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aircraft noise technology

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Project		Document Title
AN074	BANOERAC	D1. Final report Part 0: Executive Summary

Summary

This document gives an overview of the main objectives and achievements of the BANOERAC project.

Document revision

Issue	Date	Affected pages	Modifications
1	14/10/2009	All	First issue
2	-	-	-
3	06/11/2009	All	Incorporation of EASA comments 06/11/2009

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Introduction

Two developments in aviation industry will shortly have reached a phase where actual rulemaking work will have to commence. These developments are the preliminary studies on supersonic business jets and the revived interest in so called 'open rotor' engines. They have a common factor in that they will potentially create non negligible noise levels on the ground, not only when flying in the terminal area around airports but also while the aircraft are climbing, cruising and descending at distance from airports (hereafter referred to as "en-route noise"). If aircraft with such technology would be numerous, this would essentially mean that aircraft noise would be audible literally everywhere. The political discussion and the impact assessment will therefore require factual data on existing so called background noise levels and on actual noise levels of 'classical' aircraft in cruise in Europe and elsewhere. Such data will make it possible to put the noise levels of these new technologies in perspective with the existing situation.

EASA issued an Invitation to Tender (ItT) for a study on “Background noise level and noise levels from en-route aircraft”, with acronym BANOERAC. The contract was awarded to the proposal from the consortium, formed by Anotec and Labein-Tecnalia, both from Spain.

Before the present study EASA contracted two pilot studies with direct relation to BANOERAC.

One study, performed by SINTEF, concluded that no data is readily available on existing background noise. It was reported however that a first approximation of the background noise levels can be derived from population density. The present project intends to use this concept to establish a detailed database of estimated background noise levels in Europe.

The other study, performed by Anotec, concluded that very little and mainly outdated information on en-route noise from aircraft was available, but that it would be possible to collect meaningful information with a measurement campaign. BANOERAC aimed at carrying out such measurements.

The aim of this study is to improve insight in background noise levels in Europe and the en-route noise from aircraft. It is realised though that the scope of the study does not allow to claim that the results would be representative for all of Europe.

According to the proposal the work performed was divided in 3 parts:

Part 1. Calculation of approximation of background noise levels
Calculation of background noise levels based on population density for each EU country, building on the SINTEF report and proposing some correction for extreme situations.

Part 2. Actual measurements of background noise and aircraft en-route noise
Measuring of actual noise levels in a number of locations representative for a quiet rural area, with very low levels of background noise from man-made sources.
Noise measurements from actual passages of aircraft that are en-route (i.e. climb, cruise and descent phases).

Part 3. Final analysis and results
Analysis of the measured data and presentation and discussion of the results for both background noise and aircraft en-route noise.

1. Calculation of approximation of background noise levels

The aim of Part 1 was to generate a Background Noise Level Map for the EU27, referred to a spatial grid of 10 x 10 km resolution. In this report Background Noise (BGN) is understood as the sound at a location from a number of more or less identifiable sound sources when the direct sound from prominent sources is excluded.

In a previous study, developed by Sintef, a first approximation of the background noise levels derived from population density was defined. In an analogous way, this part of the BANOERAC project is based on this concept to establish a detailed database of estimated background noise levels in Europe and the intention was to complement this approach proposing some corrections for extreme situations; this is, incorporating the effects of transport and urban noise, including a minimum threshold for quiet rural areas, and analyzing data from Strategic Noise Maps developed by Member States as an answer to the European Noise Directive.

In the BANOERAC project Background Noise Levels are expressed by the percentile level L95 in different periods of the day (day, evening and night). L95 is the sound level exceeded for 95% of the time, so only in 5% of the time the sound level is less than L95. The unit of L95 is dB(A). This is illustrated in Figure 1.

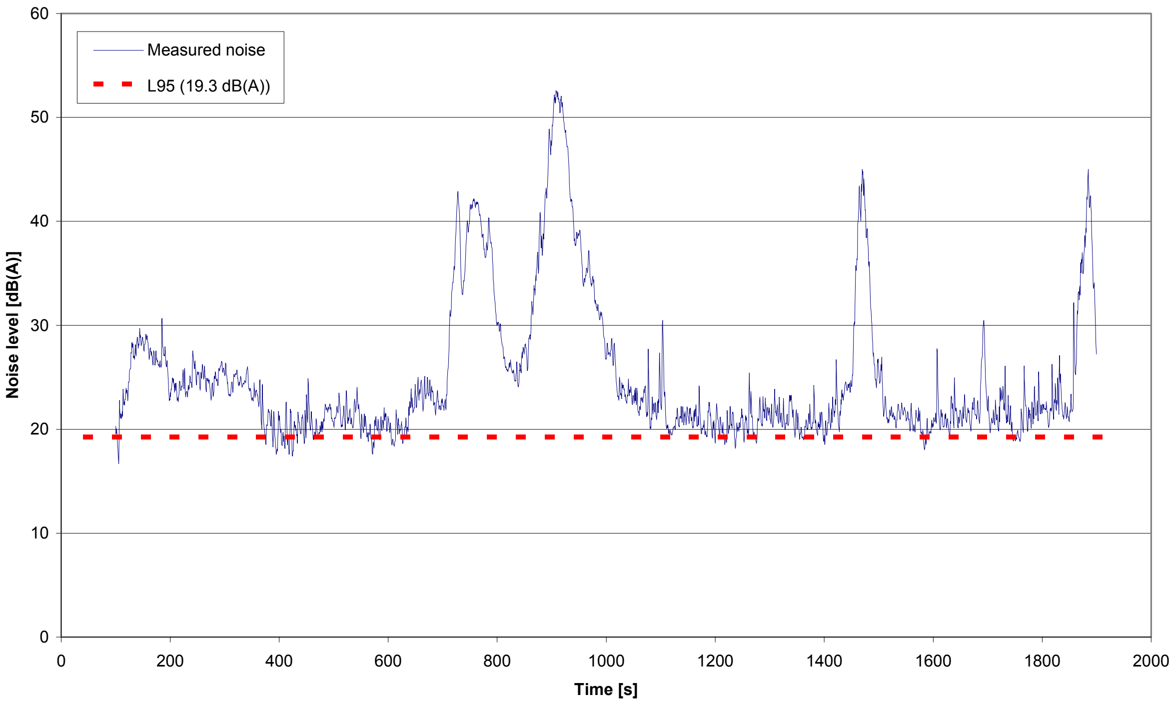

Figure 1. Example of Percentile level L95

Whereas not much information is available on L_{95}, large datasets for L_{den} are readily available for large areas as a result of the ongoing Strategic Noise Mapping exercise. This metric was therefore used as an intermediate value to calculate the L_{95} values. Thus, appropriate percentile levels are predicted on the basis of L_{den} values. In this project the assumption is that representative noise levels in each cell are understood as the acoustic energy in the cell, extended to its whole surface. This premise is applied to all acoustic parameters used in this project: $\mathbf{L_{den}}$, $\mathbf{L_{day}}$, $\mathbf{L_{evening}}$, $\mathbf{L_{night}}$, $\mathbf{L_{95,day}}$, $\mathbf{L_{95,evening}}$, and $\mathbf{L_{95night}}$.

The grid used as spatial reference to build the BGN Maps is the ETRS89 Lambert Azimuthal Equal Area 52N 10E grid, recommended by EEA.

Input data needed for development in Part 1 refer to population density data, Strategic Noise Maps, transport Infrastructure information and noise monitoring data.

The application of the methodology allows building four BGN datasets:

- Basic BGN dataset. It estimates BGN levels considering only population density data.
- Agglomeration BGN dataset. It estimates BGN levels in urban agglomerations.
- Transport BGN dataset. It estimates BGN levels in areas acoustically affected by major roads.
- Rural Quiet BGN dataset. It estimates BGN levels in areas with very low population density values. It represents the minimum threshold noise level caused by natural sounds.

These BGN datasets should not be considered independently. The BANOERAC BGN Map is built by combining values from the four datasets. As a general rule, the final value of every cell is the maximum value of all existing values coming from any dataset. Results obtained in the project have been checked by different validation procedures.

The final results achieved in this part of the BANOERAC project are the following:

- A database with all values linked to a 10 km reference grid for the EU27 countries, which contains both fundamental information for each 10 km cell and the resulting noise data. An updating tool to recalculate automatically all information is also provided.
- Printed maps with the background noise levels plotted in A4 format and also delivered as digital files in PDF format.
  Figure 2 shows an example of a final BANOERAC European BGN Map.
- Easy-to-use desktop mapping tools to visualize and consult the maps, as well as other relevant reference information.

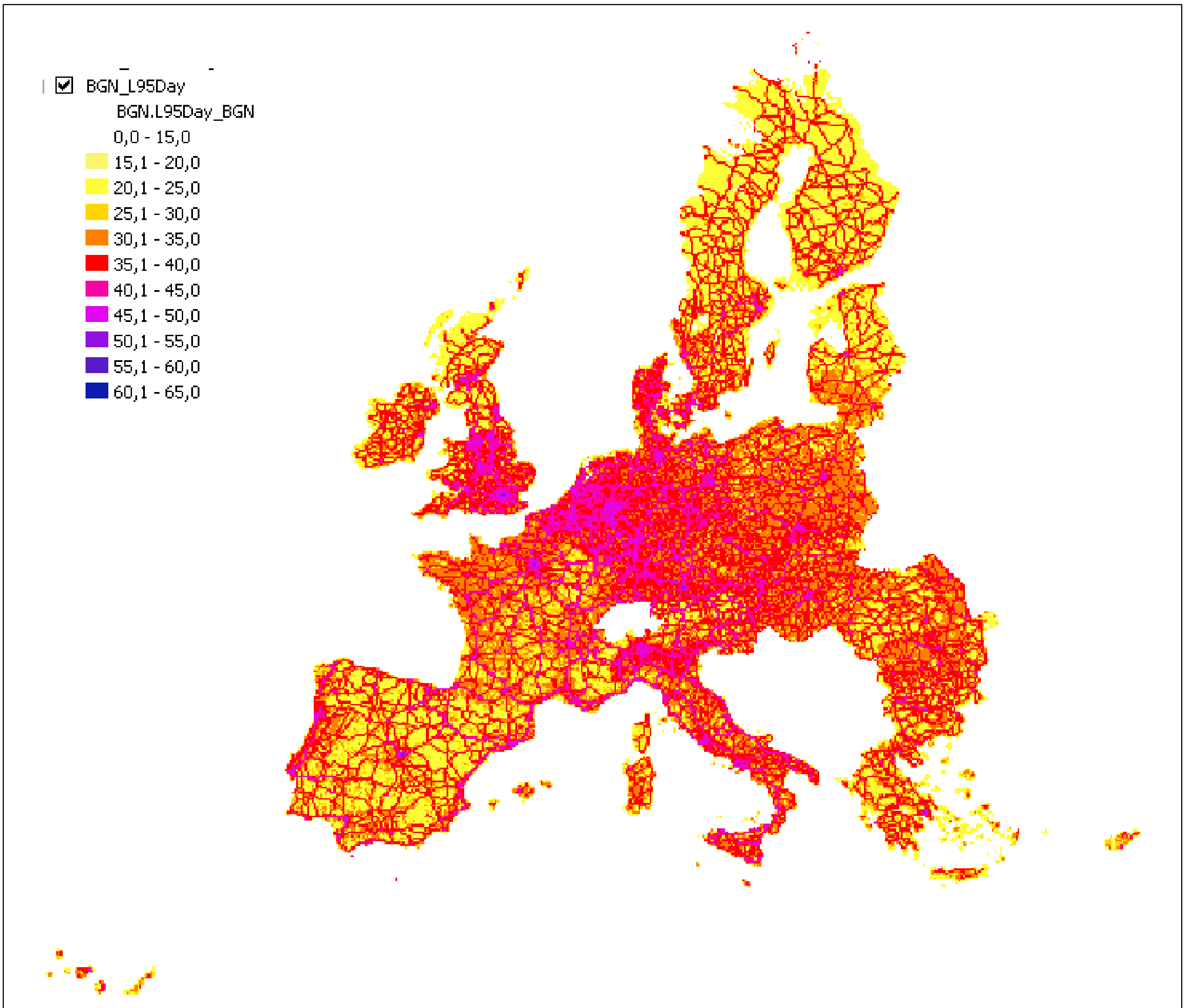

Figure 2. Background noise map (L95day)

2. Measurements of background noise and aircraft en-route noise

The main objective of Part 2 of the BANOERAC study was the performance of measurements in order to establish actual background noise levels in various environments and also to determine the noise levels of current aircraft types when en-route.

Test site selection
Due to the expected low noise levels to be measured, the test sites had to be selected carefully. Especially the aircraft en-route noise measurements required specific additional attention with respect to the proper selection of the test sites (underneath major airways).

Two test sites were defined for the dedicated background noise measurements (Diego Alvaro in Avila and Los Tablones in Granada), which were representative for Natural park and agricultural/hilly. For the aircraft en-route measurements 2 sites were selected relatively close to Madrid (Cebreros and Colmenar). It is noted that during the background noise sessions also some aircraft noise events were recorded and that during the aircraft noise sessions also some background noise could be measured.

Measurements performed

		Background noise	**Aircraft en-route noise**
Test site	**Period**	**Nº hours**	**Nº valid events**
Diego Alvaro	July	31.5	41
Los Tablones	July	48	21
Cebreros	Feb-May	35	780
Colmenar de Oreja	June-July	20	276
Total	**6 months**	**134.5**	**1118**

Table 2 Total nº hours/nº events obtained during the measurements

For background noise a total of 90h was planned, whereas for aircraft en-route noise a minimum of 1000 valid events was targeted. Both objectives have fully been met.

3. Final analysis and results

The main objective of Part 3 of the BANOERAC study was the analysis of the data obtained during the measurements of Part 2, in order to establish actual background noise levels in various environments and also to determine the noise levels of current aircraft types when en-route.

Determination of background noise level

The objective of the background noise measurements was to obtain the noise levels representative for very quiet areas, in order to correct the SINTEF curve (see Part 1) at the lower end (i.e. at very low population density). The Diego Alvaro site appeared the quietest site and the measurements made here were used to feed Part 1.

All noise events generated by non-natural sources (e.g. cars, aircraft) were excluded from the measurements in order to derive the background noise levels, generated by natural sources only. These noise levels of only natural origin were used in the further analysis of background noise in this part.

The following table contains the average values for the 3 periods Day (7-19h), Evening (19-23h) and Night (23-7h). These values were used in Part 1.

Period	LAeq [dB(A)]	L95 [dB(A)]
Day	29	23
Evening	27	22
Night	23	19

Table 3 Average values of background noise from natural sources only, for the 3 periods of day (Diego Alvaro site)

Figure 3 shows all the background noise measurements performed at the four test sites which cover a period of 6 months. It can thus be considered a representative dataset.

At the Los Tablones test site the background noise levels appeared to be significantly higher than elsewhere. This site was dominated by noise generated by insects such as cicadas. It is recognized that this noise is not representative for the whole of Europe, but it certainly is for the whole Mediterranean region. A correction factor might be added to the model developed in Part 1 in order to account for these local/regional effects.

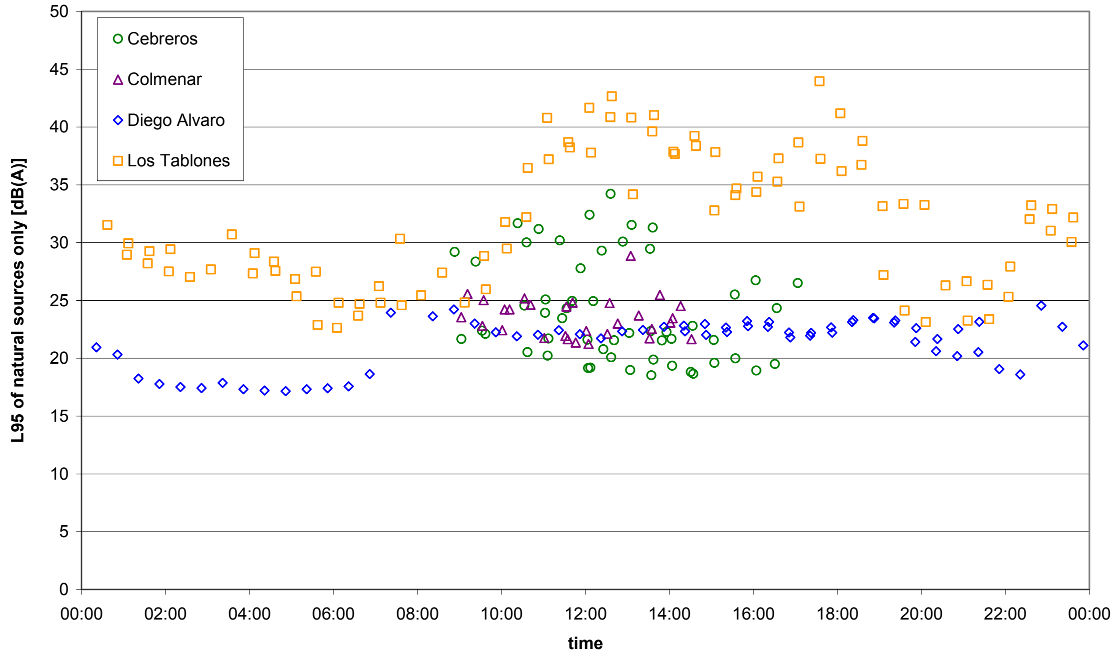

Figure 3. Recorded Background noise levels

Determination of aircraft en-route noise levels

Early in the analysis stage it became apparent that the noise from birds completely masked the aircraft noise levels. A new metric was defined by which this noise could be filtered from the results by using a cut-off for all noise above 1 kHz. It was demonstrated that for aircraft noise events this metric was fully equivalent with the standard metrics normally used. All further analysis was therefore done with this new metric.

The following classification of aircraft types was used in the final analysis.

Code	Class	Typical Models
RJ1	Regional Jet (Gen1)	F70/F100
RJ2	Regional Jet (Gen2)	CRJ, ERJ
MR1	Medium Range (Gen1)	MD80/90
MR2	Medium Range (Gen2)	A318-A321 B737-300…800
LR2	Long Range Twin	A-310, A330, B767, B777
LR4	Long Range Quad	A340, B747
Prop	Heavy Prop	ATR, ATP, DH8, F50
BJ	Business Jet	Gulfstream
GA	Small propeller	Cessna, Beechcraft
Heli	Rotorcraft	EC135, A-109
MIL	Military jet aircraft	Eurofighter

Table 4 Classification of aircraft models

Most valid events were found in the MR2, LR4 and GA classes.

The aircraft events were distributed over the 3 flight phases of interest (climb, cruise and descent) in a ratio of approximately 20%/60%/20% respectively.

The following conclusions were drawn:

- An extensive dataset on aircraft en-route noise has been obtained through high quality measurements. These measurements were performed at four different test sites over a six month period, covering winter to summer. Some measurements have been made at night. This dataset thus covers a variety of environmental conditions which makes it representative for the noise levels of current aircraft when en-route, which was the main objective of BANOERAC.

- For different aircraft classes the noise levels in climb, cruise and descent phase were obtained. A wide range of distances is covered by the dataset.

- Against initial expectations, noise in the descent phase is clearly audible.

- Comparison of the results with similar studies performed in the past, confirmed that current aircraft types are quieter in all phases of flight. Based on these studies it was also noted that at present cruise altitudes appear to be higher than in the past, thus also contributing to a reduced noise level on the ground.

- The scatter in the data was in the same order of magnitude as found in earlier studies. Although probably the influence of atmospheric conditions is very important for the noise propagation and thus the received noise levels, this was certainly not the only contributor to the observed scatter.

- Although wind speeds were always well within the established limits, it was found that the combination of even relatively low wind speeds with low elevation angles appears to give rise to an increased scatter in the data.

Figures 4 to 6 provide the final datasets for the 3 flight phases, combining all jet aircraft types in a single dataset. The datapoints contaminated by noise of wind and/or insects have been excluded from these graphs. These graphs provide the maximum noise level of the aircraft events as a function of the distance from microphone to aircraft. The distance is used here rather than the height, in order to allow its use also for operations with a certain lateral position with respect to the microphone..

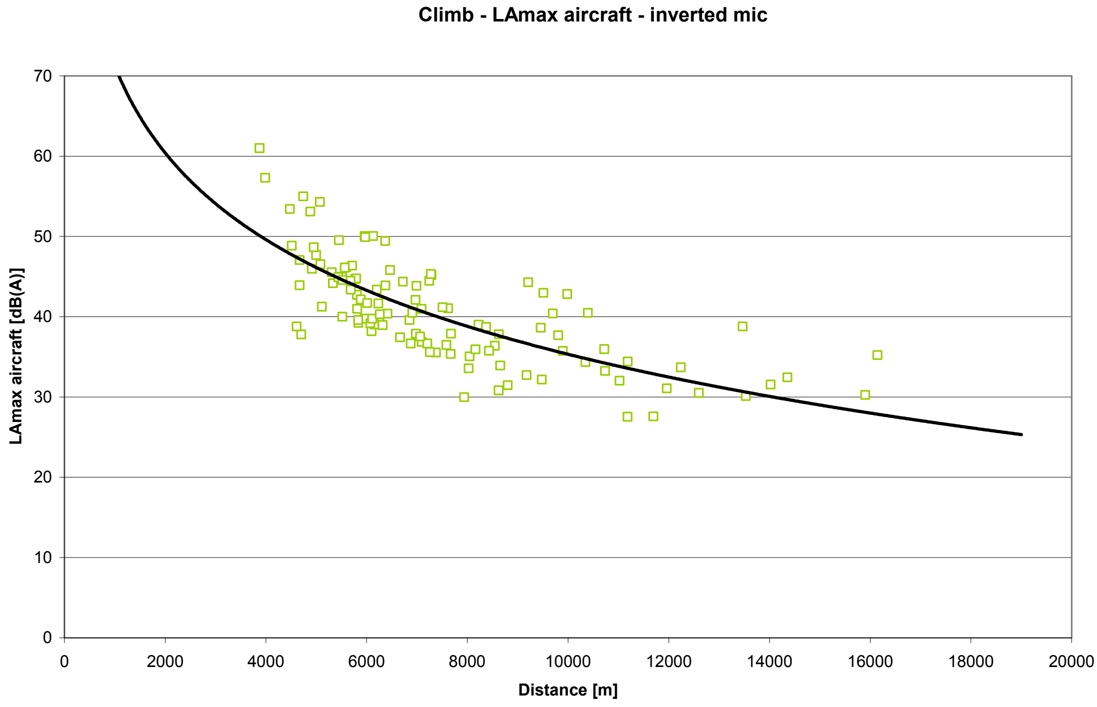

Figure 4 LAmax for all valid jet aircraft events (CLIMB phase)

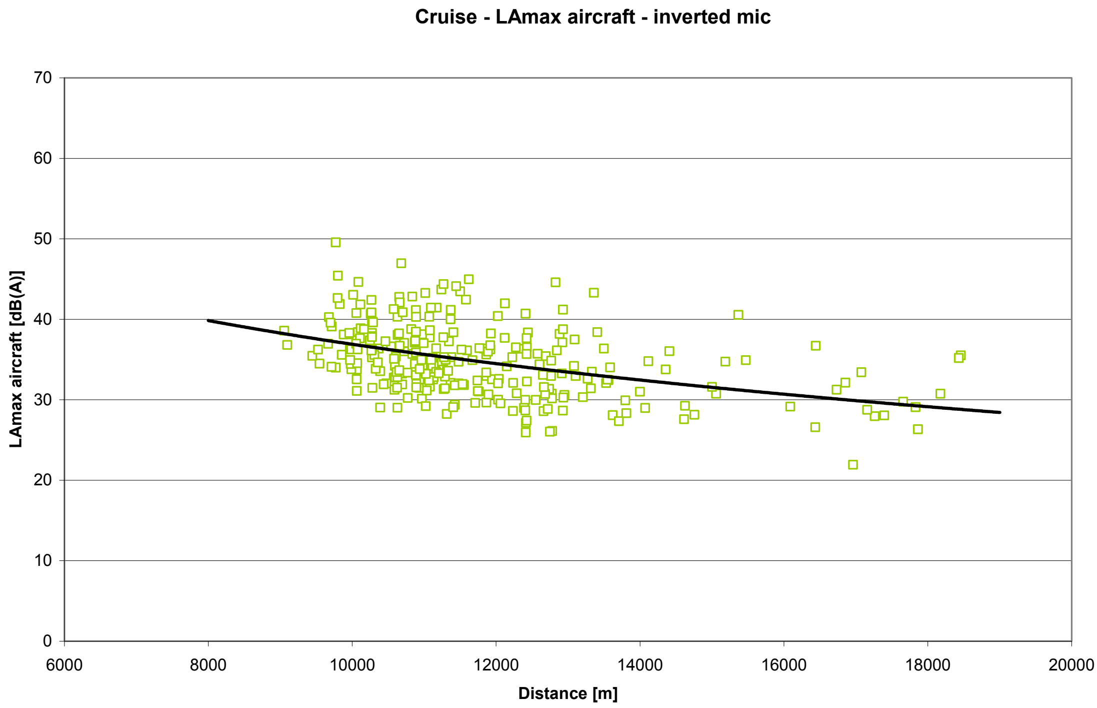

Figure 5 LAmax for all valid jet aircraft events (CRUISE phase)

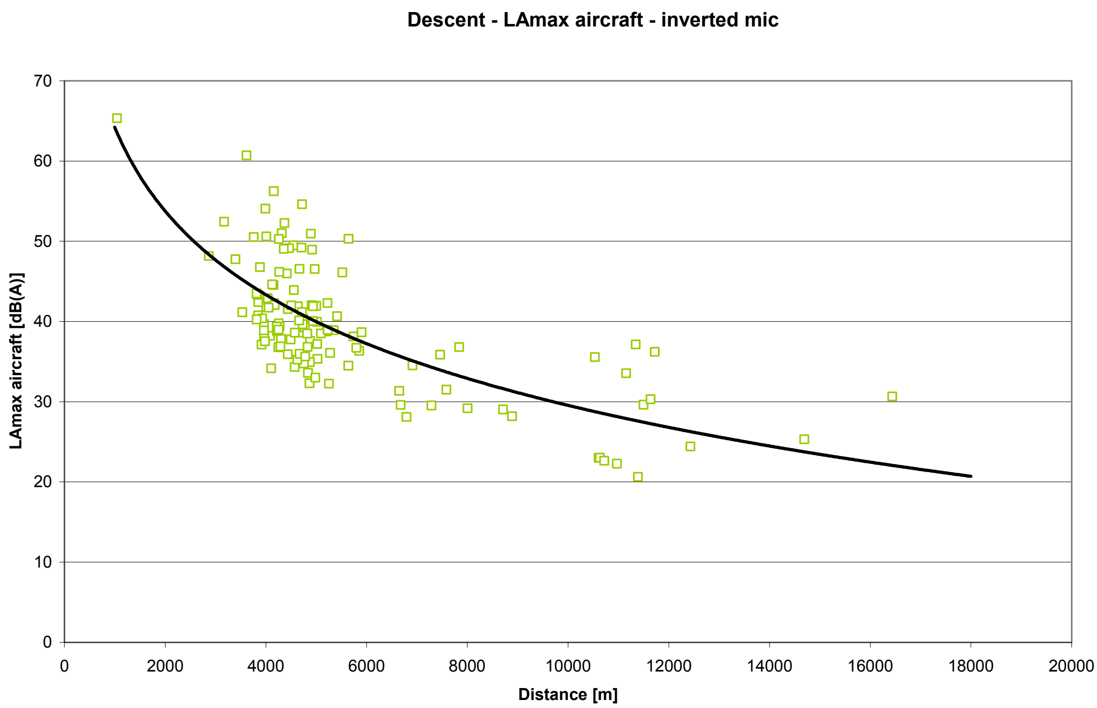

Figure 6 LAmax for all valid jet aircraft events (DESCENT phase)

The following table presents the resulting noise level at an arbitrary reference distance (5 km for climb and descent, 10 km for cruise), following the regression curves derived above.

Flight phase	Ref. dist [m]	$LAmax_{ref}$ [dB(A)]	Standard deviation* [dB(A)]
Climb	5000	46.1	4.3
Cruise	10000	36.9	4.0
Descent	5000	40.0	5.4

* when all datapoints collapsed to the reference distance by using the regressions curves

Table 5 Average noise level at reference distance (inverted mic)

It should be noted that these levels are an average level for all jet aircraft types at the indicated distance. Deviations of up to ±10 dB(A) from this average have been observed.