Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Executive summary

Noise measurement analysis during a noise abatement departure procedure trial

Problem area
At Amsterdam Airport Schiphol and at many other airports aircraft follow the so-called ICAO Noise Abatement Departure Procedures (NADP). The procedure that is currently operational at Schiphol (NADP1) intends to provide a noise reduction close by the airport. The NADP2 procedure aims to reduce noise at residential areas further away from the airport.
Noise reduction is not the only driver of these procedures. For NADP2 procedures a fuel reduction of 3 to 4 percent is also expected. Hence tradeoffs are to be made between noise exposure close by the airport, noise exposure further away from the airport and fuel consumption. To gain knowledge to support the trade-off process, flight trials have been performed for NADP2 departures.

Description of work
Noise measurement data and actual flight data recordings were analysed. Simulator studies and noise modelling results provided additional information.

Results and conclusions
The results show the expected fuel reduction for NADP2 procedures. Additionally the measured noise levels in residential areas show positive effects.
It was also observed that, based on the dose-response relationship, the number of highly annoyed people living in het vicinity of Schiphol decreases.

Applicability
The analyses methods developed during this study can be applied during similar noise measurement studies. The results obtained can be used as the basis for further optimization of the departure procedures at Amsterdam Airport Schiphol.

Report no.
NLR-TP-2012-324

Author(s)
H.W. Veerbeek
M.A. Brouwer

Report classification
UNCLASSIFIED

Date
July 2012

Knowledge area(s)
Vliegtuiggeluidseffecten op de omgeving

Descriptor(s)
Aircraft Noise
Noise Measurement
Noise Abatement Procedures

This report is based on a presentation held at the InterNoise 2012, New York, August 20-22, 2012.

Noise measurement analysis during a noise abatement departure procedure trial

Nationaal Lucht- en Ruimtevaartlaboratorium, National Aerospace Laboratory NLR

Anthony Fokkerweg 2, 1059 CM Amsterdam,
P.O. Box 90502, 1006 BM Amsterdam, The Netherlands
Telephone +31 20 511 31 13, Fax +31 20 511 32 10, Web site: www.nlr.nl

provisional issue
NLR-TP-2012-324

Noise measurement analysis during a noise abatement departure procedure trial

H.W. Veerbeek and M.A. Brouwer[1]

[1] Amsterdam Airport Schiphol

This report is based on a presentation held at the InterNoise 2012, New York, August 20-22, 2012.

Customer	National Aerospace Laboratory NLR
Contract number	- - -
Owner	National Aerospace Laboratory NLR
Division NLR	Air Transport
Distribution	Limited
Classification of title	Unclassified
	July 2012

Approved by:

Author "Hier naam intikken"	Reviewer "Hier naam intikken"	Managing department "Hier naam intikken"
Date:	Date:	Date:

Contents

Noise measurement analysis during a noise abatement departure procedure trial

H.W. Veerbeek [a)]
National Aerospace Laboratory NLR
Anthony Fokkerweg 2
1059 CM Amsterdam, The Netherlands

M.A. Brouwer [b)]
Amsterdam Airport Schiphol
Evert v/d Beekstraat 202
1118 CP Schiphol, The Netherlands

At Amsterdam Airport Schiphol and at many other airports aircraft fly the so-called ICAO Noise Abatement Departure Procedures (NADP). The procedure that is currently operational at Schiphol (NADP1) intends to provide a noise reduction close by the airport. The NADP2 procedure aims to reduce noise at residential areas further away from the airport.
Noise reduction is not the only driver of these procedures. When flying NADP2 procedures 3 to 4 percent less fuel is used during take-off and climb than when flying NADP1. Hence trade-offs are to be made between noise exposure close by the airport, noise exposure further away from the airport and fuel consumption. To gain knowledge to support the trade-off process, flight trials have been performed for an alternative departure procedure. Noise measurement data and actual flight data recordings were analysed. Special attention was paid to the statistical analyses of the noise measurement data. Simulator studies and noise modelling results provided additional information.
The results show the expected fuel reduction for the alternative procedure. Additionally the measured noise levels in residential areas show positive effects. Based on calculated noise levels and dose-response relationships, the number of highly annoyed people living in het vicinity of Schiphol can be decreased if the trial procedure would become the standard departure procedure.

[a)] email: Henk.Veerbeek@nlr.nl
[b)] email: Brouwer_M@schiphol.nl

1 INTRODUCTION

Given today's fuel prices an airline can realise substantial savings when following the right strategy for fuel saving. Amongst others this strategy concerns the development of the flight procedures for the take-off and climb phases of a flight[1]. Fuel reduction results in a positive contribution to our climate. For the airline a direct financial benefit can be achieved related to fuel costs and related to the EU Emission Trading Scheme (ETS).

Airport operators, like Amsterdam Airport Schiphol, face quite different challenges when optimising departure procedures. They have to deal with the impact on capacity and, more specific, the environmental capacity and aircraft noise. At Schiphol airport this environmental capacity limits control the potential growth of the airport.

First desktop studies were started to study the trade-offs while flying optimised departure procedures. The studies showed that all parties involved might benefit. Along with fuel reduction the number of highly-annoyed people was expected to reduce. Secondly it was decided to extend the study with real trials to gather and analyse measured data. With this data the generally accepted statements regarding the noise effects on different departure procedures are challenged.

2 NADP TRIAL

The noise abatement departure procedure basically describes the procedure in which the aircraft transits from the high take-off power having extended flaps and slats settings towards a climb phase using climb power and all flaps and slats retracted[5,6]. There are certain degrees of freedom in this transition process. First of all, it can be chosen which action should come first, the thrust cutback or acceleration towards the (first) flap retraction. Furthermore, altitudes can be set for both actions, taking into account the minimum altitudes required to meet safety aspects.

This freedom in design leads to a very wide range of possible procedures. Still, types or 'families' of noise abatement departure procedures can be distinguished. The NADP-1 family, often called the 'close-in community departure procedure' is based on the application of thrust cutback before the flaps and slats retraction. As the name suggests, this procedure aims to provide a noise reduction for areas located close to the airport. The current default departure procedure at Amsterdam Airport Schiphol, the ICAO-A procedure, belongs to the family of NADP-1 procedures. If this procedure is followed, climb thrust is selected at reaching 1500 ft altitude. At 3000 ft, the pitch angle is reduced such that the aircraft will climb and accelerate simultaneously. As the speed increases, the flaps and slats are retracted on schedule.

The NAPD-2 family, or 'distant community departure procedure' is based on the initiation of flap and slat retraction at reaching a prescribed minimum altitude, e.g. 1000 ft. With this procedure, thrust cutback is either executed simultaneously with the flap and slat retraction, or is delayed until the point where the aircraft attains the clean configuration. In comparison with the 'close-in' procedure, the distant procedure intends to provide noise reduction for all other noise sensitive areas, typically further from the airport.

The trial discussed in this paper is based on executing an NADP-2 procedure where the acceleration required for flaps and slats retraction starts at 1500 ft. The thrust cutback is performed simultaneously. This means that although the trial procedure is an NADP-2, it is still very similar to the current default NADP-1 (ICAO-A) procedure in the sense that the thrust regime remains unchanged. The only difference is the altitude at which the aircraft starts accelerating. This altitude is reduced from 3000 to 1500 ft.

A home based carrier was the sole operator that took part in the trial, which lasted three months and was performed in the summer of 2010. Both aircraft types in their fleet, the Boeing 737-800 and the Boeing 767-300 participated in this trial.

The trial procedure was first of all expected to save fuel (~ 20-60 kg fuel per departure[1]), and as such to reduce costs and to cut carbon emissions. However, model-based calculations (see figure 1) also showed that the overall result with respect to noise was should improve as well. The remainder content of this paper looks into the noise measurements that have been analysed with the purpose of confirming the calculated noise impact reduction.

3 EXPERIMENTAL DESIGN

The aim of the present experiment is to determine the real (measured) sound effects of the alternative departure procedure using the noise monitoring system of Amsterdam Airport Schiphol (i.e. NOMOS). This system is equipped with more than 25 noise monitoring terminals located in residential areas around the airport[2].

The unmanned measurements should always be interpreted with extra attention. Besides the systematic measurement error of the measurement system itself (which is considered very small), the detected noise event might also be caused by accidentally passing ground vehicles or other surrounding sources.

Even in a highly controlled environment in which no background noise is present, it is not easy to isolate the impact of the alternative departure procedure. Variations in measured noise levels of departing aircraft can be explained by two types of variations: airline dependent and external factors. Airline dependent variations may be caused by:

- The manual flying or flying with the autopilot: differences in the position of the plane can affect the sound measurements (i.e. distance and directivity influences).
- Loading of the aircraft: the utilisation of the aircraft and its destination determine the TOW (Take-Off Weight). A heavier aircraft climbs less steep compared to a lighter aircraft, resulting in higher noise levels.
- The application of derated thrust take-off procedures. This reduced thrust setting is an active action performed by the pilot. It is also an external cause (see below), because the use of derated thrust depends on the ambient local temperature and aircraft TOW.

Besides airline dependent variations the following external causes may also affect the measured noise levels:

- Propagation of noise through the air. The way sound propagation through the atmosphere takes place and the degree of attenuation depends among others on the air pressure, temperature, humidity, wind speed, wind direction etc. Differences in measured noise levels are likely to be noticeable in the different seasons of the year.
- The prevailing wind speed and wind direction: departing aircraft climb faster with increasing headwind.
- Ambient temperature: at high temperatures, typically above 25-30 degrees Celsius, less power is available and climb performance is impacted accordingly.
- Additional instructions: Air Traffic Control (ATC) might give additional instructions to deviate from the selected standard instrument departure route (SID).
- Departing from runway intersections. Some (usually lighter) aircraft may start further down the runway from a runway intersection rather than from the beginning of the runway. This will lower the fly over height of these aircraft, especially at noise monitoring points close to

the runway. Indirectly, this effect also depends on the prevailing visibility conditions: for safety reasons ATC does not allow departing from intersections during poor visibility conditions.

To determine the isolated effect of the alternative departure procedure a suitable experimental design is necessary. The experiment should eliminate the above-mentioned undesirable variables. In practice, it is not feasible to conduct both the alternative and the conventional departure procedure simultaneously under the same conditions. Thus, it is considered necessary to perform a number of pairwise comparisons in which the measurements from an experimental group are compared with the measurements of multiple control groups. In the present experiment the following groups are distinguished:

- Experimental Group: in this group it is known that only flights are selected using the alternative departure procedure from the experimental operator during the experimental period.
- Control Group 1: This group consists of flights of a (different) reference operator with the same aircraft and using the same runway/SID combination as the experimental group. This group has the same ICAO type designation (in the underlying case B738 or B763), but also has the same engine type. The flights from Control Group 1 are performed in the same reference period as the period during which the reference departure procedure by the experimental operator is applied (in accordance with AIP).
- Control Group 2: These flights are conducted by the reference operator during the experimental period using the reference procedure.
- Control Group 3: These flights are conducted by the experimental operator during the reference period using the reference procedure.

Through hypothesis testing one can determine the likelihood of any difference in noise which may be caused by the alternative departure procedure. Figure 2 shows a schematic representation of the experimental design. The yellow/green arrows represent the relevant comparisons of experimental and control groups.

3.1 Hypotheses testing

Test A: difference analysis Experimental Group and Control Group 3

With this test a key insight is obtained into whether there is an indication that the alternative departure procedure results in lower (or higher) measured noise levels. The present test is one sided. Other airline dependent variables that may have an influence on the measured noise levels are unintentionally tested. Also, bearing in mind that external factors which have an impact on the noise levels may influence the result.

Test B: difference analysis Control Group 1 and Control Group 3

This test aims to determine whether the reference operator is comparable with the experimental operator. Although the same type of aircraft, engine type and runway/SID are considered, differences may occur due to airline dependent variables such as using the autopilot and different TOW. It is verified that both operators use the default (prescribed) departure procedure in accordance with the AIP (ICAO-A departure). Since the reference flights are conducted in the same period, it is assumed (H_0) that the effect of external influences for both groups is the same resulting in equivalent noise events. If the null hypothesis H_0 is rejected, it indicates that the flights in both control groups are executed under different external influences.

Test C: difference analysis Control Group 1 and Control Group 2

This test aims to determine if the two reference periods are comparable with respect to external influences. This test is performed on the same reference operator. If the null hypothesis H_0 is not rejected, it is assumed that the external conditions in the reference and the experimental period are equivalent.

In figure 2 the dotted (black) arrow represents the test between Experimental Group and Control Group 2. This test is not relevant because the outcome is logically follows from the results of the other three tests. The experimental design described above is called a Multiple Time Series Design (see e.g. Sheskin[3]).

3.2 Qualification levels

Due to the influence of external and airline dependent "disturbances" it is not possible to determine with a one hundred percent certainty whether the alternative departure procedure results in higher or lower noise levels or a shorter or longer duration of the sound. Although the introduction of several control groups does not eliminate the influence factors mentioned above, the results give a qualitative judgment about the likelihood of the effect of the alternative departure procedure. To this end, four qualification levels are defined. Table 1 lists the criteria of these qualification levels. The asterisk indicates that it is irrelevant whether or not a statistically significant difference is found.

- *Likely Impact*

The highest level of qualification is achieved when a significant effect has been observed between Control Group 3 and the Experimental Group, while for all other tests no indications of differences are found.

- *Probable effect*

The second highest level is reached when it is shown that the external conditions in the experimental and reference period seem to be equal, but that the reference operator is not comparable with the experimental operator.

- *Possible effect*

There is an indication that the departure procedure may result in different noise levels, but it is also possible that the difference is explained by external conditions present or airline dependent parameters.

- *No significant effect*

There is no evidence of significantly higher or lower noise.

4 STATISTICAL METHODS

Flying the alternative departure procedure aims for lower noise levels and/or a shorter duration of the noise events. Using statistical methods, it can be objectively concluded from the data whether or not this objective is reached. Statements whether an experimental procedure will lead to an increase or reduction of noise levels cannot be made with 100% certainty. There is always a small chance that incorrect conclusions are drawn. For the statistical hypothesis tests used in the present study, the probability α of the so-called error of the first kind, i.e. the probability of wrongly rejecting the null hypothesis H_0, was set to 5%.

4.1 Censored datasets

The present experiment frequently involved censored data. This occurs because the noise event of some flights was not high or long enough. For each monitoring station a threshold is set to the LA_{max} and in addition the duration of the noise event must exceed a certain level to avoid incorrect noise-flight correlation. Not accounting for flights in which the thresholds were not exceeded may result in an overestimation of the average noise level. The determination of the (sample) mean of the noise is therefore not simply the sum of measured noise events divided by the sample size. To overcome this problem the so-called trimmed mean has been used. This means that at a given b% censoring rate (percentage of flights for which no measurements are available), the dataset is sorted increasing and subsequently the largest b% of the measurements removed. Thus, there remains 100%-2b% measurements over which an average can be determined. The disadvantages of the choice of the (trimmed) average are:

- The sample average or mean becomes more sensitive to outliers.
- The underlying probability distribution is effectively assumed to be symmetrical. This assumption is unlikely to be true for the noise-related variables LA_{max} and SEL because of the logarithmic nature of these quantities.
- Besides the inevitable, censored observations, a similar proportion of observations are "discarded", which results in worse confidence intervals.

Partly on the basis of the above disadvantages, the median rather than the average is chosen as the statistic to use. The (sample) median can be determined as follows. First, the order statistics $\theta_{(1)},\theta_{(2)},\ldots,\theta_{(n)}$ of the sample $\theta_1,\theta_2,\ldots,\theta_n$ are determined, where n denotes the total number of flights observed (by radar). Suppose that no noise data is available for the first points $\theta_{(1)},\theta_{(2)},\ldots,\theta_{(i)}$, where $i < n$. The (point) estimator of the median is the middle value of the order statistics if n is odd and the average of the two central values when n is even. It is noted that the sample median can also be determined for a censored data set, provided that the censoring rate is less than 50%.

4.2 Hypothesis testing

In the previous section it was shown that the experimental design provides an experimental group and three control groups. It was noted earlier that for some flights, no data are available because the thresholds for LA_{max} or the minimum duration of the event are not achieved. Such cases are called left-censored. The word ‘left’ denotes the fact that no measurements less than the threshold are available, while it is observed that there have been flights.

Censoring is a familiar concept within the field of lifetime distributions, e.g. medicine and hardware reliability. This type of studies deals also with censored data because the experimental time is limited. For example, research into the lifetimes of machines is discontinued after a certain time, because the experimental time is limited. In medical studies, patients may want to discontinue their participation prematurely. The available literature is mainly focused on right-censored problems. However, with a simple transformation one can transform a left-censored problem into a right-censored problem as follows. Consider the following random variables, which represent a measured parameter of a cluster (unique combination of track, route and aircraft type).

$$
\begin{aligned}
Y_E &= \mathrm{M}_E - X_E \\
Y_{C_1} &= \mathrm{M}_{C_1} - X_{C_1} \\
Y_{C_2} &= \mathrm{M}_{C_2} - X_{C_2} \\
Y_{C_3} &= \mathrm{M}_{C_3} - X_{C_3}
\end{aligned}
\qquad (1)
$$

The variables X and Y refer to the measured variables LA_{max}, *SEL* or the duration of the sound event Δt. The indices E, C_1, C_2 and C_3 represent the experimental group and the three control groups respectively. M is an arbitrary constant, which is larger than the maximum observed value within the data set.

The following statistical procedure is completed for all clusters with at least 10 observations of detected noise events and a maximum censor rate of <50% (upper limit for determining the median) for each group (see also Higgins[4]).

1. Firstly a test is conducted to determine whether there is any “deviant” sub data set (integral). If the null hypothesis is not rejected, it may be concluded that no significant effect is observed. For a given variable for a combination of runway/route, measurement station and aircraft type, all measurements from all control- and experimental groups are combined. Then, the so-called log-rank scores are determined for the resulting data set and the Kruskal-Wallis is applied to the set of log-rank scores.
2. If the null hypothesis under 1) is rejected, there is obviously a significant effect. The three tests A, B and C (see Experimental Design) are carried out. These tests are all so-called log-rank tests for right-censored data.
3. Application of the classification levels (see table 1) results in statements about how likely it is that the alternative departure procedure outperforms the standard departure procedure.

It is noted that the tests between the control groups are two sided, because it is expected that there are no differences between the control groups. The test with the experimental group and control group 1 is one sided because one may expect the experimental procedure to perform different.

5 RESULTS: MEASUREMENTS & MODEL CALCULATIONS

The results of the measurement campaign and the statistical post-processing are listed in Table 2. Figure 3 shows the relevant NOMOS noise monitoring stations and the runway/route combinations. For each combination of monitoring station, aircraft type, runway and SID a statistical qualification is made. When the experimental departure procedure results in lower noise levels a ‘+’ sign is used. Negative signs are used when the experimental procedure results in higher values. In the last column the maximum group censor rate is presented. These values are determined by taking the maximum of the censor rates for all four groups. Only measurements with a maximum group censor rate <50% are presented.

The data show that in most cases the duration of noise events above a certain threshold will decrease. For some monitoring stations the change is statistically not significant. One may expect these results because the experimental procedure results in a higher flight speed. Also, the measured *SEL* data shows that the average noise levels in most cases will decrease when applying the alternative departure procedure. Surprisingly, most measurement stations show that the maximum noise level LA_{max} decreases or there is no significant impact observed. Only measurement station 21 shows a ‘likely negative effect’ for the B738 for runway/route combination 36L-PAM. The statistical evidence for this outcome has the highest qualification level. The negative effect on this location is assumed to be related to the location of the noise monitoring terminal (close to the departure route) and the distance flown at that location.

In table 3 the differences between the medians of the control group 2 and the experimental group are shown. They give the best qualitative indication of the difference between the default and experimental procedure. Not surprisingly, the larger this quantitative difference, the better the statistical evidence is found.

In order to challenge the predictability of the theoretical models, the expected difference is also calculated with the Integrated Noise Model (INM). As far as SEL levels are concerned, the calculated and measured differences match rather well (within 0.5 dB(A)). The measured LA_{max} levels show a more positive effect compared to what was expected based on INM calculations. Further investigations on possible reasons for this observation were not performed within the scope of this project.

6 DISCUSSION AND CONCLUSIONS

Departure procedures do have several parameters which can be varied. It is not solely these parameters that determine the final environmental impact. Also the standard instrument departure routes in combination with the locations of residential area play an important role. This makes the situation unique for each airport. Without considering all local parameters a clear preference for either NADP1 or NADP2 is not always evident. It is worth to investigate the optimisation of departure procedures for the specific situation.

The measured results which came available from the trial on experimental departure procedures at Amsterdam Airport Schiphol showed positive results: a reduction for fuel consumption as well as lower *SEL* levels in residential areas. The lower *SEL* levels provide confidence in the results of modelling studies performed. These results showed an overall reduction of the number of highly annoyed or sleep disturbed people in the vicinity of the airport.

Measurement data gathered did meet the expected reduction on fuel consumption and *SEL* levels. As far as the peak noise levels are concerned, an increase was expected for noise monitoring locations close to the airport. This increase however was seen in the measured data for only one of the locations. Further investigation on this finding is recommended.

During the analysis great effort was put in the statistical analyses of the results. The way the results were finally presented provided the confidence needed to make further steps to improve the departure procedure at Amsterdam Schiphol Airport.

7 ACKNOWLEDGEMENTS

We would like to thank the members of the project team ‘Alternative departure procedure Schiphol’ for all their enthusiastic participation during this project. Special thanks go to the local operator ArkeFly, who made the underlying measurement campaign possible during the operational trials with their B738 and B763.

8 REFERENCES

1. William Roberson, James A. Johns, “Fuel conservations strategies: take-off and climb”, Boeing aero magazine QTR_4.08, (2008).

2. Amsterdam Airport Schiphol, http://194.229.29.150/nomos/main.mxml, noise monitoring system website.

3 David J. Sheskin, Handbook of parametric and non-parametric statistical procedures, Chapman & Hall/CRC, (2007).

4. J.J Higgens, Introduction to Modern Nonparametric Statistics, Duxburry Advanced Series (2004).

5. FAA, Noise abatement departure profiles, advisory circular AC 91-53A, July 1993.

6. ICAO, procedures for air navigation services, aircraft operations, volume I flight procedures, Doc 8168.

Table 1 - Qualification matrix.

Qualification	Control group 1 – Control group 3	Control group 1 – Control group 2	Exp. group – Control group 3	Notation positive/negative effect
Likely effect	No difference	No difference	Significant difference	+++/---
Probable effect	Significant difference	No difference	Significant difference	++/--
Possible effect	*	Significant difference	Significant difference	+/-
No effect	*		No difference	o

Table 2 - Statistical qualification levels measured data for various monitoring stations, aircraft type/runway-route combinations.

Monitoring station	Aircraft type/ runway-route	ΔLA_{max} dB(A)	ΔSEL dB(A)	Δt sec.	Max. group censor rate
10	B738/18L-ARN	o	o	o	5%
25	B738/18L-ARN	o	++	+++	5%
12	B738/24-ARN	+++	+++	+++	15%
13	B738/24-ARN	+++	+++	++	19%
21	B738/36L-PAM	---	o	++	15%
12	B763/24-VAL	+	+	+++	18%
14	B763/24-VAL	o	+	+	10%
16	B763/24-VAL	+++	+++	+++	17%
1	B763/36L-GRL	o	+	+	17%
19	B763/36L-GRL	o	o	o	21%

Table 3 - Measured differences point estimators medians control group 3 and experimental group vs. INM calculations.

Monitoring station	Aircraft type/ runway-route	Δ*SEL* dB(A) measured	Δ*SEL* dB(A)[1] calculated	ΔLA_{max} dB(A) measured	ΔLA_{max} dB(A) calculated
10	B738/18L-ARN	o	-0.7	o	+2.0
25	B738/18L-ARN	-1.7	-1.4	o	+1.2
12	B738/24-ARN	-2.6	-2.1	-1.2	+0.1
13	B738/24-ARN	-1.8	-1.4	-1.4	-0.3
21	B738/36L-PAM	o	+0.1	+0.9	+0.1
12	B763/24-VAL	-2.0	n/a	-1.7	n/a
14	B763/24-VAL	-1.3	n/a	o	n/a
16	B763/24-VAL	-2.2	n/a	-1.1	n/a
1	B763/36L-GRL	-1.2	n/a	o	n/a
19	B763/36L-GRL	o	n/a	o	n/a

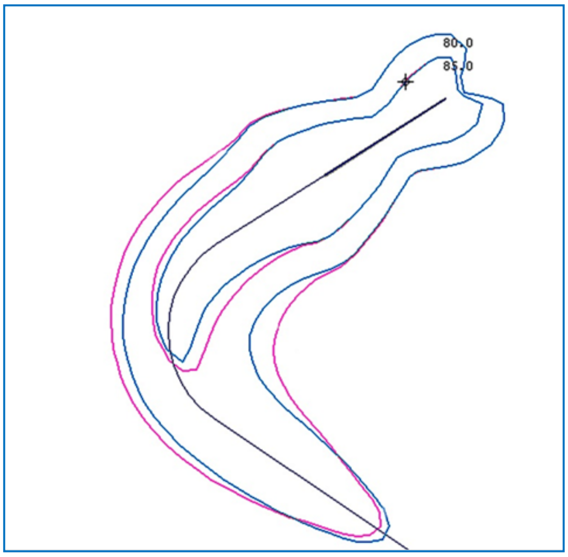

Fig. 1 - SEL footprint of B737-800 showing reduced noise levels for experimental departure procedure (blue line) and the reference (red line).

[1] INM does not support the engine-airframe combination for the 767-300 as used by the experimental operator. The corresponding entries in the table have been marked 'n/a'.

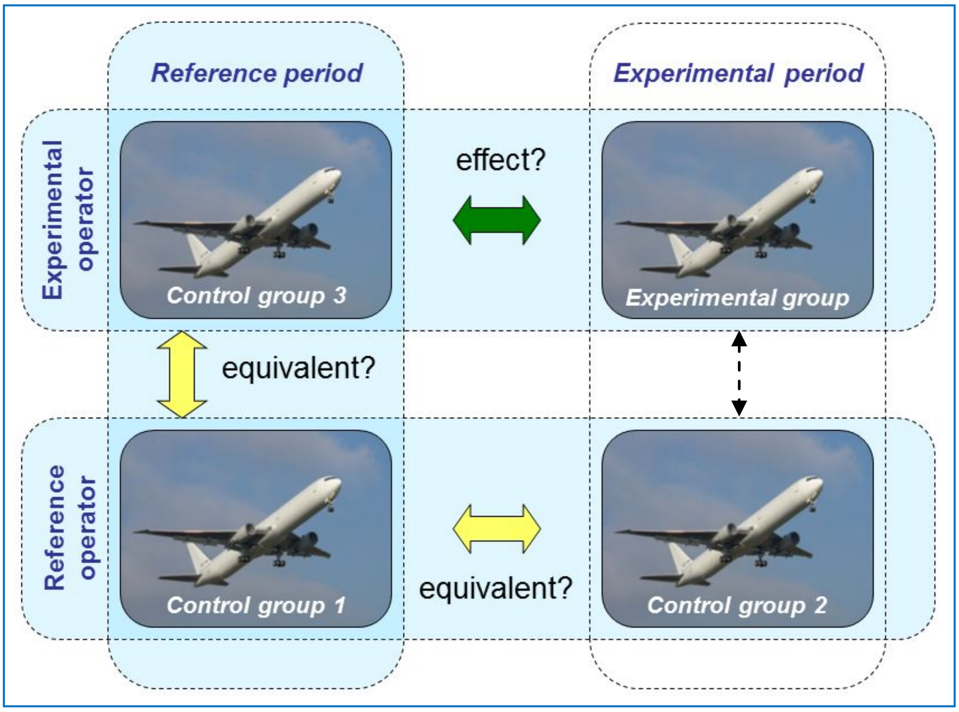

Fig. 2 - Schematic representation of the experimental design.

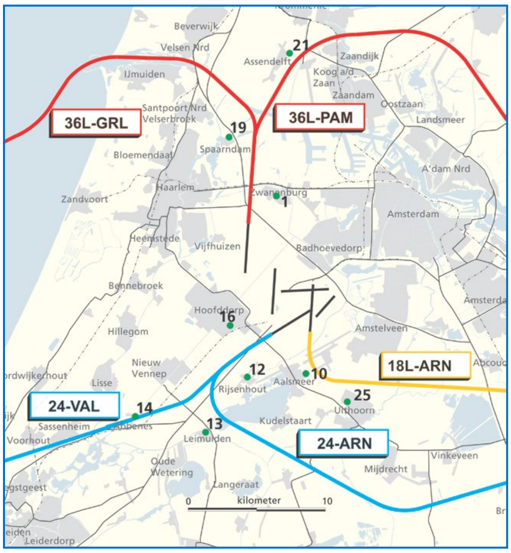

Fig. 3 - Location of relevant NOMOS measurement stations and runway/route combinations.