Project 007 Civil, supersonic over-flight, sonic boom (noise) standards development

The Pennsylvania State University

Project Lead Investigator

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- FAA Award No.:13-C-AJFE-PSU Amendment 3
- Period of Performance: August 4, 2014 to December 31, 2015
- Task(s):
    1. Study of Variability Effects

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- P.I.: Kathleen Hodgdon, Research Associate, Penn State Applied Research Laboratory
- FAA Award No.:13-C-AJFE-PSU Amendments 4
- Period of Performance: August 4, 2014 to December 31, 2015
- Task(s):
    2. Community Engagement

Project Funding Level

This project supports the Civil Supersonics Overflight Sonic Boom (Noise) Standards Development by providing research support on multiple tasks at the Penn State University. FAA funding to Penn State in 2014-2015 was $100,000 comprised of $40K to Task 1 and $60K to Task 2. Boeing provided $40K matching funding in 2015. The Penn State Applied Research Laboratory provided $42,664 matching funding in 2014-2015. Additional matching funding is expected in 2015-2016 that will meet additional cost share needs in both years 1 and 2.

Investigation Team

For 2014-2015 the investigation team included:

Penn State

- Victor W. Sparrow (Co-PI)
- Kathleen K. Hodgdon (Co-PI)
- Graduate Research Assistant Erik Petersen (atmospheric absorption investigation, described in ASCENT Project 5)
- Graduate Research Assistant Joshua Palmer (variability effects investigation)

Advisory Committee Members

- AERION: Jason Matisheck, Clint Baylog, *et al.*
- Boeing: Hao Shen, Bob Welge, *et al.*
- Cessna: Kelly Laflin, *et al.*

- Gulfstream: Robbie Cowart, Brian Cook, Joe Gavin, *et al.*
- Lockheed Martin: John Morgenstern, Tony Pilon, *et al.*
- Volpe-The National Transportation Systems Center: Juliet Page, Bob Samiljan, et.al.
- Wyle: Kevin Bradley, Chris Hobbs, *et al.*

Project Overview

Currently, the FAA is participating in ICAO CAEP effort to formulate new civil, supersonic aircraft sonic boom (noise) certification standard. To achieve this, ICAO Working Group 1 is addressing the sonic boom phenomenon, the signal acquisition and analysis of boom and making vibro-acoustical analyses and correlations with human response. This effort relies on extensive and on-going research not only to define the aircraft design and its performance, but equally important, to define an understanding of the acoustical annoyance over a range of sonic boom responses that are unacceptable to imperceptible. There are a number of areas which need to be addressed to support the standards setting process, but one of the primary ones is metrics validation and sensitivity studies for a wide range of boom levels, inclusive of rattle (for indoor) and startle (for outdoor).

Additionally, the research tasks are designed to support NASA activities on supersonics and sonic boom research. 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 "Study of sonic boom variability effects"

The Pennsylvania State University

Objective

The objective of this activity is to initiate 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), Supersonics Standards Group (SSTG). This research will ensure that the behavior of the sonic boom metrics considered in the SSTG discussions are well-understood prior to down-selecting a finalized metric or metrics for use in possible sonic boom certification and/or rulemaking.

Research Approach

Various sonic boom noise metrics have been calculated for a number of sonic booms, N-wave signatures. The newly computed metrics dataset utilized high-quality recordings from the Superboom Caustic Analysis and Measurement Program (SCAMP) and Farfield Investigation of No-Boom Thresholds (FaINT) experiments conducted by NASA. With these signature datasets comprised of microphone measurements by long linear arrays, one can assess the waveform variability due to atmospheric turbulence influences across the arrays. Preferred boom events from these NASA datasets were then chosen after review of the flight conditions, flight objectives and actual waveforms generated in order to study only the non-focused, N-wave sonic boom signatures. The sonic boom noise metrics calculated for the preferred boom events include Stevens Mark VII Perceived Level (PLdB), un-weighted Sound Exposure Level (SELz) as well as Sound Exposure Level with A, B, C, D, and E weightings applied to the waveforms. The results show, for example, that the A-weighted sound exposure levels and Steven's Mark VII Perceived Levels had standard deviations in the range of 1.4 dB to 6.1 dB for the SCAMP measurements. Such sensitivity results should be helpful in assessing the applicability of sonic boom metrics for use in future en-route certification standards for civilian supersonic aircraft.

The metrics selected for sensitivity analysis were chosen due to their high correlation with human perception data, simplicity of calculation and availability within the engineering community. For Sound Exposure Levels, each weighting function was applied to the waveform according to ANSI S1.42-2001. Sound exposure level was calculated according to ANSI/ASA S1.4-2014, where sound exposure is the time integral of the square of a frequency-weighted signal over a given time interval. Sound exposure was then converted to a decibel level using a standard reference value of $E_0 = 400 \times 10^{-12}$ Pa^2s. Perceived Level was calculated in accordance with the Mark VII method using a combination of Matlab providing input for FORTRAN code originally developed at NASA Langley. The calculation of each of these metrics was verified with crosschecking in conjunction with other organizations. Figure 7.1 below depicts results of the PLdB metric calculated for four SCAMP flights.

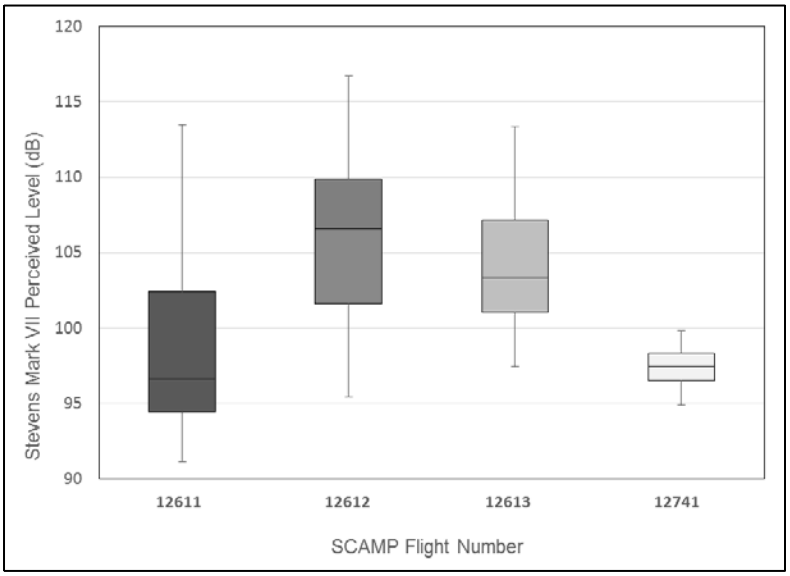

Figure 7.1: Steven's Mark VII Perceived Level for SCAMP flights shown.

The first three flights were flown on-track, directly overhead the microphone array. The last flight is an example of a typical off-track flight, flown parallel to the microphone array but offset a distance of 18,700 feet (5700 m). There were sixty microphones in the array used in this analysis, each spaced at a distance of 125 feet (38.1 m). This box and whisker plot shows the maximum and minimum measured values at the ends of the whiskers. The top and bottom of the box represent the first and third quartiles of the data with the central line representing the median. A large amount of variance is observed in the three on-track flights, with a noticeable decrease in the variability in off-track flight measurements. The cause of this variability decrease is currently being reviewed but may be due to an increase in the propagation path length, allowing more time for absorption to take place particularly in the high frequency regime.

Flights selected for analysis from the FaINT program include flights that were targeted for lateral cutoff procedures but did not exhibit cutoff at the end of the microphone array. A distinct and very important difference between these results and the SCAMP results are the flight paths. FaINT flights were flown over the microphone array perpendicular to the direction of the array; this is contrasted to a parallel flight path that was used in all SCAMP measurements. Sixty microphones were also used in the FaINT linear array, with a spacing of 125 feet (38.1 m) between each. FaINT results have shown that there are similar amounts of variance in metrics for both types of flight path. Typical results for four flights from the FaINT program are shown below in Figure 7.2.

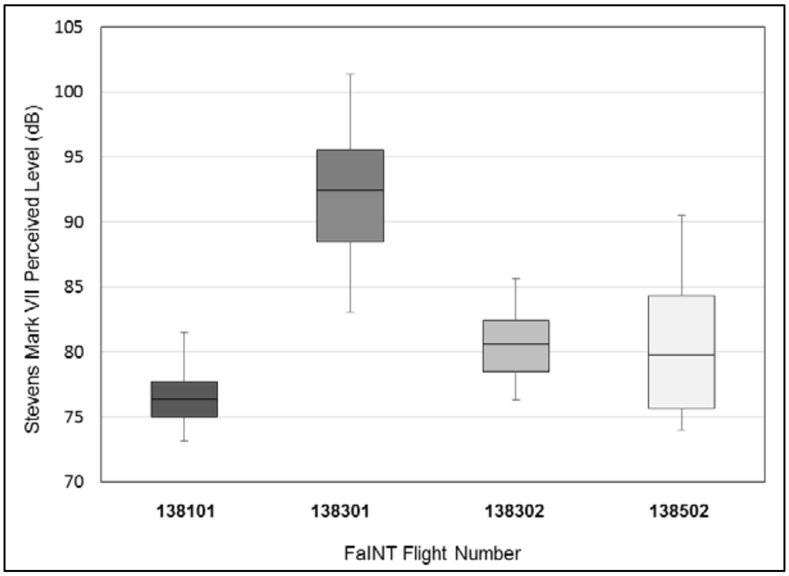

Figure 7.2: Steven's Mark VII Perceived Level for FaINT flights shown.

The first flight shown in the figure can be described as more of a U-wave type sonic boom, whereas the other three flights are closer to typical N-wave sonic boom events (as was seen in all SCAMP measurements used in analysis). PLdB standard deviation values for all flights analyzed ranged from 2.2 dB to 10.7 dB. As with SCAMP flights, a high amount of variability is seen in these measurements for not only PLdB (shown) but also all SEL weighted metrics. At least part of this variability is caused by turbulence as the sonic boom waveform propagates through the atmosphere to the ground.

Milestone(s)
N/A

Major Accomplishments
It was determined that NASA's SCAMP and FaINT datasets could be used to assess the sensitivity of sonic boom metrics to variability in recorded sonic boom signatures. Substantial variability was seen in the sonic boom metrics due to atmospheric turbulence.

Publications

Peer reviewed journal publications:

N/A

Published conference proceedings:

J. Palmer and V. Sparrow, "Measured N-wave sonic boom events and sensitivity to sonic boom metrics," Proc. of 20th Intl. Symposium on Nonlinear Acoustics and 2nd Intl. Sonic Boom Forum, July 2-3, 2015, Lyon, France (American Institute of Physics, 2015) [in press].

Outreach Efforts
Throughout the project the team has provided information to the ICAO's Committee on Aviation Environmental Protection (CAEP) through its Noise Working Group (WG1) and Supersonic Task Group (SSTG).

Awards
None.

Student Involvement

Graduate Research Assistant Joshua Palmer was the primary person working on this task. He will graduate with an M.S. in Acoustics in December 2015, and at the time of this writing he is currently looking for employment. The Co-PIs greatly thank the Penn State Applied Research Laboratory for providing a Walker Assistantship to Joshua Palmer during 2013-2015. The authors also thank the Penn State College of Engineering for providing travel support for Joshua Palmer to participate in the 2nd International Sonic Boom Forum in Lyon, France.

Plans for Next Period

- Focus on additional metrics under consideration for certification procedures
- Provide guidance for placement of multiple microphones
- Assess if de-turbing procedures will work for low-boom signatures, as this could possibly mitigate the influence of atmospheric turbulence on signatures used for certification purposes

References

- S. Liu, V. Sparrow, and Y. Makino, "Establishing new noise standards for civil supersonic aircraft: status report," International Civil Aviation Organization (ICAO) Environmental Report 2013: Aviation and Climate Change, pp. 73-77 (2013).
- D. Maglieri, P. Bobbitt, K. Plotkin, K. Shepherd, P. Coen, and D. Richwine, Sonic Boom: Six Decades of Research (NASA, 2014), NASA/SP-2014-622, p. 51.
- 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.
- FaiNT: Farfield Investigation of No-boom Thresholds. http://www.nasa.gov/topics/aeronautics/features/faint_sonic_booms.html#.VCVvUEskOvI

Task 2 Community Engagement

The Pennsylvania State University

Objective

The research is being conducted in anticipation of future low boom community field tests. The community engagement task was undertaken to facilitate a pro-active approach to interacting with communities participating in future field tests.

Research Approach

The research approach includes identifying recommended methods to interact with communities and outreach strategies that can utilize options for observing on line discussions and social dynamics in the community during the field test.

Milestone(s)

Identified community engagement and outreach based strategies in support of future NASA sponsored low boom community impact field tests. Conducted an initial evaluation of methods to monitor social media that could be used as a means to identify community specific content for development of outreach materials.

Major Accomplishments

An approach for engagement was identified that parallels strategies recommended by the Centers for Disease Control for researchers conducting health based community efforts and an initial investigation into social media monitoring was conducted.

The CDC defines community engagement as the process of working collaboratively with groups of people who are affiliated by geographic proximity, special interests, or similar situations. Engagement principles arise from a variety of scientific fields, requiring that the researcher adapt the science in ways that fit the community and the purposes of specific engagement efforts. (www.cdc.gov). The approach implements the following communications strategies for engaging a community on a research based effort.

Define and implement coordinated multi-agency community specific effort

- Formulate community collaboration engagement methods
- Clearly identify goals of effort
- Identify communications strategy, informational message content, release forums
- Optimize information delivery methods
- Consider Formal News Media sources: Printed, TV, Radio, Web-based, newsletters

Acknowledge individuality of each community

- For each field test community assess community infrastructure
    - Be knowledgeable about demographics; government infrastructure; norms
    - Be aware of cultures and diversity within community
- Identify and work with leaders in local government and community organizations
    - Local city, borough and township officials
    - Identify other relevant community organizations

To engage a community successfully the research team should work to establish relationships with local community leaders and be cognizant of the unique aspects and factors relevant to each community.

Effective outreach is a primary component of community engagement. Pro-active outreach material can be developed that provides informational education on low boom research. Reactive outreach materials can be identified or drafted during the test to address concerns that arise in the community. One method of identifying community concerns is by monitoring social media. The social media monitoring task is evaluating options that would allow us to observe the social dynamics in the overall community response during a low boom community field test. By monitoring on line discussions we have the opportunity to identify concerns within the community related to the proposed or ongoing low boom community field test. The research team could then engage the community with targeted Outreach materials that address issues observed on posts to social media. This engagement task allows us to provide information that addresses concerns that we observe in the social media discussion. Community dynamics can be monitored using traditional approaches or monitoring on line.

Multi-Media Method for Observation of Community Dynamics

- Formal News Media: Printed, TV, Radio, Web-based
- Population-centric technologies: Social Media: Facebook, Twitter, Instagram, blogs
- Social Media Monitoring Tools
    - Comments/forums: Comment Sniper, Board Reader and Google Trends
    - Social campaigns; WildFire's Social Media Monitor
    - Social networks/blogs: SocialMention, Google Reader, BlogPulse, AllTop, Google Realtime

On line social networks have grown exponentially in recent years. Users of social media create and consume content, sharing information, ideas and perspectives with a wide variety of contacts. The on line forum allows users to post information and opinions, engage in discussions, to simply agree with a user's post, or to share perspectives and spread information in an almost instantaneous manner. In this application the observations are intended to inform the researchers of social climate and dynamics within community and are not intended as subjective response test data. Even as observations of community dynamics, the approach needs to acknowledge the presence of any potential bias. For instance, Twitter data sources are filtered by Twitter affording only about 7% of the data. As such, investigation of applicable methods is ongoing.

The review of social media as a monitoring approach revealed biases inherent to that approach. The use of social media monitoring as a method affords the means to observe a community response to an event, provided the biases and limitations of the approach are included with the observations.

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 7 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
None

Plans for Next Period
The effort to expand the ability to observe the response within a community to a low boom field test led to the decision to also evaluate additional instrumentation and methods to document the noise impact across the community.

- The Research Instrumentation task will assess the fidelity of lower cost noise monitors to optimize noise measurement requirements and minimize costs in future field tests.
- The Monitoring task will further evaluate social media as a means to observe social dynamics in the community that provide insights that afford the opportunity for subsequent Outreach.

References
Principles of Community Engagement, CDC/ATSDR Committee on Community Engagement, Centers for Disease Control and Prevention, Public Health Practice Program Office
Atlanta, GA., 1997 http://www.cdc.gov/phppo/pce/part3.htm

Ruths, D., and J. Pfeffer. "Social Media for Large Studies of Behavior." *Science* 346.6213 (2014): 1063-064. 28 Nov. 2014. Web. 10 Feb. 2015.