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Auralization and visualization of future air traffic from Lelystad Airport

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The general aviation airport of Lelystad (the Netherlands) will be transformed into a commercially operated regional airport. Regional aircraft are expected to fly passengers to their holiday destinations. This means that several communities will be affected by new aircraft noise. Besides noise contours, there was a strong desire to inform the public regarding the actual sound that aircraft would generate in their communities. To that end, auralizations of aircraft noise were created to inform communities on the expected sound in their environment. NLR's Virtual Community Noise Simulator allows combining auralization with visualization. Short videos of each individual scenario were made and presented to disseminate the information. Each video comprised locally recorded background noise and aircraft noise that was tailored to represent the projected future flight paths near each location. The resulting videos (32 in total) were presented at six consultation evenings to inform the general public. Besides a plenary presentation, the videos were also presented in smaller rooms in combination with a loudspeaker system and a recording device to replay the videos at a calibrated level. This setup proved to be very valuable and provided the additional information desired by the public in a comprehensive manner.

1 INTRODUCTION

The current main airport of the Netherlands, Amsterdam Airport Schiphol (AAS), is facing limitations regarding its future growth in air traffic. Schiphol accommodates both continental and intercontinental flights from the Netherlands and also serves as a major transfer airport.

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Due to the limitations on future growth at Schiphol, flights are outplaced to other airports within the Netherlands. However, not all projected air traffic can be accommodated at the current (regional) airports. Therefore it was investigated if a different airport could be opened as an alternative. There is one prospective area in the Netherlands that would best suit all the requirements of such an airport and that is the general aviation airport at Lelystad.

Studies were executed to operate Lelystad airport commercially and the results indicated that the plans were viable. This started the process of asking the government for a permit to build/expand this airport. A part of that process is presented in a report, describing the environmental impact of such a permit, referred to as an Environmental Impact Study or EIS. This EIS compared the effect that different air routes have on the environment. This whole process included several representatives from the government and local communities in order to create, among others, a social basis. Meetings of all these parties were conducted within the structure of the 'Alders-tafel Lelystad', a local deliberation platform for all the involved parties. Standard in such a EIS report is the inclusion of future air routes, implications on gaseous emissions and aircraft noise. The latter aircraft noise projections are included as noise footprints depicting the LDEN metric. This metric basically combines the Sound Exposure Levels (SEL) of all the flights, corrects for the exposure period (one year) and also penalizes the flights that occur in the evening and night.

During consultation evenings, the results of this study were presented to the local communities so that they could inform themselves but also raise their objections. In the first session questions were raised by the public on the presented noise contours. It was, for instance, impossible to compare the LDEN contour to the daily experience of a passing aircraft. Hence, the public could not get an actual impression on what they could expect in their actual surroundings which resulted in lack of trust. As a consequence there was a clear need for additional, preferably audible, information regarding the implications of the future air traffic.

The National Aerospace Laboratory of the Netherlands (the NLR) was asked if they could supply this additional information. At the NLR, the Virtual Community Noise Simulator (VCNS) can be used to provide an experience of an aircraft flyover. To that end, a person is immersed in a virtual reality scenario aided by audible cues supplied by headphones. However, to use such a system to provide several visitors of a consultation evening with an impression was a stretch. Hence, it was decided to make videos of the scenarios in the VCNS and replay those videos during the six consultation evenings.

This paper describes the process and underlying steps necessary to produce these videos. It is a new way of presenting information about aircraft noise. Our expectation is that more people are confronted with similar questions by inhabitants near airports. Hence, we hope that others might learn from this experience and of the setup used to relay information regarding aircraft noise to the audience.

2 VCNS SCENARIOS

2.1 The VCNS approach

The VCNS is a dummy of NASA's CNoTE [1] system and dubbed VCNS by the NLR. It comprises a real-time audio rendering capability (through the Ausim Goldserver [2]) within a virtual reality environment. NLR obtained the initial system in 2007 and has cooperated with NASA and AuSim to further improve the simulation capabilities. A photograph of the VCNS is shown in figure 1 to provide an impression of the system.

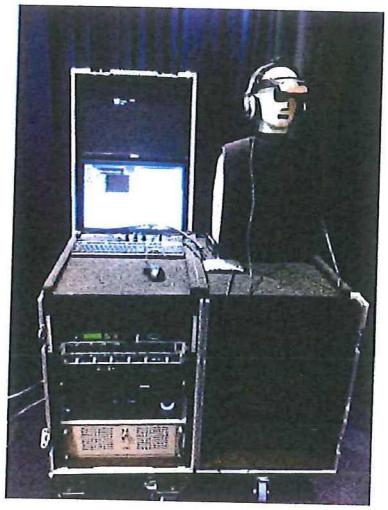

Fig 1. - The VCNS is a simulator that combines virtual reality and acoustics in one experience. The visuals are projected by a Helmet Mounted Display (HMD) whereas the audible stimulus is presented by headphones. Both the HMD and headphones are worn by the dummy which can be used to calibrate (acoustically) the entire system.

Auralization can be based on fully synthesizing an aircraft noise prediction, i.e. based solely on calculations. NASA has conducted a lot of research in auralization including, but not limited to, exotic aircraft [3] and advanced source noise synthesis [4]. NLR has researched the possibilities for advanced propagation algorithms and filters [5-6]. Furthermore, NLR presented a comparison of auralization results to actual measured flyovers as recorded in a noise monitoring terminal near Schiphol [7]. An accurate and updated list of (aircraft) noise synthesis research of both NASA, the NLR and other research establishments, can be found on the internet.*

The VCNS system is capable to present either synthesized auralizations or recordings of a particular flyover. Synthesized aircraft noise can be, in the author's opinion, very credible if simulated properly. However, during a consultation evening we did not want to risk running into a debate whether or not the results sounded artificial or not. Such a discussion could potentially disqualify the entire approach and the message that we were trying to communicate. Therefore, the choice was made to base the simulations on recorded aircraft noise rather than on a fully synthesized aircraft flyover.

The difficulty with a recorded scenario is that one needs an aircraft flying exactly the same procedure, with respect to a particular location, as is expected for the future air traffic near Lelystad. Obviously such a situation is very rare. Hence, a hybrid approach between the fully synthesized and measured approach was chosen to be integrated in the VCNS. This will be explained later.

The noise of the aircraft is just a part of the total soundscape. To present a viable scenario at the consultation evenings, the people should be able to relate themselves to the surroundings. Since background noise is an important part of such an experience, the local background noise was measured. Hence, people were able to find e.g. their church bells in the scenario and judge these as a known reference.

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* https://vastcon.wordpress.com/

The virtual reality scenario in the VCNS is based on a 3D spherical photo that is projected by the HMD (see figure 1) before a person's eyes. The HMD was not explicitly used in the current setup were videos of the simulated scenario were recorded. To keep the scenery of each location close to what the local public would expect and recognize, it was chosen to base the visual scenes on Google-streetview images. The obtained spherical photo was processed extensively to allow the rendering of a virtual aircraft flyover through that scene.

2.2 Acoustic aspects

The selected (hybrid) auralization approach modifies a recorded signal according to the differences in propagation losses that may be expected due to a different flight path that is flown. (Compared to the inherited flight path underlying the recorded aircraft noise) The recorded signal was taken from accurate measurements of departing, or approaching, aircraft near Schiphol. For the baseline recordings the aircraft trajectory was obtained through radar data. An overview of the situation of each hybrid auralization is provided in figure 2.

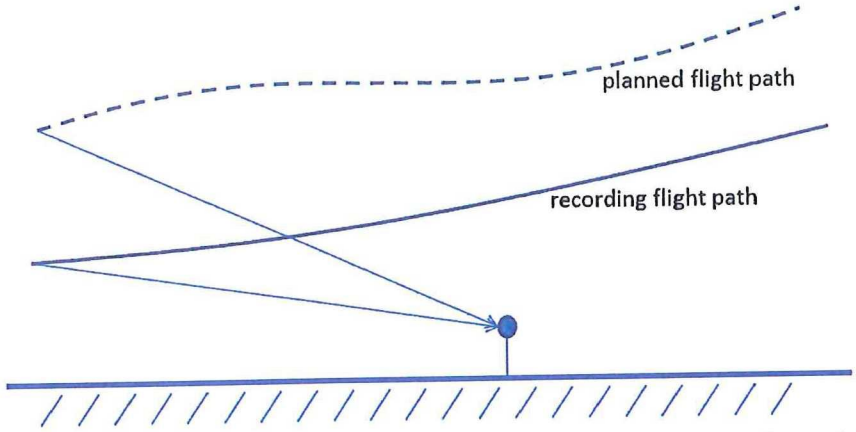

Fig. 2 – Each recording inherits a flight path, which is different from the planned (future) flight path near Lelystad airport. This leads to a difference in propagation distance (denoted by the two arrows) that can be accounted for.

At the basis of each VCNS simulation is an acoustic recording. Different measurements were used for the simulations if large deviations in operational conditions (or airspeed) were expected. For instance, along a departure route an aircraft either flies straight or climbs. In the latter case a different recording was necessary since the thrust setting during a climbing segment is, in general, higher. The recordings were as 'clean' as possible, i.e. without too much disturbing background noise (a high Signal to Noise Ratio, SNR). Furthermore, the baseline recordings were cleaned up by removing disturbing background noises as far as possible. During the final simulation of a scenario in the VCNS, the background noise measurements conducted in each particular community were integrated.

The aircraft noise measurements had to be updated to account for the expected differences in propagation loss, i.e. spherical spreading and atmospheric absorption. By using similar signal processing steps as used for a fully synthetic flyover noise simulation [8], i.e. gain, filters and overlap-add, the recording can be processed to reflect the calculated difference. However, the source characteristics were not changed, i.e. the same directivity, airspeed and Doppler shift of the aircraft included in the recording was used. Consequently, the scenarios are representative

estimations of a flight for a new location near Lelystad airport although deviations can be expected to occur in comparison to the real situation.

The best results of this hybrid method are obtained if the distance to the simulated situation is larger than was implicitly included in the recording (as is the case in figure 2). In that case, the noise from the aircraft is further attenuated. Consequently, in that case there is no risk of 'blowing up the signal' during signal during processing. This can especially happen for high frequency noise, where the impact of absorption can be dramatic, at low SNR. Careful consideration was given to prevent such situations to occur. Figure 3 shows a typical example of the used baseline recordings for approaching and departing conditions.

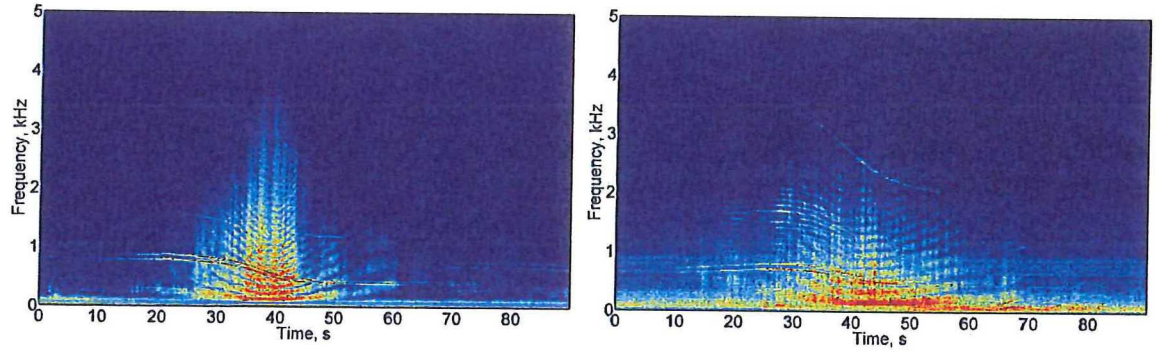

Fig. 3 – Typical measurement results for the baseline approach (left) and departure (right). The closest distance of the departure flight was (much) higher than for the approach.

The difference in distance with respect to the new (to be flown) trajectory is calculated. As a result, a difference in spherical spreading and atmospheric absorption is found and applied to the measurement. Other measurement parameters such as microphone height or wind conditions were unaltered. A typical result from this procedure is shown in figure 4.

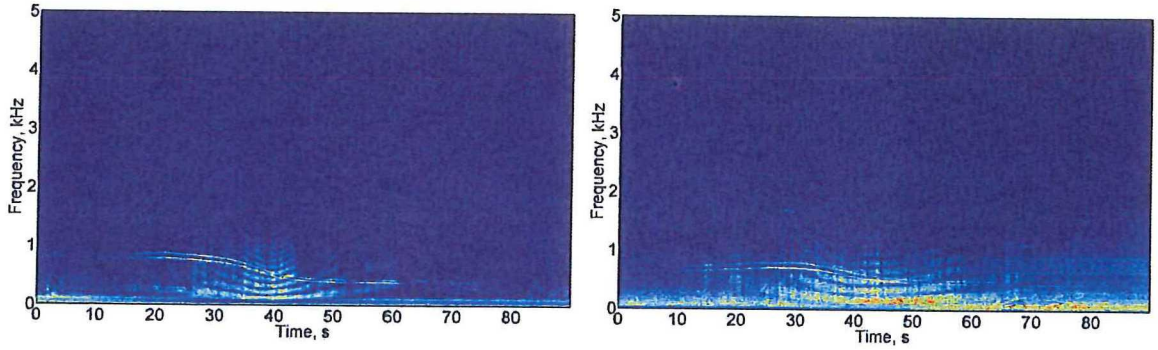

Fig. 4 – Typical results when processed for an undisclosed village. As in the previous figure, the approach is shown on the left and the departure on the right.

Please notice that in figure 3 the sound levels (especially at higher frequencies) have dropped dramatically. It seems that especially at the point of closest distance (roughly around 40 seconds) the reduction is the largest. This is due to the fact that the relative difference in range is the largest when the aircraft is relatively close. For instance, imagine two aircraft flying having

the same ground track but one is at 1000ft altitude whereas the other is at 2000ft (similar to figure 2). If the aircraft are relatively far away from the recording/simulation location, say at 5km, the difference in altitude does not matter so much due to the fact that the slant distance is not so much affected. If the aircraft is directly overhead, this difference is a factor of 2 which is a relative large difference.

The processed sound is replayed on the VCNS in conjunction with the background noise. In the VCNS, the aircraft noise is rendered binaurally with an Head Related Transfer Function, the background noise is not. In general, the background noise that made it into the final scenario was timed in such a way that when the aircraft was at its shortest distance the background noise would not exceed the aircraft noise level.

2.3 Selection of locations

During the consultation evenings, a lot of people were expected to visit that lived in the vicinity of the projected flight paths. To offer everyone a tailored simulation at their location of interest would be too extensive. Hence, a down-selection had to be made into a reasonable amount of locations. The most optimal route lay-out, as proposed in the EIS, would not lead aircraft directly over the center of larger villages or cities. Therefore, the maximum sound exposure would be expected at the edge of such a village or city as this was closer to the flight path. On the contrary, closer to the edge of such a village, less people could actually relate such an area to their own experience since they are unfamiliar with it. Therefore a trade-off was made. In general, one scenario/video per passing procedure (either approach and/or departure) was created near a 'relatable' area of the village, i.e. a landmark, church, mall, or otherwise recognizable structure. Furthermore, one scenario/video was created near the edge of a village, i.e. the nearest to the projected flight path leading to the highest sound exposure.

This also lead to cases were the aircraft were not exceeding, or were on par with, the background noise levels. Such scenarios were in general dropped. Figure 5 shows an overview of the locations that were selected for simulation.

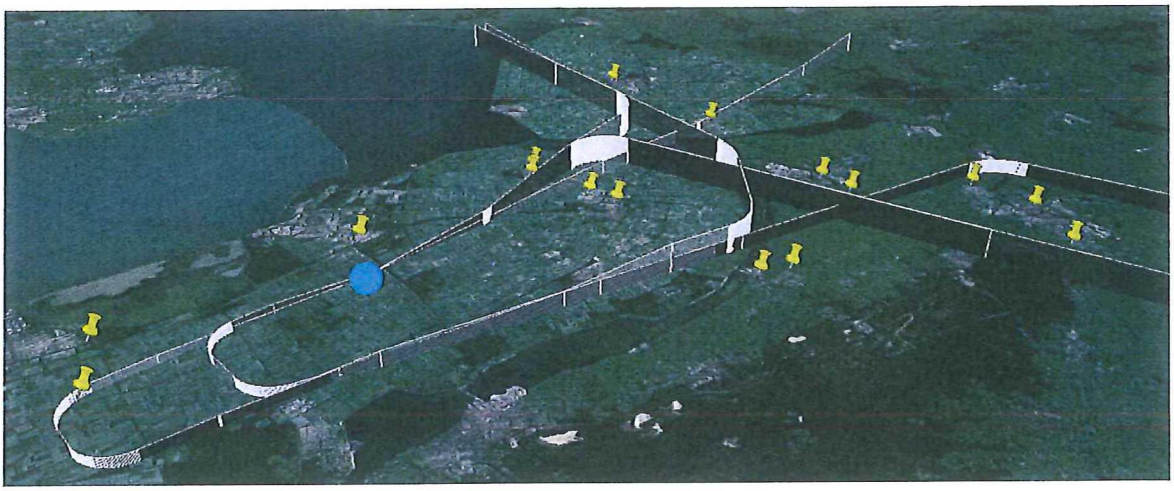

Fig. 5 - A 3D Google-Earth screenshot (looking North) from the locations (yellow pins) where scenarios were created near Lelystad airport. The white lines form the standardized departure and approach flight paths from and to the airport (blue dot).

As a result of the down-selection, a total of 11 communities were simulated leading to a total of 32 videos. The simulated aircraft was kept equal for all communities, i.e. all communities were subjected to the same aircraft. In this particular case the Airbus A-319 was chosen. It is representable for a medium-range airliner that could execute the flights planned for Lelystad airport.

3 PRESENTATION OF RESULTING VIDEOS

The videos were created using a standardized format where, at first, the situation was sketched. This provided information on the trajectory (height) and closest distance to the observer. All of the resulting videos can be found online.*

During the six consultation evenings the videos were presented during a plenary session (see figure 6, left). Throughout the different evenings the size of the crowd differed severely (100-700 people). Several questions could directly be addressed in the plenary session. In addition, there was a dedicated room where the audience could take a close look at the videos using a large television (see figure 6, right). Furthermore, there was a separate sound system in place to reproduce the audio truthfully. This was demonstrated by placing a microphone before the setup that showed the live-measured sound level to the audience. As such people could get an impression of the actual sound level that was expected and, furthermore, get a feeling for how loud the expected sound level was.

The setup during the dedicated information sessions proved to be very valuable. People could see the scenario from close up and experience the aircraft noise levels. Additionally, by replaying the sound at a level that they could check (by means of the live measurement) they also got a better understanding of how loud a particular aircraft noise level is. People had a lot of information sources, i.e. internet provides much (dis)information, but the current setup provided an accurate feedback to their questions. Since acoustical experts were on site, they could directly raise their questions (e.g., 'can I measure LDEN with my smartphone app?', 'what is the difference between LDEN and SEL?', 'how does a dB work?'...) and get into a discussion regarding the subject. The direct interaction and understandable (aural) information regarding aircraft noise proved to be appreciated in addressing the questions existing in the communities.

Fig. 6 –The plenary presentation of the video (left) and the dedicated information session (right).

* http://www.alderstafel.nl/routes-en-geluid.html

4 CONCLUSIONS

A hybrid method, i.e. modifying measured results to represent appropriate changes in (future) aircraft flight paths, could be used to obtain realistic representations of aircraft noise. This approach was adopted to create impressions of future flight paths near Lelystad airport. The simulated scenarios were embodied in videos that were disseminated amongst local communities. These videos and their presentation provided valuable additional aural information compared to the traditional noise contours. The current setup and presentation of this aural information aided in the process of informing communities what the expansion of Lelystad airport would mean for their local environment. Furthermore, being able to directly contemplate with the communities helped in answering questions and allowed to put the noise contours into a more informed perspective. The inhabitants appreciated this overall process which contributed significantly in the communication of the future expansion of Lelystad airport.

5 ACKNOWLEDGEMENTS

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