EPISODE 3

Single European Sky Implementation support through Validation

Document information	
Programme	Sixth framework programme Priority 1.4 Aeronautics and Space
Project title	Episode 3
Project N°	037106
Project Coordinator	EUROCONTROL Experimental Centre
Deliverable Name	Required enhancements of existing assessment noise models to validate SESAR Operational Improvements steps
Deliverable ID	D2.4.4-03
Version	2.00
Owner	
Peter Lubrani	INECO
Contributing partners	
EUROCONTROL - Frank Jelinek, Laurent Cavadini	

Issued by the Episode 3 consortium for the Episode 3 project co-funded by the European Commission and Episode 3 consortium.

- This page is intentionally blank -

DOCUMENT CONTROL

Approval

Role	Organisation	Name
Document owner	INECO	Peter Lubrani
Technical approver	EUROCONTROL	Giuseppe Murgese
Quality approver	EUROCONTROL	Frederique Senechal
Project coordinator	EUROCONTROL	Philippe Leplae

Version history

Version	Date	Status	Author(s)	Justification - Could be a reference to a review form or a comment sheet
1.00	19/06/2009	Approved	Peter Lubrani Frank Jelinek	Approval of the document by the Episode 3 Consortium.
2.00	02/10/2009	Approved	Peter Lubrani Laurent Cavadini Frank Jelinek	Further information on the STAPES model added and minor other modifications implemented.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This Episode 3 document takes into account the results coming from document D2.4.4-02 - Environmental and Meteorological Screening & Scoping of the SESAR OISs concerning Noise. The Operational Improvement Steps (OISs) there identified to be influencing the noise domain, have been used by this study to evaluate the capability of the current Noise assessment tools in characterising them correctly.

The wide use of Noise assessment tools in conducting Environmental Impact Assessments around airports, must match their capability to characterise and show the benefits delivered by new and improved operational procedures, as developed or under development in SESAR. This study tries to asses their readiness to evaluate the future OISs.

The main noise sources coming from aircraft flight procedures are listed and explained together with the basic methodology integrated models use to assess an aircraft operational procedure.

The assessment of Noise Abatement operational Procedures (NAPs), in particular Continuous Descent Approaches (CDA), through integrated noise models has shown in the past to be very limited. Past projects (e.g. Sourdine II among others) highlighted such short-comes and identified a list of requirements with which to improve, in particular, the INM software.

The validation of SESAR's Operational Improvement Steps (OISs), above all if based on the CDA concept, cannot be performed on the actual "as is" models. This is due to certain limitations, which have been carefully highlighted. Software models used for validation should be checked: taking good care to overcome their current limits in order to be able to reflect and justify the improvements introduced by SESAR.

The study lists the wide array of Noise models currently existing on the market focusing on the widely and most commonly used ones (standard) which are based on the same methodology (contained in DOC 29 3rd Edition) and noise assumption (an integrated segmentation model assumption). Among this list, two main Noise Assessment models have been analysed in depth against the OISs: these are INM, Enhance/INM and STAPES. The information concerning the ANCON 2 model was estimated not enough for this in depth analysis, although many results can be applied to it since it is based on the same methodology.

The study proposes three main solutions/requirements to overcome the limitations in characterising the OISs, these include:

- The update of the ANP/INM database through new NPD curves and a/c performance data (specifically for CDAs), together with the introduction of multi-configuration NPD curves (specifically for the approach segment of flight);
- Expanding their capability to calculate new metrics as NA (Number of aircraft Above XdB) and possibly exposure to Low frequencies;
- Improving sensibility to weather conditions (since they influence the a/c performance) and topography for noise propagation (although it has a second order of influence).

The benefit of implementing certain Operational Improvements is strictly linked to the capacity of the evaluation models to reflect this enhancement through quantitative data, and to be able to support the decision maker and the public with clarity.

The development of a new model capable of surpassing these limitations is desired, although as a first step it is the update of the ANP database by far the most important step forward.

1 INTRODUCTION

1.1 Purpose of the document

The purpose of this document is to highlight the short comes and needed enhancements currently found in the Noise Assessment tools, when applied to the validation of SESAR's Operational Improvement Steps (OISs). The capability to model these Operational Improvements and to weigh their true mitigating potential is key for their implementation, comparison and future development and enhancement.

If the OISs' benefits cannot be verified or demonstrated, due to the Assessment tool's insensibility to one or more parameters, then it is very difficult to be able to justify the required cost for their implementation.

The scope of the study is limited to evaluating Enhance/INM (models based on the noise modelling methodology described by SAE AIR 1845 [52], ICAO Doc 9911 [48] and ECAC Doc.29 3rd Edition [51]), when applied to the validation of Episode 3's OISs which are considered to mitigate noise and for which, the validation requires a Noise Assessment tool.

The highlighted limitations and possible solutions can be extrapolated to other models for their communality of architecture, input data, database dependency, etc…

Uncertainty often exists to some degree in any type of modelling [1]. Nevertheless, what is important is that the right tools are used for the right purposes.

1.2 Intended Audience

The intended audience includes:

- EP3 partners;
- SESAR community;
- SES JU WP16.3, in particular SWP 16.3.1 where the development of new environmental assessment models will take place.

1.3 Document Structure

The document structure is divided accordingly to the tasks of the study:

- Collection/listing of most commonly used standard tools for noise assessment, including its availability to the public and if possible its validation stage. (Sections 3, 4); introduction to the noise metrics available (Section 5);
- Highlight the basic limitations of the current models and their strengths, when conducting a noise impact assessment (Section 6);
- Highlight the specific limitations, which spring up when the tools are applied to the validation of the Noise OISs (previously highlighted by the Scoping and Screening process) (Sections 7, 8 and 9) ;
- Features and functionalities (if available) needed to evaluate thoroughly the OISs; propose possible solutions to solve these limitations (Section 10);
- Conclusions (Section 11).

1.4 Background [2]

Episode 3 is a European Commission 6th Framework Programme research project funded by Directorate-General Transport and Energy (DG TREN). The objective of the project is to begin the validation of the Air Traffic Management operational concept developed by SESAR for medium term deployment (2020). In order to do so WP2.4.4 was tasked to pinpoint the OISs, which influenced the Environment area, and in particular the two main key performance indices: Noise and Emissions.

The Screening and Scoping task delivered a list of OISs [56], which would benefit the Environment by mitigating both Emissions and Noise.

In any validation exercise, the use of Assessment Models is key to indicate the foreseeable benefits/drawbacks of a change made to the system. These models however need to be correct and sensible enough to capture the improvements or changes introduced.

The aircraft flight paths currently used during airport noise and emissions analysis are typically generated using guidance from standards documents such as the Society of Automotive Engineers (SAE) Aerospace Information Report (AIR)-1845 [52] or the European Civil Aviation Conference (ECAC) Document 29 [51]. These documents describe methods for calculating aircraft flight paths using performance data and flight profiles supplied by aircraft manufacturers. The two main sources for these data accessible by the general public are the standard database from the Federal Aviation Administration's (FAA) Integrated Noise Model (INM), and EUROCONTROL's created Aircraft Noise and Performance (ANP) database[1]. The two databases are consistent with each other and conform to SAE-AIR-1845 and ECAC Document 29 guidance.

The INM and ANP databases contain manufacturer-supplied approach and departure profiles for most aircraft in the world's commercial aircraft fleet. These profiles were developed to represent how each aircraft would normally fly at typical commercial airports. There are several profiles defined for departure operations, representing a range of operating weights. For approach operations, however, there is typically only one flight procedure defined per aircraft. Models like the INM allow users to modify the standard flight profiles contained in the database or even create their own profiles, however experience shows that the majority of airport noise and emissions analyses rely on the standard, manufacturer-supplied profiles. Experience also shows that there can be large differences between the manufacturer-supplied approach profiles used for environmental modelling and the approach profiles actually being flown at airports.

There have been several recent efforts that involve the modelling of CDAs for a small number of flights. These efforts include the CDA testing and analysis at Louisville International Airport (KSDF) [4] performed by the FAA/NASA/Transport Canada sponsored Partnership for Air Transportation Noise and Emissions Reduction (PARTNER), and the EC's Sourdine II [5], [6] and OPTIMAL [7] project. The PARTNER work focused on designing and implementing CDAs, and investigated the noise and emissions benefits from a small number of actual flights following CDA profiles developed specifically for late night operations at KSDF. While this effort did include the implementation of actual CDAs as well as an attempt at quantifying their environmental benefits, it was a limited experiment and further work is needed relative to both the CDA design and environmental modelling aspects of the capability demonstration in order to further CDA implementation.

The Sourdine II project looked at enhancing the current method of predicting aircraft source noise levels purely as a function of thrust by also considering aircraft configuration and speed. Through the development of configuration-specific Noise-Power-Distance (NPD) curves, it is possible to consider the airframe noise generated, which is especially important when attempting to accurately model noise levels from low-thrust CDAs.

The OPTIMAL project looked at enhancing the CDA procedure design and on the evaluation through simulator and flight trials; noise calculations and analysis were performed both through INM and through Airbus's proprietary software. Other evaluations of CDAs have also

---

[1] http://www.aircraftnoisemodel.org/FrontOffice/scripts/makepage.php?Start=

been performed recently at the Nottingham East Midlands [45] airport in the UK and Schiphol Airport in the Netherlands. Like the Louisville Airport, USA effort [47] , these evaluations focused on CDA design and implementation.

Further evaluations for Basic CDAs are currently ongoing in Europe through the AIRE framework, joint program by the FAA and the SJU.

A need to overcome these limitations and to adapt to new requirements from the public was found to be now even more important for the future implementation of SESAR.

1.5 GLOSSARY OF TERMS

Term	Definition
A-weighted	A-weighted decibels, abbreviated dBA, or dBa, or dB(a), are an expression of the relative loudness of sounds in air as perceived by the human ear. In the A-weighted system, the decibel values of sounds at low frequencies are reduced, compared with unweighted decibels, in which no correction is made for audio frequency. This correction is made because the human ear is less sensitive at low audio frequencies, especially below 1000 Hz, than at high audio frequencies.
ACDA	Advanced Continuous Descent Approach
ACI	Airports Council International
AEDT	Aviation Environmental Design Tool
AIP	Aeronautical Information Publication
AIRE	Atlantic Interoperability Initiative to Reduce Emissions
ANCON2	United Kingdom Civil Aviation Authority Aircraft Noise Contour Model
ANP	Aircraft Noise and Performance database *Online data resource facility available at www.aircraftnoisemodel.org.*
APP	Approach
APT	The Airport Research Area at EEC.
ARR	Arrival
CAEP	Committee on Aviation Environmental Protection
CDA	Continuous Descent Approach
CREDOS	Crosswind - Reduced Separations for Departure Operations
dB(A)	A-weighted decibel
DEP	Departure
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DNL	Day-Night Level *It is a descriptor of noise level based on energy equivalent noise level (Leq) over a whole day with a penalty of 10 dB(A) for night time noise.*
EATM	Pan-European Air Traffic Management
EC	European Commission
ECAC	European Civil Aviation Conference
EEA	European Environment Agency
EEC	EUROCONTROL Experimental Centre

Issued by the Episode 3 consortium for the Episode 3 project co-funded by the European Commission and Episode 3 consortium.

Term	Definition
EEMA	Economic and Environmental Modelling system for Aviation
EHQ	EUROCONTROL Headquarters, at Brussels (Belgium)
ENHANCE	European Harmonized Aircraft Noise Contour Modelling Environment
EU	European Union
EUROCONTROL	The European Organisation for the Safety of Air Navigation
FAA	US Federal Aviation Administration
GUI	Graphical User Interface
ICAO	International Civil Aviation Organization
INM	Integrated Noise Model
LAmax	Maximum value of sound pressure level vs. time (dBA)
L_{DAY}, L_{EVE}, L_{NIGHT}	Respectively day-time, evening-time and night-time Leq
L_{DEN}	Day-Evening-Night Level
Leq	Equivalent (continuous) sound level (dBA)
LTO	Landing and Take Off
MAGENTA	Model for Assessing Global Exposure to the Noise of Transport Aircraft
N/A	Not Applicable
NA	Number of events Above - dB
NAAP	Noise Abatement Approach Procedure
NADP	Noise Abatement Departure Procedure
NASA	National Aeronautics and Space Administration
NPD	Noise-Power-Distance
OIS	Operational Improvement Step
OPTIMAL	Optimised Procedures and Techniques for the Improvement of Approach and Landing
PARTNER	Partnership for Air Transportation Noise and Emissions Reduction
PRISME	Pan-European Repository of Information Supporting the Management of EATM
RWY	Runway
SAE	Society of Automotive Engineers
SEL	Sound Exposure Level (dBA)
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking
SOURDINE	Study of Optimisation procedURes for Decreasing the Impact of NoisE II
STAPES	SysTem for AirPort noise Exposure Studies
STAR	Standard Arrival Chart Instrument
TMA	Terminal Manoeuvring Area
UK CAA	United Kingdom Civil Aviation Authority
V&V	Verification and Validation

Issued by the Episode 3 consortium for the Episode 3 project co-funded by the European Commission and Episode 3 consortium.

Term	Definition
WT	Wake Turbulence

2 OBJECTIVE OF THE STUDY

The objective of the study is to evaluate the capability of current Noise models in assessing the OISs found to be mitigating the Noise impact as described and listed in Episode 3's D2.4.4-02 – Environmental and Meteorological Screening & Scoping of the SESAR OIs [56].

The Study covers the evaluation of the main current Noise assessment models (based on integration) but is limited to only three of these, specifically: the Enhance/INM, INM and STAPES . The information on ANCON 2 was not regarded as sufficient.

The Study only looks into the models' limitations in characterising correctly or extensively the OI Steps (OISs), no benchmarking among them has been done. On the other hand recommendations have been made.

Limits of the study

The limited number of software studied is due to the following factors:

- Public availability of the software. Accessibility to the software/owner of a licence;
- Familiarity (as Users) with the software. Experience obtained in past R&D projects when encountering the limits of the models when used [63];
- Wide use and standard among the aviation community;
- The work was conducted in the frame of the Episode 3 project and is focused only on the capability of the models to characterise the OI Steps found to be directly mitigating noise;
- Communication with the owners or sufficient public information.

What the study tries to do (bearing in mind the OI Steps):

- Highlight the limitations of the Noise assessment models used when asked to validate the OI Steps;
- List/Summarise the mitigation proposals given by the aviation community to overcome these problems.

What the Study does not cover:

- It does not cover all the Noise assessment models available;
- It does not compare noise assessment models or intends to validate them;
- It does not promote one Noise model compared to another;
- It does not, with a limit, assess the problems the noise models may have if not related to the OI Steps it is studying.

3 NOISE [9]

3.1 INTRODUCTION

Aviation noise is primarily associated with arriving and departing aircraft in the vicinity of airports. Aircraft noise is produced from the engines and the airframe. Engine noise is the primary source at take-off. For approach and landing, airframe noise is the primary source, due to the turbulent airflow created around the aircraft (Royal Academy of Engineering 2003).

Noise can also arise from the following activities:

- Engine testing, Auxiliary Power Units (APUs) and other operations at airports;
- Surface traffic accessing the airport and airport ground support vehicles;
- En route phase of aircraft flight (including sonic boom from military aircraft);
- Low flying aircraft – general aviation (GE), helicopters and military activities.

Noise pollution and disturbance is a complex issue, depending on the individual, the noise source, its frequency of occurrence, duration and its energy, among others. The main disturbance occurs in the vicinity of airports. The UK Parliamentary Office of Science and Technology reported that despite technological improvements in individual aircraft and other noise regulations, the increase of frequency in occurrence is a cause of concern for communities.

The US FAA [10] indicated approximately 5 million people in the US lived in areas with noise levels above 55 dB DNL in 2000 due to aviation[2]; while past estimates have suggested that 10% of the EU population may be highly disturbed by air transport noise. Noise levels around several large airports in the EU have fallen in recent years as a result of the phasing out of noisier ‘Chapter 2’ aircraft [10] and the following restriction for marginally compliant Chapter 3 [11] but traffic growth is expected to reverse this trend. The number of people highly annoyed by noise is predicted to increase at a rate of 1 to 4% per year, depending on the scenario considered [13].

3.2 NOISE AND ITS COMPONENTS

Aviation noise source is complicated and it varies according to mode of flight, weight of aircraft and proportional to thrust involved. A large change during flight is registered due to fuel use (change in weight of the aircraft), aircraft configuration gear up/down, flaps, slats etc. The airframe sources can contribute to up to 50% of total noise production during approach. The aircraft noise sources are illustrated below in Fig. 1.

[2] See [10], Section 3.1, page 13, for more information.

Fig. 1 Noise sources from aircraft (Photo JM. Pozo-Sierra)

While the following (Fig. 2) shows the contribution of the different sources to the total airframe noise.

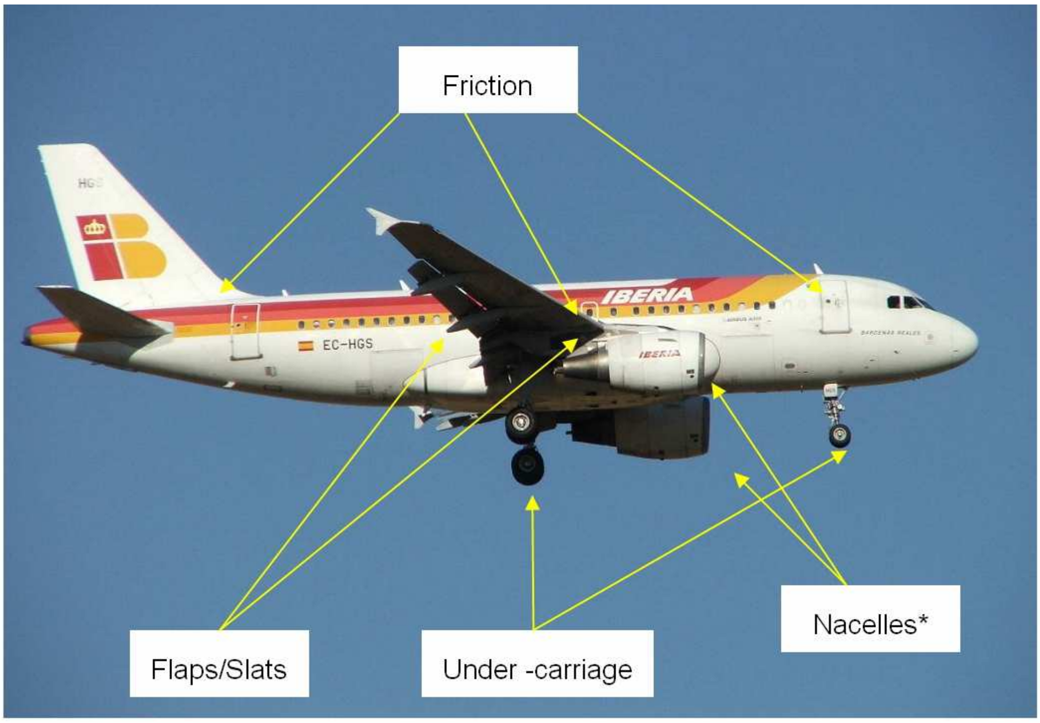

Fig. 2 Airframe Noise sources from approaching aircraft (Photo JM. Pozo-Sierra)

**Nacelles are actually an engine problem, not an airframe, but otherwise source of aerodynamic noise [14].*

3.3 NOISE CALCULATION [15]

Noise calculation requires taking the noise characteristics from a given aircraft and, based upon its expected flight trajectory; determine the propagation of that noise to ground level. Noise effects are non-linear and the summation of the effects of individual flights at any given airport requires the analysis of each individual flight and its trajectory in the region of the airport. Once ground level noise contours have been established, based on accepted noise measures which account for, for example, time of day sensitivities, these contours can be combined with population data to produce a count of the number of people exposed to noise i.e. the number of people living and/or working within a given noise contour. This is, in reality, the beginnings of an impact calculation. A methodology to carry out this calculation, which has been generally accepted in Europe, and now worldwide, is ECAC Doc.29 3rd Edition [51].

3.4 NOISE MODELLING [16]

Traditional models for aircraft noise operating at an airfield or airport are based on an integrated (segmentation model) assumption owning to computational limits when they were first developed. These assumptions include flat earth, average annual atmospheric effects, and simple integrated source noise. Using these simplifying assumptions, the cumulative noise exposure from aircraft operations is estimated. These assumptions work well for a uniform environment (no winds, standard atmospheric profile and flat earth). However, recent developments for both INM (FAA) and NoiseMap (US Dept. of Defence) have included the effects of topography, to a certain extent, of aircraft noise propagation.

This inclusion has led to better calculation of DNL for certain cases, but it has shown that other effects also need to be considered: source directivity, non-linear propagation and seasonal weather effects.

Traditional Approach to Noise Modelling [17] [51]

Current best practice models are based on segmentation to calculate the aircraft noise single event levels.

Segmentation modelling is supported by a comprehensive aircraft noise and performance database (ANP), which has been assembled through the years and updated by the aircraft manufacturing industry together with the noise certifying authorities.

The ANP database contains for any specific aircraft Noise–Power-Distance (NPD) relationships. These define, for steady straight flight at a reference speed and reference atmospheric conditions and in a specified flight configuration, the received sound event levels, both maximum and time integrated, directly beneath the aircraft as a function of distance. For noise modelling purposes, the propulsive power of the aircraft is represented by a noise-related power parameter. The ANP database is the strength but also the Achille’s heel of any model based on integration (its quality and range of data are important).

Segmentation is a process by which the recommended noise contour model adapts the infinite path NPD and lateral data (lateral directivity due to engine installation effects and lateral attenuation) to calculate the noise reaching the receiver from a non uniform flight path, i.e. one along which the aircraft flight configuration varies. In order to calculate the sound event level of an aircraft in movement, complex paths are divided into straight-line finite segments. The maximum level of the event is simply the greatest of the individual segment values.

The time integrated level of the whole noise event is calculated by summing the noise received from a sufficient number of segments (those making a significant contribution).

Issued by the Episode 3 consortium for the Episode 3 project co-funded by the European Commission and Episode 3 consortium.

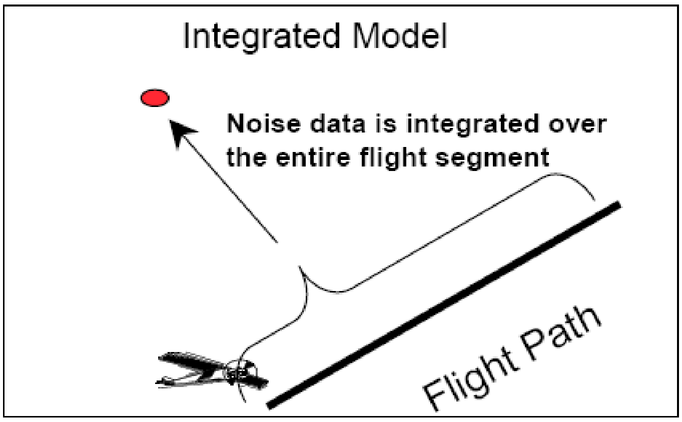

Fig. 3 Flight segment noise estimation

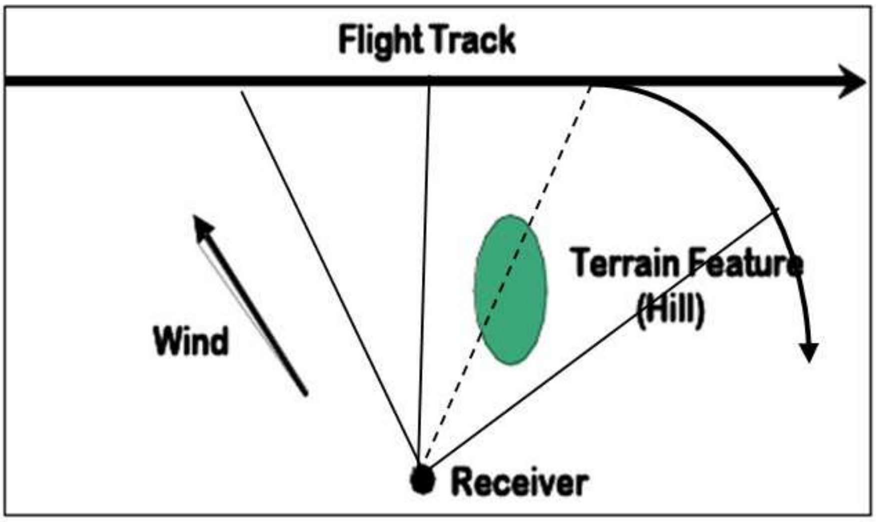

Fig. 4 Terrain block age and line of sight (LoS)

The integrated noise models consider Line-of-sight (LoS) during their calculation, which accounts only for distance to the source point (3D): obstacles that screen the LoS are only considered with a limited range of default attenuation coefficients. This means that the models based on this method accept terrain but only calculate the line of sight distance to the source of noise; otherwise, terrain is considered as flat.

Even though noise propagation is an important factor due to different topography, the LoS is in fact the best method to be used on airports (generally flat areas) since the predominant high levels of noise come from the aircraft once it is off the ground.

Issued by the Episode 3 consortium for the Episode 3 project co-funded by the European Commission and Episode 3 consortium.

4 LIST OF STANDARD NOISE ASSESSMENT TOOLS

4.1 INTRODUCTION

This section lists and introduces to the reader the most common and standard tools (computer-based tools) which use measured aircraft noise data[3] to estimate noise exposure levels resulting from aircraft operations at and around airports.

The main models known to carry out this type of modelling are:

- INM/MAGENTA (FAA) now part of the AEDT platform together with HNM;
- ENHANCE/INM;
- STAPES (EUROCONTROL);
- ANCON2 (CAA[4]);
- SONDEO (ANOTEC)[5].

The first of these models uses proprietary airport data in the MAGENTA element of the model and, whilst INM is publicly available, the overall INM/MAGENTA package is not available for use outside the FAA.

While the INM is public and globally available through licence, the ANCON is not available to public while the SONDEO model is privately funded and subject to licence for its use (but has had no further development since 2007).

The four models [18] are compliant with [51]. The only major difference between the three models is their geographic scope. AEDT/MAGENTA includes over 194 global airports in Shell 1, and over 1500 in Shell 2.

ANCON includes three London airports and SONDEO includes 51 European airports. The FAA is currently working with the Airports Council International (ACI) to make available to other CAEP modellers the AEDT/MAGENTA input decks. In addition to not maintaining global input data for noise modelling, development work on ANCON and SONDEO would be necessary to support global population assessment.

STAPES, in its final development phase by EEC, is the new regional ECAC noise model. The objective is to include in the model a sufficient number of airports to cover more than 90% of the European population exposed to significant noise levels. [19].

All the above models are based on integration (as described in 3.4) and rely on an ANP database. In the case of ANCON this database reflects the current three UK airport scenarios, due to this its application is regionally limited in scope.

4.1.1 Other Noise Assessment Tools

Based upon or using the INM engine, other tools exist which add new interfaces and calculation modules to pre or post-process the INM data for different purposes (e.g. the calculation of the NA metric as TNIP and DICERNO).

Mainly these modules add an extra support to the decision making process.

---

[3] The ANCON2 model uses empirical noise data, please see 4.4 for more details.

[4] UK Civil Aviation Authority.

[5] Aircraft NOise TEChnologyConsulting, S. L.

These tools here listed can be of public use or restricted, propriety or given under licence. Some of these tools, as previously said, can be considered as add-ons in the sense that they pre-process or post process the data to be inserted or coming out of the noise assessment tools (i.e. INM).

The following are some examples:

- DICERNO (Decision Support tool);
- TNIP [6](Transparent Noise information Package);
- Noise Integrated Routing System (NIRS) & NIRS Screening Tool (NST) (FAA);
- Etc…

A wider list of noise assessment tools can be found in Appendix 1 (13).

As reminded in the objectives of the document, the study will focus on the Enhance/INM capability and limitations, to assess the improvements to noise around the airport delivered by the specific SESAR OISs.

Add-on modules as ENHANCE and TNIP which do pre- or post-processing of data have been included under the software they support.

4.2 INM [53]

4.2.1 Introduction

The FAA's Integrated Noise Model is an airport noise contouring tool whose modelling principle is derived from the methodology described in the AIR-1845 guidance [52], issued by the Society of Automotive Engineers (SAE) in the 80s. The INM algorithms have evolved since, incorporating in particular a segmentation process, not described in the original guidance. The INM algorithms are described in the INM7.0 Technical Manual [55]. The version 7.0 incorporates additional updates (in particular an updated lateral attenuation model), making that version fully compliant with the updated ECAC Document 29 3rd edition guidance [51].

Along with the noise calculation engine (the 'heart' of the system), INM includes different modules to define the input data which are required to calculate noise levels – basically the 4-D flight path (i.e. 3-D position and speed) of each aircraft around the airport, along with an additional flight parameter characterizing the aircraft noise source state (the engine power settings) [50].

The (INM) tool represents a de facto 'standard' in the domain of airport noise contour modelling, and is widely used throughout the world and incorporates current modelling 'best practice'.

4.2.2 INM7.0a

INM Version 7.0 is a significant improvement over the 6x series. In addition to several updates related to aircraft noise/performance for commercial aircraft, Version 7.0 includes detailed modelling of helicopter noise based on the Federal Aviation Administration's (FAA) Heliport Noise Model (HNM[7]) Version 2.2, and algorithms consistent with updated guidance

---

[6] Australian Transport Safety Bureau, Bureau of Infrastructure, Transport and Regional Economics.

[7] Helicopters are considered as air traffic when subject to IFR and when under VFR they enter an area under ATC control.

documents, including the ECAC Doc 29 [51] "Report on Standard Method of Computing Noise Contours around Civil Airports".

4.2.2.1 New Features

INM Version 7.0 includes the following new operational and computational features:

- Improved helicopter noise modelling capabilities;
- Compliance with ECAC Doc 29 [51]:
  - New SAE-AIR-5662 Lateral Attenuation algorithms;
  - Updated Thrust Reverser implementation;
  - Bank angle implementation;
  - Updated flight path segmentation;
  - Additional procedural profile step types.

These improvements to the noise and flight performance modelling algorithms in INM Version 7.0 may produce minor changes in output results when compared to previous versions of INM. The magnitude of these changes is study dependent.

Many of the aforementioned updates to INM are in preparation for its integration into FAA's Aviation Environmental Design Tool (AEDT).

AEDT is a comprehensive suite of software tools that will allow for thorough assessment of the environmental effects of aviation. The main goal of the effort is to develop a new capability to assess the interdependencies between aviation-related noise and emissions effects, and to provide comprehensive impact and benefit-cost analyses of aviation environmental policy options.

4.2.3 How INM works [50]

To calculate aircraft noise exposure around airports, INM uses successive values of five basic parameters to describe the noise-source trajectory: (x, y) ground position, height, speed and thrust. INM usually takes the (x, y) values from nominal ground tracks. All the aircraft of a given studied fleet mix are assumed to follow these nominal tracks (with possibly a Gaussian dispersion around the backbone tracks to integrate more realism).

For each aircraft type, values for height speed and thrust corresponding to the successive ground positions are then obtained by INM in one of two different ways, depending on the available data in the INM aircraft databases:

- Fixed-point profiles: values for height, speed and thrust (as a function of ground distance along the track) are pre-defined in a standard fixed-points profile database.
- Procedural profiles: successive values for height, speed and thrust are calculated by INM from pre-defined take-off or approach procedures, using an aircraft performance model (based on methodology described in SAE AIR-1845 [52]) and an associated aircraft performance database (including jet coefficients, drag-over-lift coefficients, etc.).

With the second option, the resulting (calculated) flight profiles (in terms of height, speed and thrust as function of ground distance) vary with aircraft operational weight, meteorological conditions (temperature & pressure) and procedure parameters (e.g.: flap settings schedule, thrust cutback) which can be user input parameters.

From these input data describing the flight trajectories, the noise engine calculates the noise footprint produced by each single event, using a Noise Power Distance (NPD) database (Fig. 5). This database provides for each aircraft type a set of curves specifying perceived noise levels as a function of source to receiver distance, for different thrust settings. These curves are developed for a single aerodynamic configuration and a reference (constant) true airspeed of 160kt, according to guidelines specified in [52].

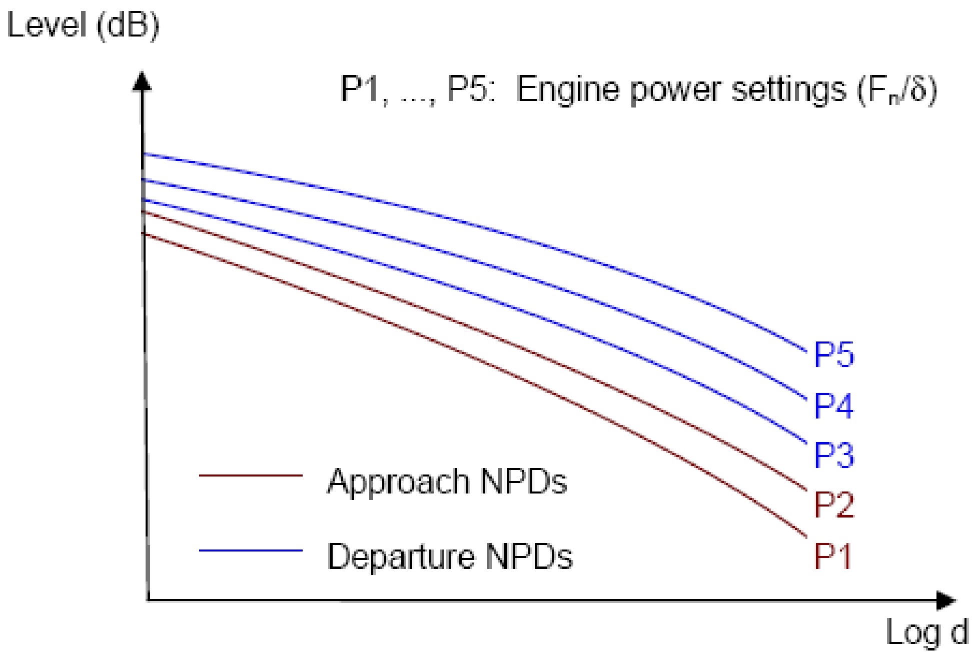

Fig. 5 NPD data by operating mode

4.2.3.1 Procedural profiles

With the procedural profile form, the flight procedure is described by a set of successive procedural instructions/steps, as flown by the crew (ex: takeoff climbs, accelerate, descend, etc.). These procedural steps include additional operational information such as the engine power settings, the flap settings, target speeds and rate of climb (for acceleration segments).

Using its aircraft performance model, along with appropriate aircraft performance coefficients (engine and aerodynamic coefficients, available in a database for most of modern aircraft), INM calculates the vertical profile (in terms of height, speed and thrust as a function of travelled ground distance, as required for the 3-D flight path construction) associated to the procedural profile. The calculated flight profile varies with the aircraft operational weight, meteorological conditions (temperature, pressure, wind speed) at the airport and procedure parameters (ex: flap settings schedule, thrust cutback, etc.), which can be adjusted by the user to meet local conditions.

The equations and algorithms of the INM aircraft performance model are described in the INM 7.0 Technical Manual [55].

4.2.3.2 Fixed-Point profiles

With the fixed-point profile form, tabulated values of height, speed and thrust at specific ground distances are directly provided by the database. They represent flight profiles resulting from standard procedures flown under standard conditions (standard atmosphere, airport at sea level, headwind less than 8 kts). These can not be automatically adjusted to account for other specific local conditions at the studied airport.

Usually, standard procedures are provided in the form of fixed-point profiles when the aircraft-specific performance coefficients are not available to calculate vertical profiles from the procedural definition of the procedure, or in the case of specific standard procedures where using the INM aircraft performance model would not be adequate because of some modelling limitations. For instance, approach procedures including idle thrust segments and/or level-off segments with deceleration are provided in the form of fixed-point profiles, because using the INM approach-specific thrust equation would over-estimate thrust levels associated to this kind of segments[8].

4.2.4 ENHANCE [48]

The EUROCONTROL Experimental Centre has developed over the last few years the ENHANCE tool. The tool provides an environment to support the preferred noise modelling tool via a user friendly graphical user interface. Highly adaptable, to suit the noise modelling needs, ENHANCE combines intuitive data management facilities with a valuable noise modelling database relating to Airline fleet mixes and operating conditions.

ENHANCE relies on an open architecture that supports the easy integration of an existing noise model (noise engine) through which consistent and reliable modelling scenarios can be constructed.

4.2.4.1 Better noise contour modelling

ENHANCE uses simulator data, radar data and meteorological data, together with new databases provided by EUROCONTROL and their contractual partners including aircraft profiles and airport procedures at many European airports, to provide better noise contour modelling using a pre-existing noise model.

The ENHANCE approach is based on existing noise contour calculation software (for example, the Integrated Noise Model from FAA), but through a pre-processor function and "European" database, it allows more accurate data input, including radar data and simulation data.

Through the user-friendly graphical interface ENHANCE allows to:

- Define a noise study on a PC via a user-friendly interface;
- Fully respect the 3D trajectories of each flight in the input data (radar or simulated data);
- Compute realistic flight profiles as input to the noise model (height, speed and thrust) using validated databases of aircraft performance and flight operations;
- Insert default values where real-world input data is missing or incomplete, using a standard and consistent database;
- Easily perform noise calculations that cover large numbers of flight operations.

ENHANCE uses radar or simulated aircraft tracks and altitude/speed profiles to create more realistic noise contours maps with a pre-existing noise model.

4.2.5 TNIP [20]

TNIP Expert is the latest version of the main TNIP program. It has a very different user interface to the previous version (TNIPv3.6).

TNIP Expert is a tool which takes data either from Noise and Flight Path Monitoring systems, or from noise modelling studies carried out using the US Federal Aviation Administration's Integrated Noise Model (INM), and produces 'real' information about aircraft noise.

[8] The new version of ECAC Document 29 [51] includes updated and additional thrust equations which address the issue, but require using additional aircraft performance coefficients, which are still to be developed and supplied by manufacturers.

It can be used to produce a range of flight path and aircraft movement based noise descriptors or to produce and manipulate conventional noise contours.

TNIP Expert enables the user to 'look inside' noise contours and easily see the number and types of aircraft that have been allocated to the flight tracks which underpin the contours. The allocations of aircraft to tracks can be altered in a way that allows the carrying out of rapid 'what-if' analyses. These analyses show how the noise exposure patterns around an airport would change if some of the operations at the airport changed (e.g. different runways or aircraft types were used). This can be done either for conventional logarithmic contours or for Number Above contours such as the N70 (NA70) which are now generating a great deal of interest. A description of how to use TNIP Expert to generate N70 contours is provided here.

TNIP Expert needs to be set up for an airport by a person with specialist expertise and who has access to aircraft noise monitoring and modelling data for the airport. Once TNIP [9]Expert has been set up a non expert can easily interrogate data sets and generate aircraft noise information for time periods that are of interest. For example, specific information can be generated for sensitive time periods like early mornings or evenings.

4.2.6 NIRS & NIRS Screening Tool (NST) [53]

In order to analyse the environmental impacts of changes in airspace design over wide areas, the FAA produced the following standard noise assessment model together with a pre-determined screening tool:

- Noise Integrated Routing System (NIRS) Version 6.1;
- NIRS Screening Tool (NST) Version 6.1.

4.2.6.1 Noise Integrated Routing System (NIRS) Version 6.1

The Noise Integrated Routing System (NIRS) is a noise-assessment program designed to provide an analysis of air traffic changes over broad areas. It is intended to work in conjunction with other Air Traffic modelling systems that provide the source of routes, events, and Air Traffic procedures such as altitude restrictions.

The outputs of NIRS include population-impact and change-of-exposure reports and graphics. Population centroids are evaluated as improved or worsened based on their change of exposure. A hierarchy of rules based on FAA guidance and local requirements are then employed to determine if an airspace alternative is likely to be controversial based on noise considerations. Where possible, the system identifies the principal source of the change of exposure. Having identified the route set responsible for an increase, the air traffic planner can begin the evaluation of possible mitigation alternatives.

4.2.6.2 NIRS Screening Tool (NST[10])

The NIRS Screening Tool (NST) is an application designed to provide guidance in evaluating potential noise impacts as a result of changes in airport arrivals and departures above 3,000 feet above ground level (AGL). This is accomplished by screening [11] the proposed changes to determine whether there is the potential to increase noise levels over communities beneath the aircraft route.

---

[9] TNIP Expert is freeware and a copy of this can be obtained by contacting Dave Southgate at david.southgate@infrastructure.gov.au.

[10] NST is currently available for use only by FAA employees. Persons in FAA service areas or facilities may contact the Environmental Program Group for information.

[11] The screening criteria have been established in accordance with FAA Order 1050.1E, the Federal Interagency Committee on Noise (FICON), and the Final EIS for the Expanded East Coast Plan.

4.3 MODELS FOR ASSESSING GLOBAL EXPOSURE TO THE NOISE OF AIR TRANSPORT

The MAGENTA and STAPES models are two examples of noise assessment tools created with the objective of assessing the impact of Noise from the air transport on a wider area.

Their objective being the same, but their scope is regionally different: MAGENTA covers in detail US airports while STAPES covers European Airports.

4.3.1 MAGENTA [53]

MAGENTA is a computer model used to estimate the number of people exposed to significant aircraft noise worldwide. The original MAGENTA model development was done with the Committee on Aviation Environmental Protection (CAEP) under the International Civil Aviation Organization (ICAO) to assess the worldwide aviation noise climate. The computational core of MAGENTA is FAA's Integrated Noise Model (INM), the most widely used computer program to calculate aircraft noise around airports. Major assumptions on local traffic use come from getting INM datasets developed for an airport.

The noise studies obtained from U.S. airports have gone through thorough public review; either under the National Environmental Policy Act (NEPA) requirements or as part of a land use compatibility program.

A U.S. version of the global MAGENTA model was developed to determine the noise exposure in the U.S. using data on aircraft and operations specific to U.S. airports. The general, regional FESG forecast used in the CAEP version of MAGENTA was replaced by the FAA Terminal Area Forecast (TAF), which provides current and accurate information on how traffic will increase at each US airport.

The U.S. version of MAGENTA has evolved over time as more comprehensive databases were incorporated to improve the accuracy of the model. The data source for airport traffic changed from the Official Airline Guide (OAG) to the FAA Enhanced Traffic Management System (ETMS). Unlike OAG, the ETMS database includes unscheduled air traffic, which allows for more accurate modelling of freight, general aviation, and military traffic. The ETMS also provides more details on aircraft type for a more accurate distribution of aircraft fleet mix. Under the old model, unscheduled traffic was estimated and adjustments in the number of people exposed were made at the national level.

MAGENTA is an FAA government research tool, not for release to the public. MAGENTA is used in support of CAEP noise analysis and will eventually become part of the Aviation Environmental Design Tool (AEDT). The U.S. version of MAGENTA is used to support the DOT Government Performance Review Act (GPRA) performance goal and FAA's own Flight Plan performance goal by tracking the number of people in the US exposed to significant aircraft noise.

4.3.2 STAPES [19]

STAPES is a joint EC/EASA/EUROCONTROL project to develop a model capable of calculating the total number of people exposed to certain noise load levels at major airports in Europe, for use in EU and ICAO noise policy work. Core noise model is based on specifications from ECAC Doc 29, 3rd Edition [51] and ICAO Document 9911. The STAPES noise model has been validated [12] against UK ANCON2 model, but the software is a complete new development.

---

[12] This V&V process includes a capability demonstration consisting of running STAPES on a CAEP-specific sample case, and comparing the results against those produced by a reference - CAEP approved – noise model (ANCON2, the UK aircraft noise model).

The initial version includes data for 27 European airports, representing approx. 90% of total number of European people exposed to significant noise levels (above 55 L_{DEN}).

Specific airport data has been collected for these airports, through national/airport contacts, to update available info. This covers specifically runway usage, SID distribution and actual route usage, which are not always available from the directly relevant authorities.

A prototype version of STAPES was released at the end of 2008, with the following characteristics:

- The model enables the calculation of noise contours for exposure-based metrics including L_{DEN}, L_{DAY}, L_{EVE}, L_{NIGHT} and DNL, and counting of the number of people in these contours;
- Due to the number of airports to process , the modelling system operates in a multi-processing environment (multi-threaded calculation), in order to keep the computation times at an acceptable level;
- Once calculated, noise contours are post-processed by the ArcView® GIS software, in order to calculate the number of people inside the different contour bands. The population information comes from a geo-referenced European population database, developed and maintained by the European Environment Agency (EEA);

The prototype should further evolve to enable improved integration/interfacing with different databases available (or to be developed) at EUROCONTROL, including the PRISME data warehouse and the EEMA data warehouse concept. In particular, this should provide a future capability to undertake interdependency/trade-off analyses between noise and emissions. STAPES should also evolve to enable more relevant impact assessments of the SESAR OIS. For instance new metrics could be added to compute the number of people exposed to maximum levels of noise above pre-defined threshold, enabling a better assessment of the benefits of CDA.

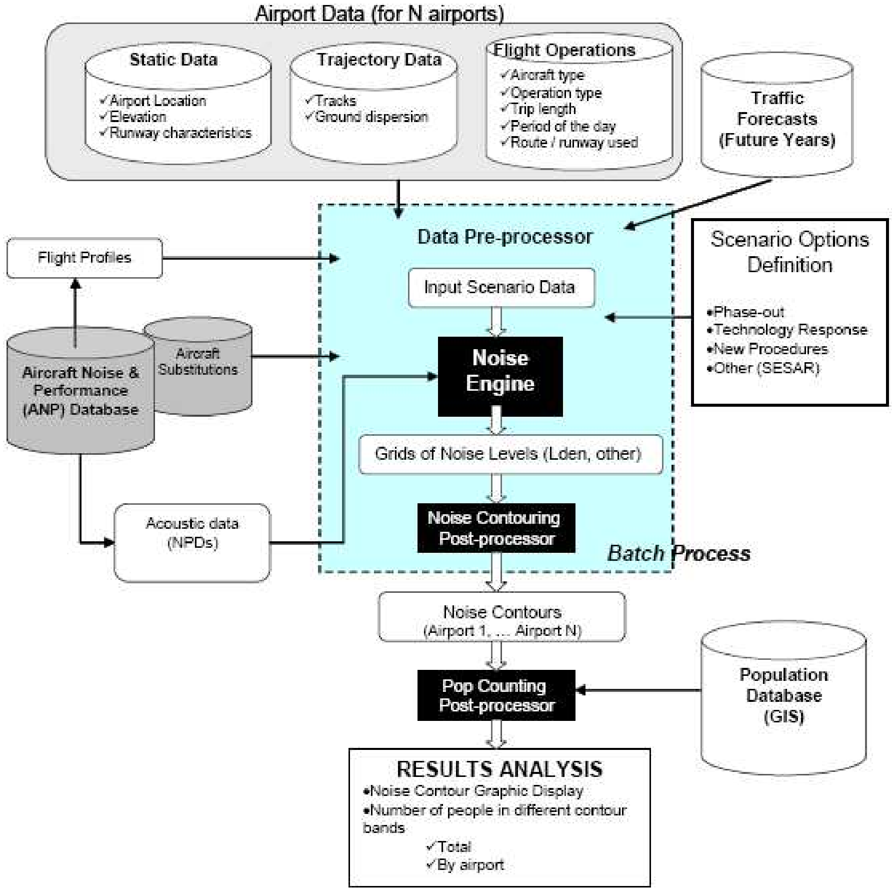

Fig. 6 Overall Architecture of STAPES

The STAPES output will only be made available on aggregated level for evaluated scenarios; no data on individual airports will be released.

4.4 ANCON2 [21] [22]

ANCON, described hereafter, is a European National model, which follows the methodology detailed in [65].

ANCON is the mathematical model used to produce the annual Leq(16-hour) aircraft noise exposure contours[13] published by the Department of Environment, Transport and the Regions (DETR) and previously by the Department of Transport (DoT). It is also used to produce noise exposure forecasts for use in airport planning studies and similar aircraft noise models are used in many other countries. In general, such models may be described as being either empirical or deterministic[14].

Empirical models are those which mainly rely on relating aircraft noise and flight path measurements made around the airports of interest, whilst deterministic models synthesise aircraft flight paths and noise emissions, making use of aircraft noise and performance data (usually provided by aircraft manufacturers: INM is a good example). To calculate noise

[13] For the 'designated' airports Heathrow, Gatwick and Stansted.

[14] The distinction here between 'empirical' and 'deterministic' is not a rigorous one; most, if not all, noise contour models rely to some extent on empiricism.

exposure patterns, both types of model define ground tracks of arriving and departing aircraft along with their 'flight profiles' - the variations of height and speed along the flight tracks, which are then related to noise emissions.

There are significant similarities between the FAA's Integrated Noise Model (INM) and ANCON, having both been created from the same guidance material produced by SAE [3], ECAC [4] and ICAO [5]. Both can be classed as deterministic models where the noise source is related to the flight trajectory. INM synthesises its flight profiles based on assumptions regarding aircraft takeoff weight, engine power settings and airline operating procedures. In contrast, ANCON uses observed flight profiles gathered from aircraft operating at Heathrow, Gatwick and Stansted and estimates engine power setting and airline procedure from this data.

Both models follow international recommended practice and use industry supplied NPD data to relate aircraft thrust and height with noise emission for individual aircraft types. In fact, using identical input data produces similar results with either model. However, at the London airports, over one third of movements are made by aircraft with no matching INM NPD data available. It is for this reason that a local database has been developed by adjusting the basic NPD data [23].

ANCON calculates Leq at a point on the ground by summing the SELs caused by all passing aircraft. The SEL caused by one aircraft depends upon its flight path (in three dimensions), the amount of noise it emits along that path and the way the sound propagates from the aircraft to the ground. A crucial factor governing SEL is that, for each aircraft, the flight path and the noise emission are linked: both depend upon the way the aircraft is flown, i.e. upon the operating procedure - particularly the way in which engine power is varied. For this and other reasons, noise event levels caused by different movements of the same or similar aircraft type can vary markedly.

4.4.1 Features of the ANCON noise modelling process [24]

4.4.1.1 Analysis of flight tracks and profiles form radar data

Where feasible, the UK CAA analysis local airport radar data to ensure the highest degree of modelling accuracy. Extensive in-house radar analysis tools are used to generate mean flight tracks and the associated lateral dispersions for each route, and average flight profiles of height, speed and thrust for different aircraft types.

The diagram below shows a typical representation of a departure route at Heathrow using mean and dispersed tracks, together with the underlying radar data.

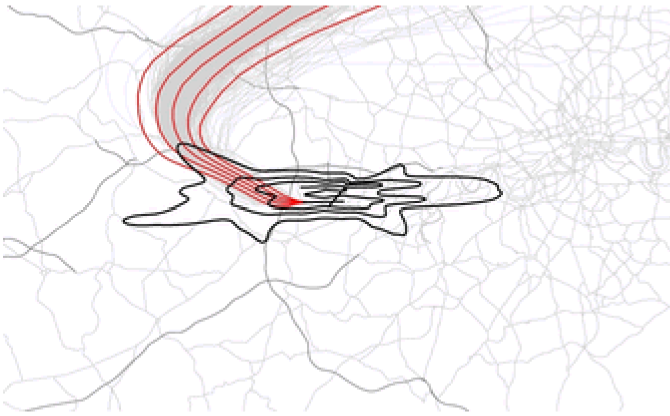

Fig. 7 Typical departure mean tracks © Crown copyright

A typical representation of arrivals at Heathrow using multiple 'spur' tracks is shown below:

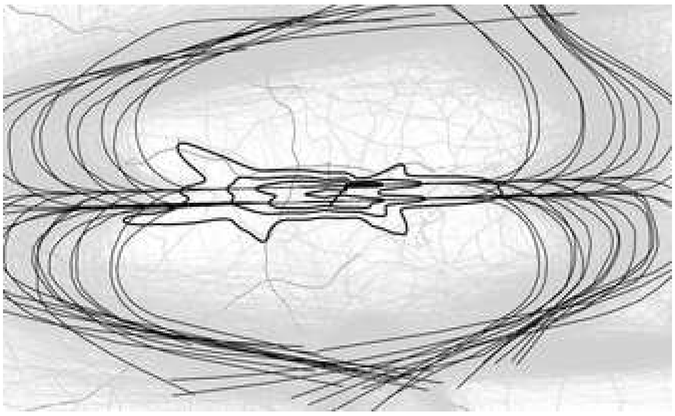

Fig. 8 Typical arrival mean tracks © Crown copyright

It is important to determine flight profiles for the noise dominant types at an airport using local radar data, since they may differ significantly from the 'default' profiles supplied in some noise models. For example, the following diagram shows the difference between the average departure height profile for the Boeing 767 as measured at the London airports, and a 'default' profile contained within another noise model.

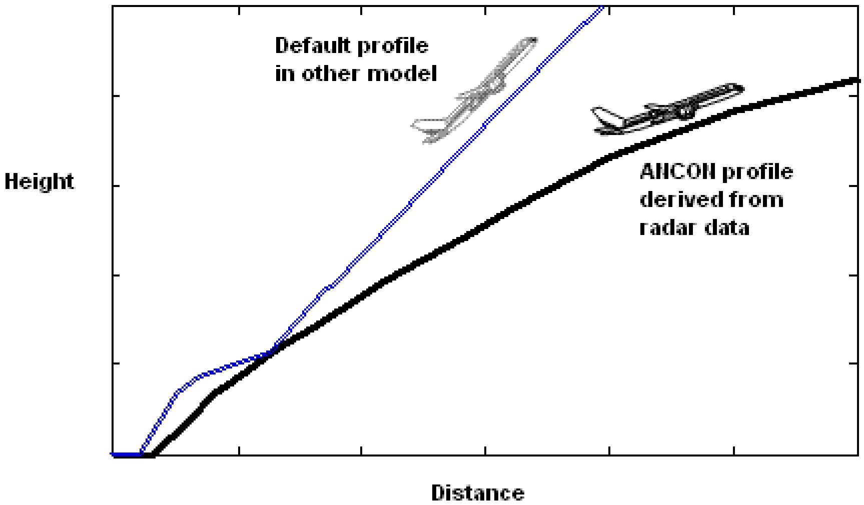

Fig. 9 Comparison between ANCON and another noise model's default profile for Boeing 767

4.4.1.2 Noise database verification

ANCON's noise database is checked and updated on an annual basis by taking several hundreds of thousands of noise measurements around Heathrow, Gatwick and Stansted airports each year. The noise database contains data for specific airframe/engine combinations in the form of 'noise-power-distance' (NPD) curves, thus it is applicable to any airport. In particular, the database contains extensive noise information for the majority of aircraft types that operate from UK airports, unlike other noise models.

4.4.1.3 Terrain modelling

The Environmental Research and Consultancy Department (ERCD-UK CAA) is able to include the effects of terrain in the noise modelling process for any UK airport. Ordnance Survey's 'Meridian 2' terrain data are used to make corrections for the distance between the aircraft noise source and ground receiver position. Locations that are higher than the runway level will be closer to the noise source and thus experience higher noise levels, and vice versa.

Terrain can often have a significant effect on the shape and size of contours, especially where an airport is located in close proximity to hills or valleys.

4.4.1.4 Population database

Through ANCON the UK CAA can estimate the areas, populations and number of households enclosed within each contour level using our population database, which is based on the latest UK Census (2001) and updated annually in the light of new data.

The population and households' data are referenced to individual postcodes (shown as the square dots in Fig. 10 below).

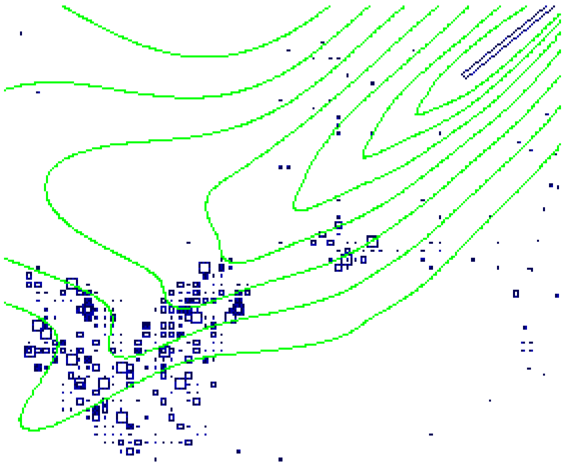

Fig. 10 Population plot

4.4.1.5 Noise sensitive buildings database

Using the selected 'Points of Interest' database, the UK CAA is also able to determine the numbers of noise sensitive buildings (e.g. schools and hospitals) within a particular noise contour, as well as providing detailed information such as the name and address of each building.

Most noise models take aircraft noise data from the aircraft manufacturers to derive estimates of the noise emitted in flight; ANCON differs from most models in this regard because the noise data used is derived from actual noise measurements of aircraft at a range of points around airports.

4.5 SONDEO (ANOTEC) [13]

The software developed by Anotec consists of a pre- and post-processor for the existing noise model software, already developed by Anotec under private funding.

The contour module (NCM) calculates noise contours of L_{den} and L_{night} according to [17] (including the latest recommendations, issued by the EC [25]. The noise and performance databases used are those provided by INM (Version 6.1), since these are one of the few globally accepted datasets publicly available.

The population module (PM) is capable of overlaying the noise contours from NCM on population maps, so as to determine the number of people affected by noise.

A schematic overview of the software ("SONDEO" model) is given below in Fig. 11.

Issued by the Episode 3 consortium for the Episode 3 project co-funded by the European Commission and Episode 3 consortium.

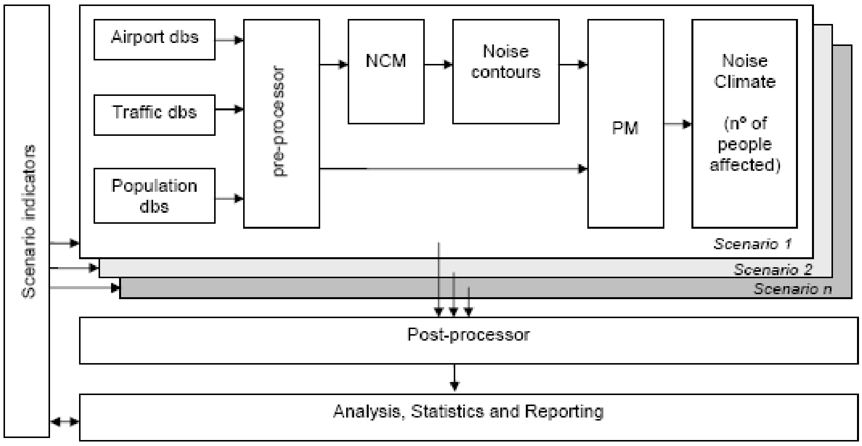

Fig. 11 Schematic overview of SONDEO model.

4.5.1 Noise Contour Module [26]

The NCM is an existing noise model engine, developed by Anotec which uses segmentation to describe the flight profiles.

The NCM requires the following input data:

- Airport data (Location, elevation, meteorological conditions);
- Runway data (ID, location, orientation, length, thresholds);
- Tracks (ID, SIDs, STARs);
- Traffic (Aircraft type, nº of movements per track, runway, stage length and period of day).

The output is: Noise contours.

4.5.2 Population Module [30]

The noise contours as calculated are passed to the Population Module (PM), together with scaling information. This information is necessary in order to link the noise contours with the map of the affected area around the airport, previously digitised at a convenient scale. The link is made by means of the coordinates of 2 points (i.e. the thresholds of the principle runway), together with the known distance between these points (i.e. the runway length). From this data the coordinate system used in the NCM module can thus be reconstructed by the PM and the scale of the digitised map can be deduced.

All residential areas with know population (nº. of inhabitants, density + area, etc.) were previously indicated on the digital map and stored in the Population database.

The PM is capable of combining the noise contours with this population map in the manner as presented in the following graph.

For a grid of points within each populated area the corresponding noise level is calculated by the NCM. With this information the relationship between number of inhabitants exposed and the relevant noise metrics can be determined:

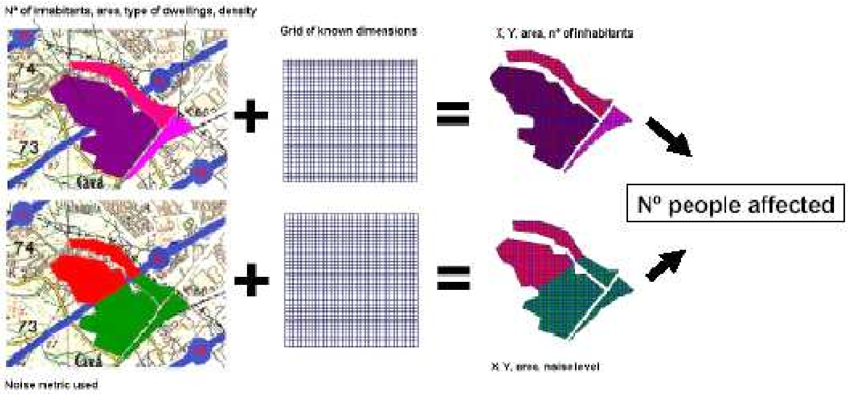

Fig. 12 Combining noise contours and population data (Anotec, 2003)

The number of people affected by noise levels above specific thresholds can then be estimated and, using dose-effect relationships, the number of 'little annoyed', 'annoyed' and 'highly annoyed' people can be calculated.

In 2003, the Commission received a report from ANOTEC that modelled noise contours at 53 airports in the then EU and produced forecasts of future exposure. In 2007 further work was performed with SONDEO building on the additional analysis of the 2003 work: detailed analysis of aircraft movements at 70 airports was added spanning the enlarged EU, EEA and Switzerland, including a detailed study of five representative airports [28].

5 NOISE METRICS AND SUPPLEMENTAL NOISE METRICS [24]

5.1 INTRODUCTION

This section introduces to the reader the standard and most commonly used noise metrics, as well as introducing supplemental ones which are currently becoming very useful in explaining to the public the Airport's noise maps.

Various noise metrics or noise indicators are in use globally to portray the impacts of aircraft noise around airports.

The most common ones are described below:

Leq - This is the 'equivalent continuous sound level', i.e. the average sound level calculated over a defined measurement period.

SEL - 'Sound Exposure Level' noise footprints are sometimes plotted to depict the noise from an individual aircraft movement, such as a departure or landing. SEL is effectively a 1-second Leq, i.e. the sound energy from a single event is normalised to a reference time period of one second. The 90 dBA SEL corresponds to the threshold of sleep disturbance based on large scale studies in the UK.

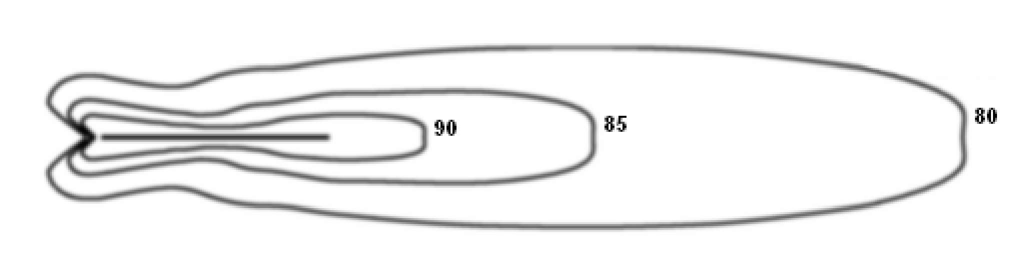

Fig. 13 Departure SEL footprints

N70 - N70 is a metric which originated from Australia and it describes the number of noise events (N) exceeding an outdoor maximum noise level (Lmax) of 70 dBA. The 70 dBA outdoor level was chosen because it corresponds to the Australian standard for the onset of indoor speech interference of 60 dBA (10 dB attenuation by the building fabric with open windows is allowed for). The Australian FDTRS computes its N70 contours indirectly by using INM to produce a detailed TA70 grid and then computing the number of non zero events [32].

5.2 EUROPEAN DIRECTIVE NOISE METRICS FOR NOISE MAPPING

Under EU Directive 2002/49/EC [27], noise maps were generated for major airports in 2007 (for the year 2006) using the following noise metrics:

- L_{DEN} - the A-weighted annual average 24-hour Leq, with penalties of 5 dB for evening (1900-2300) and 10 dB for night-time (2300-0700).
- L_{night} - the A-weighted average sound level over the 8 hour night period (2300- 0700 hours generally). This noise indicator is used to determine the alterations in sleep.

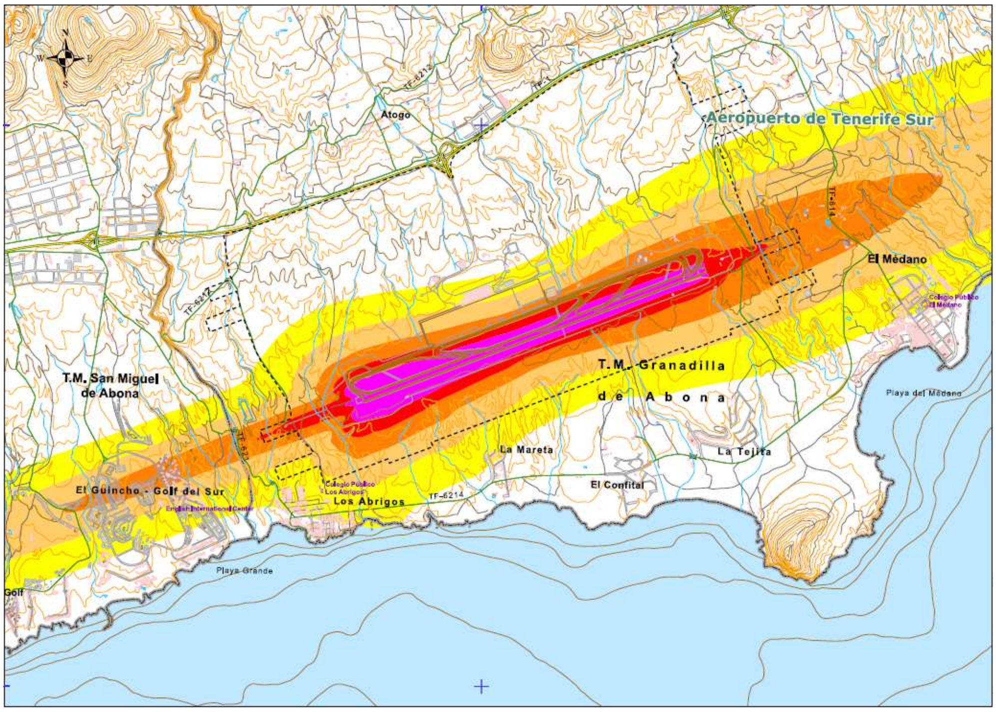

Fig. 14 L_{day} - the annual average 12-hour Leq for daytime (0700-1900) example.

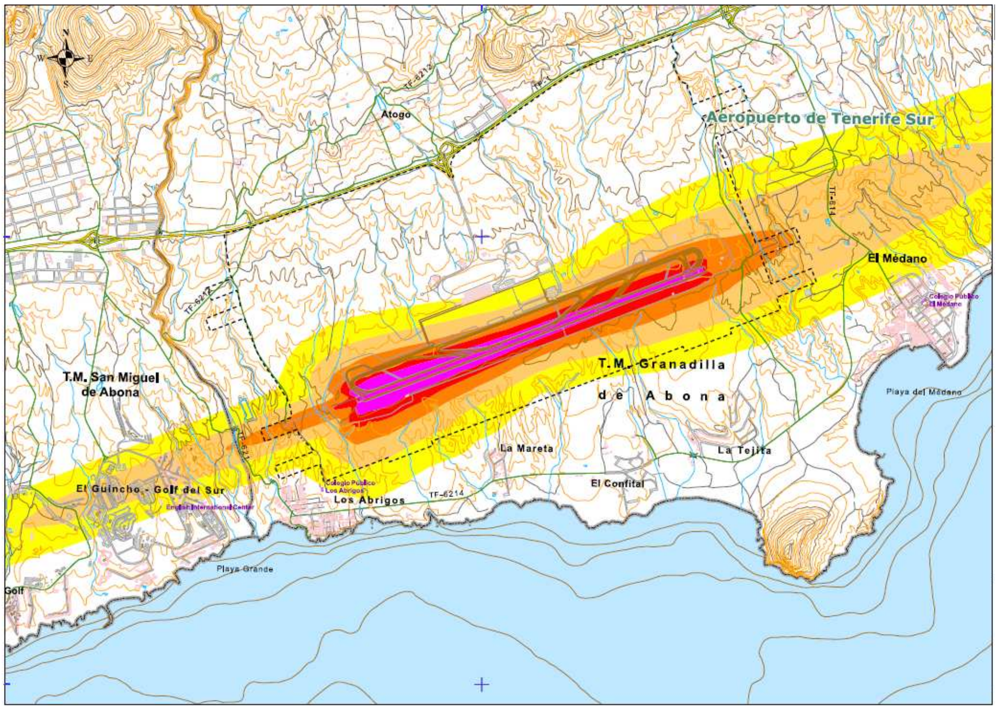

Fig. 15 $L_{evening}$ - annual average Leq evening period (1900-2300) (example).

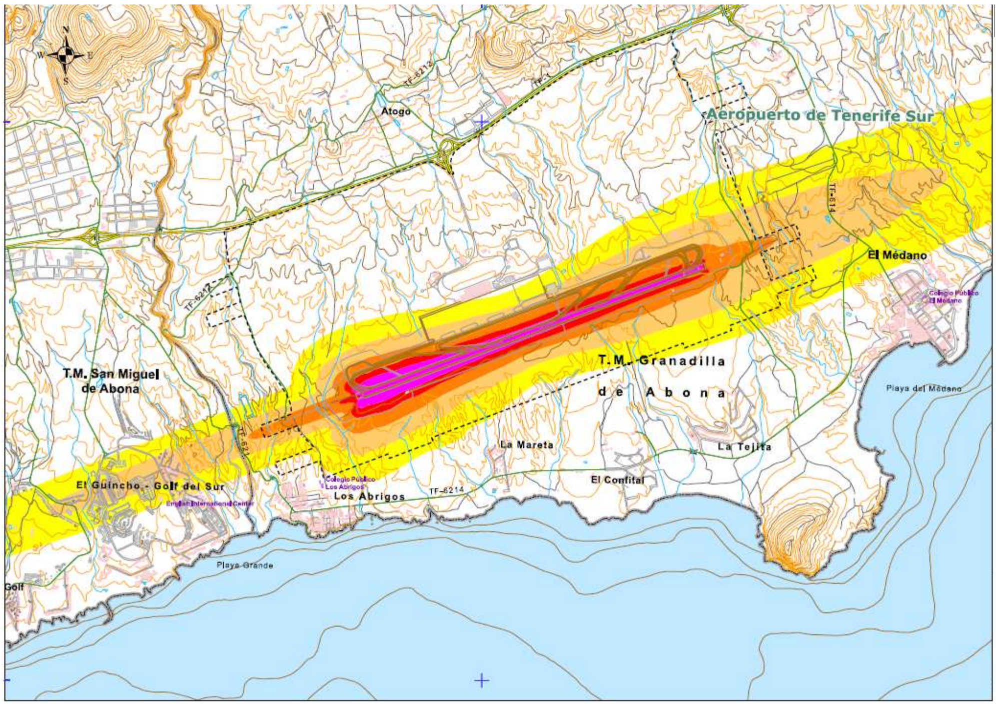

Fig. 16 L_{night} - the annual average Leq night-time (2300-0700) (example).

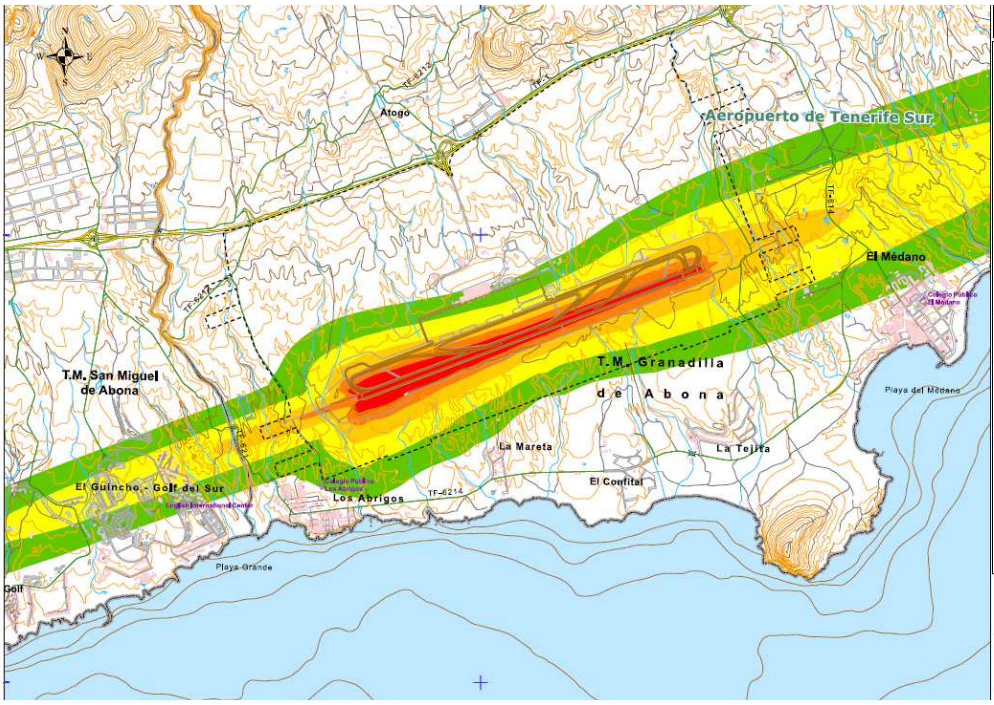

Fig. 17 L_{DEN} - the annual average 24 hour values (example).

5.3 AIRPORT OPERATIONS DIAGRAMS

'Airport operations diagrams', which are based on a concept originating from Australia, are sometimes used to supplement conventional noise contours. They are a useful non-technical means of describing the potential noise impacts around an airport without referring to actual noise levels.

The swathes followed by aircraft on different routes can be shown on the diagram, along with useful statistics such as the frequency and range of daily aircraft movements.

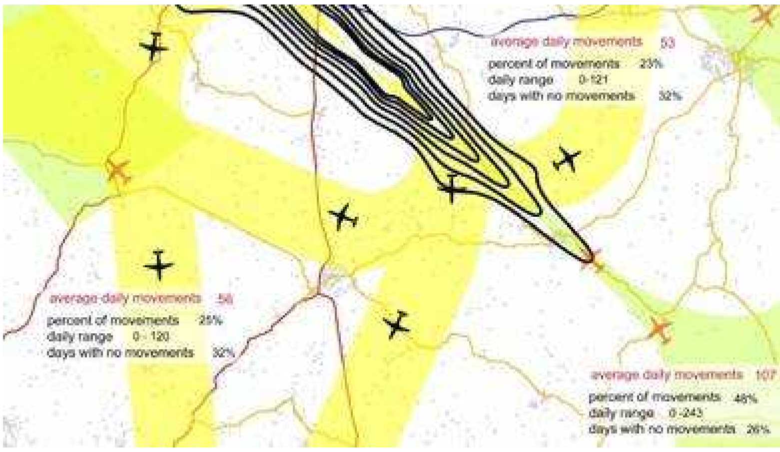

Fig. 18 Airport operations diagram[15]

5.4 COMMONLY USED AND SUPPLEMENTAL NOISE METRICS

In recent years the necessity to communicate and better explain the results coming from a Noise Assessment study to the neighbourhoods affected by noise coming from the airports, has called for the use of supplemental metrics. These together with the currently required ones as LDEN or DNL help to deliver a clearer and more complete view of the situation.

TA - Time Above is the total time that Noise exceeds the threshold during the time period.

NA - Number of Events Above. Counts how many times noise exceeds the selected threshold level in a time period.

Affected population - Number of people near the airport included within the limits of the Lden noise contour at 55dB.

The most appropriate metric for a study varies. It depends on the purpose of the analysis, the audience, and several other factors.

The most commonly used additional metric is the NA. This is because it asks the question, "How often will I hear airplanes and how loud will they be?".

The TA and NA are often used to supplement the DNL metric. This is because the TA and NA break the DNL metric into its component parts. These metrics measure the number of times noise above a certain level is produced in a given time period (NA) and the total time you hear such noise in a given time period (TA).

TA is currently available to INM while NA is post processed by add-on modules not included in INM (see TNIP).

---

15 www.caa.co.uk

5.4.1 The N70[16] - Combining Movement Numbers and Noise Levels

L_{eq} contours do not give information about single event levels, and therefore the impact of one individual noise event is 'lost' within the averaged L_{eq}. The Sound Event Level (SEL) for a single event can be shown as a 'footprint' over the geographical area.

However, a noise footprint does not give any indication of how often such events occur. In order to overcome these problems 'Number Above' contours can be used. These contour maps in effect combine information on single event noise levels with aircraft movement numbers. In the Australian approach contour maps showing the number of events louder than 70 dB(A) have been adopted as the normal presentation i.e. lines showing the number of events above 70 dB(A).

Other noise levels can be used, with different combination of times of day as required. Intuitively it is very easy to conceptualise noise impact using an N70 because it reports aircraft noise in the way that a person perceives it - as a series of noise events some of which are perceptibly intrusive. The N70 is particularly attractive to the layperson in that it is an arithmetic indicator. All other things being equal, if the number of movements over an area doubles the N70 doubles - a very different outcome to logarithmic indicators such as L_{eq}. An example for Sydney airport is shown below.

[16] N70 stands for NA – Number of events above 70 dB.

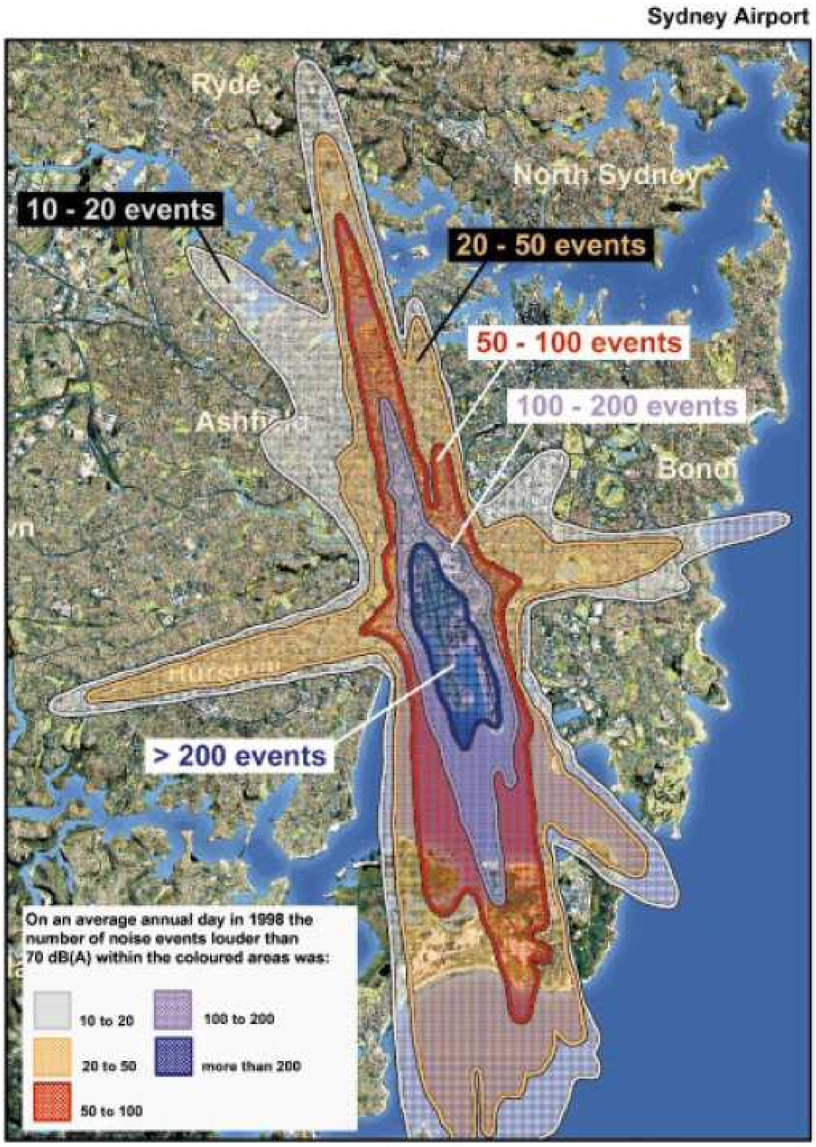

Fig. 19 N70 Average day (1998), Sidney airport [29]

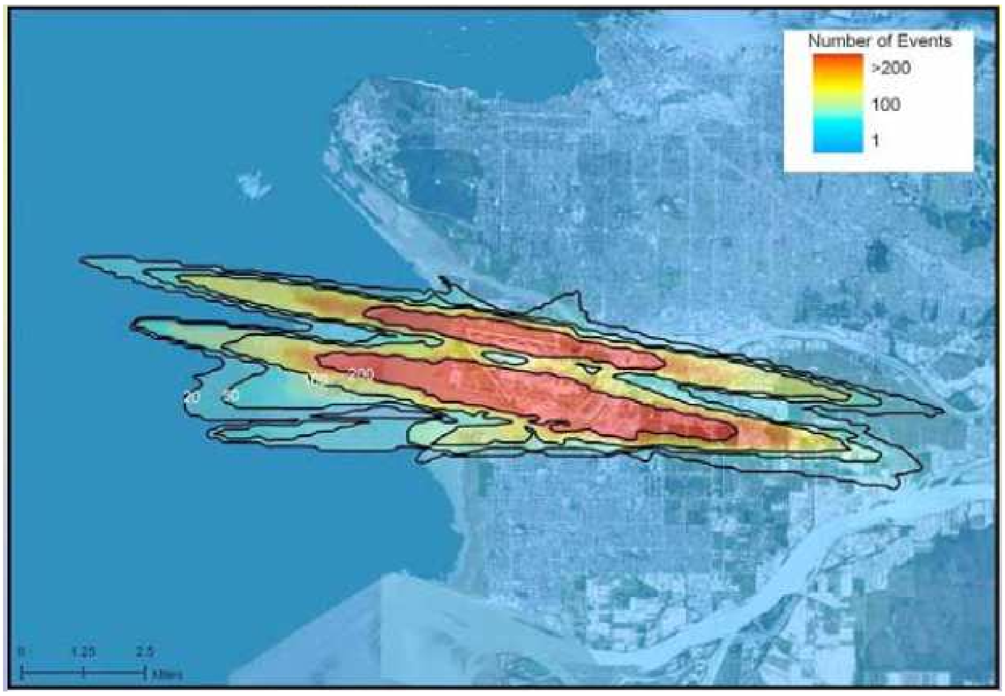

Fig. 20 NA70 metric to assess impacts of various Master Plan Alternatives [31]

5.4.2 Time Above (TA) [31]

The TA metric expresses the amount of time that aircraft noise levels are greater than a given continuous sound level threshold. For a given point, the amount of time each aircraft operation generates noise above the threshold level is calculated. The TA is not a sound level; instead, it is expressed in minutes. The TA is calculated to the nearest minute. A given TA of 0 minutes may actually be a fraction of a minute, which was rounded to zero.

The TA is a useful descriptor of the noise impact of an individual event, or for many events occurring over a certain time period. When computed for a full day, the TA can be compared to the DNL in order to determine the sound levels and durations of events that contribute to the DNL.

In the example below (Fig. 21 Time Above at all sites for all threshold levels [34] the Time Above at each grid point is output by the INM. The TA, expressed in minutes, is then computed for the following sound level thresholds: 55, 60, 65, 70, 75, 80, 85, and 90 dB. These thresholds were selected to begin at a relatively low sound level, and increase until the Time Above was equal to zero at most sites.

Issued by the Episode 3 consortium for the Episode 3 project co-funded by the European Commission and Episode 3 consortium.

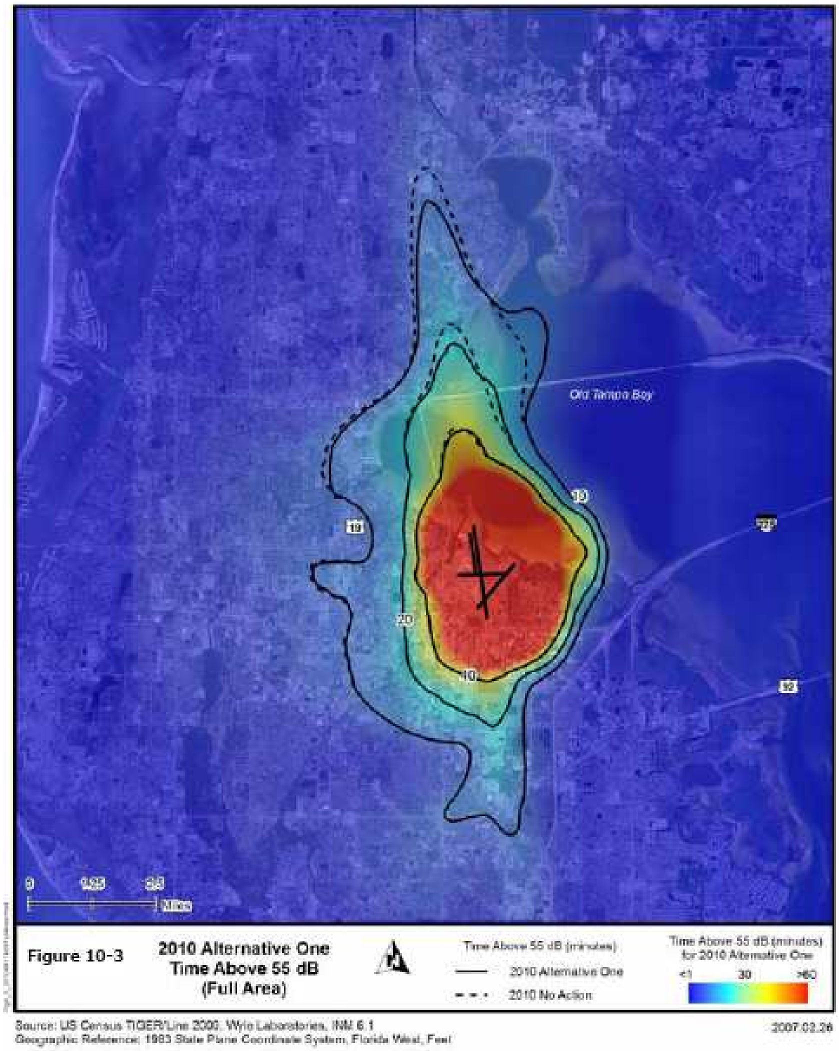

Fig. 21 Time Above at all sites for all threshold levels [34]

This figure shows cumulative values: the TA at higher thresholds is included in the TA at lower thresholds.

6 KNOWN LIMITATIONS OF THE CURRENT INM MODEL WHEN ASSESSING NOISE ABATEMENT PROCEDURES

The scope of NAPs and their development and optimisation is to deliver mitigation of noise on the ground during their operation.

The following section highlights the main limitations of the software making emphasis on the assessment of Noise abatement Procedures. The main body of information is based on a rigorous study conducted under the Sourdine II project during which a noise assessment was performed on newly designed NAPS (CDA based for approach) by using the ENHANCE/INM model (later only the INM model with new NPD curves and a/c profiles delivered by the manufacturers was used).

The limitations and solutions the project highlighted are still valid when applied to NAPs evaluation with the current commercial version of the model.

Part of these limitations have been mitigated through the Sourdine II project's model requirements (see Appendix. 14 and [48][50] for in depth information): enhancements to the model included multiconfiguration NPD curves and updated a/c performance databases. But its availability is not public and its database is still restricted to a small number of aircrafts.

6.1 Section Structure

This section is divided into two main parts:

- The first part tackles the limitations found during the Sourdine II project linked to the analysis of NADPs and NAAPs;
- The second part includes further limitations of the software model which affect any phase of flight (below 10000ft).

6.2 INM limitations with NADPs and NAAPs [48]

The application of the noise assessment model to noise abatement procedures highlighted two main limitations:

- The first one related to a/c performance data, profile characterisation (input profile and a/c operation);
- The second related to the approach phase and the fact that there are no NPD curves to characterise the different slat/flat configuration changes (only one aerodynamic noise state is accounted for at full configuration).

While only the first limitation applies to departures, both limitations apply to approach operations.

6.2.1 Departure procedures

During departure procedures, the noise source state varies mainly with the engine power settings, as the engine component is the dominant source. Therefore, standard departure NPDs, which provide overall noise levels for tabulated power settings spanning normal operating values, provide a good representation of how the noise source state varies during departure operations.

NADPs are based on different operational techniques aiming at increasing the source-to-receiver distance (higher attenuation of sound) and/or setting the engine power to a minimum value (noise reduction at the source). The resulting noise impact on the ground of a given

NADP can be properly estimated by standard INM, provided that a detailed and accurate description of the resulting vertical flight profile – in terms of height, speed and thrust values along the ground position – is available: height (combined with the ground track) determines directly the source-to receiver geometry, speed affects the duration of the noise event (through the duration correction term– for exposure metrics only), whereas thrust determines the noise source state.

The INM aircraft performance model enables to calculate accurate vertical profiles associated to a set of standard departure procedures (based on their *procedural* definition). The calculation process accounts in particular for operational parameters like aircraft takeoff weight, airport elevation, atmosphere and wind conditions. INM provides a series of procedural step options enabling to create user-defined procedures or modify standard ones (these include for instance a “minimum thrust” option, specifying that a step/segment is flown using calculated thrust levels based on the one engine- out procedure).

Even if the *procedural* form, combined with the INM performance model, could be reasonably used to generate the vertical profiles associated to the SII NADPs (close-in and distant procedures), it seemed however preferable (for reliability reasons) to use as far as possible flight profiles directly calculated by manufacturers.

6.2.2 Approach procedures

Standard approach NPDs implicitly take into account an airframe noise state, associated to a specific approach configuration (and speed value). When using standard approach NPDs to model the noise impact resulting from a given approach procedure, the estimated noise levels reflect changes of the engine noise component as thrust varies (through interpolations between the NPD data, provided for different tabulated approach thrust values) but cannot account for any change of the airframe noise component resulting from configuration and/or speed changes. In other words, the predicted noise levels depend only on the flight path geometry and the power setting (along with speed, as far as the duration of the noise event is concerned). The varying configuration and speed parameters during the procedure are only taken into account indirectly, through their effect on the resulting engine power settings (to balance the other forces).

Further studies also demonstrated this by bringing to the fore that parameters such as the ID of the flaps hardly modified the results obtained for the least favourable case by 1 dB [32].

Below in Fig. 22 the difference can be noticed between using the standard NPD and the multiconfiguration NPDs, on the same procedure. The difference between the red and blue areas is in fact what was missed out by the current INM.

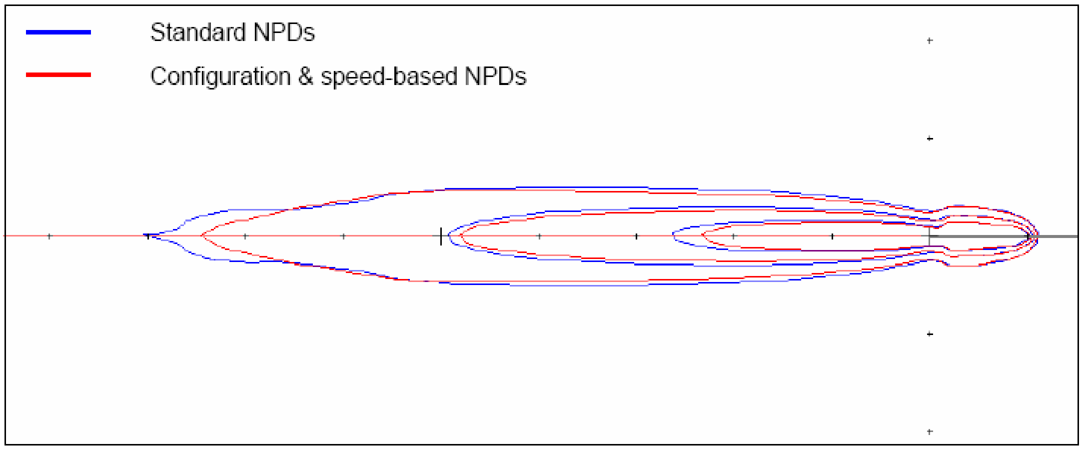

Fig. 22 L_{DEN} contours (55 to 65dBA[17])

However new multiconfiguration NPDs do not solve all the problems linked to the assessment and characterisation of NAAPs.

Another difficulty when assessing on an airport scale the noise impact of advanced approach procedures like those studied in Sourdine II, deals with the detailed definition of the vertical flight profiles associated to each aircraft type, when flying the procedures. Indeed, the generic definition of the SII approach procedures (both baseline and CDAs) resulted in variable altitude, thrust and/or speed profiles from one aircraft to another, as these depended on the aircraft performance characteristics and other operational parameters or constraints. Additionally, the flap settings along the flight profiles have also to be known, as the aircraft configuration is an additional input parameter for the new noise calculation module mentioned above. Again, the flap setting schedule depends highly on the aircraft type, as flap/slat deflection to next position is usually performed at specific speed values, which vary from one aircraft type to another.

The INM aircraft performance model, which calculates vertical profiles associated to *procedural* profiles, has some limitations in the case of approach procedures. In particular, it does not perfectly model thrust values associated to flight segments with deceleration and/or idle thrust (the basis of any CDA procedure). Additionally, the *procedural* definition of flight procedures requires anyway the specification of aircraft configuration and speed information on some of the segments, which can only be provided by manufacturers for each aircraft type.

6.3 Other Limitations of the INM Software

6.3.1.1 User Defined Flight Profile Variables

This option allows user-defined flight profiles to be built up to suit study requirements by specifying position, thrust, speed, and configuration. However, errors arise due to oversimplification of the actual flight path, and the approximation of the aircraft's performance.

Similar errors will arise when using the standard departure and approach profiles included in the INM, due to the differences between an aircraft's actual profile and the profile that is being modelled.

Dispersion of the flight path can be modelled within the INM. However individual variations in aircraft position due to air traffic control vectoring and variations in performance for a given configuration may give a much larger dispersion both laterally and vertically.

---

[17] Procedure II comparison, SII_WP5_D5-2_v10.pdf (Sourdine II project).

Different campaigns evaluating the influence of real vs. modelled (INM option) lateral dispersion (i.e. Madrid Barajas, 2007) have shown, comparing radar data dispersion of air traffic with modelled dispersion through INM, that the difference in dBs is negligible.

6.3.1.2 Headwind Speed and Direction

A datum headwind of 8 knot (4.12 m/s) is used by the INM.

In addition to altering an aircraft's flight profile which directly affects the noise results, the direction and magnitude of the headwind affects the propagation of aircraft noise and the level of turbulence. These effects although of a second order compared to the influence on a/c performance, do cause distortion of the noise level.

6.3.1.3 Crosswind and Wind Gradient

INM does not account for crosswind conditions or wind gradient when calculating the noise footprint. Crosswind and wind gradient have two effects:

- Influence on the a/c's performance:

  Maintaining the a/c on a fixed APP (i.e. PRNAV route) or a fixed DEP corridor may require under the above conditions of wind, increases in thrust and possibly a certain degree of dispersion, which would not be accounted for by INM. Although the occurrence of crosswind may well be statistically diluted on a yearly study, the evaluation of a concept based on using it or taking advantage of it would fail into showing any change from the normal operations.

  Wind gradient is instead very important in order to rightly characterise the a/c's performance during an APP or a DEP.

- Noise propagation:

  The result is that the noise footprint produced will not take into account wind direction thus noise unbalance cannot be detected. This limitation can possibly hinder the assessment of those operational concepts based on taking advantage of crosswind conditions.

6.3.1.4 Airport Noise Taxi-APU[34]

At present, modelling tools that approach the evaluation of the environmental noise in the vicinity of an airport in a global way do not exist: that is to say considering all the sources involved. The models normally used (INM Integrated Noise Model, FAA) only bear the aircraft noise attending take off, landing and overfly operations. They do not consider other sources such as taxi or handling operations, specially the utilization of the auxiliary power units.

An internal study conducted by INECO, recently developed a specialized methodology for the acoustical characterization of the main sources that take place along the taxiways and the ramps of an airport. The study also analysed the introduction of the measured data into commercial software by means of an MS Access® database structure and its interconnection with the results obtained from INM.

As a result, the model obtains the noise effect caused by the airport considering all the above quoted sources.

6.4 Summary of Current Limitations when conducting an airpot scale a study [17]

The evaluation of operational improvements concerned with improved flight operational procedures would be very limited and possibly masking the benefits since:

- Limited configuration change data:
  - New procedures (as CDA) do not use only standard aircraft configuration schedules;
  - Radar does not provide aircraft configuration;
  - Modelling capability is there but need information from outside sources (updated ANP/INM database).
- Limited aircraft performance data:
  - EUROCONTROL currently working with Airbus to supply necessary data for entire Airbus fleet, FAA working on additional Boeing data.
- Limited use of wind data:
  - Need to balance accuracy requirements vs. publicly available wind data sources Current Limitations.
- Supplemental Noise Metrics:
  - TA – Time Above (only estimated);
  - NA – Number of Events Above (only if post-processed from TA with ad-on module.
- Other general limitations:
  - No value or option for TAXI Noise;
  - INM only calculates noise based on line of sight distance and only applies a default damping coefficient for loss of sight.

The result is that procedural profiles are not good for CDA characterisation since neither the NPD curves characterise the aerodynamic noise, plus the aircraft performance data is not showing the procedures improvement correctly. While fixed point profiles should be Industry delivered or reverse engineered (with the problems related to validation of that process).

Issued by the Episode 3 consortium for the Episode 3 project co-funded by the European Commission and Episode 3 consortium.

7 LIST OF OPERATIONAL IMPROVEMENT STEPS: MITIGATING NOISE

7.1 INTRODUCTION

During the Screening and Scoping Task of Episode 3's [56] a list of OISs was isolated for their direct/indirect/OIS enabler contribution to the mitigation of noise.

The following OI Steps are the ones for which a Noise assessment tool would be applied for validation purposes.

Table 1 presents the list of OI Steps that would be analysed for validation.

Operational Improvement Steps	Phase of flight
AOM-0701 - Continuous descent approach (CDA)	APP
AOM-0702 - Advanced Continuous descent approach (ACDA)	APP
AOM-0703 - Continuous climb departure.	DEP
AOM-0705 - Advanced continuous climb departure.	DEP
AOM-0704 - Tailored arrival.	ARR/APP
AO-0301 - Crosswind Reduced Separations for Departures and Arrivals	ARR/DEP
AO-0303 - Fixed Reduced Separations based on Wake Vortex Prediction	ARR/DEP
AO-0702 - Improved relations to neighbours.	ALL

Table 1 Episode 3 OISs mitigating Noise

AO-0702 relies on the noise assessment models as one of the main sources of information and data (noise footprints, flight frequencies, etc...) to communicate improvements or impacts.

The link between the software model and the OIS is very important: the use of certain metrics and graphic solutions to clarify the noise results to the public is a paramount objective for this OIS.

7.2 OPTIMIZING CLIMB/DESCENT

7.2.1 AOM-0701 - Continuous descent approach (CDA)

The goal of this OIS is that under specific circumstances (i.e. low traffic density) a basic CDA is used on approach through adapted procedures (no need for further ground system automation).

Effect [36], [37]:

- The conventional approach (Standard Approach):

  With the conventional aircraft approach, an aircraft would be given clearance by Air Traffic Control from the bottom level of the holding stack (normally an altitude of 6000 or 7000 feet) to descend to an altitude of typically 3000 feet. The aircraft would then fly level for several miles before intersecting the final 3 degree glide path to the runway. During this period of level flight, the pilot would need to apply additional engine power to maintain constant speed.

- The Continuous Descent Approach (CDA):

  In contrast to a conventional approach, when a CDA procedure is flown the aircraft stays higher for longer, descending continuously from the level of the bottom of the stack (or higher if possible) and avoiding any level segments of flight prior to intercepting the 3 degree glide path. A continuous descent requires significantly less engine thrust than prolonged level flight.

Benefits:

- Higher for longer:

  Because the aircraft flying a CDA is higher above the ground for a longer period of time, the noise impact on the ground is reduced in certain areas under the approach path.

- Less engine thrust:

  Noise on the ground is reduced further because a CDA eliminates the period of level flight when additional engine thrust would have been used.

- Use of reduced landing configuration when possible from FULL, lowering aerodynamic noise;

- Noise reductions up to 5 decibels:

  Depending on the location and aircraft type, the noise benefit from a CDA compared to a conventional approach could be up to about 5 decibels (a change of 3 decibels is just noticeable to the human ear).

Limitations:

Benefits are only perceived away from the airport, commonly between 10 and 25 miles from the airport's RWY. Benefits are thus limited to certain locations.

The procedure cannot always be flown: it may sometimes not be possible to fly a CDA due to airspace constraints, or overriding safety requirements. Also, when flying a CDA an aircraft may still require a short segment of level flight in order to reduce speed or to reconfigure.

7.2.2 AOM-0702 - Advanced Continuous descent approach (ACDA)

This improvement involves the progressive implementation of harmonized procedures for CDAs in higher density traffic. Continuous descent approaches are optimized for each airport arrival procedure. New controller tools and 3D trajectory management enable aircraft to fly, as far as possible, their individual optimum descent profile (the definition of a common and higher transition altitude would be an advantage).

Effect:

The implementation of this OIS compared to AOM-0701 solves[18] many of the limitations:

- Such as the repeatability of the procedure by nearly all the air traffic in approach, and the possibility to overcome airspace or traffic constraints;

- Performance managed use of the slats/flaps for low power/low drag approach;

[18] Sourdine II and OPTIMAL European funded Projects results.

- Also the noise mitigation delivered would not be limited to the 10 to 25 miles area but could be delivered up to 3/4NM from the RWY [6], [7].

7.2.3 AOM-0703 - Continuous climb departure.

Managed Departures, managed thrust on take off, continuous climb departure routes all contribute to fuel efficiency and noise reductions. When traffic and the urban areas around the airport permit, continuous climb departure is used to reduce noise by a higher altitude trajectory around the airport. Fuel consumption is reduced by flying optimized profile (no vertical containment required).

Effect:

This OIS provides mitigation to the noise perceived on take-off by increasing the distance to noise. The benefits on the other hand will depend upon tailoring the managed procedure to the location of the neighbourhoods surrounding the airport.

7.2.4 AOM-0704 - Tailored arrival.

This procedure is a kind of Continuous Descent Approach (CDA) in which descent is made mostly on idle power. The objective is to minimise fuel consumption (operating cost) as well as noise production. In an operating environment with low traffic volume these optimized approaches can easily be made (as already done at several airports worldwide, especially during night time) but in case of high traffic volume the concept has still to be proven.

Effect:

For this OIS the same holds apply as for the CDA procedure (AOM-0701). Especially if the horizontal segment at or below 3000 ft is not flown. Trials made by ANZ19 (Air New Zealand) allowed a/c to make full use of the interlinked onboard and ground technology to descend into San Francisco airport with minimal direct Air Traffic Control (ATC) intervention.

A/C by being able to continuously descend into the airport, rather than flying a series of level segments as required under standard ATC procedures, can reduce noise as well as fuel consumption.

7.2.5 AOM-0705 - Advanced continuous climb departure.

Managed Departures, managed thrust on take off, continuous climb departure routes all contribute to fuel efficiency and noise reductions. The goal is to use continuous climb departure in higher density traffic. This should be enabled by system support to trajectory management.

Effect:

For this OIS the same holds as for the continuous climb departure procedure (AOM-0703). If this OIS leads to a higher number of continuous climb departures, this means that the effect of this OIS will be stronger compared to the effect of AOM-0703.

[19] Air Transport Intelligence news; San Francisco Tailored Arrival Trials Boeing Perspective Brad Cornell, Senior Engineer, 777 Flight Crew Operations, March 21, 2007.

7.3 NEIGHBOUR AND PUBLIC RELATIONS

7.3.1 AO-0702 - Improved relations to neighbours.

ATM stakeholders have to improve their understanding of the existing and emerging perceptions, and needs and expectations of society, especially in terms of the management of adverse socio-environmental impacts. A better understanding by the local community of the real disturbance is achieved through provision of more accurate and accessible information (noise, tracks, air emission, etc.) as well as through improvements in decision-making, consultation process and impact management (better transparency towards community). A commonly agreed development path for the airport and the surrounding communities is achieved (incl. e.g. noise protection zones, noise protection programs).

Effect:

This OIS does not mitigate noise rather the relationship between the noise producer and the noise receiver trying to make the perception more acceptable: feedback, improved relations with local communities, use of alternative non acoustic measures [38], common decision making, etc...are part of this OIS.

The OIS has been included since Noise Metrics and the capability of calculating them and showing them (output of the noise results) is increasingly important as shown by many studies such as done in Australia or the USA.

7.4 CROSSWIND REDUCED SEPARATIONS DESCRIPTION

Under certain crosswind conditions, it may not be necessary to apply wake vortex minima.

7.4.1 AO-0301 - Crosswind Reduced Separations for Departures and Arrivals

Suspension, could be granted for WT (Wake Turbulence) separations on departure and arrival, under suitable crosswind conditions.

7.4.2 AO-0303 - Fixed Reduced Separations based on Wake Vortex Prediction

Reduction could be granted on WT separation minima on arrivals, under suitable crosswind conditions.

7.4.3 Rationale

The objective of the two OISs is to reduce dependency on wake vortex operations which under suitable weather conditions, will lead to reduced arrival / departure intervals, with a positive effect on delays and runway throughput.

The question of reducing/suspending WT separations during departures has been analysed inside the CREDOS project as part of its Environmental Case.

The conclusions of the EIA (based on the INM 7.0 software) suggested that wind unbalance could be included by any Noise Assessment tool in order to evaluate the shift in noise footprint when the concept is applied under crosswind conditions. Only headwind conditions are, of course, included.

Another point that was raised is that since INM only works with number of aircrafts per period, the temporary application of the concept (variable weather conditions and peak hours) could not be modelled without incurring in a cumbersome workload for the modeller.

8 SURVEYED NOISE MODELS LIMITATIONS' APPLICABLE TO THE VALIDATION OF THE SESAR OISS

The phases of flight considered by the models (only to a height of 10,000ft), during an assessment are the following:

- Approach (APP);
- Landing (Final APP);
- TAXI [20];
- Take-off (DEP);
- Climb (DEP).

The next two sections are dedicated to the analysis of the models for which enough information was available to compare the OIS modelling requirements with the models' capabilities to do so.

An in depth study was possible only for ENHANCE/INM-INM and STAPES. This was possible thanks to the overwhelming information found and the support of EEC. However many of the results can be extrapolated to the other models based on the communality of the methodology use and the compliance to [51], often reminded in the document.

For each model, two tables were produced:

- The first one lists the OISs with their corresponding flight phase together with the specific improvement it delivers to the Noise sphere. Later pointing out the specific modelling limitation;
- While the second table contains the recommended solutions (or the short-term mitigating possibilities currently available).

8.1 ENHANCE/INM AND INM

List of OISs	Flight Phase	Specific improvement	Related INM Limitation
AOM-0701 - Continuous descent approach (CDA)	APP	Performance based profiles Higher for longer Less engine thrust Reduction in level segments Use of reduced landing configuration when possible from FULL	Approach procedures (Sec. 6.2.2)
AOM-0702 - Advanced Continuous descent approach (ACDA)	APP	Performance based profiles Performance managed use of the slats/flaps for low power/low drag approach.	Approach procedures (Sec. 6.2.2)

[20] TAXI phase is not included by the INM, so noise during TAXI is not accounted for.

List of OISs	Flight Phase	Specific improvement	Related INM Limitation
AOM-0703 - Continuous climb departure	DEP	Performance based profiles	Missing a/c performance data (Sec. 6.2.1)
AOM-0705 - Advanced continuous climb departure	DEP	Performance based profiles	Missing a/c performance data (Sec. 6.2.1)
AOM-0704 - Tailored arrival[21]	ARR/APP	Performance based profiles	Only below 10.000ft. Approach procedures (Sec. 6.2.2)
AO-0301* - Crosswind Reduced Separations for Departures and Arrivals	ARR/DEP	Noise footprint reflects wind direction (propagation)	Crosswind not accounted for by INM. TAXI noise (Sec. 6.3.1.4)
AO-0303* - Fixed Reduced Separations based on Wake Vortex Prediction	ARR/DEP	Noise footprint reflects wind direction (propagation)	Crosswind not accounted for by INM TAXI noise (Sec. 6.3.1.4)
AO-0702 - Improved relations to neighbours	ALL	Limited number of supplemental noise metrics	NA not included. Affected people limited geographic scope
*: AO-0301 (and 0303) OIs improve airport capacity. The only (marginal) effect they might have in terms of noise exposure is through the resulting distribution of operations over day, evening and night time periods.			

Table 2 Specific limitations of Enhance/INM and INM per OISs

Nº.	OISs	Recommendation/Mitigation	CASE
1	AOM-0701 - Continuous descent approach (CDA)	Updated Procedural Profiles delivered by industry* Use multi-configuration and multi-speed approach NPDs	A
2	AOM-0702 - Advanced Continuous descent approach (ACDA)	use the multi-configuration and multi-speed approach NPDs Updated Procedural Profiles delivered by industry*	
3	AOM-0703 - Continuous climb departure.	Updated Procedural Profiles delivered by industry* Better characterisation of the	

[21] Arrivals include STAR-APP-Final APP and Landing.

		profiles	
4	AOM-0705 - Advanced continuous climb departure.	Updated Procedural Profiles delivered by industry* Better characterisation of the profiles (ENHANCE)	
5	AOM-0704 - Tailored arrival.	Updated Procedural Profiles delivered by industry*	
6	AO-0301 - Crosswind Reduced Separations for Departures and Arrivals	Include displacement due to wind direction and different a/c performance	B
7	AO-0303 - Fixed Reduced Separations based on Wake Vortex Prediction	Include displacement due to wind direction and different a/c performance	
8	AO-0702 - Improved relations to neighbours.	Use of STAPES/MAGENTA for wider scope; TNIP or other module/update to deliver supplemental noise metrics	C
*Updated and expanded INM/ANP database (see Sec. 6.4).			

Table 3 OISs Recommendation and Mitigation proposals

8.2 Overview of the INM and ENHANCE/INM models [39]

8.2.1 CASE A Mitigation/Recommendations

While INM can considerably model well Departure OIS (Nº. 3 & 4) the same cannot be said about the Approach OIS (Nº. 1-2-5) as far as noise assessment is concerned, the phase of approach is particularly complex, since the airframe noise component during this phase may exceed the contribution of engines noise itself. Therefore, efforts should be carried out to produce more NPD curves (configuration curves) to better evaluate the impact of the aircraft configuration changes (flaps and gear) on the overall noise on one hand, and on the engines thrust level on the other hand [40].

The "Golden Standard" and the only way to mitigate and solve the problem is to update the profiles to the ANP database by adding:

- Further A/C performance data (CDA, TO and Climb);
- More and updated NPD curves which allow for multi-configuration noise modelling (flaps, slats, landing gear up/down);
- New thrust and Drag coefficients.

And make sure these are taken into account by the model's engine.

This is the only way these OISs can be analysed correctly and sensibly. Moreover it allows their benefits to be shown.

Again if the above is not the case ENHANCE can be used when the aircraft profiles are not available from industry, but the results are not comparable to the above[22].

ENHANCE supports the assessment of these OISs since it provides the INM with the fixed point profiles through calculating the engine thrust level of the aircraft through a "reverse-engineering" approach, on the basis of the available data (position, altitude and speed i.e. coming from RADAR [40]).

Results show a fairly good correlation between the calculated thrust and the one given by manufacturer, especially during idle thrust phases. Main differences appear during phases of quick configuration changes, mainly because of some imprecision in the assessment of drag and lift, and also because configuration changes are modelled as instantaneous. A constant shift in thrust is also observed during the final approach segment, which is probably linked to the aircraft angle of attack.

8.2.2 CASE B Mitigation/Recommendations

INM does not include crosswind direction when producing the noise footprints.

OISs nº. 6-7 under the CREDOS hypothesis, for example, showed that they do not impact the noise perception around the airport as shown by its Environmental Case [65]. Rather the OIS modifies the traffic noise distribution along the periods of the day (among Day, Evening, Night period) making sure it corresponds to the scheduled one.

On the other hand, the conclusions of [65] (based on the INM 7.0 software) suggested that wind unbalance (propagation along the wind direction) could be included possibly as an option in any Noise Assessment tool. The option would evaluate the shift in noise footprint when the operational concept is applied under crosswind conditions (even though the influence of wind on Noise is of a second order).

Another point that was raised is that since INM only works with number of aircrafts per period, the temporary application of the concept (due to variable weather conditions and peak hours) cannot be modelled without incurring into a cumbersome workload for the modeller.

8.2.3 CASE C Mitigation/Recommendations

Supplemental Noise Metrics as NA, detailed in Sec. 5, are increasingly important to show to the public (i.e. the neighbourhoods), together with standard metrics, the changes in noise pattern but also the supposed benefits or improvements of implementing new operations. Currently this is offered through private or publicly available post-processing software modules as TNIP.

The number of population affected by noise, depending on the geographic scope and position, can be obtained by using census data, but the geographic range is restricted to the particular airport surroundings. At the time only the MAGENTA software had the wider capability of covering the USA (only). In Europe in the near future through the STAPES model this capability will be available too.

[22] The analysis of the CDA based NAAPs of the Sourdine II project was performed through a limited (in aircraft fleet) "Golden Standard", ENHANCE was only used to match these profiles to the horizontal tracks given by RADAR.

8.3 STAPES

As for the ENHANCE/INM-INM tools, the same analysis was made for STAPES, the newly developed multi-airport noise assessment model.

List of OISs	Flight Phase	Specific improvement	Related Limitations
AOM-0701 - Continuous descent approach (CDA)	APP	Performance based profiles Higher for longer Less engine thrust Reduction in level segments Use of reduced landing configuration when possible from FULL	STAPES includes an aircraft performance calculation module enabling to compute flight profiles (for both APP and DEP ops) from standard or user-defined flight procedures. For CDAs (and APP in general), the current main limitation is the lack of appropriate manufacturer-supplied aircraft performance data to run the module. However, this issue is being addressed, in collaboration with manufacturers: Airbus has produced and delivered the required performance data, which will be added in ANP (and therefore STAPES) this year. For Boeing (and other manufacturers), the work has still to be done. On the noise modelling side, STAPES uses standard approach NPDs, which capture a specific - fixed - airframe noise component. By using such NPDs, STAPES does not account for the variations of the airframe noise component with speed and aerodynamic configuration changes during approach and landing.
AOM-0702 - Advanced Continuous descent approach (ACDA)	APP	Performance based profiles Performance managed use of the slats/flaps for low power/low drag approach	Same as above. In addition, some specific ACDA might require to update the aircraft performance calculation module of STAPES to support additional procedural steps.

List of OISs	Flight Phase	Specific improvement	Related Limitations
AOM-0703 - Continuous climb departure	DEP	Performance based profiles	The STAPES aircraft performance calculation module can model that sort of procedure.
AOM-0705 - Advanced continuous climb departure	DEP	Performance based profiles	Might need an update of the aircraft performance calculation module to account for additional procedural steps (in the case of optimised thrust management for instance).
AOM-0704 - Tailored arrival[23]	ARR/APP	Performance based profiles	Same remarks as for AOM-0701.
AO-0301 - Crosswind Reduced Separations for Departures and Arrivals	ARR/DEP	Noise footprint (propagation along the wind direction)	Crosswind can be accounted for by the STAPES aircraft performance calculation module (crosswind meaning zero headwind from a climb performance point of view).
AO-0303 - Fixed Reduced Separations based on Wake Vortex Prediction	ARR/DEP	Noise footprint (propagation along the wind direction) See above	Same as above.
AO-0702* - Improved relations to neighbours	ALL	Limited number of supplemental noise metrics	LAmax-based metrics (including NA70) would need to be supported as well, especially to quantify the noise benefit of CDAs, which is mostly visible outside the "usual" noise exposure contours (e.g. Lden 55).
*: Using the European population database developed and maintained by the European Environment Agency (EEA), STAPES can estimate the number of people inside noise contours, what ever their size. However, the noise metrics currently supported by STAPES are only exposure (SEL)-based metrics (e.g. Lden, DNL, Leq, etc.).			

Table 4 Specific limitations of STAPES per OISs

[23] Arrivals include STAR-APP-Final APP and Landing.

Nº.	OISs	Recommendation/Mitigation	CASE
1	AOM-0701 - Continuous descent approach (CDA)	Updated and expanded INM/ANP database. Use the multi-configuration and multi-speed approach NPDs.	A
2	AOM-0702 - Advanced Continuous descent approach (ACDA)	See above, plus the potential need to update the aircraft performance calculation module of STAPES to support additional procedural steps.	
3	AOM-0703 - Continuous climb departure.	Covered.	
4	AOM-0705 - Advanced continuous climb departure.	Might need an update of the aircraft performance calculation module to account for additional procedural steps (in the case of optimised thrust management for instance).	
5	AOM-0704 - Tailored arrival.	Covered.	
6	AO-0301 - Crosswind Reduced Separations for Departures and Arrivals	N/A.	B
7	AO-0303 - Fixed Reduced Separations based on Wake Vortex Prediction	N/A.	
8	AO-0702 - Improved relations to neighbours.	Update the STAPES model to enable the calculation of LAmax-based noise metrics, including in particular the NA70 (or NAxx) metric.	C

Table 5 OISs Recommendation and Mitigation proposals

8.4 OVERVIEW OF THE STAPES MODEL

8.4.1 CASE A Mitigation/Recommendations

On the aircraft performance modelling side, ensure that Boeing (and possibly other manufacturers) delivers the same sort of APP performance data as recently done by Airbus.

On the noise modelling side, seek approval from Airbus and Boeing to use the multi-configuration and multi-speed approach NPDs developed for the Sourdine II project (due to the sensitive nature of such data). There would also be a need to expand the list of aircraft having multi-conf approach NPDs (currently, 8 Airbus + 4 Boeing aircraft), through contracts with manufacturers.

Update the STAPES model to support the use of multi-conf/speed NPDs.

Another option could be to develop and apply speed (and configuration) adjustments to the current standard approach NPDs. But this would require significant development and V&V work.

8.4.2 CASE B Mitigation/Recommendations

The same recommendations as in Sec. 8.2.2 apply with the caveat that STAPES due to its wider scope will be used to evaluate a *standard day* in the ECAC area.

The occurrence of crosswind conditions, depending on the airport considered, is variable in time, strength and direction, i.e. a further probabilistic value which would not add more information to the noise assessment (this also taking into account that the effect of wind on noise propagation is of a second order).

8.4.3 CASE C Mitigation/Recommendations

Support for LAmax-based metrics and updating of the model with a post processing module (for NA estimation).

8.5 GENERAL REQUIREMENTS

In order to properly evaluate the noise impact of NAPs on an airport-scale, i.e. on the basis of a fleet composed of different aircraft types, the noise modelling system has to account for the different acoustic effects/mechanisms (described in Section 3). These determine the overall noise produced by the NAPs and vary from one procedure to another, and from one aircraft type to another.

In particular, given that the evaluation of the noise benefit of NAPs has to be done in a relative way (i.e. against a reference/baseline procedure), a fundamental requirement is to produce accurate noise level differences between different procedures. Achieving such a level of “relative” accuracy requires a good sensitivity of the model.

As the overall noise perceived on the ground is a combination of noise source characteristics (varying as a function of specific flight parameters) and propagation effects (directly linked to the source-to receiver geometry), the noise modelling system has to meet two types of requirements:

- Ensuring that the noise calculation method (along with its associated noise database), properly accounts for the variations of the aircraft noise source state as the flight parameters directly influencing noise at the source vary (sensitivity requirement). This has to be achieved for each aircraft individually; as such variations are highly aircraft type-dependant.
- Ensuring that the input flight path information needed by the noise calculation module (3-D position of the aircraft for the definition of the source-to-receiver geometry, along with all the required flight parameters to determine the noise source state), correctly reflect the behaviour of each aircraft type when operating the NAPs, especially in terms of vertical flight profiles. Indeed, for a given NAP, the resulting flight profile depends on the aircraft performance characteristics and other operational parameters like its operating weight.

As discussed in the following paragraphs, the required developments/adaptations of the INM to meet these general modelling requirements differ with the type of procedures (approach or departures).

9 CURRENT MODEL LIMITATIONS APPLICABLE TO THE VALIDATION OF THE SESAR OISS

The following tables summarise the limitations and the features, which need to be improved in the models: only the main limitations are listed, by degree of importance and influence.

Table 6 highlights the features in common and the scope of the four main Noise Assessment Models.

Models	Database	Supplemental Metrics	Scope
STAPES	ANP	Not available	Multi-airport (ECAC objective)
INM/MAGENTA	ANP	Yes, through post processing	INM: airport level MAGENTA: multi-airport USA level
ENHANCE/INM	ANP	Yes, through post processing	Airport Level
ANCON2	Proprietary/ANP	Not available	Airport scale (data available only for three UK airports).

Table 6 Summary: common Noise assessment models' features

Table 7 (below) highlights the most important and common needed improvements.

Models	ANP update	Multi-configuration APP NPD curves	Scope	Suppl. Metrics
STAPES	yes	yes	NO	yes
INM/MAGENTA	yes	yes	NO	yes
ENHANCE/INM	yes	yes	NO	yes
ANCON	yes	yes	yes	yes

Table 7 Summary: common Noise assessment models' required improvements

Issued by the Episode 3 consortium for the Episode 3 project co-funded by the European Commission and Episode 3 consortium.

10 FEATURES AND FUNCTIONALITIES NEEDED TO EVALUATE THOROUGHLY THE OIS

A good aviation model should consider all sources integrated into data. The current models are based on standard aircraft flight profiles, noise being correlated only to the power settings. The research has shown that it is not easy to model new procedures where aircraft configuration changes from standard. The research version of INM7S used by the Sourdine II project proved the difference, but there is not enough data.

In general, it is important to have the flight profiles as representative and as detailed as possible for their analysis, if these together with the NPD multi-configuration curves were available the envisioned benefits coming from the OISs would be shown.

10.1 NEXT STEPS ON CURRENT MODELS

The following list summarises the requirements and short-term solutions found by the study, to be needed by the noise assessment tools:

- Update and enhancement of the INM/ANP database:
  - Obtain and incorporate additional aircraft performance data and NPD multi-configuration curves;
  - New thrust and Drag coefficients.
- Support development of and incorporate standardized methodology for deriving thrust from aircraft position data (partially covered by ENHANCE);
- Develop guidance on appropriate vertical dispersion techniques;
- Evaluate CDA demonstration methodology at a number of airports;
- Make use of modern air absorption standards;
- Account for terrain and topography;
- Perform significant validation work on any new computational methods developed;
- Integration of airborne and ground noise sources.

An example (limited in aircraft fleet range) of the first point can be found in Section 14 Appendix 2: the Sourdine II [48] specific development.

10.2 RECOMMENDATIONS WITH CURRENT SOFTWARE MODELS [42] [36]

The results show that in general and under as controlled conditions as is possible in the field, predicted noise levels correlate well with measurements when using the industry supplied NPD data. However, in some areas differences arise that may be due to the lack of NPD data for specific airframe-engine combinations. Clearly, the dominant types will vary airport to airport, but it is recommend that industry endeavour to supply more information covering the major aircraft types.

It is also recommended that industry delivers the accuracy and applicability of current NPD data to operations at low power settings (by adding further conf. NPDs), which are associated with optimised approach procedures.

Although most large airports now operate noise and flight path monitoring systems, these do not directly show how aircraft are operated, nor provide details on aircraft configuration and engine power settings. However, it is possible to estimate some of these parameters from radar data and attempts have been made to validate this additional process. Until such methods mature, reliable detailed aircraft performance information is best obtained from onboard aircraft Flight Data Recorders (FDR). Such information is difficult to obtain but may be regarded as ‘gold standard’ data for validation of subsequent processes [42].

Acoustic interference is a perpetual obstacle to reliable noise monitoring. One consequence of data loss is a risk of overestimating average noise levels. Thus careful siting of microphones and rejection of measurements made during poor weather is essential. Microphone siting is a particular problem around London Heathrow due to the lack of free space and the presence of other noise sources e.g. roads, railway lines. The criteria for screening of weather effects are similar to those laid down for aircraft noise certification.

In general these limit wind speed to a maximum of 10 knots and temperature/humidity variation such that atmospheric attenuation rates do not exceed 12dB/100m at 8 kHz.

10.3 Future solutions with new models

Simulation modelling seems to be a good way for noise modelling: in fact with a simulation based formulation received noise can be described in more detail relative to the integrated formulation.

Currently source data are primarily measured 1/3 octave band sound data collected under controlled conditions and processed into data hemispheres (Fig. 23 NMSim modelling on the next page).

However, each hemisphere represents a unique operating condition for the aircraft. Thus, a large matrix of sound hemispheres is required to model an aircraft’s noise. These at the time are not available and would need a long campaign of flight trials [44], [17].

Simulation Modelling Features [44], [43], [17]

Simulation modelling is built around point source moving incrementally on track:

- Computes noise time history;
- Requires 3-D noise sources;
- Takes into account:
    - Fixed/rotary wing aircraft;
    - Source spectrum/directivity;
    - Local ground surface;
    - Terrain;
    - Buildings (shielding);
    - Atmospheric conditions (wind, temp gradients).
- Computes any metric, such as Time Above, that integrated models can only estimate.

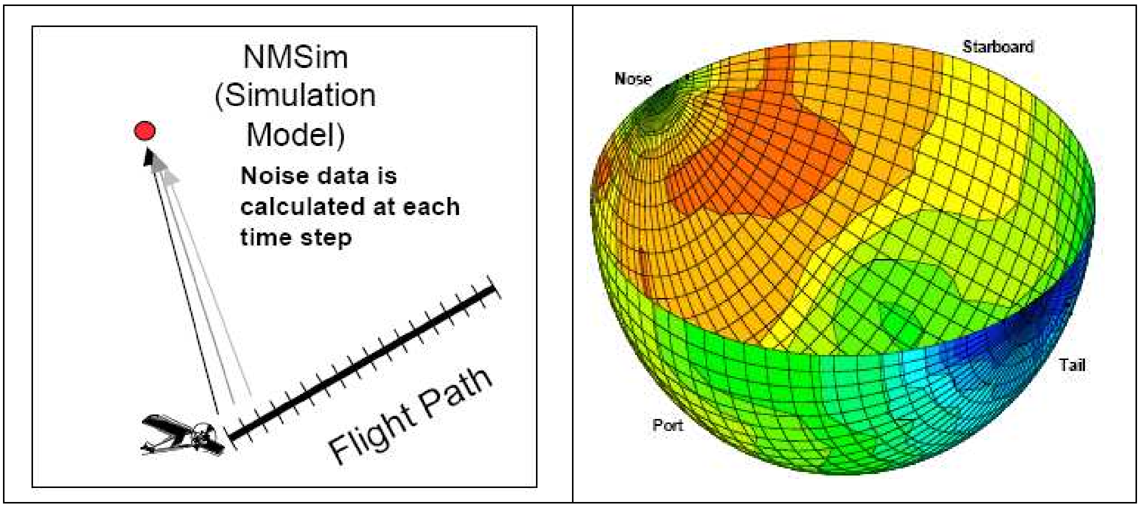

Fig. 23 NMSim modelling

11 CONCLUSIONS

Operational Improvements including CDA operations and Continuous Climb can have significant noise benefits. The extent of these benefits can vary between areas around the airport depending on the differences between existing flight profiles and ground tracks and OISs profiles and ground tracks.

In the case of CDA modelling, there are several gaps in both available data required for environmental modelling and methods normally used for defining aircraft flight profiles that may reduce the ability to accurately quantify their benefits. More robust CDA analyses in support of ATM decisions will require these gaps to be filled, including the inclusion of performance data for more aircraft types within the AEDT/ANP databases and standardized methods for defining realistic distributions of current non-CDA approach profiles using aircraft position data from sources such as radar [38].

The study shows that models, based on integration, as the ones analysed by the study, may miss out on most of the improvements the OISs would deliver. Although some of the short-comes may well be mitigated, there are still many factors to be resolved.

In fact if an airport noise assessment study had to be done nowadays including any OISs regarding CDA approach procedures, it would end up showing the following limitations:

- Lack of Specific OI Step Performance Profile Definitions;
- Limited Aircraft Performance Data;
- Limited number of NPDs available;
- Limited Use of Wind Data (and direction of wind);
- Limited number of supplemental Noise Metrics available.

Despite these limitations, the INM7.S modelling capability during the Sourdine II project together with a limited set of NPD curves and fixed point profiles (delivered by Airbus and Boeing) did show a robust capability to model the environmental benefits, which in turn supports the goal for more wide-spread CDA implementation

The creation of new modules for pre and post processing developed for INM use for example, do come in handy to solve some of these limitations as is the case of TNIP.

While, in parallel, it is important that aircraft and noise performance databases (INM/ANP) are updated with more accuracy, frequency, detail and availability by the Industry.

STAPES, jointly developed and maintained by EUROCONTROL, EC and EASA, has the capability to undertake noise impact assessments at a global - European - level, with a high level of details for each of the covered airports. Additionally, the model fully complies with international (ICAO/ECAC) standards which are recognised as representing current best modelling practice, and supported by a near future comprehensive aircraft noise and performance (ANP) database, which includes manufacturer-supplied data. This tool already includes promising features which, with a few improvements, should enable both global and local estimations of future benefits brought by SESAR regarding noise, in full compliance with SESAR’s performance based validation approach.

12 REFERENCES AND APPLICABLE DOCUMENTS

12.1 REFERENCES

[1] **Federal Interagency Committee on Aviation Noise**, FICAN Findings and Recommendations on Tools for Modelling Aircraft Noise in National Parks, February 2005

[2] **7th USA /EUROPE AIR TRAFFIC MANAGEMENT R&D SEMINAR** Determining the Environmental Benefits of Implementing Continuous Descent Arrival Procedures Paper #594 Eric P. Dinges ATAC Corporation, 2007

[3] **European Civil Aviation Conference**, "Report on Standard Method of Computing Noise Contours around Civil Airports", ECAC.CAEC Doc 29, Third Edition, 2006

[4] **PARTNER -** "Development, design, and flight test evaluation of a continuous descent approach procedure for night time operation at Louisville International Airport" Report No. PARTNER-COE-2005-002, by Clarke, John-Paul, et al., January 2006

[5] **Sourdine II project**, SII_WP9_D9-1_Final_report_v1 1.pdf, September 2006

[6] **Sourdine II project**, "Sourdine II Results of noise and emission analyses" WP5 D5.4, June 2006

[7] **OPTIMAL -** WP7-AIF-231-CDA noise benefits on single event and airport scale for Airbus aircraft-V0.2.doc, April 2007

[8] **COOPERATIVE APPROACH TO AIR TRAFFIC SERVICES (CAATS-II)** CII-WP1.5-ICL-D22-V1.07-DE-CO (D.22 Environmental good practice).doc, 2008

[9] **Council Directive 89/629/EEC**

[10] **A National Vision Statement, Framework for Goals and Recommended Actions,** Report to the US Congress by the US FAA Aviation and the Environment -, available at [http://web.mit.edu/aeroastro/partner/reports/congrept_aviation_envirn.pdf], 2004

[11] **Directive 2002/30/EC** of the European Parliament and of the Council, 2002

[12] **EEA 2003a** "European Environment Agency (EEA) Europe's environment: the third assessment", Copenhagen, available at [http://reports.eea.europa.eu/environmental_assessment_report_2003_10/en], last accessed May 2003

[13] **European Commission** Study on Current and Future Aircraft Noise Exposure at and around Community Airports, ANOTEC (2004), available at [http://ec.europa.eu/transport/air_portal/environment/studies/doc/aircraft_noise.pdf] November 2008

[14] **IMAGINE** WP4 - An Aircraft Noise Model for the Future Peter H.C. Hullah EUROCONTROL Experimental Centre Budapest, 25th October 2006

[15] **Study on a Basic Economic and Environmental Modelling System for Aviation (EEMA)** FINAL REPORT authors: C.Eyers (QinetiQ), I de Lepinay, A Celikel (Envisa), P Brok (NLR), EASA contact Steve Arrowsmith, September 2007

[16] **The 33rd International Congress and Exposition on Noise Control Engineering** 1/8 Noise Simulation Modelling for Airport Noise Analysis J. Micah Downing , Wyle Laboratories, Inc., 2001

[17] **Flying Green Symposium,** "Green Aviation" by Ben Sharp, Palm Springs, USA, 2007

[18] **CAEP/7-WP/20** COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION (CAEP) SEVENTH MEETING Montréal, ICAO Working Paper, February 2007

[19] **STAPES -** DRAFT Highlights of the 37th Meeting of the ACI EUROPE Environmental Strategy Committee, Brussels, Belgium, 9-10 October 2008 d. STAPES: development of an EU regional noise model by EASA c.s.

[20] http://www.infrastructure.gov.au/aviation/environmental/ transparent_ noise/ tnip.aspx

[21] **Environmental Research and Consultancy Department** R&D REPORT 9842 **-** The UK Civil Aircraft Noise Contour Model ANCON: Improvements in Version 2, by ERCD authors: J B Ollerhead D P Rhodes M S Viinikainen D J Monkman A C Woodley, www.caa.co.uk, 1999

[22] **FUTURE DEVELOPMENT OF ANCON** "Improvement of lateral attenuation modelling (Reference 1: paragraphs 4.20 - 4.24). www.caa.co.uk

[23] **VALIDATING THE CAA AIRCRAFT NOISE MODEL WITH NOISE MEASUREMENTS available at** http://www.caa.co.uk/docs/68/Valid_ANCON.pdf

[24] www.caa.co.uk/default.aspx?catid=68&pagetype=90&pageid=9266

[25] **European Commission** "Recommendation 2003/613/ECof, concerning the guidelines on the revised interim computation methods for industrial noise, aircraft noise, road traffic noise and railway noise, and related emission data", August 2003

[26] **European Commission** "Development of a methodology to assess population exposed to high levels of noise and air pollution close to major transport infrastructure: Final Report " by Entec UK Limited, April 2006

[27] **DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL,** relating to the assessment and management of environmental noise, 25 June 2002

[28] **EUROPEAN COMMISSION DIRECTORATE-GENERAL FOR ENERGY AND TRANSPORT DIRECTORATE F -** Air Transport Study of Aircraft Noise Exposure at and around Community Airports: Evaluation of the Effect of Measures to Reduce Noise Final Report Tender N°TREN/F3/15-2006 Submit ted by: M P D Group Limited, October 2007

[29] "Expanding ways to asses and describe aircraft noise", by David Southgate, Director Sydney Environment, Airports Federal Department of Transport and Regional Services, Australia, 2000

[30] **Episode 3 -** D2.4.1-04 Performance framework v3.0.3, March 2009

[31] Public Response to Airport Growth Projects by Bill Albee, Wyle Aviation Services March 5, 2007

[32] **INM -** Sensitivity of the FAA Integrated Noise Model to input parameters by J. Clementea, et all, Polytechnic University of Valencia, Spain, September 2004

[33] **INM -** Error Sensitivity Analysis of the Integrated Noise Model EEC/ENV/2002/006 Kevin Restrick, 2002

[34] **Aena Airports -** Characterization and modelling of global noise in airports (integration of airborne and ground noise). Aena/INECO. 2006-2007

[35] **Aviation Environmental Design Tool (AEDT)** Continuous Descent Approach (CDA) Capability Demonstration Presented to: CDA Workshop, NASA Ames By: Eric Dinges, ATAC Corporation Date: 7 June 2007

[36] "Basic Principles of the Continuous Descent Approach (CDA) for the Non-Aviation Community" by the Environmental Research and Consultancy Department (ERCD) of the Civil Aviation Authority, 2003

[37] EUROCONTROL Harmonised Continuous Descent Approach Concept, 2008

[38] LVNL, Air Traffic Control the Netherlands, Research report: "Noise Annoyance Mitigation at Airports by Non-Acoustic Measures Inventory and Initial Analysis" by Ruud Vader R&D/Research, Amsterdam, October 2007

[39] SISOM 2007 - Aviation and the Environmental Noise Directive: an analysis of difficulties and gaps in the implementation Dr. Delia Dimitriu1 Manchester Metropolitan University UK, May 2007

[40] ICRAT 2004 - New Engine Thrust Calculation for Arrivals Based on a Dynamic Equilibrium Equation extended abstract by Ivan de Lépinay, ENVISA, Paris, France, Laurent Cavadini, EUROCONTROL Experimental Centre, Brétigny, France, 2004

[41] CREDOS - D424_INECO_DLV_4-14_Environmental Case_v1.doc **(Not Public)**

[42] The 2001 International Congress and Exhibition on Noise Control Engineering The Hague, The Netherlands. Aircraft Noise Model Validation DP Rhodes, JB Ollerhead Environmental Research and Consultancy Department, Civil Aviation Authority, **CAA**, August 2001

[43] The 2001 International Congress and Exhibition on Noise Control Engineering The Hague, The Netherlands, The Role of Aircraft Noise Simulation Models Kenneth J. Plotkin Wyle Laboratories, August 2001

[44] Internoise 2004, Prague – Noise Simulation Modeling for Airport Noise Analysis by J. Micah Downing, Wyle Laboratories, 2004

[45] Paper for 7th USA/Europe Air Traffic Management R&D Seminar ADVANCED NOISE ABATEMENT APPROACH ACTIVITIES AT NOTTINGHAM EAST MIDLANDS AIRPORT, UK - Tom G. Reynolds, University of Cambridge, Cambridge, UK, Liling Ren & John-Paul B. Clarke, Georgia Institute of Technology, Atlanta, GA, USA, July 2007

[46] ICAO PANS-Ops 8168

[47] PARTNER (Report No. PARTNER-COE-2005-02) - Development, design, and flight-test evaluation of a continuous descent approach procedure for nighttime operation at Louisville International Airport. John-Paul Clarke, et al. January 9, 2006

12.2 APPLICABLE DOCUMENTS

[48] ICAO Doc 9911 - Recommended Method for Computing Noise Contours Around Airports

[49] Sourdine II - SII_D5-2 Airport Noise and Emission Modelling Methodology V1.0, April 2006

[50] Sourdine II - D5-1 Description of noise and emission modelling requirements V1.0, June 2002**.**

[51] ECAC.CEAC Doc29 3rd Edition Report on Standard Method of Computing Noise Contours around Civil Airports, Volume 1: Applications Guide, Volume 2: Technical Guide, European Civil Aviation Conference, December 2005

[52] Society of Automotive Engineers, Committee A-21, Aircraft Noise, "Procedure for the Computation of Airplane Noise in the Vicinity of Airports" Aerospace Information Report No. 1845, Warrendale, PA: Society of Automotive Engineers, Inc. March 1986

[53] **Federal Aviation Administration (FAA),** "Aviation Environmental Models", FAA Office of Environment and Energy, http://www.faa.gov/about/office_org/headquarters_offices/aep/models/, 2006

[54] **SAE ARP 866A** Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity, March 1975

[55] **INM 7.0** Technical Manual , 2007

[56] **Episode 3 -** D2.4.4-02-Screening & Scoping of the SESAR OIs v1.0, March 2009

13 APPENDIX 1: LIST OF NOISE ASSESSMENT OR NOISE RELATED MODELS [63]

Model	Description	Output	Uses	Availability / Data available	Maturity / recognition	Developer / Owner	Web link
AEDT	Aviation Environmental Design Tool	Air quality, noise	Research	N/A		FAA (USA)	http://www.faa.gov/about/office_org/headquarters_offices/aep/models/toolsfaq/index.cfm?print=go#aedt
AEM	Area Equivalent Method	Noise	Research	Public	Mature	FAA (USA)	http://www.faa.gov/about/office_org/headquarters_offices/aep/models/aem_model/
ANCON2	ANCON2	Noise	Research, policy			CAA (UK)	http://www.caa.co.uk/default.aspx?catid=68&pagetype=90&pageid=50
APMT	Aviation Environment Portfolio Management Tool	Air quality, economics, noise	Research, policy analysis	Under development		FAA (USA)	http://web.mit.edu/aeroastro/partner/projects/project3.html
ASAP	Airport Scenario Analysis Platform, simulation program for environment and safety	Noise, third party risk	Research	Under development		NLR (NL)	-

Model	Description	Output	Uses	Availability / Data available	Maturity / recognition	Developer / Owner	Web link
CONSAVE	Constrained Scenarios on Aviation and Emissions	Air quality, emissions, noise	Research, policy analysis			DLR (DE)	http://www.dlr.de/consave/
DAISY	Air Traffic Noise Web-application	Noise	Research	Available to purchase		Frontier (NL)	
DICERNO	DICERNO	Noise	Assessment	Available to purchase		Wylee Labs	
ENVIRA	Environmental Impact Research Analysis	Noise	Policy analysis		Mature	NLR (NL)	
FANOMOS	Flight track and aircraft noise monitoring system	Noise	Policy analysis		Mature	NLR (NL)	http://www.nlr.nl/eCache/DEF/293.html
FLULA		Noise	Research			Switzerland	
GSP	Gas turbine Simulation Programme	Air quality, engines	Research			NLR (NL)	

Model	Description	Output	Uses	Availability / Data available	Maturity / recognition	Developer / Owner	Web link
HNM[24]	Heliport Noise Model	Noise	Research	Public	Mature	FAA (USA)	-
INM	Integrated Noise Model	Noise	Research	Public	Mature	FAA (USA)	http://www.faa.gov/about/office_org/headquarters_offices/aep/models/inm_model/
JCAB model	Japanese Civil Aviation Bureau Model	Noise	Research			Japanese Civil Aviation Bureau (JP)	http://www.mlit.go.jp/koku/english/index.html
MAGENTA	Model for Assessing Global Exposure to the Noise of Transport Aircraft	Noise	Research	N/A	Mature	Federal Aviation Administration (USA) (ICAO)	http://www.faa.gov/about/office_org/headquarters_offices/aep/models/magenta/
NAxx tool	Determination of NAxx from INM output	Noise	Research			NLR (NL)	
NIRS	Noise Integrated Routing System	Noise	Research, policy analysis			METRON aviation (USA)	http://www.metronaviation.com/nirs.php
NMSIM 3.0	Noise Model Simulation	Noise	Research	Publicly available	Mature	Wyle Labs	http://www.wylelabs.com/products/acousticsoftwareproducts/nmsim.html

[24] Integrated since INM 6.0c from HNM version 2.2.

Model	Description	Output	Uses	Availability / Data available	Maturity / recognition	Developer / Owner	Web link
NODSS	National Park Service Overflight Decision Support System	Noise	Research			US National Park Service (USA)	http://www.webref.org/acoustics/n/nodss.htm
NOISEMAP		Noise	Research			(US DOD)	
NOMOS	Noise Monitoring System	Noise	Research		Mature	AAS (NL)	http://www.schiphol.nl/nomosonline
NORTIM		Noise	Research			Norway	
OCEAN(E)	OCEAN(E)					DGAC (FR)	http://www.dgac.fr/
RNM	Rotorcraft Noise Model	Noise	Research			National Aeronautics and Space Administration (USA)	http://www.hq.nasa.gov/office/aero/docs/ar99/obj3.html
SONDEO	SONDEO	Noise				Anotec consulting (UK)	http://www.anotecc.com/
STANLY Track	Live (30 minutes delay) radar tracks, operational at Frankfurt	Flight tracks	Research	Public at Frankfurt		NLR (NL)	http://stanlytrack.dfs.de/stanlytrack/stanlytrackEDDF.jnlp

Model	Description	Output	Uses	Availability / Data available	Maturity / recognition	Developer / Owner	Web link
STAPES	SysTem for AirPort noise Exposure Studies	Noise	Research	Under Development		EASA /EUROCONTROL	http://www.eurocontrol.int/eec/public/standard_page/WP_Environment_Impact_Assess.html
SVERIM		Noise	Research			Sweden	
TNIP	Transparent Noise Information Package	Noise	Research	Publicly available		Australian Dept. of Transport and Regional Services	http://www.dotars.gov.au/aviation/environmental/transparent_noise/tnip.aspx
TRACK	Audibility of aircraft in park environments	Noise				US National Park Service (USA)	

14 APPENDIX 2: SOURDINE II SPECIFIC NOISE MODELLING SYSTEM DEVELOPMENT [48]

14.1 OVERVIEW

In order to meet the modelling requirements described earlier (please see Chapter 3 [49]), a specific noise modelling system has been developed, on the basis of the INM7.0 version. Its main characteristic is to better account for the airframe noise component (which varies with aircraft configuration - flaps/gear – and speed) during approach procedures, through the use of multi-configuration and multi-speed NPD data.

The different elements of this noise modelling system are illustrated in Fig. 24 below:

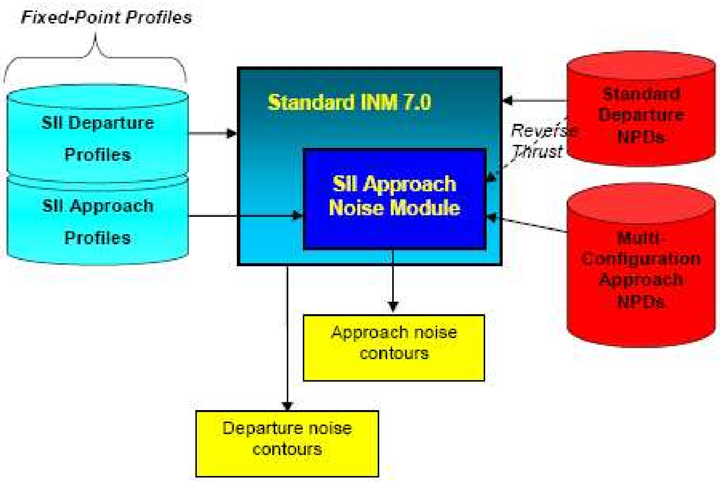

Fig. 24 The SII noise modelling system

As shown in this figure, the standard noise calculation method of INM (i.e. based on standard departure NPDs) is used for the evaluation of NADPs, given that standard NPDs properly cover the different states of the aircraft noise source during departure operations (engine noise being the dominant component).

For the evaluation of the SII CDAs, the system includes a specific approach noise calculation module, which uses a database of configuration and speed-based approach NPDs (*Multi-configuration approach NPD* database). This module, along with its specific noise database, improves the sensitivity of the noise modelling system to the configuration and speed variables (by accounting for their direct effect on the airframe noise component). As shown in Fig. 24 there is one exception where the *Multi-configuration approach NPD* database is not used, which is for the reverse thrust segment after aircraft touchdown: in the same way as for standard INM. The noise contribution of this segment is calculated using standard departure NPD curves instead, because of the higher noise levels (resulting mainly from engine noise) associated with reverse thrust.

FAA, in collaboration with Volpe Labs and ATAC, have modified the INM stream code to implement this approach noise calculation module, based on the Sourdine II specifications. In support of the new modelling method, Airbus and Boeing have produced a set of configuration and speed-based NPD data for twelve aircraft types (eight Airbus and four Boeing), using their in-house modelling facilities.

Additionally, in order to have input flight path data describing with the required level of details how different aircraft types actually fly the different SII procedures, the noise modelling system includes a SII-specific flight profile database. This database incorporates mainly data supplied by manufacturers (Airbus and Boeing) for the twelve aircraft types for which multi-configuration NPD data have been produced. For each aircraft type, flight profile data are available in the form of *fixed-point* profiles, for all the studied SII procedures (both CDAs and NADPs) and for baseline procedures as well.

This chapter describes in more details the developed SII approach noise calculation module. In particular, Section 14.2 describes the concept of configuration and speed-based NPD data, and the dataset which has been produced by Airbus and Boeing. Section 14.3 presents the modifications of the INM noise calculation process to support this new type of noise data. It includes in particular a description of the associated noise data interpolations.

14.2 CONFIGURATION & SPEED-BASED APPROACH NPD[25] DATA

14.2.1 Principle

The configuration and speed-based NPD data represent a generalised matrix of conventional NPD data, which covers more aircraft noise source states, as a function of speed, aircraft configuration and engine power.

The use of these multi-configuration NPD data in the form of curves that represent overall aircraft noise levels as a function of source-observer distance for different thrust values is compatible with current practice and requires relatively minor modifications to the INM source code. The resulting modified INM version can use both these new configuration and speed-based NPD data and conventional NPD type data. It allows the manufacturer, as data developer, to add similar data in a similar format as provided in the current situation for additional parameter values (i.e. aircraft configuration and speed). Additionally, as the power parameter (corrected net thrust) remains one dimension of the “matrix”, these NPD data implicitly account for the variations of the relative contributions of the airframe and engine components to the overall noise.

An alternative method, in which engine and airframe components would have been delivered in separate tables and added up to overall noise in INM, would have required additional information on spectral content for correct summation of the different components. This would have required a too significant adaptation of INM source code and data requirements to handle within the timeframe of the Sourdine II project.

[25] During the Sourdine II project specific NPD curves were produced for 12 aircraft (8 Airbus and 4 Boeing). Airbus also produced standard departure NPD data, as these aircraft were not available in standard INM at the time. These additional departure NPD data were needed to evaluate the noise impact of the SII NA(A)DPs and to model the noise contribution of reverse thrust segments for approach procedures.

Fig. 25 below illustrates the concept of configuration and speed-based NPD curves, as a generalised form of standard NPDs.

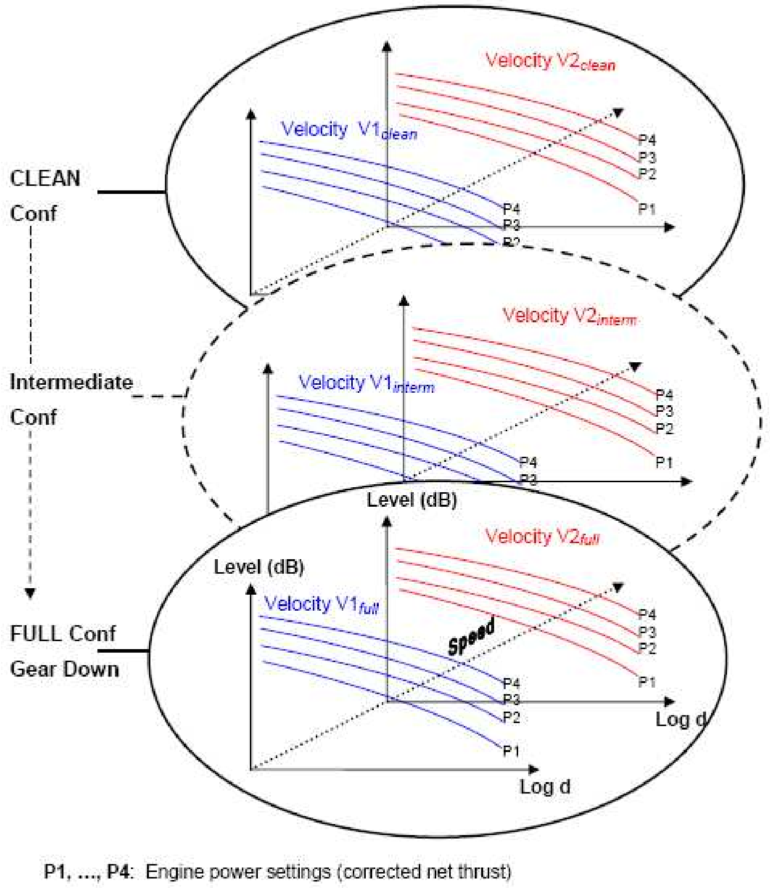

Fig. 25 The multi-configuration/multi-speed approach NPD data matrix

Whereas conventional approach NPDs are provided for a single – specific – configuration and speed value, the configuration and speed-based NPD matrix provides NPDs for the different configurations likely to be used by the aircraft during approach. From clean configuration (with gear up) to final landing configuration (with gear down), and for several (configuration-specific) approach speed values (at least two speed values, in order to enable an additional speed interpolation/extrapolation (described in [48] Section 4.3.3, page 41).

Fig. 25 illustrates how this multi-configuration NPDs matrix is accessed during the noise calculation process: for each segment of the flight path, INM identifies the configuration in which the segment is flown, and then selects the subset of NPD curves associated to that configuration, in order to perform the required noise interpolations.

The subset of NPD data associated to a given configuration and approach speed value are similar to standard NPDs and, as such, represent noise levels perceived underneath a notionally infinite straight flight path, flown at constant speed; this constant speed being the tabulated approach speed value to which the NPDs are associated. Additionally, these are normalised to the same standard conditions [26] as conventional NPDs (see [48] Section 2.2.1, page 12), except for the reference speed in the case of exposure metrics.

Unlike standard NPDs, the configuration and speed-based NPDs for exposure metrics (SEL) are not normalised to the 160 knot reference speed, meaning that each NPD curve includes the noise duration effect associated to the configuration-specific tabulated speed value for which it has been derived. Before performing interpolations in these NPDs (described in [48] Section 4.3.3, page 41), INM will preliminarily normalise all the NPD data of the database to the same 160 knot reference speed, such as they all include the same duration effect, whatever their associated tabulated speed value is.

14.2.2 Production of a configuration and speed-based NPD database

Airbus and Boeing have produced configuration and speed-based NPDs for twelve specific aircraft.
Using their in-house modelling facilities. These aircraft types are listed in Table 8 below:

Manufacturer	***Airframe***	***Engine***
Airbus	A319-111*	CFM56-5B5/P
	A320-211	CFM56-5A1
	A320-214 *	CFM56-5B4/P
	A320-232	V2527-A5
	A321-211 *	CFM56-5B3/P
	A321-232	V2530-A5
	A330-301	CF6-80E1A2
	A340-313 *	CFM56-5C4
Boeing	B737-800	CFM56-7B26
	B737-300	CFM56-3B-1
	B757-200	RB211-535E4
	B777-200	GE90-90B

Table 8 List of aircraft with configuration and speed-based NPDs

(*) For these aircraft, Airbus has also produced standard departure NPD data, as these aircraft are not available in standard INM. These additional departure NPD data are needed to evaluate the noise impact of the SII NADPs and to model the noise contribution of reverse thrust segments for approach procedures.

[26] Unlike for standard NPDs, configuration and speed-based NPDs can not be adjusted to user-specified temperature and relative humidity conditions. Therefore, airport noise studies using configuration and speed-based NPD data deliver noise contours for standard atmosphere only.

The configuration and speed-based noise data have been derived using the manufacturer-specific computerised methods enabling the calculation of standard NPD data according to the SAE AIR-1845 guidelines. Such methods calculate aircraft noise levels at an observer position for a given aircraft type, flight trajectory (including the specification of power settings, aircraft configuration and speed) and source-observer geometry. Engine and airframe sound pressure level spectra are usually calculated separately and added logarithmically, to obtain the overall aircraft noise spectrum perceived at the observer position. The observed noise spectra are calculated as a function of time, on basis of which maximum and exposure based noise metrics are calculated.

The engine noise spectra are usually calculated by projection of noise data obtained from static engine tests into flight conditions. The method and data are adjusted using noise data obtained from certification flight tests. In a similar way, airframe noise spectra are calculated using semi-empirical methods, calibrated on the basis of results of airframe noise flight tests.

As configuration and speed-based NPDs represent a generalised form of standard approach NPDs (i.e. a larger set of approach NPDs covering more aircraft states in terms of configuration and speed), they have been derived using these computerised methods in a same way, each subset of NPDs being produced for a specific (fixed) configuration and speed value.

For each of the aircraft listed in Table 8, NPD data have been hence produced, both for SEL and LAmax metrics. For each metric, NPD curves (one curve being a set of noise levels at the ten tabulated distances, associated to a given combination of configuration, thrust and speed values) have been generated for:

- 4 or 5 approach thrust values;
- 5 or 6 aerodynamic configurations (from clean-gear up to full landing-gear down configurations);
- 3 to 6 configuration-specific speed values.

The above number of tabulated values (of thrust and speed) and aerodynamic configuration states depend on the aircraft type. The different aerodynamic configurations for which NPD curves are provided cover most of the aircraft states during normal approach operations. The time at which the landing gear is extended is aircraft type dependent, and is generally associated to a specific intermediate configuration. For this particular configuration, NPDs are provided both with the gear up and gear down options. The configuration-specific airspeed values cover, as far as possible (see the limitations in 4.2.3), the operational speed ranges which are likely to be associated to each of the configurations.

14.2.3 Limitations

The development of configuration and speed-based approach NPD data (as standard approach NPDs) is more complicated than the development of departure NPD data, for several reasons. As the flight trajectories used to calculate these NPD data differ significantly from the certification and airframe noise flight trajectories, a part of the methodology to calculate source noise and propagation effects relies on extrapolations as the computerised methods are used outside their domain of validity.

In particular, the low thrust levels require usage of data at the lower limit of the available engine noise data. Moreover, for exposure-based NPDs (such as SEL, EPNL), the emitted sound pressure levels being relatively low, the 10dB-down periods[27] may be extremely long, requiring a

[27] It is the period during which, the instantaneous perceived sound pressure level is higher than the maximum perceived noise level (LAmax) minus 10dB. Practically, integrating instantaneous sound

significant amount of extrapolations, especially for the lower thrust levels combined with zero/intermediate flap settings and retracted landing gears.

The NPD data points for large source-observer distances (16000ft and 25000ft) have been obtained using simplified extrapolation procedures (accounting mainly for spherical spreading of sound and air absorption). However, the noise levels associated to these tabulated distance values are normally not used when producing approach noise contours starting at L_{DEN} 55 or L_{night} 50.

As a consequence, the most extrapolated noise level data may be less reliable than the others. This occurs notably for noise levels associated to:

- Large source-to-receiver distances (but this is not a critical issue, as already explained above);
- Lowest tabulated thrust values, especially when combined with clean and intermediate configurations (with gear up);
- Highest tabulated speed values associated to clean configuration with gear up.

14.2.4 Control of NPD extrapolations for high speeds

Initial segments of approach procedures are usually flown with clean-configuration (and idle thrust) combined with high speed values, quite above the highest tabulated speed values for which NPDs could be reasonably derived. INM will have therefore to extrapolate noise levels to these operational speed values from the configuration and speed-based NPDs (see [48] Section 4.3.3, page 41). Such extrapolations are likely to produce uncontrolled excess of noise far from touchdown (due to increasing airframe noise).

To avoid this situation, it has been decided to “saturate” the extrapolations above 220kts, through the addition of a NPD dataset for 250kts, which is identical to the dataset associated to 220kts (this results in “horizontal” extrapolations).

14.2.5 Modification of the input flight path definition

The modified single-event noise calculation method uses the aircraft configuration in which each finite segment is flown as an additional parameter characterizing the aircraft noise state. As standard INM flight profiles do not contain flap/gear state explicitly (given that this type of information is not required in the standard INM noise calculation process), the format of *fixed-point* profile[7] data has been modified to include flap/gear state as additional input parameter. With this modified format, the vertical profile database provides the configuration state of the aircraft at each point of the profile. All flap/gear labels used in the profile points definition must match the configuration labels used in the multi-configuration NPD database.

The 3-D flight path synthesis (where INM merges ground tracks and vertical profiles – see [48] Section 2.3.3 page 24) has been adapted to account for this additional parameter. In particular, during the calculation of the contiguous straight flight path segments, each segment is assigned a single configuration (flaps/gear) label, treated as a discrete state throughout the entire segment.

14.3 Validation of the noise modelling concept

In order to validate the configuration and speed-based NPD methodology/concept, comparisons have been made between noise levels estimated using this method and those produced by

pressure level over such a defined period accurately represents the sound energy level produced by a single flight event.

Airbus's noise prediction tools. The graph of Fig. 26 shows, for a specific aircraft type, comparisons of noise levels (LA_{max} under the flight path) associated to a "standard" procedure (including a level segment at 3000ft followed by a 3-degree glide slope).

The SII modelling system reproduces well the behaviour of noise as a function of configuration and speed changes, if not necessarily in terms of absolute values. It has to be noted that the manufacturer's model takes into account the transition period between two configuration states, whereas the SII modelling system assumes an instantaneous flap change, occurring when the flap change is complete. As a consequence, the manufacturer's model tends to predict noise increase starting earlier, as soon as the flap deployment to next position starts (which can lead also to higher noise levels, when speed at the start of flap deployment is higher than at the end, on deceleration segments). In order to better match manufacturer's noise predictions with the SII modelling system, a simple solution has consisted of specifying earlier flap changes (to next position) in the flight profile. The above comparisons have been made only on a few examples, and only for a specific aircraft type. Such comparisons demonstrate mainly the validity of the modelling principle. In particular, the quality of the results strongly depends on the reliability of the configuration and speed-based NPD data. There was no mean to verify and validate systematically all the NPDs of all the aircraft types of the list. Keeping in mind the limitations inherent to the production of configuration and speed-based approach NPD data (described in Section 14.2.3), further investigation, consisting of more detailed analysis of the noise data, should be therefore required, in close collaboration with manufacturers.

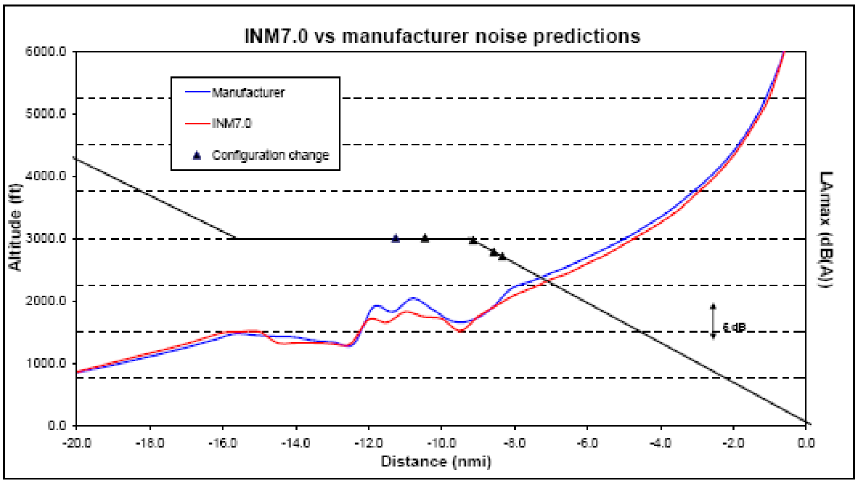

Figure 4-5: Validation against manufacturer-predicted noise levels

Fig. 26 Validation against manufacturer – predicted noise levels

14.4 Improved sensitivity – worked examples

14.4.1 Single-event example

The example below illustrates the improved sensitivity of the noise modelling system - compared with standard INM - to the approach configuration and speed parameters.

Noise levels resulting from two procedures flown by a same aircraft type have been compared, using respectively standard INM (i.e. with standard approach NPDs) and the configuration/speed-based NPD method. These procedures include both a level-off segment at 3000 ft before intercepting a 3-degree glide. They differ by their deceleration profile and their flap setting schedule (one procedure having delayed deceleration and flap deployment sequence), as illustrated in Fig. 26.

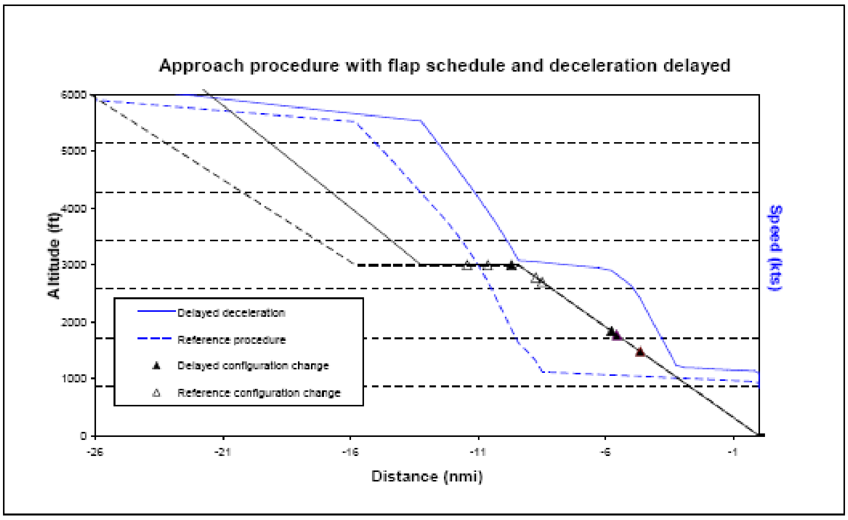

Fig. 27 Reference and "delayed" procedures description

The following graphs (Fig. 28 & Fig. 29) compare noise levels (LA_{max} under the flight path) resulting from these two procedures, when calculated using respectively standard NPDs and the configuration/speed-based NPD method. With the standard NPDs, there is nearly no difference between the two procedures, the slight difference coming from differences in the thrust profiles (as, in this example, standard INM can only reflect the thrust differences between the two procedures). The noise levels produced with the new method show clearly the additional sensitivity of the system to the speed and configuration variables. In particular, the procedure with delayed deceleration involves final flap deployment at higher speeds, which results in a noticeable noise increase, via the airframe noise component.

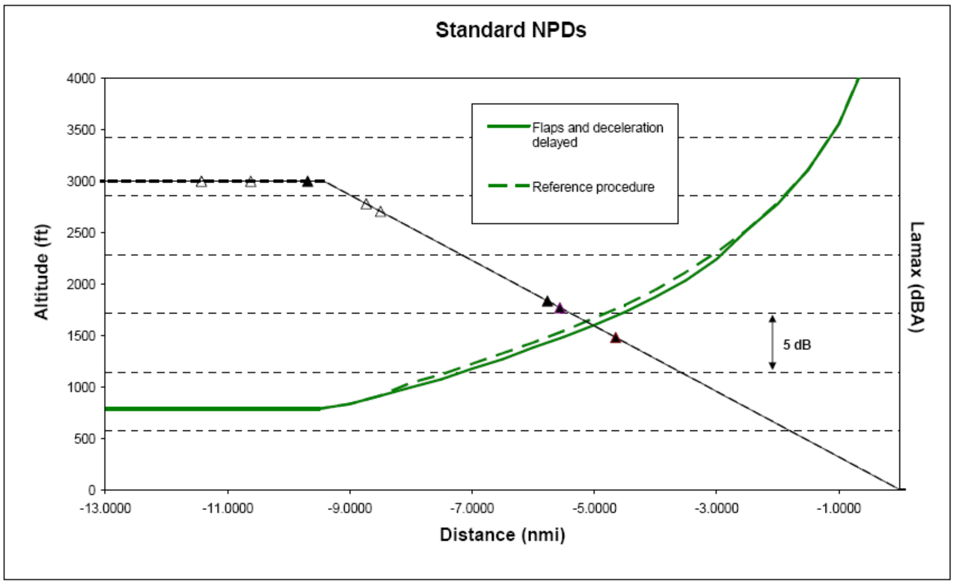

Fig. 28 Noise level comparisons using standard INM

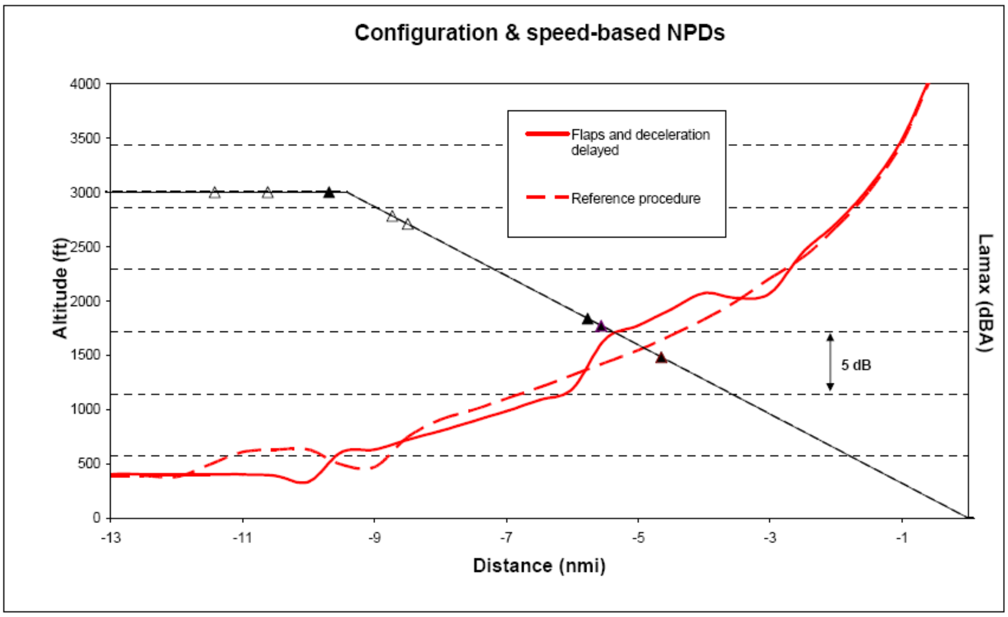

Fig. 29 Noise level comparisons using configurations and speed based NPDs

Airport-scale noise contour examples

The following examples compare, on an airport-scale, noise contours produced using respectively the standard and multi-configuration NPD methods. The purpose is to evaluate the actual effect on the shape and size of L_{DEN} contours (starting at 55 dBA) of better accounting for the airframe noise component, as a function of speed and configuration.

Contours have been calculated for three SII procedures (baseline, Procedure III and Procedure V -see Appendix A for their definition), applied to about 450 movements of a theoretical fleet. The graphs below compare, for each procedure, contours produced with the two methods.

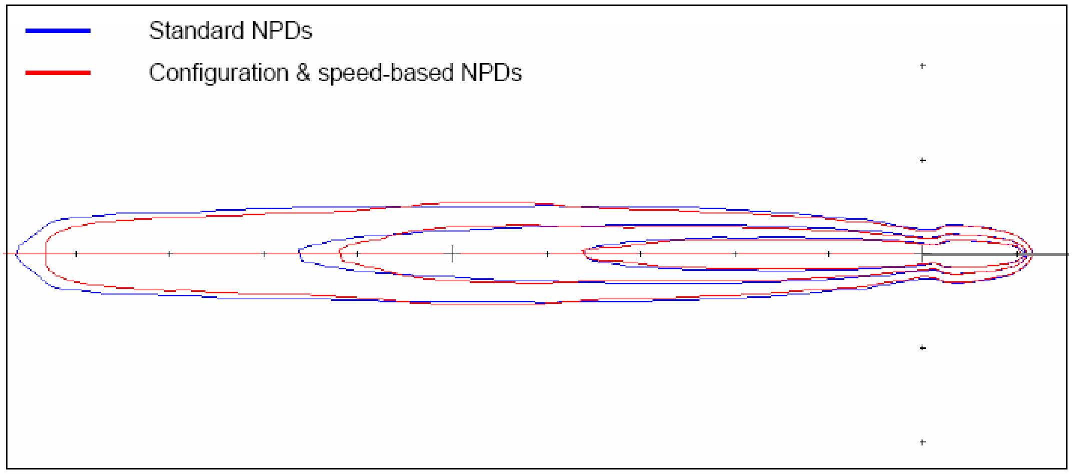

Fig. 30 L_{DEN} contours (55 to 65dBA) for the SII baseline and procedure

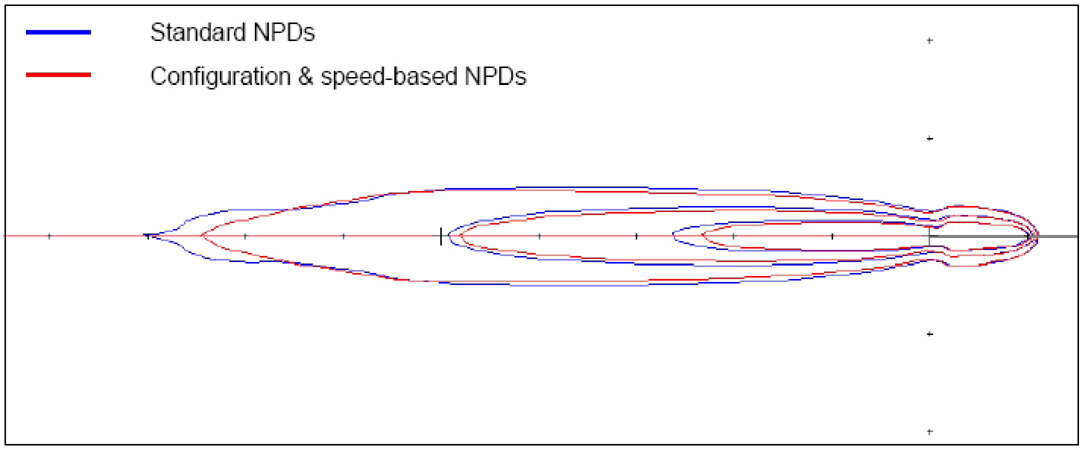

Fig. 31 L_{DEN} contours (55 to 65dBA) for the SII Procedure II

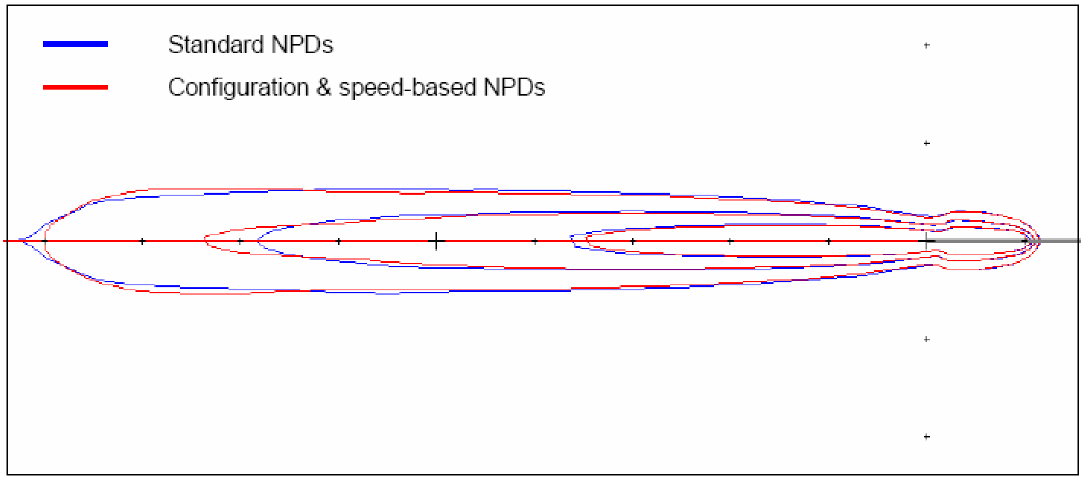

Fig. 32 L_{DEN} contours (55 to 65dBA) for the SII Procedure II

As shown in Fig. 30 and Fig. 31, the use of multi-configuration NPDs instead of standard ones tends to reduce the length of contours, both for baseline procedure and Procedure III. This phenomenon is due to the fact that some aircraft types of the list have standard approach NPDs which have been derived for a configuration close to the final landing configuration with gear down, but for the 160 knot reference speed, which is a high speed value for that kind of configuration. The airframe noise component associated to such an aircraft state (and implicitly captured by standard approach NPDs) is rather conservative and tends therefore to over-estimate the actual airframe noise likely to be produced under the circumstances of these two procedures. However, it can be noticed that the contour size reduction (resulting from using the multi-configuration NPDs) depends on the noise level threshold of interest and, even more important, on the procedure.

As a consequence, the evaluation of the noise benefit of Procedure III, compared with the baseline (in terms of relative contour area reduction) gives different results, as indicated in Table 9, depending on the method used to produce the contours. In this example, the multi-configuration method predicts a better noise reduction than the standard method.

For Procedure V, the trend is even different: for L_{DEN} 60, the multi-configuration NPD method predicts a “longer” noise contour as compared with the standard INM method. This comes from the characteristics of the procedure, in which flaps and gear are extended earlier (i.e. at higher altitudes), and at higher speed values (above the reference speed value for which standard NPDs have been derived). In this case, the actual airframe noise contribution becomes higher than the one which is implicitly captured in standard NPDs. In the case of this procedure, the noise impact results (compared with the baseline procedure) depend on the modelling method used to produce the contours: for the L_{DEN} 55 for instance, whereas standard INM method predicts a (slight) reduction of around 5%. The multi-configuration NPD method shows that Procedure V does not provide any noise benefit in this situation, compared with the baseline procedure (Table 9).

	Procedure III		Procedure V	
	Standard NPDs	Multi-configuration NPDs	Standard NPDs	Multi-configuration NPDs
55 dBA	-26.4%	-28.0%	-4.8%	+1.0%
60 dBA	-26.3%	-32.0%	+1.8%	+5.1%
65 dBA	-28.2%	-34.3%	-5.6%	-3.7%

Table 9 Relative contour area variations vs. baseline procedure

END OF DOCUMENT