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ENHANCE: AN EVOLUTIONARY IMPROVEMENT TO AIRCRAFT NOISE MODELING

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ABSTRACT
International guidance material is provided by ICAO (Circular 205), defining how to compute noise contours for aircraft around airports. However, it is acknowledged within the noise modeling community, that significant errors can exist between modeled noise levels, and those measured "on the ground" for similar scenarios. The aim of the project is to better understand the sources and magnitude of these errors, and attempt to mitigate for them in the modeling process. The project will deliver an "Enhanced" Noise study tool, enabling more accurate predictive studies to be conducted for European airports and fleets, and will directly support the evolving European Commission Common Noise Policy. The tool 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, allows more accurate data input, eliminating, or at least reducing, known errors. The project is a combination of tool development and validation exercise, and is based around a significant data collection task, with the cooperation of operators and airport administrations. It is a program of collaborative work in Europe, sponsored by EUROCONTROL, as a complement to the work being conducted in voluntary CAEP (ICAO Committee on Aviation Environmental Protection) working groups, which will ultimately propose revisions to the Circular 205 methodology.

1 - INTRODUCTION

Although more and more airports are equipped with noise monitoring systems, many airport authorities rely on noise modeling to demonstrate conformance with local by-laws for current air traffic operations. Moreover, noise models allow airport authorities to predict the noise exposure for different situations, such as different combinations of aircraft type, changes to operating procedures or routes.

Whilst noise models offer a convenient means to predict the impact of changes to current practice, it is recognized among the modeling community that current models can suffer from a number of limitations. These limitations induce errors in the calculated noise values resulting from limitations in the modeling algorithms, errors in the input data or non-standardisation of the model being used

Most of the models in use throughout the world are based on the SAE-AIR-1845 [1] and SAE-AIR-1751 [2] algorithms. Although any given model may be well suited for one particular environment or the needs of one user, there is no standardized model that allows users to compare results from measurements at different sites.

In keeping with the spirit of a harmonized air traffic system in Europe, Eurocontrol needs a validated noise model that will be accepted by all Eurocontrol member states. Also, through the work being undertaken by international bodies such as ICAO CAEP model 1 working group in the context of updating the Circular 205 document [5] and the European Commission Sourdine project [3], it is clear that airport authorities and the general public require a consistent, validated, method of predicting noise at airports.

The ENHANCE project is contributing to the work to improve aircraft noise models in three areas:

- Development of a noise study tool to 'enhance' existing noise models.
- To provide improved aircraft performance data and procedures that will lead to a noise model validated for the European environment.

- Study of how target position errors influence the calculated noise contours through case studies at selected European airports when using radar data as the source of target position.

2 - ERROR SOURCES

2.1 - Overview of error sources

The errors in calculated noise may either result from limitations in the modeling algorithms or errors in the input data.
The errors in the calculated noise due to inaccurate modeling of:

- Effects of the atmosphere on sound propagation − many models assume a standard homogeneous atmosphere. Errors occur when ambient conditions depart from the standard conditions (15°C, 1013.25hPA, 70% humidity). The main reasons are changes in atmospheric absorption (temperature and air humidity) and refraction effects (wind speed and temperature gradients).
- Terrain effects − effects due to variations in terrain and local topography (complex ground reflections and scattering).
- Aircraft noise sources − engines, flaps, undercarriage and aerofoil surfaces.

Input data errors are caused by:

- Inaccurate aircraft position information − the use of theoretical flight paths or errors in the measured position from radar data.
- Inaccurate flight procedures for departure and arrival. When measured target position data are not available the model must rely on idealized synthetic trajectories following Standard Instrument Departures (SID) or Standard Arrival routes (STAR), standard profiles, take-off weights, thrust cut-back procedures, etc.
- Inaccurate estimation of engine thrust.
- Incomplete knowledge of the atmospheric conditions − both on the ground and the space surrounding the aircraft.
- Operational data: aircraft type and accuracy of type substitution, weight, engine fit.

2.2 - Atmospheric attenuation effect

Most of the models estimate noise levels under standard conditions (air temperature: 15°C, humidity: 70%), when in fact atmospheric sound attenuation depends strongly on these two factors. In this way, for a given noise source (i.e. an aircraft type), moving along a given flight path, the perceived noise levels on the ground will vary significantly, depending on the atmospheric conditions at the time of the event. The following simple case estimates that effect on the Sound Exposure Level (SEL). Let us consider an aircraft flying straight ahead, with a constant speed V (and a constant height H). The sound exposure level resulting from that event is calculated at different lateral positions on the ground, for different values of air temperature and humidity, as shown below:

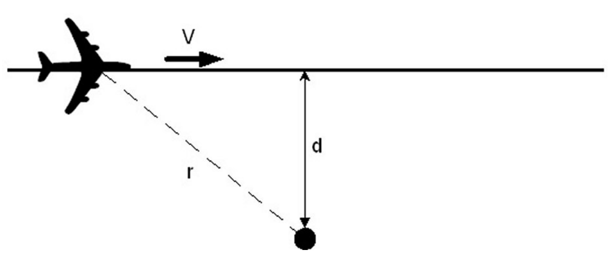

Figure 1: The noise source spectrum is assumed to be a white noise; the aircraft directivity diagram is neglected (spherical waves); ground reflection is not taken into account.

The sound exposure level (SEL) is then expressed as follows:

$$SEL = 10\log\frac{1}{t_{ref}}\int_{-\infty}^{+\infty}\left(\int_{f}\frac{C^{2}}{r^{2}\left(t\right)P_{ref}^{2}}10^{\frac{-\alpha(f).r(t)}{10}}df\right)dt \quad (1)$$

where:

- $t_{ref} = 1\text{s}$
- $p_{ref} = 20\ \mu\text{Pa}$
- C = white noise spectrum constant
- $\alpha(f)$ = sound attenuation coefficient − taken from [6] − at frequency f (dB/m)

and

$$r\left(t\right) = \sqrt{d^{2} + V^{2}\left(t - t_{0}\right)^{2} + H^{2}}$$

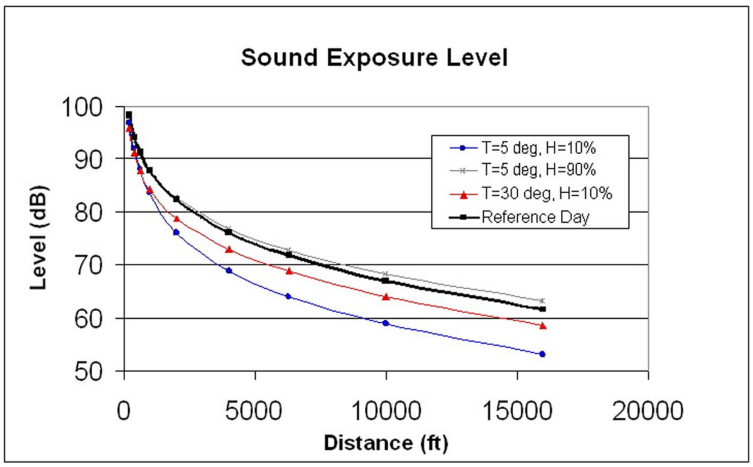

Figure 2: Sound exposure as a function of lateral separation (d).

A numerical integration of (1), performed using a third-octave band analysis, provides the following graphs, showing the SEL as a function of the lateral distance *d*, for different values of air temperature and humidity: the variations with temperature and humidity can be as great as 8dB at 4000 feet slant range.

3 - ENHANCE PRE-PROCESSOR

All noise models require thrust to calculate the noise generated by an aircraft. Thrust estimates are a function of weight, airspeed, atmospheric conditions (temperature and pressure) altitude, airframe and engine type.

Designed to work as shell around a 'host' noise model program, the Enhance Pre-processor comprises a pre-processor and a Windows(TM) GUI. The pre-processor fully takes into account the target position, height, speed, temperature and pressure at the time of the event. It calculates the thrust for discrete position events, these may be periodic such as a surveillance radar plot with a 4 second scan rate.

Discrete position events for aircraft flight operations data can be imported from a variety of sources − surveillance radars, air traffic simulators or noise monitoring systems.

The pre-processor automatically prepares the necessary data files for the host noise model.

The GUI allows the user to manage the various noise study files and cases, importing and editing of aircraft and airport data.

4 - VALIDATED AIRCRAFT PERFORMANCE DATA

The current aircraft performance databases tend to be 'too theoretical' and insufficient for the European environment.

To ensure that the aircraft data are up-to-date and validated, Eurocontrol has contracted Aerospatiale-Matra to provide data for selected Airbus models. The selected models are most representative of the

Airbus range − A340, A320, A319. The data are provided in a format compatible with INM. Due to the larger similarity between the Airbus models it is not deemed necessary to model every Airbus model. Future versions of IN will incorporate the new data.

5 - POSITION ERROR STUDY

The accuracy of the noise calculations can be improved by using Air Traffic Control Surveillance radar position data instead of theoretical flight profiles, for example Winter [4]. The errors introduced into the noise footprint results due to uncertainty in the horizontal position of the target have been estimated to be as great as 10dB. However, it is not fully understood to what degree the errors in target position contribute to the error in the calculated noise. This enhance position error study aims to quantify the contribution of surveillance position errors to the calculated noise levels by comparing calculated against measured noise levels obtained on the ground at different European Airports using the LAmax and SEL indices.

The measured position data will be derived from multi-radar data. Supplementary data will be derived from on-board Flight Data Recorder and airfield noise monitoring system for selected flights. The on-board aircraft data will provide parameters such as gross weight, thrust settings, air speed, flap settings, altitude, etc. The noise monitoring system will provide aircraft position derived from airfield surveillance radar and noise levels at relevant noise monitors near the flight path.

Although Surveillance radar provides a cost effective means of measuring target position, radar systems have their own characteristics that must be adequately accounted for.

The study will also focus on the practical aspects of collecting and correlating the data from aircraft, noise monitoring system and radar systems using the Enhance Pre-processor and shell together the baseline noise model (INM).

5.1 - Factors involved

Errors in measured position incurred by the radar seeing the target are principally due either to missing information or erroneous measurement. In turn, the errors are function of distance from the radar, the radar resolution and trajectory orientation relative to radar (radial speed). Errors may also be incurred as a function of target elevation and sensor constellation.

Missing data

There are two categories of Missing data − blanking and scan-to-scan detection losses.

Scan-to-scan losses in detection cause most errors during target maneuvers. Rectilinear flight segments, such as take-off roll, present less of a problem as the model can use linear interpolation from the start of the runway.

Blanking is used to avoid saturation of the Radar system with replies from targets close to the radar and in areas where the radar data is not used. For our study blanking is mainly a problem for targets on the runway − noise monitoring systems are normally connected to the approach radar. However, as the radar is normally optimized for ATC use − to survey targets in the approach and departure phases of flight − targets on the runway may be blanked out.

Position errors

Radar errors comprise two components − fixed bias (systematic) and residual random errors. The bias errors occur in position of the radar sensor (Latitude, Longitude, height) and measurement bias (range, azimuth and time).

The azimuth bias may also account for alignment of the radar to magnetic north − ATC surveillance radars are conventionally aligned to True North.

Correct estimation of the bias errors requires overlapping multi-radar information or an external reference position for a test target.

The random errors are represented by the standard deviation of range and azimuth errors after correction for the bias errors.

Height above ground

Current Air Traffic Control (ATC) Secondary Surveillance radar (SSR) provides aircraft height information as Flight Level (Flight Level is a pressure altitude with respect to the standard atmosphere (1013.25hPa); to determine the true altitude of an aircraft the Flight Level must be corrected for the regional pressure QNH) with a precision 100 feet. Aircraft on-board altitude is derived from the Static Pressure (Altimeter). In the study the on-board recordings of Altitude and Radio Altitude will be used as reference during the data validation process.

To avoid errors due to correction of local pressure (QNH) it is intended to derive the height of target above airfield using the Flight Level information of targets on the airport (taxying).

Time stamping

Most current noise models use time independent position information to produce noise contours. This makes it difficult to correlate noise model data with conventional surveillance and on-board information, both of which rely on time stamped information.

Careful manual correlation of noise events will be required to ensure the events correlate with the position of the target.

The recorded Flight Data Recorder and Noise Monitor data will be time stamped in UTC to a precision of 1 second or better. Radar data are generally time-stamped with a precision of 0.1 seconds or better.

Coordinate transformation

Radar systems measure position in terms of Range and azimuth from the radar location. Before use the data are projected onto a suitable coordinate reference. For this study all data will be transformed onto Cartesian coordinates with the airport datum as origin. INM assumes a flat earth. Radar data will be stereo-graphically projected using WGS84 parameters. Since the study will concern data to 10000 feet above the aerodrome, the horizontal position error induced due to projection is estimated to be negligible.

Update frequency

The study will utilize conventional ATC Terminal Movement Area surveillance radar having scan rates of 4 seconds. Flight Data Recorder information is usually updated every 4 seconds. The Noise Monitoring system updates are synchronized to the source radar.

6 - CONCLUSION

The Enhance project is contributing to the goal of improved, standardized aircraft noise models.

A user group will be formed to develop the Enhance pre-processor.

A significant improvement to the aircraft noise data in INM is underway for Airbus models.

The study of the effects of radar position errors has identified error categories. Results of the study will be available during the 2^{nd} quarter of 2000.

REFERENCES

1. **Society of Automotive Engineers Aerospace A21 committee**, *Procedure for the calculation of airplane noise in the vicinity of airports*, Information Report - SAE AIR-1845, 1986

2. **Society of Automotive Engineers Aerospace A21 committee**, *Prediction of Lateral Attenuation of airplane noise during takeoff and landing*, Information Report - SAE AIR-1751, 1981

3. **Sourdine Project Group**, Sourdine Requirements for tools, *SOURDINE/ISR-DOC-D4-011*, 1999

4. **Frank-Thomas Winter**, Aircraft noise - a comparison of computation and measurement, In *Euro-Noise 98*, pp. 1179-1184, 1998

5. **International Civil Aviation Organization**, Circular 205, *Circular 205-AN/1/25*

6. **International Civil Aviation Organization**, *Annexe 16*, 3rd edition, 1993