3321	11509	0.0 (-1.1)	1.7 (0.2)	71.5 (61.4)	2957	7072	-0.7 (-4.1)	0.1 (-2.3)	71.1 (17.5)
F100	2293	8639	0.9 (-0.7)	0.3 (-2.0)	46.6 (51.2)	2195	7385	-0.4 (-3.3)	-0.8 (-4.3)	61.9 (25.5)
F70	1770	7239	1.0 (-0.6)	0.3 (-2.0)	38.6 (42.7)	1797	7072	-0.3 (-0.3)	-0.0 (-0.8)	63.4 (60.8)
SF34	1415	4867	0.7 (-0.7)	3.4 (-2.2)	51.3 (59.0)	930	998	-0.6 (-5.0)	1.5 (-2.0)	57.1 (17.5)
B737	1050	3336	0.6 (-0.4)	2.1 (0.7)	48.1 (62.6)	993	2491	-0.0 (-0.7)	1.1 (0.8)	83.3 (70.3)
BE20	1111	3581	-0.1 (0.9)	-1.6 (-0.7)	61.5 (45.8)	728	770	0.9 (-1.3)	2.3 (-0.5)	49.7 (49.9)

Acrft	Arrivals					Departures				
	# Flts	# Meas.	L_{Amax} Δ	SEL Δ	% < 2 dB	# Flts	# Meas.	L_{Amax} Δ	SEL Δ	% < 2 dB
A359	671	2651	1.2 (0.0)	0.7 (-0.1)	45.4 (58.9)	688	2343	-0.3 (-1.8)	0.7 (-0.7)	69.0 (47.6)

Notes:
1. Number of flights ("# Flts") indicates the number of flights for that aircraft and operation with data that was used in the analysis (i.e., not including excluded data).
2. Number of measurements ("# Meas") indicates the number of noise measurements for that aircraft and operation with data that was used in the analysis (i.e., not including excluded data). Each measurement typically includes both L_{Amax} and SEL.
3. Difference in L_{Amax} ("L_{Amax} Δ") indicates the median difference between the modelled and measured L_{Amax}. The difference is defined as the modelled L_{Amax} minus the measured L_{Amax} – negative values indicate underprediction. The "best-fit" value is shown, with the baseline also indicated in brackets.
4. Difference in SEL ("SEL Δ") indicates the median difference between the modelled and measured SEL, as in the same manner as L_{Amax} (above).
5. Percent of data with good calibration ("% < 2 dB") indicates the proportion of data – discrete noise levels at NMTs – whereby the modelled L_{Amax} is within 2 dB of the measured L_{Amax}.

5 CONCLUSION

This report details the development of a calibrated aircraft noise model for Brisbane Airport.

Calibrating the aircraft noise model is an integral part of best practice aircraft noise modelling.

Calibration measures have been developed, namely:

- the use of user-defined profiles and procedures;
- the use of user-defined aircraft, based on standard ANP aircraft but having modified NPD data; and
- selection of the "best-fit" modelling parameters for each flight in the historical data, applied as a calibration profile for forecast modelling scenarios.

The calibration process greatly improves the model's capability to accurately represent aircraft noise levels. Mean and median errors in the L_{Amax} and SEL are -0.1 dB and 0.7 dB or less. Each is improved compared to the simple baseline model.

Examination of calibration results for specific aircraft and NMTs further confirms that the calibrated model greatly outperforms the baseline scenario.

Following the verification process, the majority of aircraft and operations are able to be modelled such that reasonable agreement between the modelled and measured profiles and noise levels is achieved. In this regard, the use of AEDT in this manner is considered to be validated.