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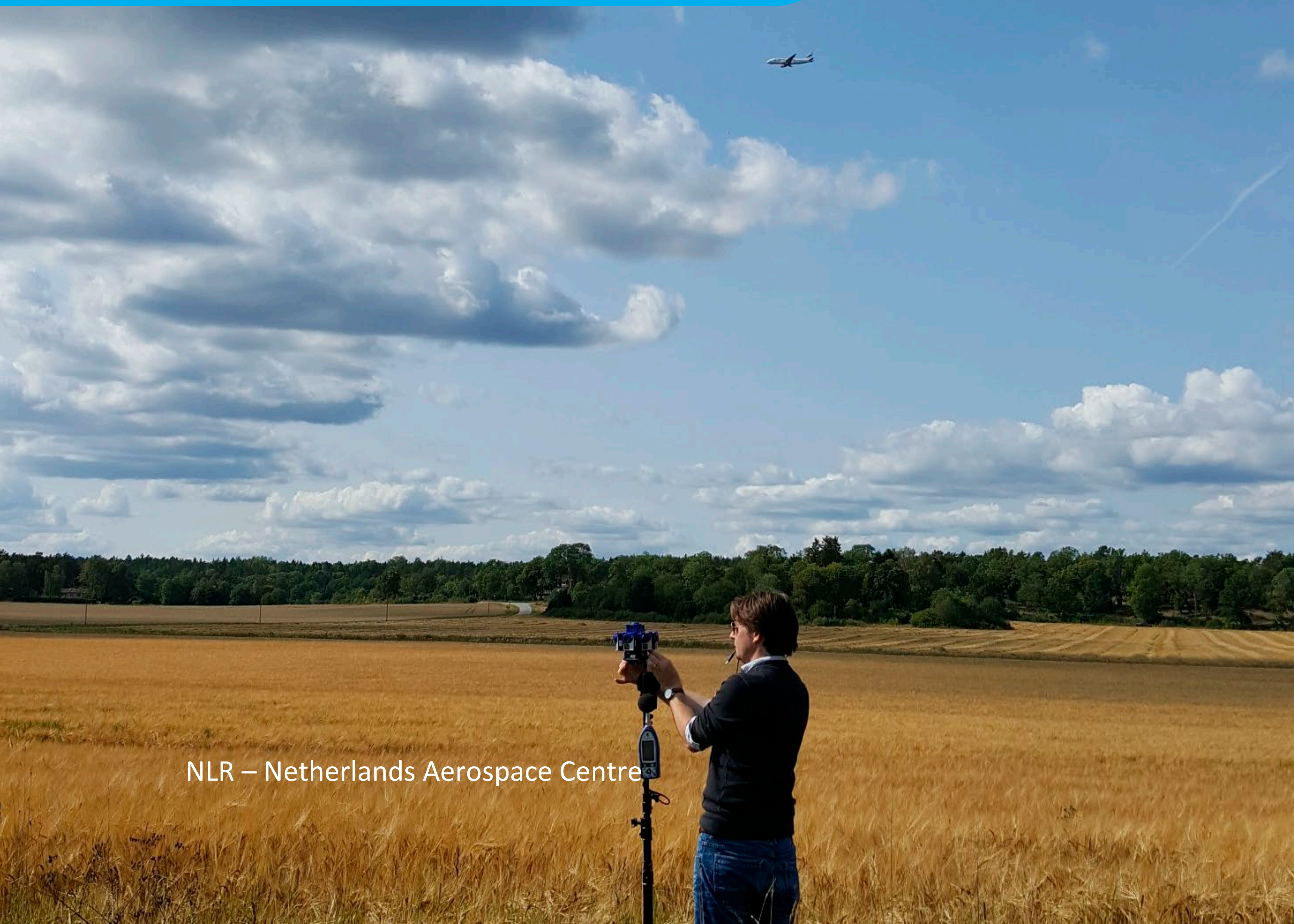
NLR-TP-2018-431 | November 2018

Virtual Reality Aircraft Noise Simulation for Community Engagement

CUSTOMER: Netherlands Aerospace Centre



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EXECUTIVE SUMMARY

UNCLASSIFIED

Virtual Reality Aircraft Noise Simulation for Community Engagement

Problem area

Aircraft noise is the most significant cause of adverse community reaction related to the operation and expansion of airports. The impact of aircraft noise on the quality of life for people living around busy airports is significant. This is expected to remain the case in most regions of the world for the foreseeable future. The goal is to address noise problems on an individual airport basis and to identify the noise-related measures that achieve maximum environmental benefit most cost-effectively using objective and measurable criteria.

Description of work

The Netherlands Aerospace Centre (NLR) developed an aircraft noise simulator with virtual reality glasses and a calibrated headset to demonstrate future changes around airports that impact the noise experience for communities. The simulator was used at different community engagement events in the Netherlands and Sweden to explain expected sound characteristics and sound levels.

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KNOWLEDGE AREA(S)
Aircraft Noise
Air Transport software (development) technology

DESCRIPTOR(S)
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noise annoyance

Results and conclusions

Public at the meetings experienced the simulation as realistic. It gave them a good understanding of what to expect from the proposed changes by the authorities. They agreed on the added value of the tool during the debate on complex topics like aircraft noise. There are indications that the personal attention for each of the individuals helped with understanding and accepting the changes to come, and supports research done already on non-acoustic aspects of annoyance.

Applicability

The impact of aircraft noise on the environment is difficult to address to local communities. Traditional approaches where communication to the public is done using legislative means such as noise values and contour maps describing noise levels, can still be done but are hard to understand by non-acoustic experts in community meetings. With a noise simulation system, supported by visual feedback, an immersive experience can be realized where new aircraft operations can be presented. Virtual reality technology, and 360 degrees recordings, help to communicate the impact of aircraft noise to the local situation in the community. The sensory experience of the proposed procedures enables cost-effective decision making in cooperation with all stakeholders of the airport.

GENERAL NOTE
This report is based on a presentation held at the 47th International Congress and Exposition on Noise Control Engineering Impact of Noise Control Engineering (INTERNOISE 2018), Chicago, Illinois, USA, 26-29 August 2018.

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INTER-NOISE 2018
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Virtual Reality Aircraft Noise Simulation for Community Engagement

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ABSTRACT

Aircraft noise is the most significant cause of adverse community reaction related to the operation and expansion of airports. The Netherlands Aerospace Centre (NLR) developed an aircraft noise simulator with virtual reality glasses and a calibrated headset to demonstrate future changes around airports that impact the noise experience for communities. The simulator generates aircraft sound simulations that are superimposed to ambient noise recordings. For visualization, a 3D aircraft model flying aircraft trajectories is mixed with 360 degrees video recordings made in the community. The simulator was used at different community engagement events in the Netherlands and Sweden to explain expected sound characteristics and sound levels. In the Netherlands, the routes of a new airport were presented to concerned communities at a number of town hall meetings. In Sweden, an increased glide slope procedure was presented in comparison with the original procedure. Public at the meetings experienced the simulation as realistic. It gave them a good understanding of what to expect from the changes as proposed by the authorities. A validation of the effects of using the simulation for communities is a topic for further study.

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1 INTRODUCTION

Aircraft noise is the most significant cause of adverse community reaction related to the operation and expansion of airports[1]. The impact of aircraft noise on the quality of life for people living around busy airports is significant. This is expected to remain the case in most regions of the world for the foreseeable future. The Balanced Approach to Aircraft Noise Management identifies four elements to address noise mitigation: First, reduction of aircraft noise at the source. Second, Land-use planning and management. Third, noise abatement operational procedures. And fourth, operating restrictions for airports. The goal is to address noise problems on an individual airport basis and to identify the noise-related measures that achieve maximum environmental benefit most cost-effectively using objective and measurable criteria.

According to ICAO[2]: *"Community engagement by airport operators and other aviation stakeholders is the key link between environmental stewardship and mitigating environmental constraints to aviation operation and growth. Recognizing the importance of community engagement, CAEP undertook a task in 2013 to collect case studies of airport outreach programmes around the world and developed an ICAO Circular in 2016 highlighting both lessons learned and good practices."* One of the lessons learned[3] is: "*Modelling, simulation, and visualization techniques can be valuable to clearly and efficiently communicate project proposals. They can provide a visual illustration of the situation (i.e. show comparisons of before and after the project), as well as potential environmental impacts and mitigations. Such techniques can help describe complex topics and help avoid misunderstandings."* To assess the impact of noise measures for a community, a factual approach where noise levels are presented by numbers, graphs, or noise contour values on maps is not sufficient anymore. Noise simulation combined with Virtual Reality technology provide a new means for better information transferal to the community.

2 PURPOSE

Purpose of a noise simulator is to improve community engagement by effectively informing the public, policy makers, and other stakeholders on the impact of aircraft noise in their vicinity. Typical use cases are situations where new aircraft routes are introduced or changed, or where new aircraft types are introduced with different sound characteristics or levels.

The environmental benefit of proposed noise measures are often hard to understand, since they are calculated by complex noise models, and the results are often presented by visualizations of noise impacts such as noise contours on a map of the involved area. Typical noise metrics, such as L_{Amax} or L_{den}, both expressed in dB(A) units, are difficult to understand for non-experts. A demonstration that provides a visual and acoustic impact is better understood than if this is presented on paper by means of Environmental Impact Assessment (EIA) documents with noise levels in dB(A). On the other hand, an experience of an actual aircraft flying over may be preferred over a simulation, but this is often difficult to arrange: not only is an actual fly-over more costly, it will require more planning, including flying not-yet-published routes. Weather conditions may force a planned demonstration flight to be postponed. In some situations, for instance if the impact of a new aircraft type is evaluated, it may not be possible as the aircraft will not yet be ready to fly. Auralization techniques, on the other hand, make it possible to give an acoustic impression of routes and aircraft that are still on the design table.

3 VIRTUAL COMMUNITY NOISE SIMULATOR

In 2007 the NLR acquired their first version of the noise simulator, and named it the Virtual Community Noise Simulator (VCNS)[4]. Purpose of the simulator is to demonstrate future changes around airports that impact the noise experience for communities. The simulator presents participants an audio-visual experience of a simulated aircraft fly-over. Main capabilities of the simulator are:

- A representative binaural[a] audio replay of an aircraft fly-over, either fully synthesized using auralization techniques, or an adapted recording that is corrected for the presented conditions,
- bi-directional ambient audio replay,
- a represented visualization of the aircraft, and
- a 360 degrees visualization of the location, either virtual or based on image recordings.

The first version was based on NASA's Community Noise Test Environment (CNote) software[5] and included audio hardware solution called Gold-Server from AuSIM. Since then, upgrades have been realized on both software and hardware to improve the system and perform the necessary maintenance. These upgrades include the use of the latest generation Virtual Reality glasses and a software implementation of the audio hardware to improve the portability of the system. As the Oculus Rift CV1 glasses also included a head tracker, the hardware requirements were reduced down to one laptop, one headset, and one Oculus Rift visor. The integrated, on-ear, Oculus Rift headset proved to be unsuitable for our application and is replaced by a Bose QuietComfort 25 headphone. For locations where the VCNS is not placed in a quiet room (e.g. town hall meetings), the noise cancellation function of the headphone prevents the test subject from hearing exterior noise. Before the simulator is used, audio sound levels are checked and adjusted by a calibration test using a dummy head, See Fig. 1.

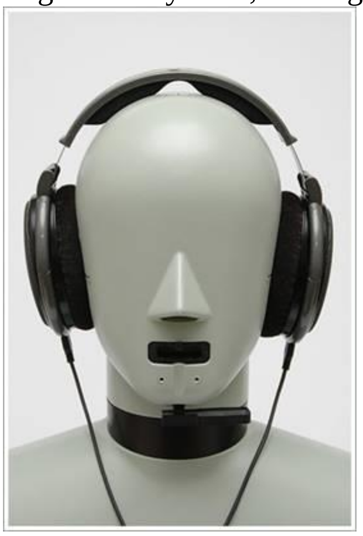

Fig. 1 – A dummy head with microphones in the ears is used for the calibration of the simulator.

[a] Supported by head-tracking technology.

For simulating the location where the aircraft noise impact is presented, 360 degrees video recordings are made with a camera rig containing 10 GoPro cameras, See Fig. 2. Video stitching software is used to combine the individual videos into a single spherical video that is used for replaying it later, See Fig. 3. Additionally, to record the ambient sound, a Zoom H2n bi-directional audio recorder is used to provide an audio experience to match the visual experience. The simulator generates aircraft sound simulations that are superimposed to the recorded ambient sound recordings. For visualization, 360 degrees video recordings are mixed with a 3D aircraft models flying aircraft trajectories.

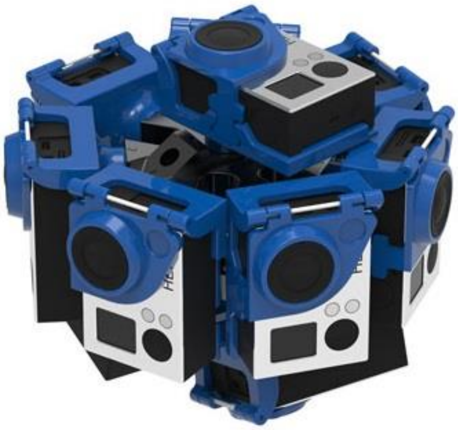

Fig. 2 – The 360 degrees camera rig for 10 GoPro cameras.

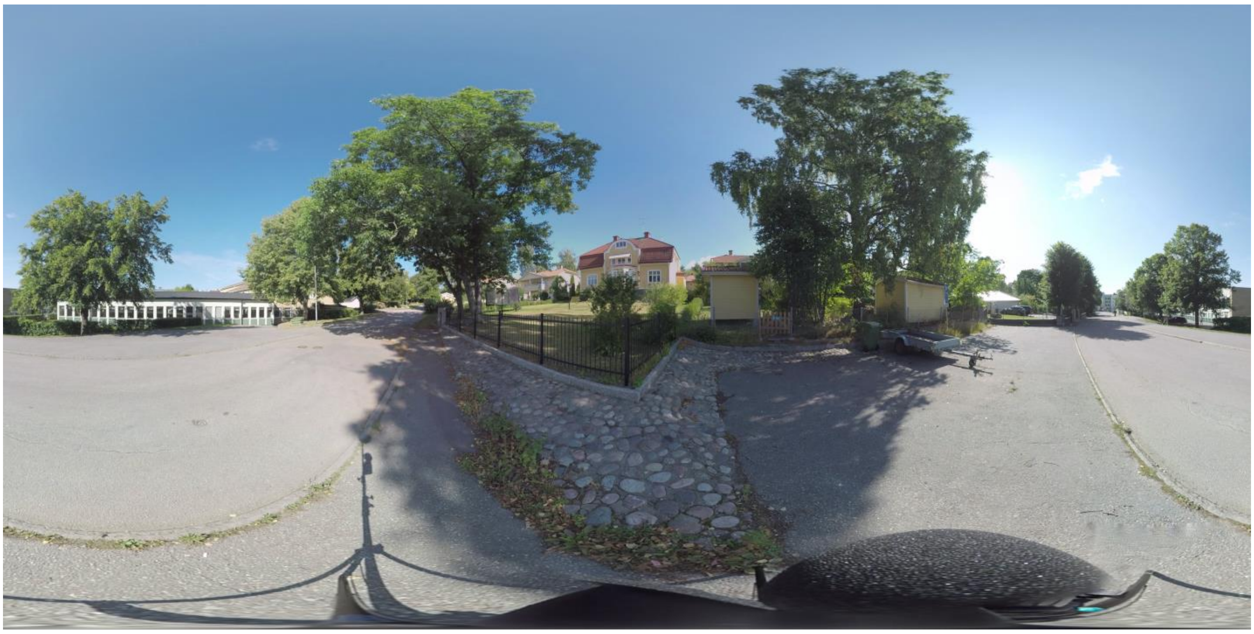

Fig. 3 – A screenshot of the stereoscopic video stitched together by the 360 camera recording.

4 USE CASES

The simulator was used at different community engagement events in the Netherlands and Sweden to explain expected sound characteristics and sound levels.

4.1 Use case 1: New airfield Lelystad in the Netherlands

The growth of Amsterdam Airport Schiphol is restricted by the environmental capacity, in particular by the number of flights. Noise annoyance is the major concern of communities around the airport. As a consequence, in 2012, an advice committee recommended that a maximum of 45.000 flight movement should be moved to the nearby airport Lelystad[6]. In 2014, after public consultation, the permission for the airport to grow was granted. However, the connecting routes to the airspace further away from the airport required airspace restructuring due to military airspace and the close proximity to existing airspace routes to Schiphol. The proposed routes from and to Lelystad Airport would have a restraint on altitude, resulting in long route segments with altitudes between 6000 and 9000 feet, causing a higher noise impact in the areas further away from the airport than was anticipated. When this became known, communities organized themselves in protest movements, while the government organized six town hall meetings to inform the public of the impact of these routes in their area.

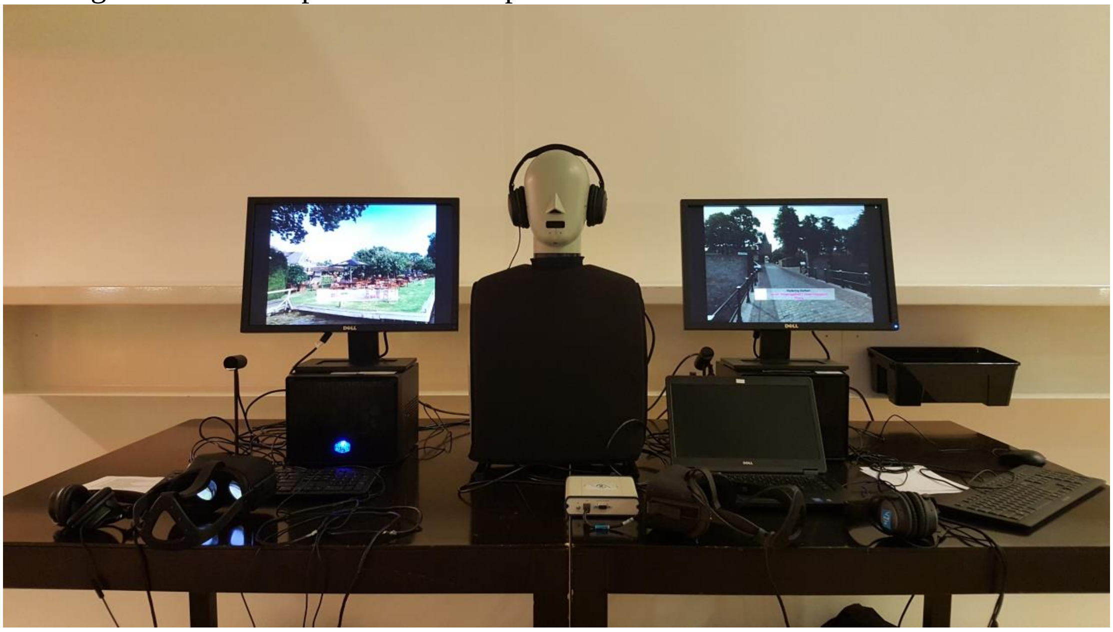

Fig. 4 – The set-up for Lelystad Community meeting with two VCNS systems and in the middle the dummy head for calibration purposes.

For these meetings, the NLR created simulations for four different, representative locations to illustrate the noise impact. The locations were Elburg, Muggenbeet, Dalfsen, and Zwolle. Elburg was a departure route, while the other locations were arrival routes with different heights. A mixture was chosen between rural areas (Muggenbeet), a village center (Elburg), an area in a city (Zwolle), and just outside a city but near a local road (Dalfsen). To support the noise simulations, at these locations, both 360 degrees video recordings and binaural audio recordings to record ambient noise were made. Aircraft noises were based upon recordings of an Airbus 319, a representative aircraft for the expected traffic. The peak level of these noise events varied between 51 and 58 dB(A) L_{Amax}. The corresponding ambient sound level at these location was around 50 dB(A), with peak levels up to 70 dB(A). Ambient noises included passing cars and boats, children playing, birds and people walking by.

The number of visitors of each meeting varied between 100 and 500 people. A video of the simulation at a dedicated location of interest was shown during the meeting, and two or three VCNS systems were available for individual demonstration before and after the plenary part of the meetings, See Fig. 4. Between 25% and 50% of the visitors actually tried the simulation.

Compared to the protest sounds during the plenary sessions, and the demonstrations that took place outside of the meeting building, participating visitors were more open for discussion and eager to experience the simulation. By providing each visitor personal attention and discuss the impact with experts who operated the simulator, concerns could be addressed and facts could be explained. One of the clarifications that could be given was that aircraft that fly to Lelystad will be medium-sized aircraft, such as Airbus 320 or Boeing 737, and not large aircraft like Boeing 747. Some visitors still found that the aircraft made a lot of noise, but were comforted that at least they now know what to expect. In some situations, visitors even reacted that they found the noise much less than expected, and didn't understand why there was so much to do about. The experience of this project is that the noise simulator can be a means to reach out to a wider public than noise contours on paper. Objective and understandable information from an independent organization can balance information that is spread by action groups against airport expansion.

4.2 Use case 2: Increased Glide slope procedures at Arlanda, Sweden

In Sweden, the VCNS was used for a scenario in a community called Upplands Väsby near Stockholm's Arlanda airport, situated 12 kilometres south under the flight path of runway 01R. This is the third runway and the latest that was constructed, and was opened in 2003. Because landing aircraft will fly straight over this village, noise mitigation measures have been examined in the past. In the European OPTIMAL project, satellite-based curved approaches have been examined[7]. Although such procedures were implemented for this runway, thereby laterally evading the village, these have not been successful, because of technical limitations. These limitations included safety restrictions for parallel runway use, and the limited number of pilots qualified to fly this specific procedure.

As an alternative, an Increased Glide Slope (IGS) procedure was presented for evaluation in comparison with the original procedure. This increased glide slope procedure included a 3.2° glide path instead of the default 3.0° glide path. A higher glide path angle would reduce aircraft noise further. The expected noise benefit was topic of debate, since airport acousticians argue that residents could not hear the change whereas it is an expensive procedure to implement.

For the simulation, a common aircraft on this trajectory, a Boeing 737(-800), was chosen for the comparison of the two procedures. For retrieving the aircraft noise, recording of this aircraft were made of a B737 flyover at 365 meters (1200 feet) around Amsterdam Airport Schiphol. These recordings were adjusted to the situation in Upplands Väsby. The aircraft were flying at a higher altitude over the village. For the 3.0° glide path, the altitude is 650 meters, while the 3.2° glide path represents a 710 meter altitude flyover. Adjustments involved atmospheric attenuation and geometrical spreading corrections. Results from real-time cockpit simulations were used to determine the change in aircraft control surface and engine setting for both procedures. Due to the larger distance between aircraft and the observer in the simulated situation compared to the measured situation the recordings are scaled down in amplitude. Any unintentionally recorded background noises are being reduced by this process as well. The left over noises are later obscured by ambient noise recordings at Upplands Väsby. The peak levels of the two flyovers are 69 dB(A) and 68 dB(A) L_{Amax} for the 3.0° and 3.2° degrees approach, respectively.

At the location in Upplands Väsby, 360 degrees video recordings were made with a 10-rig GoPro device, while background recordings were made with a 2-channel binaural Zoom H2n recorder. Ambient noise levels were checked with a Rion NL-52 measuring equipment. Background noise levels for Upplands Väsby were around 50 dB(A) and consisted of wind, bird sounds, pedestrians, and children playing further away, with a peak level of 70 dB(A) for a car driving by. The 360 degrees recording, the background recordings and the virtual aircraft, flying either the current procedure or the IGS procedure with the appropriate aircraft noise, have been added together in a VCNS simulation, See Fig. 5.

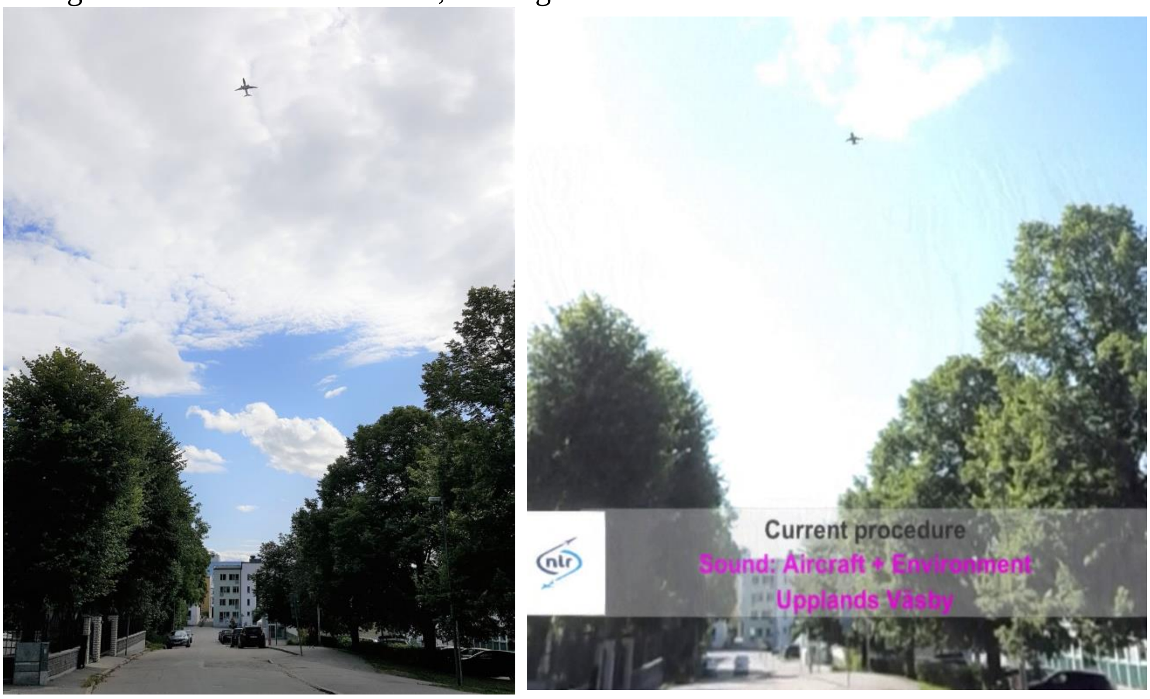

Fig. 5 – Left, a photo of the location in Upplands Väsby with an aircraft flying the current procedure. Right, a screenshot from the simulated location in the VCNS where the aircraft is virtually added to the 360 degrees recorded environment, flying the current procedure.

A meeting was organised to demonstrate the new procedure with the community of Upplands Väsby. Two VCNS systems were set up, demonstrating both the current procedure and the IGS procedure. It was not told in which order the procedures were demonstrated. Around 130 people visited the meeting, of which about half of them experienced the VCNS. The simulation of the current procedure was classified as being realistic, which gives increased trust in the simulations.

About 30 people filled in a questionnaire about the simulations. A majority (77%) indicated that the IGS procedure was less noisy, which was more than was expected based upon the limited difference in noise levels, being 1 dB(A). It must be noted that the questionnaire did not have the option to select that “no difference in sound level” was observed. Furthermore the test was done in a fixed order, where people always experienced the IGS procedure first. For this reason, and other circumstances, such as the lack of a double-blind testing, conclusions cannot be drawn from these results only. About 25 people filled in a second question which asked if they thought the VCNS would be a good tool to use in future studies, like airport expansion plans. This question had a 100% positive response.

5 CONCLUSIONS

The impact of aircraft noise on the environment is difficult to address to local communities. Traditional approaches where communication to the public is done using legislative means such as noise values and contour maps describing noise levels, can still be done but are hard to understand by non-acoustic experts in community meetings. With a noise simulation system, supported by visual feedback, an immersive experience can be realized where new aircraft operations can be presented. Virtual reality technology, and 360 degrees recordings, help to communicate the impact of aircraft noise to the local situation in the community. The sensory experience of the proposed procedures enables cost-effective decision making in cooperation with all stakeholders of the airport.

Public at the meetings experienced the simulation as realistic. It gave them a good understanding of what to expect from the proposed changes by the authorities. They agreed on the added value of the tool during the debate on complex topics like aircraft noise. There are indications that the personal attention for each of the individuals helped with understanding and accepting the changes to come, and supports research done already on non-acoustic aspects of annoyance[8].

The experience gathered at these community meetings provides positive signals that the use of a virtual reality-supported noise simulator helps in the communication about noise annoyance. In the case of the comparison of the flight procedures at Arlanda Airport, there may also be visual cues (a larger aircraft) that may indicate higher noise levels. However, this may also be due to a subjective stimulus to experience higher annoyance, and may require further research. The collection of scientific evidence on the effectiveness of the simulation in a community setting is difficult to attain at the same time. A separate study on the effectiveness to communicate about noise annoyance is needed to get validated results. A double blind test and a more general selection of test subjects are required for this purpose. A simulator such as VCNS can be an instrument to do this research.

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