Dedicated to innovation in aerospace

NLR-CR-2016-467 | October 2016

Second opinion E190-100 noise report

CUSTOMER: SWEDAVIA AB

NLR – Netherlands Aerospace Centre

Netherlands Aerospace Centre

NLR is a leading international research centre for aerospace. Bolstered by its multidisciplinary expertise and unrivalled research facilities, NLR provides innovative and integral solutions for the complex challenges in the aerospace sector.

NLR's activities span the full spectrum of Research Development Test & Evaluation (RDT & E). Given NLR's specialist knowledge and facilities, companies turn to NLR for validation, verification, qualification, simulation and evaluation. NLR thereby bridges the gap between research and practical applications, while working for both government and industry at home and abroad.

NLR stands for practical and innovative solutions, technical expertise and a long-term design vision. This allows NLR's cutting edge technology to find its way into successful aerospace programs of OEMs, including Airbus, Embraer and Pilatus. NLR contributes to (military) programs, such as ESA's IXV re-entry vehicle, the F-35, the Apache helicopter, and European programs, including SESAR and Clean Sky 2.

Founded in 1919, and employing some 650 people, NLR achieved a turnover of 73 million euros in 2014, of which three-quarters derived from contract research, and the remaining from government funds.

For more information visit: **www.nlr.nl**

Dedicated to innovation in aerospace

Second opinion E190-100 noise report

REPORT NUMBER
NLR-CR-2016-467

AUTHOR(S)
R.H. Hogenhuis
S.J. Heblij

REPORT CLASSIFICATION
UNCLASSIFIED

DATE
October 2016

KNOWLEDGE AREA(S)
Aircraft Noise

DESCRIPTOR(S)
certification noise
noise limits
Bromma
second opinion
Embraer

Problem area

In the future airlines might want to operate Embraer 170, 175, 190 and 195 aircraft to and from Bromma Airport. Since these aircraft do not always fulfil the noise limits for this airport, Embraer provided a report to indicate how the Embraer 190-100 could comply with these criteria. In this report, NLR verifies the conclusions of the Embraer report.

Description of work

NLR took the following to verify the results of the Embraer report:

1. NLR experts reviewed the Embraer report to see whether they agreed with the line of reasoning in this report.
2. NLR conducted noise computations and checked whether the results were similar to the results in the Embraer report.

Furthermore, NLR looked into the noise production of three other types of Embraer aircraft (the Embraer 170, Embraer 175 and Embraer 195) to give an indication whether these types can be operated to and from Bromma Airport.

Results and conclusions

NLR concludes that the two combinations of configuration and operational conditions of the Embraer 190 as proposed by Embraer indeed lead to an average certification noise level that complies with the noise limits of Bromma airport, as long as the aircraft is equipped with CF34-10E5A1 G07 engines. In an updated version of their report, Embraer confirms that this specific engine type should be used.

For the Embraer 170 and Embraer 175 aircraft types, NLR found several combinations of configuration and operational conditions in the EASA database that result in average noise certification levels that comply with the noise levels for Bromma Airport. For the Embraer 195, no such combination is available in the database. However, the application of a reduced flap approach and/or a further reduction of take-off and/or landing weight can result in an acceptable noise levels for this aircraft type as well. This has to be proven first before this aircraft can be operated to and from Bromma Airport.

Applicability

This report can be used as a document that provides an independent opinion on the Embraer report about the noise production of the Embraer 190. Besides that, the methodology described in this report can be applied in the future when new aircraft types are introduced at Bromma Airport for which the certification data do not directly provide sufficient clarity whether the aircraft will always comply with the noise limits for Bromma Airport.

NLR
Anthony Fokkerweg 2
1059 CM Amsterdam
p) +31 88 511 3113 f) +31 88 511 3210
e) info@nlr.nl i) www.nlr.nl

Dedicated to innovation in aerospace

NLR-CR-2016-467 | October 2016

Second opinion E190-100 noise report

CUSTOMER: SWEDAVIA AB

AUTHOR(S):

R.H. Hogenhuis Netherlands Aerospace Centre
S.J. Heblij Netherlands Aerospace Centre

NLR - Netherlands Aerospace Centre

CUSTOMER	**SWEDAVIA AB**
CONTRACT NUMBER	**---**
OWNER	**SWEDAVIA AB**
DIVISION NLR	**Aerospace Operations**
DISTRIBUTION	**Limited**
CLASSIFICATION OF TITLE	**UNCLASSIFIED**

APPROVED BY :		
AUTHOR	**REVIEWER**	**MANAGING DEPARTMENT**
R.H. Hogenhuis i.o. S.J. Hebly	R. Aalmoes	P.L.J. Eijssen
DATE 1 4 1 0 1 6	DATE 1 4 1 0 1 6	DATE 1 4 1 0 1 6

Contents

Abbreviations

ACRONYM	DESCRIPTION
AIP	Aeronautical Information Publication
ANP	Aircraft Noise and Performance
APM	Airport Planning Manual
dB	Decibel
ECAC	European Civil Aviation Conference
EPNdB	Equivalent Perceived Noise
IACN	Improved Acoustic Chevron Nozzle
INM	Integrated Noise Model
NLR	Netherlands Aerospace Centre

1 Introduction

1.1 Motivation and scope

In the coming years, airlines may want to operate Embraer 170, 175, 190 and 195 aircraft to and from Bromma Airport. Since these aircraft do not always fulfil the noise limits for this airport, Embraer provided a report to indicate how the Embraer 190-100 could comply with these criteria (ref. 1).

SWEDAVIA requested NLR to verify the findings of the Embraer report. The outcomes of this verification are provided in this report. In order to verify the results of the Embraer report, NLR took the following two steps:

1. NLR experts reviewed the Embraer report to see whether they agreed with the line of reasoning in this report.
2. NLR conducted noise computations and checked whether the results were similar to the results in the Embraer report.

Apart from this second opinion, SWEDAVIA asked NLR to look into the noise production of three other types of Embraer aircraft (the Embraer 170, Embraer 175 and Embraer 195) to give an indication whether these types can be operated to and from Bromma Airport. Like the Embraer 190, these are also aircraft types from the so-called E-jet family. These types are suited for different number of passengers and ranges and all will have a different noise production.

1.2 Document structure

The first part of the report concerns the second opinion on the Embraer report. First, in chapter 2, the review of the Embraer report is discussed. This includes a look at the noise level limits of Bromma Airport, the proposed noise reduction measures and the validity of the conclusions in the Embraer report. The related noise computations that have been performed by NLR on the effect of reduced flap landings are presented in chapter 3.

Chapter 4 deals with the second request. This chapter discusses the possibilities for the Embraer 170, Embraer 175 and Embraer 195 of operating at Bromma Airport within the noise level limitations. Finally, chapter 5 presents the overall conclusions.

2 Review of Embraer report

2.1 Noise level limits at Bromma airport

The Embraer report intends to show that the Embraer 190 aircraft complies with the noise limits of Bromma Airport. The limits are discussed in section 7.1 of the Embraer report. NLR cross-checked these limitations with to other sources (ref. 2) and the Aeronautical Information Publication of Bromma Airport (ref. 3). In the section on noise abatement procedures the most relevant part noise limit described is:

"The noise emission must not exceed 89 EPNdB, an average for the three points of measurement in accordance with ICAO Annex 16 Vol I chapter 3. Special rules concerning schedule air transport issued by Airport manager."

This refers to noise levels which are determined during the certification of an aircraft. These noise levels are determined using the so-called equivalent perceived noise level (EPNdB), expressed in decibels (dB). For the certification of an aircraft, the noise level is determined for three conditions:

- Climb
- Flyover
- Approach

The average of the three noise levels is the metric that is used for the noise limits of Bromma Airport. The Embraer report also focuses on this metric and in line with the Embraer report, this report will also consider certification noise levels to determine whether the investigated Embraer aircraft comply with the noise regulations for Bromma Airport.

With respect to the special rules mentioned above, aircraft used for scheduled service shall (according to references 1 and 2):

- *"either be certified for noise emission which does not exceed 86 EPNdB as an average for the three measuring points in accordance with ICAO Annex 16 Volume I, Part 2, Chapter 3,*

- *or be able to operate at the airport not exceeding 86 EPNdB for the three measuring points in accordance with ICAO Annex 16, Volume I, Part 2, Chapter 3.*

- *However 20,000 annual movements are permitted to be operated by subsonic jet aircraft with a seating capacity exceeding 60 seats with a noise emission which exceeds 86 by not 89 EPNdB as an average for the three measuring points in accordance with ICAO Annex 16, Volume I, Part 2, Chapter 3. The number of such operations on Saturdays and Sundays may not exceed the number of such operations during 2001."*[1]

[1] All aircraft from the E-jet family are subsonic jet aircraft with a seating capacity exceeding 60 seats.

NLR agrees with Embraer's general assumption that all aircraft that meet the specified configuration and operational conditions are expected to comply with the noise level limits that apply to Bromma airport in an operational setting. This means that individual aircraft carrying a noise certificate showing an average noise level of more than 89 EPNdB, can still meet the limits as long as they meet the required operational conditions during take-off and landing at Bromma Airport.

2.2 Measures to reduce certification noise levels

Based on expert opinion and cross-checks with publicly available data, NLR assessed the solutions proposed in the Embraer report. Summarized, Embraer discusses the following measures to reduce noise levels:

1. Lower the take-off weight of the aircraft. A lower take-off weight means that an aircraft needs less runway length to take-off and that it will climb faster. This reduces noise levels in the certification point for take-off noise.
2. Lower the landing weight. A lower landing weight means that an aircraft needs less thrust during the approach, which results in lower noise levels in the certification point for approach noise.
3. Do not use maximum flap deflections during approach. Flaps are devices used during landing and take-off to allow an aircraft to fly less fast. Since these devices result in additional drag, more thrust is needed when the flaps are deployed further. Therefore, if the maximum flap setting is not used during approach, this leads to lower noise levels in the in the certification point for approach noise, compared to a situation where this setting is used. All Embraer 190 can fly such an approach and if an aircraft is equipped with a flap inhibitor (as described in the Embraer report) this makes it possible to verify whether aircraft indeed do not use a flap 6 approach, so that it is possible to enforce the use of reduced flap approaches.

Finally, also the effect of a steeper approach is discussed in the Embraer report. This measure will result in lower noise levels in the certification point for approach noise, however, since Embraer indicates that this option is no valid way to reduce certification noise levels. Therefore, this option will not be considered in this report.

NLR agrees with Embraer that the three options described above are valid ways to reduce aircraft noise levels in certification points. This is confirmed by the fact that the European Aviation Safety Agency (EASA) provides separate tables with noise certification levels for different take-off weights, landing weights and flap settings (ref. 4). These tables show that lowering take-off and landing weights and reducing flap settings results in lower certification noise levels.

2.3 Expected reductions in noise certification levels

Embraer proposes two combinations of configuration and operational conditions to achieve the required noise certification levels:

<u>Option 1:</u>

- Operational take-off weight not exceeding 47,790 kg;
- Operational landing weight not exceeding 43,000 kg;

- Landing procedure with flap/slat 5;
- Engine CF34-10E5A1

Option 2:

- Operational take-off weight not exceeding 45,990 kg;
- Operational landing weight not exceeding 44,000 kg;
- Landing procedure with flap/slat 6 (full);
- Engine CF34-10E5A1

In both cases the average noise emission in the three certification points equals 89.0 EPNdB. This means that the aircraft complies with the limits in both cases.

NLR studied certification data provided by EASA, to determine the average certification noise level of both options. NLR concludes that both options result in a value of 89 EPNdB, **if the CF34-10E5A1 G07 is used** (thus not the CF34-10E5A1 version of the engine). This is shown correctly in tables 3 and 4 of the Embraer report, but not in the descriptions of the configuration and operational conditions. In the Embraer report, these engines are also referred to as Block 2 engines.

Embraer was informed about this comment of NLR and based on this comment, Embraer provided a new version of their report, where they confirm that the CF34-10E5A1 G07 engine should be used. With this modification, NLR considers their comment to be taken into account correctly.

The CF34-10E5A1 G07 version of the engine has additional features that result in a lower noise production, such as a so-called improved acoustic chevron nozzle (IACN) installed. This is a modification of the engine to reduce the noise production of the engine (this is discussed in chapter 2 of the Embraer report). The text below is therefore only valid for the CF34-10E5A1 G07 version of the engine.

There is no record for option 1, so information from several certification values is combined to estimate the certification noise levels:

- The use of a reduced flap approach will only affect the approach noise level, so the certification levels for take-off and lateral should not be affected. These values can be found in the EASA data, which shows that the values in table 3 are indeed correct.
- The effect of a reduced flap approach on the landing certification noise level can be estimated based on available certification data for a different combination of landing and take-off weights. This shows that the reduced flap approach results in a reduction of 0.7 EPNdB of the landing certification noise level. This value is equal to the reduction in the Embraer report.

Based on the above, NLR concludes that it is credible that option 1 indeed results in an average certification noise level of 89 EPNdB. Furthermore, in reference 1, Embraer states that these results are already approved by EASA and that they will be included in a new version of the EASA database. Based on this statement it can be concluded that option 1 will become fully certified in the future.

The average certification noise level of option 2 can directly be found in the EASA data. This shows that this option indeed leads to 89.0 EPNdB.

3 Additional noise analysis of reduced flap approaches

Additional to the findings in section 2.3, NLR performed an additional noise assessment to answer the following question.

> What is the expected effect of using a different flap setting on the certification noise of the Embraer 170, Embraer 175, Embraer 190 and Embraer 195?

The goal of this analysis was two-fold. The first goal was to confirm the noise level reduction for reduced flap approaches for the Embraer 190, as an additional check of the validity of Embraer's option 1 mentioned in section 2.3. For the other three aircraft types, the analysis was performed to support the analysis for the other E-jets, as will be discussed in chapter 4.

NLR first analysed the EASA noise certification database. This study showed that for the E-170, there are variants in database that have been certified with the 'flap 6 inhibitor' installed. By comparing the approach level values to identical configurations without this inhibitor, the noise level reduction for a reduced flap landing could be obtained. Unfortunately, for the E-175 and E-195, this method did not yield any results.

As a second step, NLR analysed the proposed reduced flap landing using the NLR noise assessment tool TUNA. This tool is compliant to Doc29 (see ref. 5), which is the best practice method for aircraft noise computations around airports. The goal of the exercise was not to produce exactly the same noise levels as in the Embraer report, but to verify whether the computations indeed show a noise reduction, and, for the E-170 and E-190, whether the reductions are similar to those in obtained from the EASA database.

The aircraft performance data required for the computations have been be obtained from the Aircraft Noise and Performance (ANP) Database of Eurocontrol. For a number of aircraft types, this database provides information on the speed, altitude and thrust of aircraft during approach and departure and on the noise production of an aircraft. For many other aircraft types, this database provides coefficients that can be used to calculate speed, altitude and thrust and ultimately the noise levels.

Finally, NLR took the following steps to complete the noise assessment. For details, please see Appendix A.

- An arrival procedure with maximum flap deflection (Flap 6) was defined for the four Embraer aircraft types. This procedure was modelled in such a way that is equivalent to the approach procedure used during certification.
- In addition, an arrival procedure with a lower flap deflection (Flap 5) was also defined for the four Embraer aircraft type. This procedure is identical to the full flaps procedure, with the exception of a reduced flap setting and a slightly increased approach speed. Since the ANP database does not contain information for the aircraft performance of these aircraft in case of reduced flap approaches, this information was derived by NLR based on an analysis of ANP data of aircraft for which reduced flap information is available.
- The arrival certification noise level was computed for both procedures, and the difference between both noise levels was determined.

The computed noise reductions due to the lower flap setting were compared to the reductions found by Embraer (in ref. 1), and those available from the EASA database. It should be noted that these are reductions of the approach noise certification level, which accounts for one-third of the average noise certification level (the noise limit for Bromma airport). For example, a reduction of 0.9 EPNdB for the landing, results in a 0.3 EPNdB for the average noise certification level. The results of this comparison can be found in Table 1.

Table 1: Reductions in approach noise levels (in EPNdB) for a reduced flap approach

	Embraer report (ref. 1)	EASA TCDSN database	Computed by NLR
Embraer 170	-	1.3-1.4[2]	1.6
Embraer 175	-	-	1.6
Embraer 190	0.7	0.7	1.3
Embraer 195	-	-	1.3

Based on these results, the following observations are made:

- The NLR analysis indeed confirms a noise reduction in the approach level with the use of reduced flaps,
- The computed reductions are, especially for the E-190, higher than those obtained from the EASA database,
- The computation results show higher reductions for the E-170 than for the E-190, which is confirmed by the data from the EASA database,
- The computation results show equal reductions for the E-170 and E-175, as well as for the E-190 and E-195.

Given the available data and results of the analysis, and considering the level of confidence associated with the different sources, NLR recommends the following:

- E-170: allowing a general 1.3 EPNdB approach level reduction for reduced flap (flap 5) approaches, or – for specific configurations where certification data supports that – a 1.4 EPNdB approach level reduction.
- E-175: expecting a 1.3 – 1.4[2] EPNdB approach level reduction as feasible, but asking for further proof from Embraer, preferably by publication of EASA data.
- E-190: allowing a general 0.7 EPNdB approach level reduction for reduced flap (flap 5).
- E-195: expecting a 0.7 EPNdB approach level reduction as feasible, but asking for further proof from Embraer, preferably by publication of EASA data.

[2] The EASA database contains several records of the E170 with and without flap inhibitor. In these records, two values are found of the noise reduction to a reduced flap approach.

4 Analyses of other Embraer aircraft types

NLR also looked into the noise certification levels of three other types of the E-jets family (the Embraer 170, Embraer 175 and Embraer 195). For the remaining types, the same noise reduction measures where considered, consisting of lowering the take-off or/and landings weights, either or not in combination with the used of reduced flap landings.

Concerning the limitation of take-off weights, it should be realised that the runway length of Bromma Airport equals 1668 metres (ref. 3). The Airport Planning Manuals (APMs) of the investigated Embraer aircraft (ref. 6, 7, 8 and 9) indicate that this is too short for most combinations of engine and aircraft to take-off with the maximum take-off weight. This means that in most cases a lower take-off weight is required anyway, which leads to lower average certification noise levels. However, this reduction in weight is not sufficient to guarantee that these aircraft always will operate within the noise limits of Bromma airport. Therefore, additional measures are required. Again, this can be a (further) reduction of take-off or landing weight, the use of a reduced flap approach, or a combination of these options.

In order to determine if other Embraer aircraft can operate to and from Bromma airport, NLR studied the EASA database with certification noise levels to determine whether combinations of configuration and operational conditions are available to achieve the required noise certification levels. For the Embraer 170 and Embraer 175 several options are found. Below, one of these options for each type is provided.

Embraer 170

- Operational take-off weight not exceeding 35,990 kg;
- Operational landing weight not exceeding 33,300 kg;
- Landing procedure with flap/slat 6 (full);
- Engine CF34-8E5

This option results in an average certification noise level of 88.8 EPNdB.

Embraer 175

- Operational take-off weight not exceeding 35,998 kg;
- Operational landing weight not exceeding 34,000 kg;
- Landing procedure with flap/slat 6 (full);
- Engine CF34-8E5

This option results in an average certification noise level of 88.9 EPNdB.

Embraer 195

For the Embraer 195 the EASA database provides no combination of configuration and operational conditions that results in a sufficiently low average noise certificate level. However, the effect of approaches with reduced flap deflection is not included in the database. The following option can result in an acceptable average certification noise level:

- Operational take-off weight not exceeding 48,790 kg;
- Operational landing weight not exceeding 45,000 kg;
- Landing procedure with flap/slat 5;
- Engine CF34-10E5

The above take-off weight will never be exceeded, since the runway length of Bromma Airport does not allow the Embraer to take-off with a higher weight. This option results in an average certification noise level of 89.3 EPNdB for a landing procedure with flap/slat 6 (full), which means that a procedure with flap/slat 5 might be sufficient to comply with the noise regulations for Bromma Airport. This has to be proven first before this aircraft can be operated to and from Bromma Airport. If this option is still not sufficient, the aircraft should be certified for lower take-off and/or landing weights in order to comply.

5 Conclusions

Embraer has provided a report to show that the Embraer 190 can comply with the noise limits for Bromma Airport. NLR verified this report and investigated whether this aircraft, but also the Embraer 170, Embraer 175 and the Embraer 195 can operate to and from Bromma Airport within the existing noise limits. The verification is done by a review of the Embraer report, a study of publically available data, and by additional computations.

Main conclusion

NLR concludes that the two combinations of configuration and operational conditions of the Embraer 190 as proposed by Embraer indeed lead to an average certification noise level that complies with the noise limits of Bromma airport, as long as the aircraft is equipped with CF34-10E5A1 G07 engines. In an updated version of their report, Embraer confirms that this specific engine type should be used.

After reading the Embraer report, NLR agrees with the main findings in the Embraer report. NLR agrees that the proposed measures (reducing take-off and landing weight and reducing flap deflections during approach) can result in lower certification noise levels.

Embraer proposes two combinations of configuration and operational conditions to comply with the noise limits for Bromma Airport. NLR agrees with Embraer that these combinations indeed result in acceptable certification noise levels as long as CF34-10E5A1 G07 engines are used (in the description of the combinations in the Embraer report the the aircraft is equipped with CF34-10E5A1 engine is mentioned, while the correct engine is mentioned in the tables in the report). One of the combinations is included in the EASA database with certification noise levels. According to Embraer the other combination will be included in a new version of this database. This means that one combination is already certified, while the other option will be certified in the future.

Noise computations performed by NLR also confirm that using lower flap deflections during approach can indeed result in a reduction in the certification approach noise level, which further increases the credibility of the proposed solution.

Summarizing this means that the following three sources confirm that the proposed combinations will indeed result in certification noise levels that comply with the noise limits for Bromma Airport:

1. The Embraer report
2. Data in the EASA database with certification noise levels
3. NLR computations that indicate that the expected reduction in the approach certification noise level can be achieved if approaches with reduced flap deflections are flown.

For the Embraer 170 and Embraer 175 aircraft types, NLR found several combinations of configuration and operational conditions in the EASA database that result in average noise certification levels that comply with the noise levels for Bromma Airport. For the Embraer 195, no such combination is available in the database. However, the application of a reduced flap approach or a further reduction of take-off and/or landing weight can result in an acceptable noise production for this aircraft type as well. This has to be proven first before this aircraft can be operated to and from Bromma Airport.

6 References

1. Embraer, *Embraer 190 Noise Levels – Technical Substantiation for Bromma Airport Operation*, report number 190NOY015
2. http://www.boeing.com/resources/boeingdotcom/commercial/noise/bromma.html, cited on 6th of October 2016.
3. www.aro.lfv.se/Editorial/View/1878/ES_AD_2_ESSB_en, cited on the 6th of October 2016.
4. EASA, Jet aeroplanes noise database, version 160406, https://www.easa.europa.eu/document-library/noise-type-certificates-approved-noise-levels#group-easa-downloads, cited on the 7th of October 2016.
5. S.J. Heblij, Tuna noise model verification: ECAC Doc.29 compliance test, NLR-TR-2016-456, October 2016.
6. https://www.flyembraer.com/irj/go/km/docs/download_center/Anonymous/Ergonomia/Home%20Page/Documents/APM_170.pdf, cited on the 6th of October 2016.
7. https://www.flyembraer.com/irj/go/km/docs/download_center/Anonymous/Ergonomia/Home%20Page/Documents/APM_175.pdf, cited on the 6th of October 2016.
8. https://www.flyembraer.com/irj/go/km/docs/download_center/Anonymous/Ergonomia/Home%20Page/Documents/APM_190.pdf, cited on the 6th of October 2016.
9. https://www.flyembraer.com/irj/go/km/docs/download_center/Anonymous/Ergonomia/Home%20Page/Documents/APM_195.pdf, cited on the 6th of October 2016.
10. Report on Standard Method of Computing Noise Contours around Civil Airports, ECAC.CEAC Doc 29, 3rd Edition, Volume 2: Technical Guide, December 2005.

Appendix A Computed effect of reduced flap approach on approach noise level

General approach

NLR performed an assessment of the expected noise level reductions that can be achieved through the use of reduced flap landings. This assessment is based on an analysis with the NLR noise assessment tool TUNA. This tool is compliant to Doc29 (see ref. 5), which is the best practice method for aircraft noise computations around airports. The main goal was not to replicate the exact absolute noise levels as specified by Embraer, but to verify whether the computations show similar noise reductions as the Embraer report.

The aircraft performance data required for the computations have been be obtained from the Aircraft Noise and Performance (ANP) Database of EUROCONTROL. For a number of aircraft types, this database provides information on the speed, altitude and thrust of aircraft during approach and departure and on the noise production of an aircraft. For many other aircraft types, this database provides coefficients that can be used to calculate speed, altitude and thrust and ultimately the noise levels. The flight path modelling (see Figure 1) was done using the integrated noise model (INM) version 7.0d, before exporting the flight paths to TUNA for the actual noise assessment.

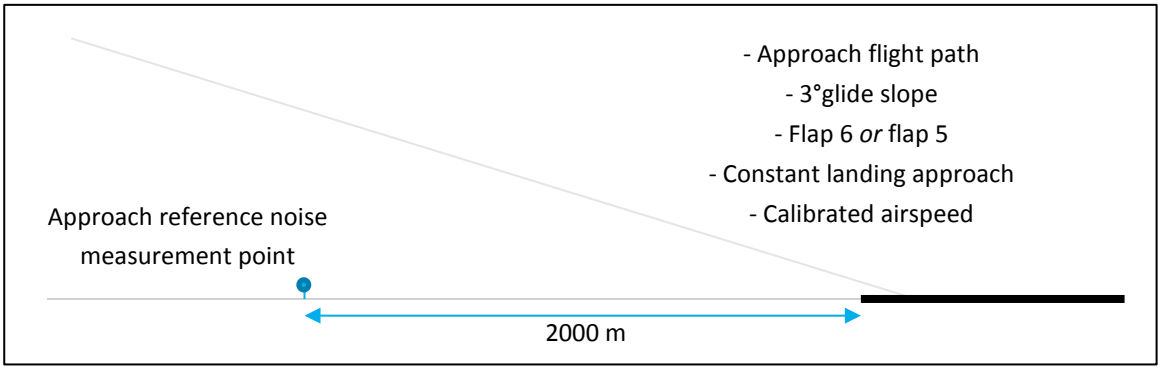

Figure 1: Setup for analysis of approach noise level reduction. The landing approach calibrated airspeed (as defined in ref. 10) is based on the selected flap setting and the modelled landing weight

During the preparations for the analysis, it turned out that the ANP Database could not provide the required flight performance data for the reduced flap landings. Instead, NLR derived estimates of these data to complete the analysis. The next section discusses this derivation, followed by the presentation of the results.

Derivation of missing coefficients

The current version of the ANP database does not contain the required flight performance coefficients for reduced flap landings for the Embraer E-jets. More specifically, this involves the two parameters from the table of aerodynamic coefficients:

1. Flap coefficient D, used for calculating the landing approach calibrated air speed, and
2. Coefficient R, which specifies the Drag-to-lift ratio.

Reduced flap landings are a common noise abatement measure and also used extensively in the Netherlands. During a recent study involving reduced flap landings, NLR analysed for which aircraft the ANP database does provide the required information to model such landings. Using this information and based on the data for 85 different aircraft types, NLR derived general relations between the coefficients for full flap landings and those of reduced flap landings.

When comparing the full flap data with the data available for the next lower flap setting available for landing it was concluded that, on average:

1. Flap coefficient D increases by 5%, and
2. Drag-to-lift coefficient R decreases by 17%.

NLR used these general relations to obtain estimates for the required flap 5 coefficients for the E-jets, by applying these factors on the available full flap (flap 6) coefficients. The resulting addition to the ANP database is shown in Table 2.

Table 2: ANP database addition based on estimates for flap 5 aerodynamic coefficients

ACFT_ID	Op Type	Flap_ID	B	C	D	R
EMB170	A	5			0.5238	0.1208
EMB175	A	5			0.5231	0.1210
EMB190	A	5			0.4561	0.1138
EMB195	A	5			0.4553	0.1140

Still, it should be noted that the derived coefficients can only be seen as estimates of the actual coefficients, which are not available in the public domain. They can be used to compute the noise level reductions of the E-jets, assuming that, from an aerodynamic point of view, the E-jets react to flap reduction as average aircraft. They do, however, not have the same status as reductions actually approved and published by EASA.

Results

The results of the noise analysis are shown in Table 3. This table also presents the landing weights that have been used in the analysis. These landing weights are based on the highest maximum landings weights available in the EASA TCDSN database (disregarding the Lineage 1000 business jet variant of the E-190).

Table 3: Computed approach noise levels for full flap and reduced flap landings. All results rounded to one decimal position

Type	Landing weight [kg]	Approach level - flap 6 [EPNdB]	Approach level - flap 5 [EPNdB]	Noise level reduction [EPNdB]
Embraer E-170	33300	94.7	93.1	1.6
Embraer E-175	34100	94.8	93.1	1.6
Embraer E-190	44000	92.9	91.6	1.3
Embraer E-195	45800	93.0	91.6	1.3

These results have been obtained using the following conditions and settings for the flight path and noise modelling:

- Atmosphere: ISA + 10°C
- Zero wind
- Sea level runway
- Default (non-recalculated) atmospheric absorption

NLR

Anthony Fokkerweg 2
1059 CM Amsterdam, The Netherlands
p) +31 88 511 3113 f) +31 88 511 3210
e) info@nlr.nl i) www.nlr.nl