Project 041 Identification of Noise Acceptance Onset for Noise Certification Standards of Supersonic Airplanes

The Pennsylvania State University

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- Period of Performance: Amendment 21: June 28, 2016 to December 31, 2017
- Period of Performance: Amendment 33: August 7, 2017 to December 31, 2018
- Task(s):
    1. Obtaining confidence in signatures, assessing metrics sensitivity, and adjusting for reference day conditions

The Pennsylvania State University Applied Research Laboratory

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- FAA Award No.: 13-C-AJFE-PSU Amendment 25,
- Period of Performance: Amendment 25: July 21, 2016 to December 31, 2017
- Period of Performance: Amendment 35: August 7, 2017 to July 31, 2018
- Task(s):
    2. Community Impact and Acoustic Acceptability

Project Funding Level
This project supports the identification of noise acceptance onset for noise certification standards of supersonic airplanes through research conducted on multiple tasks at the Penn State University. FAA funding to Penn State in 2016-2017 was $160K comprised of $50K to Task 1 and $110K to Task 2. The FAA funding to Penn State in 2017 -2018 was $221K comprised of $150K to Task 1 and $71K to Task 2. Matching funds are expected to meet cost share on both Tasks.

Investigation Team
For 2016-2017 the investigation team includes:

The Pennsylvania State University
Victor W. Sparrow (Co-PI) (Task 1)
Kathleen K. Hodgdon (Co-PI) (Task 2)
Researcher: John Morgan R&D Engineer (Task 2)
Researcher: Bernard Kozykowski R&D Engineer (Task 2)
ARL Graduate Research Assistant Will Doebler (Task 1: Signatures and metrics investigation)
ARL Eric Walker Graduate Assistant: Annelise Hagedorn (Task 2: Community Monitoring)
College of Engineering Graduate Research Assistant Janet Xu (Task 1: Signatures and metrics investigation)

Project Overview
FAA participation continues in International Civil Aviation Organization, Committee on Aviation Environmental Protection (ICAO CAEP) efforts to formulate a new civil, supersonic aircraft sonic boom (noise) certification standard. This research investigates elements related to the potential approval of supersonic flight over land for low boom aircraft. The efforts include investigating certification standards, assessment of community noise impact and methods to assess public acceptability of low boom signatures. The proposed research will support NASA in the collaborative planning and execution of human response studies that gather the data to correlate human annoyance with low level sonic boom noise. As the research progresses, this may involve the support of testing, data acquisition and analyses, of field demonstrations, laboratory experiments or theoretical studies.

Task #1: Obtaining Confidence in Signatures, Assessing Metrics Sensitivity, and Adjusting For Reference Day Conditions
The Pennsylvania State University

Objective
As national aviation authorities move forward to develop noise certification standards for low-boom supersonic airplanes, several research gaps exist in the areas of signature fidelity, metrics, metrics sensitivity to real-world atmospheric effects, adjustments for reference-conditions, etc. Research support is needed by FAA and international partners in these areas to progress toward standards.

The objective of this activity is to continue research at The Pennsylvania State University in the ASCENT COE to complement the sonic boom standards development ongoing within the Committee for Aviation Environmental Protection's (CAEP) Working Group 1 (Noise Technical), Supersonics Standards Task Group (SSTG). This research will ensure that the behavior of the sonic boom metrics considered in the SSTG discussions are well-understood, and account for sonic boom variability effects, to move forward with sonic boom noise certification standards development and consideration of subsequent rulemaking.

Task 1 in ASCENT Project 41 focuses on several, but not all, research initiatives needed to move forward toward the development of a low-boom supersonic en-route noise certification standard. In addition, this project supports the travel of V. Sparrow so that he can serve as co-rapporteur of the CAEP Impacts and Science Group (ISG).

Research Approach

Background
A review of previous work over the last few years was presented in the 2015-2016 annual report for ASCENT Project 41. Last year focused on the topics of removing the turbulence[4] in sonic boom signatures that have propagated through the atmosphere, establishing that the de-propagation technique does not work for sonic booms, and evaluating a number of sonic boom metrics regarding their stability due to turbulence effects. The latter work showed that B-weighted sound exposure level was the most robust with regard to the influences of atmospheric turbulence, among a number of metrics regarded as candidates for use in certification. This work has resulted in a new Journal of the Acoustical Society of America Express Letters paper this year.[5]

Appropriate placement and number of microphones for certification measurements
The major effort over the period October 1, 2016 to September 30, 2017 in Project 41 (Task 1) has centered on efforts to assess the minimal number of microphones that can be used for supersonic cruise certification. Because of atmospheric turbulence, each microphone in a linear array will record a slightly different pressure versus time signature. However, the effort to make such measurements is painstaking, and minimizing the number of measurement microphones will make such certification measurements easier. It is unlikely that applicants for certification will have the resources to deploy upwards of 100 microphones in the field. How many microphones are enough?

Penn State Graduate Research Assistant William Doebler worked on this problem, initially funded by ASCENT Project 41, and then as a NASA AS&ASTAR Fellowship recipient. His work was reported at a CAEP/WG1/SSTG Workshop in February 2017, at the Acoustics '17 meeting[2] in Boston, MA, USA in June 2017, and then in his M.S. thesis. The research is now summarized from the Masters of Science thesis by Ms. William Doebler.[1] The thesis was completed in November 2017, just after the completion of the project period. That thesis will be available online in early 2018 from the website: https://etda.libraries.psu.edu . It is suggested to search by author using the keyword “Doebler”.

The goal was to somewhat mimic the current subsonic aircraft certification procedure by establishing 90% confidence intervals. The available dataset that was utilized was the recordings of steady supersonic flights along linear microphone arrays from NASA's SCAMP field test.[3] W. Doebler considered this a helpful dataset as SCAMP used 81 microphones spaced at 38.1 m intervals along a 3 km linear array, substantially more than the number of microphones that would likely be available in a certification measurement.

Figure 1 shows an example result showing two plots. The left plot depicts the mean PLdB obtained as a function of the number of microphones used, as well as the confidence intervals above and below that mean, computed using the student's t-distribution. The distance between the mean and the +10% confidence interval, the “confidence radius” is then plotted on the right to show the diminishing utility of adding more microphones. For the case depicted here, one observes that perhaps 7 microphones are all that are needed to establish a confidence interval with a minimal number of microphones.

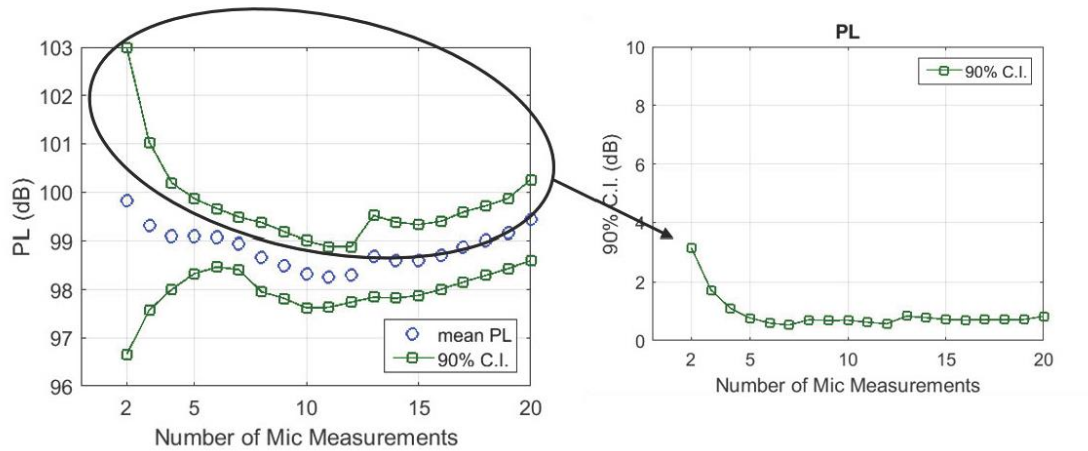

Fig. 1. The positive confidence intervals for the PL metric on the left are extracted onto the plot on the right. For this particular case, it is seen that about 7 microphones provides a minimal 90% confidence interval, and additional microphones are unneeded.

W. Doebler selected the microphones a number of different ways, including examining (1.) random placement of microphones, (2.) adjacent groups of microphones, and (3.) down-sampling across the entire microphone array. The results did not depend on which of these microphone selection methods employed. Overall, it was determined that 10 microphones were sufficient to provide a minimal confidence interval for certification. 20 microphones is more than needed, and any additional microphones do not increase the quality of the data. Further details on the processing methods used, more results, and checks on the results are available in Doebler's M.S. thesis.

Milestone(s)
A minimal number of microphones was established for future certification measurements of sonic boom noise.

Major Accomplishments
A minimal number of microphones was established for future certification measurements of sonic boom noise.

Publications
Acoustics '17 abstract.
M.S. thesis of William Doebler.
JASA Express Letters paper by Doebler/Sparrow on metric stability.

Outreach Efforts
None.

Awards
None.

Student Involvement
William Doebler is the graduate research assistant supported by the Applied Research Laboratory on Project 41 in 2016. In 2017 Doebler was supported by a NASA AS&ASTAR Fellowship. He is pursuing his Ph.D. in the Penn State Graduate Program in Acoustics. Toward the end of the report period, a new student Graduate Research Assistant Janet Xu started working on the project.

Plans for Next Period

In general, the work will continue to support CAEP WG1, SSTG, and ISG. Specifically, Graduate Research Assistant Janet Xu will be applying new signal processing techniques, such as audio fingerprinting, in an attempt to develop new methods to remove turbulence from sonic boom signals.

References

[1]W. Doebler, "The minimum number of ground measurements required for narrow sonic boom metric 90% confidence intervals," M.S. Thesis (Graduate Program in Acoustics, Pennsylvania State University, 2017).

[2]W. Doebler and V. Sparrow, "The minimum number of ground measurements required for narrow sonic boom metric confidence intervals," J. Acoust. Soc. Am. **141** (5, Pt. 2) 3625 (2017). Presented at Acoustics '17, Boston, MA, USA.

[3]J. Page, C. Hobbs, E. Haering, D. Maglieri, R. Shupe, C. Hunting, J. Giannakis, S. Wiley, F. Houtas, "SCAMP: Focused sonic boom experiment execution and measurement data acquisition," AIAA paper 2013-0933, 51st AIAA Aerospace Sciences Meeting, Grapevine, TX, January 2013.

[4]D. Maglieri, *et al.*, *Sonic Boom: Six Decades of Research* (NASA SP-2014-622, 2014), pp. 51-52.

[5]W. Doebler and V. Sparrow, "Stability of sonic boom metrics regarding signature distortions from atmospheric turbulence," J. Acoust. Soc. Am. **141** (6) EL592 (2017).

Task #2: Community Impact and Acoustic Acceptability

The Pennsylvania State University Applied Research Laboratory

Objective

This is part of a series of research efforts that were designed to provide data to help answer the question: "What is needed from a standard to reconsider 14 CFR part 91.817, which currently prohibits civil supersonic flight over land?" Supersonic flight over land is currently restricted in the U.S. and many other countries because sonic booms from *non-low-boom* aircraft create shock waves that disturb people on the ground and can potentially damage private property. This research effort supports research on the human perception of *low level* sonic booms and the assessment of community impact in noise field tests.

The research supports the regulatory standard development process and the identification of noise acceptance onset. The tasks are proposed in support of NASA in the planning and execution of human response studies, and in the development of protocols, methods and planning for Community Response Testing.

Research Approach

This research encompassed several topics that were investigated in support of future field tests to assess community noise impact and public acceptability of low boom signatures. Community noise impact research requires gathering noise data as well as community response data. This effort is finalizing the design of low cost noise monitors (LCNM) that could be used as a rapid deploy monitor to augment the use of standard higher fidelity instrumentation to gather noise data. Community response data can be gathered through formal survey methods or gleaned through observations using social media monitoring tools as a means to observe public domain comments on noise within the field test community. The evaluation of social media monitoring (SMM) tools as a means to observe the response of the general community to the noise impact was finalized. A new task was initiated to conduct a review of differences in perception between urban, suburban and rural environments to better understand the potential impact that masking has on noise field test results for human impact.

Milestone(s)

This research was conducted in support of future NASA-sponsored *low boom* noise community impact field tests. The LCNM design is being finalized. PSU researchers are teaming with researchers from Volpe, The National Transportation Systems Center on this effort. The LCNM monitor design will be shared with Volpe for further testing and development. The investigation of social media monitoring tools as a means to observe social dynamics and to provide insights into community perceptions of noise impact during the field tests was finalized. The literature review of urban vs. rural aviation noise impact is ongoing to assess the role of environmental background noise and identify methods to address it.

Major Accomplishments

The Low Cost Noise Monitor and Social Media Monitoring tasks are being finalized. These two tasks were conducted in support of efforts to gather both objective measurements and subjective observations in test communities. The literature review of the impact of environmental background noise on community noise impact is ongoing. The review of environmental masking was initiated to understand the potential impact that masking has on noise field test results for human impact. Accomplishments on each of these tasks follow.

Low Cost Noise Monitor (LCNM) Design

A report that provides an overview of the design for the Low Cost Noise Monitors (See Figure 2 and Table 1) is in development. The design will be shared with Volpe for further development and testing. The LCNM was designed as a prototype with the potential for project specific modifications when building future monitors. The evaluation of LCNM is in progress assessing the applicability of commercial off the shelf (COTS) instrumentation for this effort. Design selection was contingent on the availability of low cost parts.

Fig. 2: LCNM prototype

Table 1: LCNM Components

LCNM Components
2 Microphones
GPS Sensor
Environmental Sensor
Accelerometer Sensor
Single Board Computer (SBC)

The noise monitoring is provided through a single board computer, microphones, and batteries. The design includes two microphone channels that can be set with different dynamic ranges. This affords the ability to capture low level signals with integrity, and affords a second microphone channel set with a higher dynamic range. The monitor also includes temperature and humidity sensors as well as an accelerometer channel to provide greater applicability for a range of noise monitoring projects. The monitor will require the development of software to facilitate the ability to readily download the field data.

Social Media Monitoring Tools

The monitoring of social media was explored as a supplemental means to observe the impact of the noise field testing on the community, by observing the publicly available comments that are posted to social media. By monitoring online discussions, researchers have the opportunity to identify concerns within the community related to the noise impact.

Social media monitoring tools include the capability to use a defined geographic-based search of keywords used in social media comments during a noise field tests. A review of the comments could potentially identify unanticipated locations of concern for greater noise impact. An increase in social media comments in a specific geographic region could indicate a potential sound channel due to topography, urban canyons or environmental variability or community concerns related to the field test. Being made aware of such issue would be of valuable in helping to explain secondary influences on the primary data. The observations would be gathered from public domain information only and are not viewed as formal response data. Two commercially available social media monitoring tools were considered, GeoFeedia and EchoSec. Tests of EchoSec were conducted to assess its applicability to this effort. The observations would primarily allow the team to engage the community with targeted news releases or Outreach materials that address issues observed on posts to social media. The observations could also identify if community members have mistaken the impulsive boom noise to be an explosion, prompting the team to issue a media release to alleviate these concerns. While noise monitors will be located across the boom carpet, there is the potential that a combination of wind and terrain could produce a sound channel. The observations may indicate a “noise pocket” that could prompt stationing a noise monitor in that area. Monitoring social media provides the opportunity to identify concerns within the community related to the low boom field test.

The review of SMM tools was shared with the Waveforms Sonicboom Perception and Response (WSPRRR) team that is designing the low boom community noise risk reduction field test sponsored by NASA. The team is currently working with NASA Public Affairs on a field research design for community engagement that includes elements related to education, Outreach and potential monitoring of community response. It is likely that NASA Public Affairs will use their Facebook page as a form of education and outreach. NASA currently uses Sysomos for social media monitoring on Facebook. Sysomos is a suite of social data tools that affords the ability to monitor social trends and keywords on social media platforms. This form of observing the community response to the noise impact will most likely be utilized. The team recognizes the value of social media monitoring to proactively identify areas of concern to the community, and to afford the opportunity for engaged Outreach.

Environmental Masking (urban vs suburban/rural) Literature Review and Survey Development

This task includes a review of concepts and available literature of noise studies related to the role masking plays on the perception of noise. Masking is the extent that one noise source “covers” or masks another noise source. The *low boom* noise has been described as sounding like distant thunder, or two car door slams in quick succession. In urban areas, a car door slam may not be noticed, due to other noise sources. The same car door slam would be more clearly noticed in a quiet rural environment. The noise impact is measured by both objective noise metrics and subjective human response. The task will initially review and compile information on urban vs. rural impact of aviation noise. While the preferred noise source to investigate is aviation noise, data gathered on analysis methods for other noise sources may also prove to be relevant. A review of noise impact and analysis methods for various noise sources and environments could further identify patterns in noise impact and response, and provide a more informed approach to illuminate those patterns in future data sets. An attempt is being made to include a range of publications such as The Journal of the Acoustical Society of America, Journal of Sound and Vibration, Journal of Environmental Psychology, and Environment and Behavior. The literature review is intended to further understanding of potential differences in noise impact between such communities that could inform future research efforts. The results of this study should provide insight into the influence of background noise on the annoyance rating of aviation noise.

Publications

None

Outreach Efforts

This research task supports NASA activities on supersonics and sonic boom research. The team has provided information to the NASA sponsored Waveforms Sonicboom Perception and Response Risk Reduction (WSPRRR) team. This NASA sponsored team consists of ASCENT Project 41 team members from Penn State, Volpe, Wyle and Gulfstream working with NASA team lead APS to formulate a test plan for future low boom community field tests.

Awards

None

Student Involvement

Annelise Hagedorn has just started on this effort as an Eric Walker Graduate student, looking at aviation environmental impacts on urban vs rural communities. She is a doctoral candidate in Agricultural Economics, Sociology and Education. She is conducting a literature review of aviation noise studies to document methods, analyses and findings for aviation noise impact research conducted in different types of communities.

Plans for Next Period

The LCNM instrumentation task is being finalized. The outcome is the development of noise monitoring technology that can be used to supplement existing noise measurement methods for greater quantification of coverage at lower cost and complexity. Such technology could be used as intermediate measures among the standard higher fidelity instrumentation to confirm and interpolate data.

The literature review will be continued on noise studies related to the role masking plays on the potential low boom noise impact in differing background noise for urban, suburban or rural noise environments. The findings of the Environmental Masking literature review will facilitate interpreting noise field test results and masking due to environmental surrounding (community density), and the relevance masking has on low boom noise for such varying background environments.

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