Sound Engineering For Aircraft (SEFA)

Publishable Summary

SEFA (Sound Engineering For Aircraft) was the first project to use Sound Engineering to define optimum aircraft community noise 'shapes' (characteristics to design target sounds).

In order to be able to perform a proper **sound design for noise from overflying aircraft**, it was necessary first to record typical data, so a sample of sounds from 238 overflying aircraft (arrival and takeoff) was recorded at three different airports in Europe (in Germany and in the United Kingdom) using a microphone array in combination with a binaural microphone technique.

In a second step, for the modification of the sounds, two very efficient synthesis methods were developed based on i) spectral decomposition and ii) non-linear filtering. The quality of these synthetic sounds has been validated to be so realistic that it was not possible to differentiate between recorded and synthetic sounds. By the end of the project, a database of several hundred modified aircraft sounds had been generated using both methods.

The sound design metrics were derived by the subjective assessment of overflying aircraft noise events within extensive **psychometric listening tests** in 8 different laboratories (7 countries). For this purpose, the Semantic Differential Test and the Paired Comparison Test were chosen and the following was organised:

- General questionnaire (personal data, such as age, gender, housing, occupation)
- Noise Sensitivity questionnaire NoiSeQ (individual noise sensitivity of each subject)
- Mood questionnaire (current mood of each subject)
- Audiometric pre-screening (hearing ability of each subject)
- Translation of the questionnaires into 7 languages
- Integration of one common software tool for a standardised procedure in 8 different laboratories
- Definition of common hardware for testing.

The Paired Comparison Test and Semantic Differential Test methods have been shown to be acceptable to describe the human perception of current aircraft sounds.

The laboratory standardisation with common software and instructions was very successful.

Cultural effects - age, gender, noise sensitivity and the status of being an airport resident - were shown to have no relevance to the judgment of aircraft sounds.

From these extensive tests, the following lessons have been learned:

- The differentiation and scaling of aircraft sounds are very difficult for a typical listener. One of the reasons is that full overflying events are continuously changing typically over a period of about 40 seconds.
- The importance as a disturbing feature of any particular sound characteristics (e.g., fan tones) is largely dependent on the entire sound composition of an overflying event, i.e., on a number of other tonal and broadband components.
- Characterising target sound generally has been shown to have more dimensions than anticipated at the beginning of SEFA.

Due to the fact that the derived target sounds were specific to the aircraft type, it was not possible to define general **aircraft design guidelines** within SEFA. However, guidelines

taking into account airframe design, engine design and flight procedures have been derived according to aircraft-specific features.

This process involved the development and deployment of innovative simulation tools:
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- The **virtual aircraft** tool, which provides realistic, audible sounds for overflying virtual aircraft configurations, so generating a feedback link from target sounds to aircraft configurations.
- The **virtual listener tool,** which provides the average subjective evaluation of the sound from an overflying aircraft with respect to a preference scaling and is therefore simulating the very cost-intensive tests described above.

Finally, SEFA has provided valuable information on how the noise annoyance of aircraft can be reduced, not only by lowering noise levels, but also by improving the characteristics of aircraft noise signatures.

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